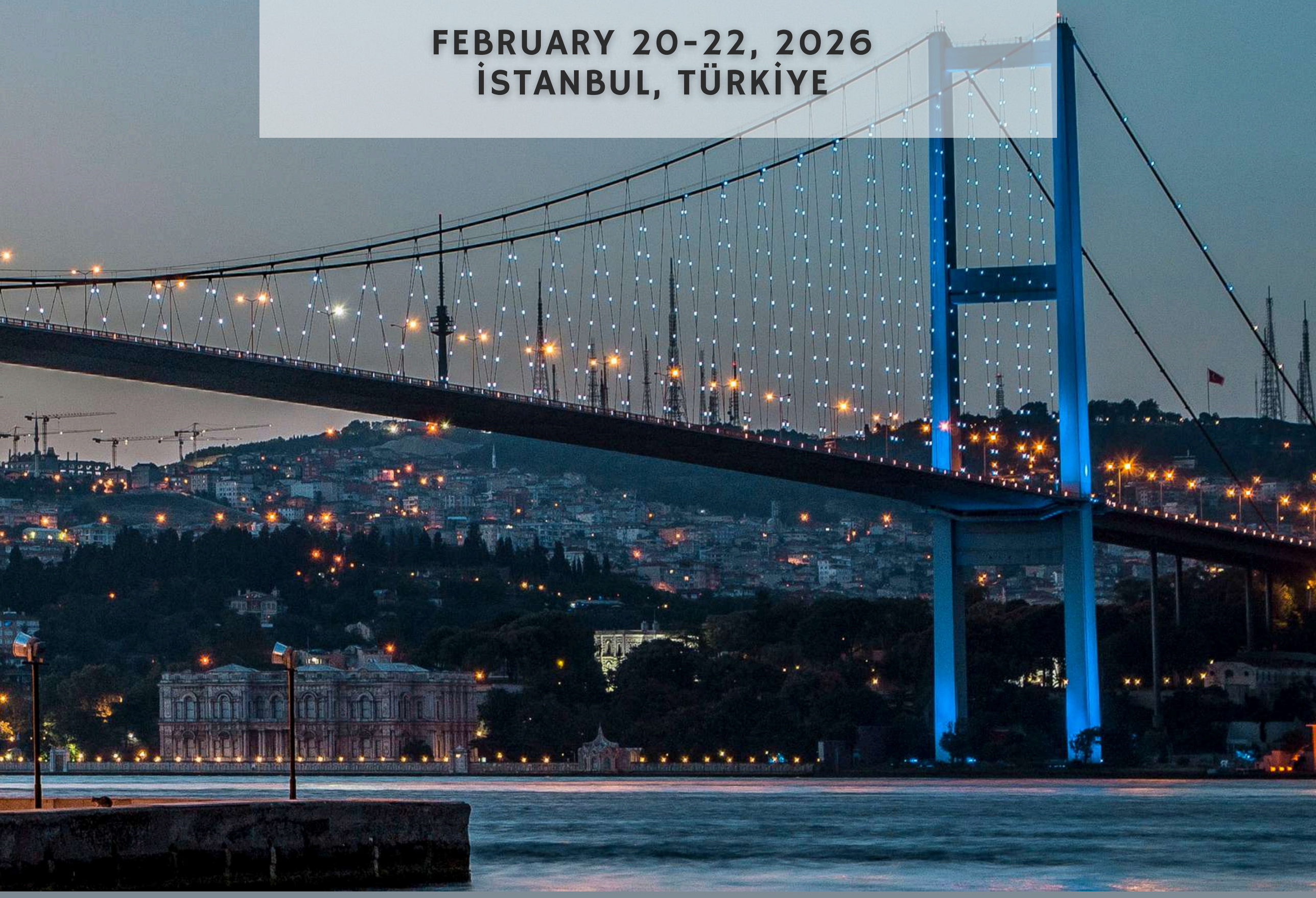
EDITORS
PROF. DR. IRINA-ANA DROBOT
PROF. DR. HABİBE ÖZMEN

24TH INTERNATIONAL ISTANBUL SCIENTIFIC RESEARCH CONGRESS ON LIFE, ENGINEERING, ARCHITECTURE, AND MATHEMATICAL SCIENCES PROCEEDINGS BOOK

FEBRUARY 20-22, 2026
İSTANBUL, TÜRKİYE



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E-ISBN: 978-9952-610-30-7
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FEBRUARY 20-22, 2026

ONLINE & IN-PERSON PARTICIPATION

ZOOM & İSTANBUL, TURKIYE

CONGRESS PROCEEDINGS BOOK

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President of Coordinators' / General Coordinator

Dr. Niyameddin SHUKUROV

ACCEPTED PAPERS

144 Turkish Participants
202 Foreign Participants
%58 Foreign Participant Rate
%42 Turkish Participant Rate

REFUSED PAPERS

3 Foreign Participants

EVALUATION PROCESS

All Submissions Have Passed a Double-Blind Referee Evaluation Process
All Responsibility for the Works Belongs to the Author

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Fen Fakültesi Dekanlığı

2025 AİLE YILI

Sayı : E-11499065-100-772444 03.02.2026
Konu : Prof. Dr. Habibe ÖZMEN'in
Dilekçesi

DAĞITIM YERLERİNE

İlgi Dilekçeniz incelenmiş olup, 20-22 Şubat 2026 tarihinde ZOOM üzerinden çevirimiçi; İstanbul'da yüz yüze olarak gerçekleşecek 24. Uluslararası İstanbul Fen, Mühendislik, Mimarlık ve Matematik Bilimlerinde Bilimsel Araştırmalar Kongresi'nde açılış konuşmacısı, Bilim ve Organizasyon Kurulu Üyesi olarak yer almanız Dekanlığımızca uygun görülmüştür.

Gereğini bilgilerinize rica ederim.

Prof. Dr. Hasan BULUT
Fen Fakültesi Dekanı

Ek:
1- Yazı (1 Sayfa)
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Dilekçesi

FEN FAKÜLTESİNE

Bölümümüz öğretim üyelerinden Prof. Dr. Habibe ÖZMEN'in **24. Uluslararası İstanbul Fen, Mühendislik, Mimarlık ve Matematik Bilimlerinde Bilimsel Araştırmalar Kongresi** ile ilgili vermiş olduğu dilekçe ekte sunulmuştur.

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Kurumunuz Fen Fakültesi, Analitik Kimya Anabilim Dalı'nda öğretim üyesi olarak görev yapan Prof. Dr. Habibe ÖZMEN'in 20-22 Şubat 2026 tarihinde ZOOM üzerinden çevrimiçi; İstanbul'da yüz yüze olarak gerçekleşecek ***24. Uluslararası İstanbul Fen, Mühendislik, Mimarlık ve Matematik Bilimlerinde Bilimsel Araştırmalar Kongresi***'nde açılış konuşmacısı, bilim ve organizasyon kurulu üyesi olarak yer almasını talep eder; ilgili görevlendirme yazısını tarafınızca arz ederiz.

Saygılarımla,

Dr. Baha Ahmet YILMAZ

BZT Turan Akademi Türkiye Temsilcisi

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20-22 ŞUBAT 2026

YÜZ YÜZE & ÇEVRİMİÇİ

İSTANBUL, TÜRKİYE

20-22 Şubat 2026 tarihlerinde ZOOM üzerinden çevrimiçi ve Türkiye'nin İstanbul kentinde yüz yüze olarak gerçekleştirilen 24. Uluslararası İstanbul Fen, Mühendislik, Mimarlık ve Matematik Bilimlerinde Bilimsel Araştırmalar Kongresi **YÖK ÜAK kuralları ve üniversiteniz yönetmeliğiniz gereği akademik teşvik kriterlerini sağlamaktadır.** Toplam 346 adet bildirinin yer aldığı kongre üç gün boyunca çevrimiçi ve yüz yüze olarak gerçekleştirilmiştir.

Türkiye dışından toplam **5 farklı ülkeden açılış konuşmacısı; 18 farklı ülkeden katılım (detaylar kongre bildiri kitabında yer alan kongre programında yer almaktadır)** sağlanmış olup, 346 adet bildirinin 202 tanesi yabancı, 144 tanesi Türk katılımcı tarafından sunulmuştur. Kongrenin yabancı katılımcı oranı %58'dir.

Bu belge ilgili üniversitenin akademik teşvik komisyonuna takdim edilmesi üzerine verilmiş.

İlgili bilgilerin detayları kongre bildiri kitabının künye kısmında yer almaktadır.

Kongremize ilginiz için teşekkür ederiz.
Saygılarımızla,

Bu belge 20-22 Şubat 2026 tarihleri arasında İstanbul'da verilmiştir.

İLETİŞİM
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24. Uluslararası

İSTANBUL

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BİLİMLERİNDE BİLİMSEL ARAŞTIRMALAR KONGRESİ

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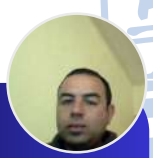
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National Taiwan Ocean University, Taiwan



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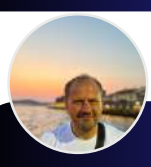
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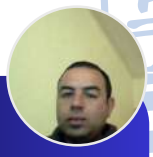
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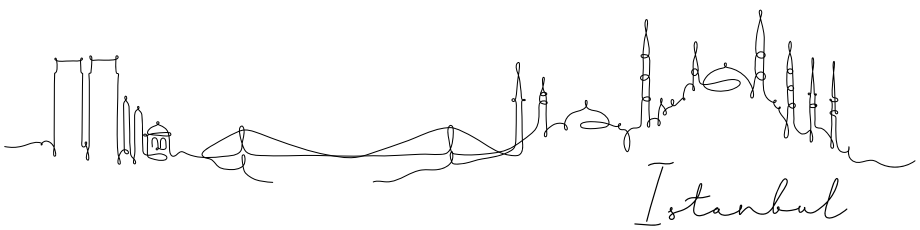


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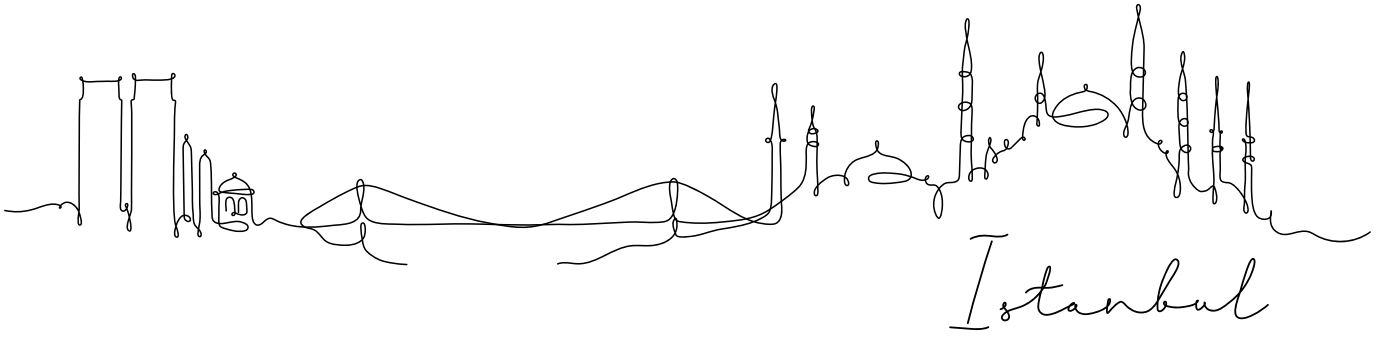
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→**PROF. DR. RAUL D. F. MOREIRA**
Porto University, Portugal

11.00 - 11.15 (TURKIYE LOCAL TIME)

"ANALYSIS OF WOOD/PLYWOOD JOINTS IN LARGE PALLETS USING NUMERICAL FİNİTE ELEMENT ANALYSIS"



PROGRAM FLOW

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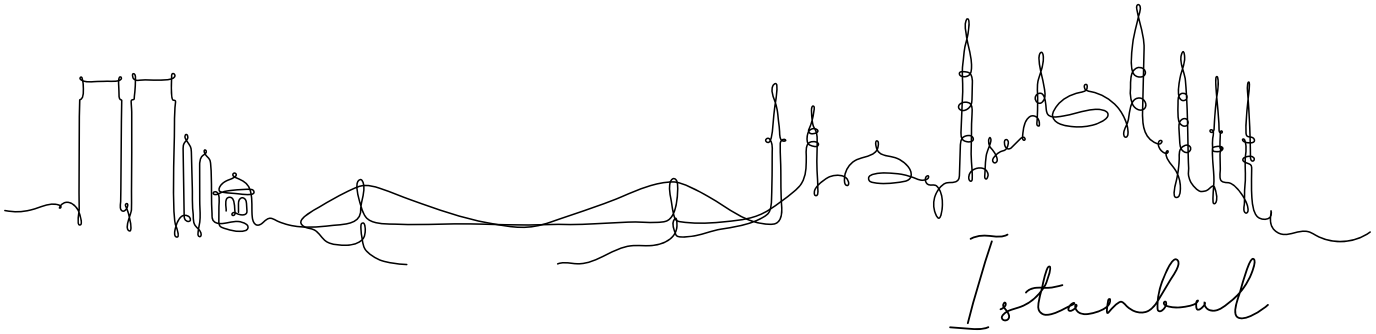


→ PROF. DR. HABİBE ÖZMEN

Fırat University,
TÜRKİYE

11.15 - 11.30 (TURKIYE LOCAL TIME)

"INVESTIGATION OF THE EFFECT OF SODIUM SELENITE (NA2SEO3) ADMINISTERED THROUGH FEED ON COMMON CARP (CYPRINUS CARPIO L.)



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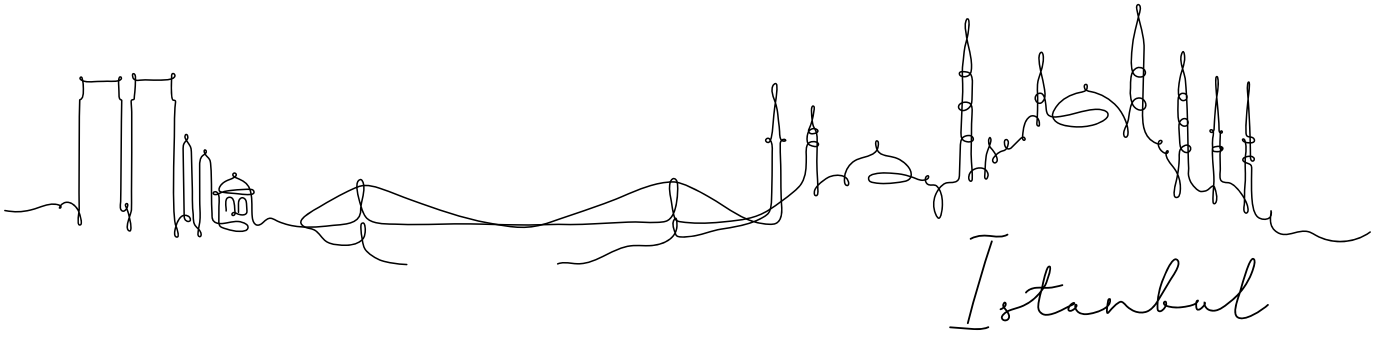


→ ASSOC. PROF. DR. EDMOND HALA

Agricultural University of Tirana,
ALBANIA

11.30 - 11.45 (TURKIYE LOCAL TIME)

"MEDITERRANEAN SEA CAGE AQUACULTURE: PRODUCTION POTENTIAL AND INSTALLATION"



PROGRAM FLOW

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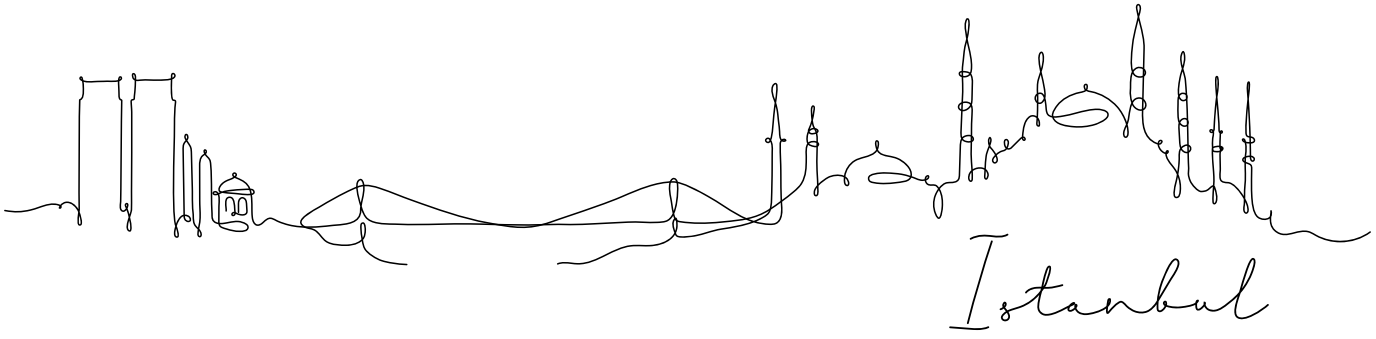


→PROF. IRINA-ANA DROBOT

Technical University of Civil Engineering of Bucharest, ROMANIA

11.45 - 12.00 (TURKIYE LOCAL TIME)

"DEVELOPING EXPRESSIVE ENGLISH FOR ENGINEERS"



PROGRAM FLOW

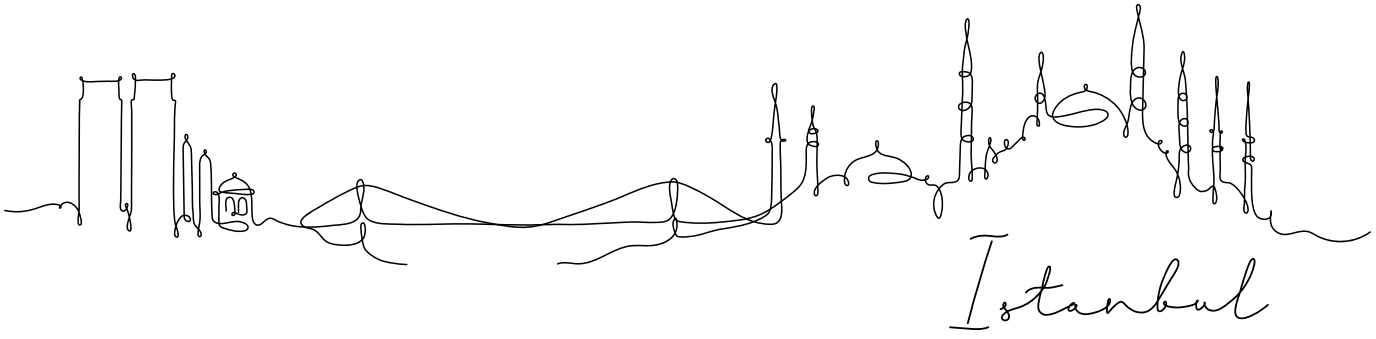
OPENING SPEECHES
IN-PERSON



→PROF. DR. MICHELLE A. DAAROL
Mindanao University, Philippines

09.00 - 09.15 (TURKIYE LOCAL TIME)

INFLUENCE OF PULVERİZED COW BONE AS PARTİAL REPLACEMENT OF CEMENT AND DEMOLİSHED CONCRETE AS FULL FİNE AGGREGATES ON PROPERTİES OF FOAM CONCRETE



PROGRAM FLOW

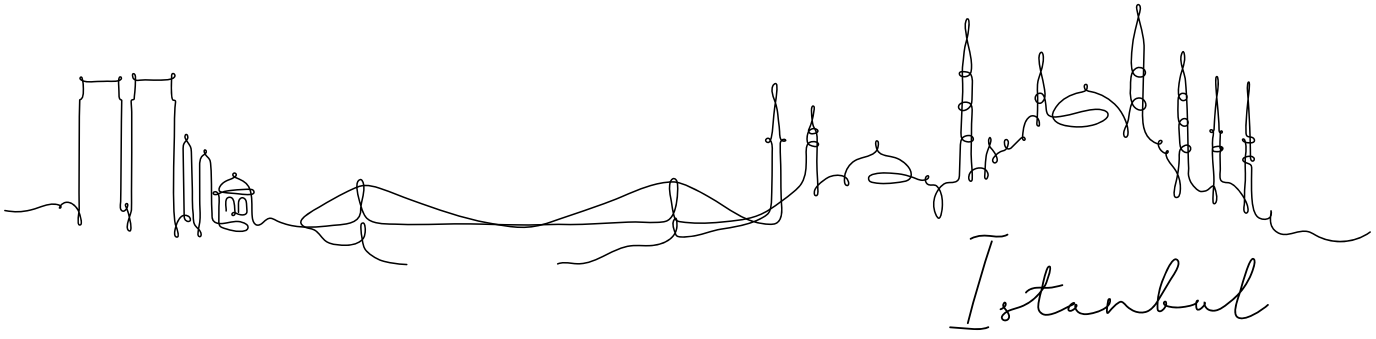
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→PROF. DR MELAHAT ABDULLAYEVA
Mindanao University, Philippines

09.15 - 09.30 (TURKIYE LOCAL TIME)

MATHEMATIC EDUCATION IN AZERBAIJAN AFTER COLD WAR PERIOD: CHALLANGES AND DYNAMICS



PROGRAM FLOW

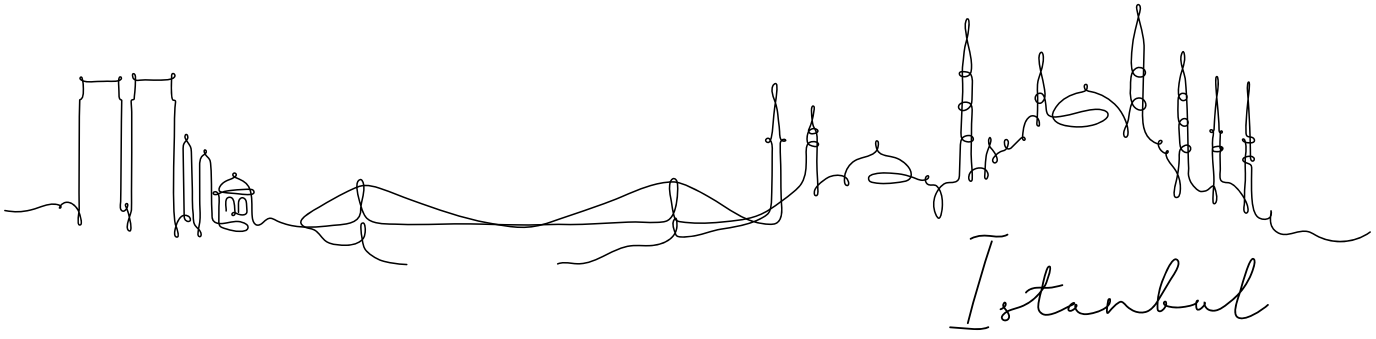
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→ASSOC. PROF. DR. NASIBA SABIROVA
AnnamalaiUniversity, India

09.30 - 09.45 (TURKIYE LOCAL TIME)

ENHANCING THE GROWTH AND PRODUCTIVITY OF SESAME (SESAMUM INDICUM L.) THROUGH DIFFERENT ORGANIC MANURES IN SANDY LOAM SOIL



PROGRAM FLOW

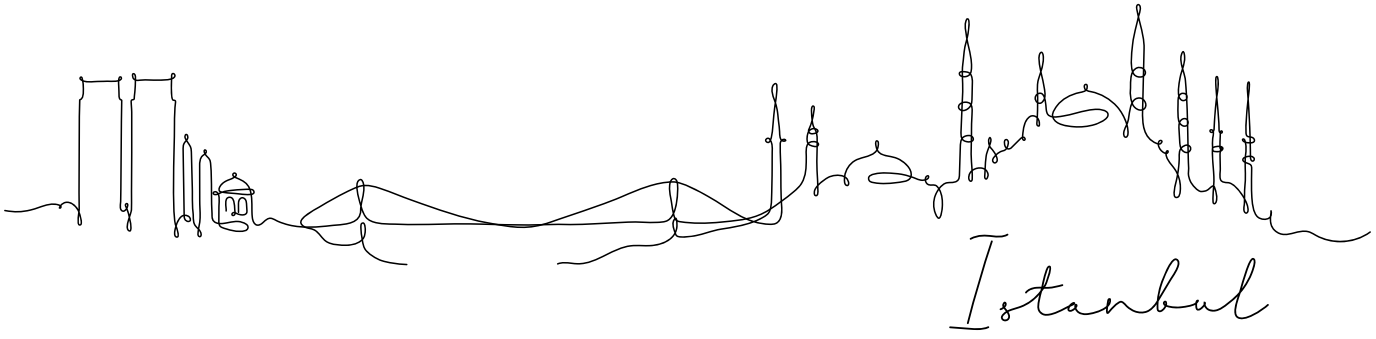
OPENING SPEECHES
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→PROF. DR. FIAZ UD DIN
Bahawalpur University, Pakistan

09.45 - 10.00 (TURKIYE LOCAL TIME)

PAKISTAN EDUCATION SYSTEM ON ENGINEERING, AND APPLIED SCIENCES



PROGRAM FLOW

OPENING SPEECHES
VIRTUAL



→PROF. DR. NESLİHAN DOĞAN-SAĞLAMTİMUR
Niğde Ömer Halisdemir University, Türkiye

10.00 - 10.15 (TURKIYE LOCAL TIME)

"TRIPLE TRANSFORMATION"

İstanbul

24TH INTERNATIONAL ISTANBUL SCIENTIFIC RESEARCH CONGRESSES ON LIFE, ENGINEERING, ARCHITECTURE, AND MATHEMATICAL SCIENCES

GÜN 1 / DAY 1 – FEBRUARY 20, 2026 / 20 SUBAT 2026
GÜN 2 / DAY 2 – FEBRUARY 21, 2026 / 21 SUBAT 2026
GÜN 3 / DAY 3 – FEBRUARY 22, 2026 / SUBAT 2026

February 20-22, 2026 | 20-22 Subat 2026
Istanbul, TURKIYE

CONGRESS PROGRAM

Online (with Video Conference) Presentation

PARTICIPANT COUNTRIES (18 COUNTRIES)

Türkiye, Azerbaijan, Iran, Algeria, India, Albania, Nigeria, Pakistan, Namibia, United States of America, Philippines, Morocco, Ethiopia, Libya, China, Kosovo, Hungary, Northern Cyprus

DAY 1 | GÜN 1
MEETING ID: 831 4835 9437
PASSWORD: 841730

DAY 2 | GÜN 2
MEETING ID: 869 4231 3188
PASSWORD: 217426

IMPORTANT, PLEASE READ CAREFULLY

- To be able to attend a meeting online, login via **https://zoom.us/join** site, enter ID "Meeting ID or Personal Link Name" and solidify the session or you directly click to

  - **DAY 1 - ZOOM LINK:** https://us02web.zoom.us/j/83148359437?pwd=ZLAfxl9WyiTIDgGvH3uqnfQxg8kjbI.1
  - **DAY 2 - ZOOM LINK:** https://us02web.zoom.us/j/86942313188?pwd=N4bMApfHFPiR4t6bVBZ356HAZdeDpT.1

- The Zoom application is free and no need to create an account.
- The Zoom application can be used without registration.
- The application works on tablets, phones and PCs.
- The participant must be connected to the session 5 minutes before the presentation time.
- All congress participants can connect live and listen to all sessions.
- Moderator is responsible for the presentation and scientific discussion (question-answer) section of the session.

Points to Take into Consideration - TECHNICAL INFORMATION

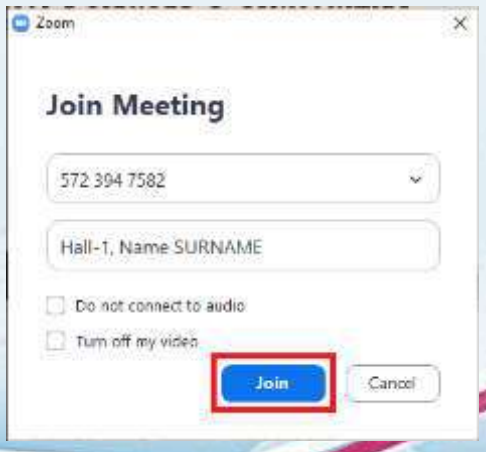
- Make sure your computer has a microphone and is working.
- You should be able to use screen sharing feature in Zoom.
- Attendance certificates will be sent to you as pdf at the end of the congress.
- Requests such as change of place and time will not be taken into consideration in the congress program.

*(All speakers required to be connected to the session **10 min before** the session starts)*

Moderator is responsible for ensuring the smooth running of the presentation, managing the group discussion and dynamics.

*Each presentation will take **10 minutes.** There will be a question and answer session for 5 minutes after the presentation.*

Before you login to Zoom please indicate your name_surname and HALL number:
exp. Hall-1, Name SURNAME



ÖNEMLİ, LÜTFEN DİKKATLİCE OKUYUN

- Bir toplantıya çevrimiçi olarak katılabilmek için https://zoom.us/join sitesi üzerinden giriş yapın, "Toplantı Kimliği veya Kişisel Bağlantı Adı" kimliğini girip oturumu başlatın. Ya da direk
- **GÜN 1 - ZOOM LINK: https://us02web.zoom.us/j/83148359437?pwd=ZLAfxl9WyiTIDgGvH3uqnfQxg8kjbI.1**
- **GÜN 2 - ZOOM LINK: https://us02web.zoom.us/j/86942313188?pwd=N4bMApfHFPiR4t6bVBZ356HAZdeDpT.1**
- Zoom uygulaması ücretsizdir ve hesap oluşturmanıza gerek yoktur.

❖ Zoom uygulaması kayıt olmadan kullanılabilir.
❖ Uygulama tabletlerde, telefonlarda ve PC'lerde çalışır.
❖ Katılımcının sunum saatinden 5 dakika önce oturuma bağlanması gerekmektedir.
❖ Tüm kongre katılımcıları canlı olarak bağlanıp tüm oturumları dinleyebilir.
❖ Oturumun sunum ve bilimsel tartışma (soru-cevap) bölümünden moderatör sorumludur.

Dikkat Edilmesi Gereken Noktalar – TEKNİK BİLGİLER

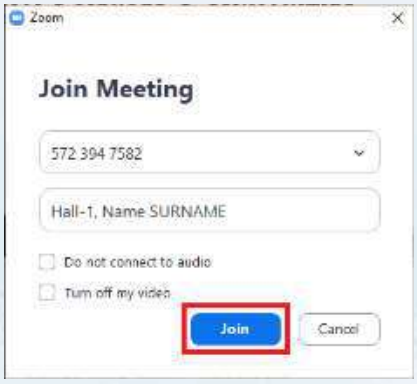
❖ Bilgisayarınızın mikrofonunun olduğundan ve çalıştığından emin olun.
❖ Zoom'da ekran paylaşma özelliğini kullanabilmelisiniz.
❖ Katılım belgeleri kongre sonunda tarafınıza pdf olarak gönderilecektir.
❖ Kongre programında yer ve saat değişikliği gibi talepler dikkate alınmayacaktır.

(Tüm konuşmacıların oturum başlamadan *10 dakika* önce oturuma bağlanması gerekmektedir) Moderatör sunumun sorunsuz ilerlemesinden, grup tartışmasının ve dinamiklerin yönetilmesinden sorumludur.

Her bir sunum *10 dakika* sürecektir. Sunumun ardından *5 dakika* soru-cevap bölümü gerçekleştirilecektir.

Zoom'a giriş yapmadan önce lütfen adınızı soyadınızı ve SALON numaranızı belirtiniz:

Örnek: Salon-1, Adı SOYADI



OTURUM (1) | GÜN (1) | SALON (1) – SESSION (1) | DAY (1) | HALL (1)

Taksim Salonu | Taksim Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14[00]-17[45] (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Nigar EMECEN EZGİN*
	Authors	**Affiliation**	**Topic title**
14[00]-14[15]	Minel KURTULUŞ	*Istanbul Gelisim University, Türkiye*	AN EXPLORATORY STUDY OF INTERIOR ARCHITECTURE STUDENTS' DESIGN PARADIGMS IN FUTURE-ORIENTED FURNITURE DESIGN USING QUALITATIVE AND VISUAL ANALYSIS METHODS
14[15]-14[30]	Yaren ŞEKERCİ	*Antalya Science University, Türkiye*	TRANSLATING AUTISM-INFORMED DESIGN PRINCIPLES INTO INTERIOR ARCHITECTURE EDUCATION: EVIDENCE FROM A UNIVERSAL DESIGN STUDIO
14[30]-14[45]	Rukiye ÖCAL M.Emin BAŞAR	*Konya Technical University, Türkiye*	SPATIAL ANALYSIS OF SERVICE ACCESSIBILITY IN AN URBAN CONSERVATION AREA: THE CASE OF KARAMAN CITY CENTER
14[45]-15[00]	Sevda AKSÖZ Özge BOZGEYİK	*Hasan Kalyoncu University, Türkiye*	EVALUATION OF STREET REHABILITATION APPLICATIONS IN THE HISTORIC MIDYAT SYRIAC BAZAAR IN TERMS OF SUSTAINABLE CONSERVATION
15[00]-15[15]	Hasan POLAT Muhammed AKYÜZ M. Nuri KOLAK	*Bingöl University, Türkiye*	INVESTIGATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF UPR-BASED POLYMER COMPOSITES INCORPORATING WASTE PAPER CUPS
15[15]-15[30]	Rabia ÇİL	*İstanbul Kültür University, Türkiye*	SPATIAL MEMORY AND STRUCTURAL TRANSFORMATION: A COMPARATIVE STUDY OF AYVALIK AND NEA IONIA IN THE CONTEXT OF THE 1923 TURKEY–GREECE POPULATION EXCHANGE
15[30]-15[45]	Şeyma KULAKAÇ	*Yıldız Technical University, Türkiye*	EXAMINATION OF EARLY PERIOD KÜLLIYES IN A FUNCTIONAL CONTEXT
15[45]-16[00]	Mervenur USTA Semih YILMAZ	*Karadeniz Technical University, Türkiye*	THE INTERPLAY BETWEEN INDOOR CLIMATE PARAMETERS AND STRUCTURAL DETERIORATION IN HISTORIC MASONRY BUILDINGS: A REVIEW OF CONTEMPORARY MEASUREMENT TECHNIQUES
16[00]-16[15]	Gökhan GENÇ	*Samsun University, Türkiye*	EVALUATION OF DIGITAL TWIN STUDIES IN CULTURAL HERITAGE STRUCTURES WITH A FOCUS ON CONSERVATION WITHIN THE CONTEXT OF STRUCTURAL AND ENVIRONMENTAL PERFORMANCE ANALYSIS
16[15]-16[30]	Ayşe KARAKAŞ	*Independent Researcher, Türkiye*	ESTABLISHMENT OF A NEW SETTLEMENT IN ANATOLIA AT THE EARLY 18TH CENTURY; MUŞKARA BECAME NEVŞEHİR
16[30]-16[45]	Müberra ZEYREK Can Ş. BİNAN	*Yıldız Technical University, Türkiye*	IMPLEMENTATION AND EXECUTION ISSUES OBSERVED IN CLASSICAL OTTOMAN MONUMENTAL STRUCTURES
16[45]-17[00]	Hatice Büşra ÇELEBİ Cenk HAMAMCIOĞLU	*Yildiz Technical University, Türkiye*	A REVIEW OF SITE SELECTION CRITERIA AND MODELING APPROACHES FOR ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

17^{00}-17^{15}	**Yunus Emre BOZ Sinem Güler UYSALER Meryem KAVAZ Yelin EVCEN**	***Gönye Design, Türkiye***	**A SPATIAL EXPERIENCE AT THE INTERSECTION OF ANATOLIAN AND ASIAN CUISINES: THE CASE OF THE MOLA ISTANBUL PROJECT**
17^{15}-17^{30}	**Yunus Emre BOZ Selen AYBİRDİ Gönül ARDAL**	***Gönye Design, Türkiye***	**FACTORS INFLUENCING CONCEPT DESIGN IN BRANDED HOUSING PROJECTS: THE CASE OF THE NIVAK FLORYA PROJECT**
17^{30}-17^{45}	**Gizem AKYOL İrfan Şefik GÜZELYOL**	***Haliç University, Türkiye***	**THE INDUSTRIAL DESIGN JOURNEY OF ART NOUVEAU AESTHETICS: AN EVOLUTIONARY ANALYSIS FROM TRADITIONAL HANDICRAFTS TO THE STYLIZED FORMS OF THE 21ST CENTURY**

OTURUM (1) | GÜN (1) | SALON (2) – SESSION (1) | DAY (1) | HALL (2)

Mecidiyeköy Salonu | Mecidiyeköy Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14⁰⁰-17³⁰ (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Mustafa ÖZER* *COORDINATOR* *Ufuk EZGİN*
	Authors	**Affiliation**	**Topic title**
14⁰⁰-14¹⁵	Muhammed ATAR	*Firat University, Türkiye*	ENHANCED DUCTILITY OF THICK T-STUB CONNECTIONS USING A SLEEVE FUSE
14¹⁵-14³⁰	Semih SATILMIŞ Redvan GHASEMLOUNIA	*Istanbul Gedik University, Türkiye*	INTEGRATED USE OF SPECIAL CONCRETE TYPES IN SUSTAINABLE AND ECONOMIC HOUSING DESIGN AND SAP2000-BASED CONCEPTUAL STRUCTURAL EVALUATION
14³⁰-14⁴⁵	Ansarulhaq KHAIRKHAH Ertan BOL	*Sakarya University, Türkiye*	SWELLING POTENTIAL OF SILTS VARYING CLAY CONTENT
14⁴⁵-15⁰⁰	Mustafa ÖZER	*Gazi University, Türkiye*	DETERMINATION OF VERTICAL STRESS INCREASE BENEATH AN H- SHAPED RAFT FOUNDATION USING AN AUTOCAD-SUPPORTED 2:1 METHOD
15⁰⁰-15¹⁵	Mustafa ÖZER	*Gazi University, Türkiye*	SHAPE CORRECTION FACTORS FOR RECTANGULAR FOOTINGS IN TERZAGHI'S BEARING CAPACITY EQUATION: A WELL-KNOWN MISCONCEPTION
15¹⁵-15³⁰	Nurullah BAŞARAN	*Batman University, Türkiye*	CLIMATE TYPE ANALYSIS OF BATMAN PROVINCE, ONE OF THE PROVINCES OF SOUTHEASTERN ANATOLIA REGION
15³⁰-15⁴⁵	Mustafa ÖZER	*Gazi University, Türkiye*	CALCULATION OF LOAD INCLINATION FACTORS FOR SHALLOW FOUNDATIONS UNDER BIDIRECTIONAL SEISMIC LOADING ACCORDING TO EUROCODE 7-3 (2025)
15⁴⁵-16⁰⁰	Fatma AĞIRMAN Fatih SAKA	*Karabük University, Türkiye*	PRECIPITATION DURATION CURVES: A CASE STUDY FOR ISTANBUL
16⁰⁰-16¹⁵	İbrahim Hakan ÜNAL Gökhan DURMUŞ	*Nuclear Regulatory Authority, Türkiye* *Gazi University, Türkiye*	STEEL REINFORCEMENT COMBINATION PROBLEMS AND SOLUTION SUGGESTIONS IN CONSTRUCTION
16¹⁵-16³⁰	El Fez Hashmi HYMABACCUS Ertan BOL	*Sakarya University, Türkiye*	EXPERIMENTAL INVESTIGATION OF THE USABILITY OF COARSE CHICKEN MANURE ASH IN SOIL IMPROVEMENT
16³⁰-16⁴⁵	Rüveyda EYÜPLER Aşkın ÖZOCAK	*Sakarya University, Türkiye*	CHANGE IN PORE WATER PRESSURE IN SINGLE AND DOUBLE-LAYERED SOILS
16⁴⁵-17⁰⁰	Aizhan ABILKHAIYRKYZY Murat ÖZTÜRK Adem DOĞANGÜN	*Bursa Uludag University, Türkiye*	EFFECT OF ELECTRIC ARC FURNACE SLAG ON THE MECHANICAL PERFORMANCE OF CEMENTITIOUS COMPOSITES
17⁰⁰-17¹⁵	Cevher Kürşat MACİT Burak TANYERİ Burak Samet ÖZGEN Mehmet TURAN	*Fırat University, Türkiye* *Fırat University, Türkiye* *SYCS Construction Cement Industry and Trade Joint Stock Company, Türkiye* *SYCS Construction Cement Industry and Trade Joint Stock Company, Türkiye*	DEVELOPMENT OF AN ENVIRONMENTALLY FRIENDLY CEM II/B-M (P-LL) 42.5R CEMENT: TECHNICAL, ECONOMIC AND ENVIRONMENTAL FEASIBILITY ANALYSIS
17¹⁵-17³⁰	Mehmet Yavuz KARABULUT	*Ankara Medipol University, Türkiye*	UHPC AND UHPRC IN CIVIL ENGINEERING

OTURUM (1) | GÜN (1) | SALON (3) – SESSION (1) | DAY (1) | HALL (3)

Başakşehir Salonu | Başakşehir Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14^{00}-17^{15} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Ersoy ÖZCAN* *COORDINATOR* *Berfin İpek SAKAOĞLU*
	Authors	**Affiliation**	**Topic title**
14^{00}-14^{15}	Hüsnü ULUÇAY Uğur FİDAN Yüksel OĞUZ	*Kütahya Provincial Directorate of Health, Türkiye* *Afyon Kocatepe University, Türkiye* *Afyon Kocatepe University, Türkiye*	ENGINEERING, ECONOMIC, AND ENVIRONMENTAL ASSESSMENT OF RETROFITTING PORTABLE MEDICAL DEVICES WITH LIFEPO$_4$ BATTERY PACKS
14^{15}-14^{30}	Ayşenur SEKİN	*Yildiz Technical University, Türkiye*	THE USE OF SMART METER DATA IN ANALYZING ELECTRICITY CONSUMPTION BEHAVIOR
14^{30}-14^{45}	Ayşenur SEKİN	*Yildiz Technical University, Türkiye*	THE ROLE OF RENEWABLE ENERGY SOURCES IN ENERGY TRANSFORMATION
14^{45}-15^{00}	Berk MERCAN	*Tekirdağ Namık Kemal University, Türkiye*	A COMPARATIVE EVALUATION OF ANALYTICAL, İNTEGRAL AND NUMERICAL APPROACHES FOR İNDUCTANCE CALCULATION İN FERROMAGNETIC MATERIALS
15^{00}-15^{15}	Harun Serhat GERÇEKCİOĞLU Selim CEYLAN	*Tokat Gaziosmanpaşa University, Türkiye*	A COLOR SENSING STUDY ON A CUSTOM-BUILT ROBOTIC ARM
15^{15}-15^{30}	Ömer ADAR Onur CİHAN	*Emory University, United States of America* *Marmara University, Türkiye*	A PROPOSED DECENTRALIZED FRAMEWORK FOR WIRELESS EV CHARGING IN GAZIANTEP
15^{30}-15^{45}	Harun Serhat GERÇEKCİOĞLU Abdourahmane BOYE	*Tokat Gaziosmanpaşa University, Türkiye*	DEVELOPMENT AND PERFORMANCE EVALUATION OF A HIGH-EFFICIENCY PMSM WITH STRATEGIES FOR TORQUE RIPPLE REDUCTION
15^{45}-16^{00}	Ersoy ÖZCAN Barış KARAKAYA	*Firat University, Türkiye*	ARTIFICIAL INTELLIGENCE–BASED FORECASTING OF ENERGY PRODUCTION IN SOLAR POWER PLANTS
16^{00}-16^{15}	Andaç KAYA	*Nurol Makina ve Sanayi A.Ş., Türkiye*	SENSOR FUSION BASED SITUATIONAL AWARENESS IN ARMORED LAND VEHICLES: CONCEPTUAL DESIGN AND ARCHITECTURAL PROPOSAL
16^{15}-16^{30}	Sedat AKSU Yüksel OĞUZ Tolga ÖZER	*Afyon Kocatepe University, Türkiye*	AN APPLICATION FOR WEATHER FORECASTING USING DEEP LEARNING BASED ON SKY IMAGES
16^{30}-16^{45}	Furkan SEVBEN Hakan PEKEY	*Kocaeli University, Türkiye*	A PROCESS-INTEGRATED CHEMICAL RISK ASSESSMENT FRAMEWORK FOR ELECTROPLATING LINES
16^{45}-17^{00}	Aziz BAŞDEMİR Erşah GÜCEL	*Vestel Home Appliances, Türkiye*	NEXT-GENERATION INTEGRATED POWER PLATFORM FOR ELECTRICAL SYSTEMS
17^{00}-17^{15}	Süleyman SAPMAZ	*Kocaeli University, Türkiye*	WASTE HEAT RECOVERY AND PCM-BASED THERMAL ENERGY STORAGE (TES) IN MOBILE DIESEL GENERATOR SYSTEMS FOR EMERGENCY APPLICATIONS

OTURUM (1) | GÜN (1) | SALON (4) – SESSION (1) | DAY (1) | HALL (4)

Başakşehir Salonu | Başakşehir Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14⁰⁰-17⁰⁰ (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Feyza KIYAR* *COORDINATOR* *Baha Ahmet YILMAZ*
	Authors	**Affiliation**	**Topic title**
14⁰⁰-14¹⁵	Nil SAZLI Deniz KARATAŞ	*Manisa Celal Bayar University, Türkiye*	PROMISING CANDIDATES FOR TYPE 2 DIABETES TREATMENT: BINDING AND ADMET PROFILES OF MICROALGAL ZEAXANTHIN ANALOGS AS INSULIN RECEPTOR KINASE MODULATORS
14¹⁵-14³⁰	Rukiye AKYÜZ Osman GÜNAY Fahrettin Fatih KESMEZACAR	*Yildiz Technical University, Türkiye* *Istanbul University-Cerrahpasa, Türkiye* *Istanbul University-Cerrahpasa, Türkiye*	THE EFFECT OF FLUOROSCOPY EXPOSURE ON THE FACIAL REGION DURING CERVICAL VERTEBRA SURGERY: A TLD-BASED DOSE ANALYSIS
14³⁰-14⁴⁵	Feyza KIYAR Kadir GÖK	*Izmir Bakircay University, Türkiye*	DIGITAL TWIN-BASED GEOMETRIC ERROR DETECTION IN DENTAL IMPLANT MANUFACTURING
14⁴⁵-15⁰⁰	Damla AYDOĞAN Seda Nur TOPKAYA Arif E. ÇETİN	*Izmir Biomedicine and Genome Center, Türkiye* *Izmir Bakircay University, Türkiye* *Dokuz Eylul University, Türkiye*	ENGINEERING A PORTABLE PLASMONIC BIOSENSOR PLATFORM FOR DETECTION OF BACTERIAL SEXUALLY TRANSMITTED INFECTION
15⁰⁰-15¹⁵	Duygu TUNÇMAN KAYAOKAY Osman GÜNAY Mustafa DEMİR Songül ÇAVDAR KARAÇAM	*Istanbul University – Cerrahpasa, Türkiye* *Yıldız Technical University, Türkiye* *Istanbul University – Cerrahpasa, Türkiye* *Istanbul University – Cerrahpasa, Türkiye*	EVALUATION OF SURFACE DOSES IN COMPUTED TOMOGRAPHY USING TLD: A COMPARATIVE PHANTOM STUDY WITH SSDE AND CTDI VOL
15¹⁵-15³⁰	Emrah DİKİCİ	*Agri Ibrahim Cecen University, Türkiye*	BEYOND TREATMENT: TRENDS FOCUSED ON RESOURCE RECOVERY AND ENERGY CONSERVATION IN MEMBRANE TECHNOLOGIES
15³⁰-15⁴⁵	Eda Nur GÜNEŞ Çiğdem YÖRÜR GÖRECİ	*Yıldız Technical University, Türkiye*	SYNTHESIS OF NEW HETEROARYL CHALCONE DERIVATIVES AND INVESTIGATION OF THEIR BIOLOGICAL ACTIVITIES
15⁴⁵-16⁰⁰	Ecem Nur DOKUZ Çiğdem YOLAÇAN	*Yıldız Technical University, Türkiye*	CLICK CHEMISTRY BASED SYNTHESIS OF NOVEL COUMARIN–INDOLE DERIVATIVES AS POTENTIAL DRUG CANDIDATES
16⁰⁰-16¹⁵	Beyzanur KAYA Yağmur YANIKTEPE Ali KARA	*Boğaziçi University, Türkiye* *Bursa Uludağ University, Türkiye* *Bursa Uludağ University, Türkiye*	EFFECTS OF THE ADSORBENT DOSAGE ON REMOVAL OF REACTIVE YELLOW 39 DYE VIA ADSORPTION
16¹⁵-16³⁰	Beyzanur KAYA Yağmur YANIKTEPE Ali KARA	*Boğaziçi University, Türkiye* *Bursa Uludağ University, Türkiye* *Bursa Uludağ University, Türkiye*	EFFECTS OF SOLUTION PH ON REMOVAL OF REACTIVE YELLOW 39 VIA ADSORPTION
16³⁰-16⁴⁵	Sarra BRIHOUM Sema Eylül AYYILDIZ Sedat KURNAZ	*Bolu Abant Izzet Baysal University, Türkiye* *Van Yüzüncü Yıl University, Türkiye* *Kastamonu University, Türkiye*	SYNTHESIS AND CHARACTERIZATION OF ULTRAFINE Fe 3 O 4 SPIONS PREPARED BY CO-PRECIPITATION

16^{45}-17^{00}	Mehmet YAŞAR	*Fırat University, Türkiye*	HEIGHT PROFILE OF THE FULL CONDUCTIVITY TENSOR (σ_{rr}–$\sigma\varphi\varphi$) IN GLOBAL COORDINATES FOR THE MID-LATITUDE IONOSPHERE

OTURUM (1) | GÜN (1) | SALON (5) – SESSION (1) | DAY (1) | HALL (5)

Ataşehir Salonu | Ataşehir Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *S.A JAFARZADE* *COORDINATOR* *Aydan RUSTEMLI*
	Authors	**Affiliation**	**Topic title**
14^{00}-14^{10}			
14^{10}-14^{20}	Ulviyya MAMMADOVA	*Ministry of Science and Education of Azerbaijan, Azerbaijan*	STUDY OF ECOSYSTEM DYNAMICS OF TUFAN GOL (LAKE) IN GUSAR, AZERBAIJAN: A COMPREHENSIVE SCIENTIFIC ANALYSIS
14^{20}-14^{30}	Rahmani MAHSA Babalar MESBAH	*University of Tehran, Iran*	EFFECT OF RATE NH4+/NO3-+NH4+TO K+, IONS UPTAKE ON PEACH TREES (PRUNUSPERSICA (L.) BATSCH. CVS. ALBERTA & ZAFERANI)
14^{30}-14^{40}	Rahmani MAHSA Babalar MESBAH	*University of Tehran, Iran*	EFFECT OF NUTRIENT SOLUTION ON VEGETATIVE TRAITS , CHLOROPHYLLS AND CAROTENOID OF PEACH TREES
14^{40}-14^{50}	Dris FARID D.Talantikite-TOUATI N.Ait AHMED	*University Of Bejaia, Algeria*	EFFECT OF ERBIUM DOPING ON THE STRUCTURAL AND OPTICAL PROPERTIES OF ZINC SULFIDE PREPARED BY HYDROTHERMAL METHOD
14^{50}-15^{00}	V VENKATASUBRAMANIAN	*Annamalai University, India*	SHORTEST JOB FIRST SCHEDULING ALGORITHM FOR TEMPORARY WIRELESS COMMUNICATION
15^{00}-15^{10}	V VENKATASUBRAMANIAN	*Annamalai University, India*	PRIORITY QUEUING FOR TEMPORARY WIRELESS COMMUNICATION
15^{10}-15^{20}	V VENKATASUBRAMANIAN	*Annamalai University, India*	BLACK HOLE ATTACK FOR MANET USING HYBRID ROUTING PROTOCOL
15^{20}-15^{30}	Dorina GUXHOLLI Valentina SHEHU	*Aleksandër Moisiu University, Albania*	STUDY OF THE HOPF BIFURTACION IN THE LORENZ SYSTEM
15^{30}-15^{40}	Huseynova Lala SAMADDIN	*Azerbaijan Medical University, Azerbaijan*	Q232Q, V245V AND L385L POLYMORPHISMS IN THE HUMAN PHENYLALANINE HYDROXYLASE GENE
15^{40}-15^{50}	Huseynova GULCHOHRA	*Institute of Soil Science and Agricultural Chemistry, Azerbaijan*	TRACES OF ECOLOGICAL TERRORISM: HAZARDOUS IMPACTS IN THE JABRAYIL DISTRICT
15^{50}-16^{00}	Ali JAFAROV Fatma ALIYEVA Musazade CASUR	*Institute of Soil Science and Agrochemistry, Azerbaijan*	AGROPHYSICAL PROPERTIES OF SOILS OF THE MUGAN PLAIN
16^{00}-16^{10}	Turkan Hasanova ALLAHVERDI Allahverdi Hasanov BIYAKIR	*Institute of Soil Science and Agrochemistry, Azerbaijan* *Institute of Control Systems, Azerbaijan*	DEVELOPMENT OF MATHEMATICAL MODELS FOR FERTILIZERS IN SHEKI REGION SOILS (AZERBAIJAN)

16^{10}-16^{20}	Samandar KOCHERLI Fatma ALIYEVA	*Institute of Soil Science and Agrochemistry, Azerbaijan*	COMPARATIVE ANALYSIS OF AGROPHYSICAL AND OPTICAL PROPERTIES OF SOILS OF THE MUGAN PLAIN
16^{20}-16^{30}	Tural Ahadov KAMAL Gunel Asgarova FARHAD	*Ministry of Science and Education Republic of Azerbaijan, Azerbaijan*	CHANGES IN MORPHOGENETIC INDICATORS OF SOIL IN THE LANKARAN REGION
16^{30}-16^{40}	Qarayev Elvin MAHIR	*ANAS, Sheki Regional Scientific Center, Azerbaijan*	NATIONAL LEADER HAYDER ALIYEV IS THE FOUNDER OF MODERN AZERBAIJAN EDUCATION
16^{40}-16^{50}	Idowu W. Akinde T. S. Adeleke R. A. Bello B. O.	*Federal University Dutsin-Ma, Nigeria* *Federal Polytechnic Ayede, Nigeria* *Federal Polytechnic Ayede, Nigeria* *University of Abuja, Nigeria*	EVALUATION OF GROWTH INDICES OF BRACHIARIA RUZIZIENSIS AS AFFECTED BY POULTRY MANURE APPLICATION AND STAGES OF HARVEST IN THE SUDAN SAVANNAH ZONE OF NIGERIA.
16^{40}-16^{50}	S.A. JAFARZADEH	*Ministry of Science and Education of Azerbaijan Republic, Azerbaijan*	RELATIVE EFFECTS ON ANTHROPOGENIC EFFECTS IN PYRUS L. SPECIES UNDER IN SITU AND EX SITU CONDITIONS IN GREATER CAUCASUS, AZERBAIJAN
16^{50}-17^{00}	Aygun Chingiz ISMAYILOVA	*Sheki Regional Scientific Centre of the Azerbaijan National Academy of Sciences, Azerbaijan*	THE DEVELOPMENT PROSPECTS OF COCOONING AND SERICULTURE IN SHEKI DISTRICT: EMPLOYMENT AND SOCIAL WELFARE IMPLICATIONS
17^{00}-17^{10}	Madina AMIRASLANOVA	*Azerbaijan National Aerospace Agency, Azerbaijan*	ANALYSIS OF MODERN METHODS OF SPACE MONITORING OF SOIL CONTAMINATED WITH PETROLEUM PRODUCTS

OTURUM (1) | GÜN (1) | SALON (6) – SESSION (1) | DAY (1) | HALL (6)

Başakşehir Salonu | Başakşehir Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Muhammad MOHSIN* *COORDINATOR* *Aytekin ZEYNALOVA*
	Authors	**Affiliation**	**Topic title**
14^{00}-14^{10}	Humaira NIAZ	*University of Agriculture, Pakistan*	MYCORRHIZAE-RHIZOBACTERIAL INTERACTION TO ENHANCE THE GROWTH, DEVELOPMENT, NUTRIENT CONTENT, AND PHYSIOLOGICAL ATTRIBUTES OF OKRA IN COMPOST AMENDED SOIL
14^{10}-14^{20}	Idowu W Akinde S T Aruwayo A	*Federal University Dutsin-Ma, Nigeria* *Federal Polytechnic Ayede, Nigeria* *Federal University Dutsin-Ma, Nigera*	PROXIMATE COMPOSITION OF BRACHIARIA RUZIZIENSIS AS AFFECTED BY COW DUNG AND CUTTING STAGES IN THE SAHEL SAVANNAH ZONE OF NIGERIA
14^{20}-14^{30}	R BOOMA M KAVASKAR	*Annamalai University, India* *Agricultural College, India*	A COMPREHENSIVE STUDY ON THE KNOWLEDGE LEVEL OF FARM YOUTH REGARDING THE CROP INSURANCE SCHEME IN THANJAVUR DISTRICT
14^{30}-14^{40}	Muhammad MOHSIN	*Hohai University, India*	SELF-ADAPTIVE PHOTONIC THERMAL MANAGEMENT BASED ON A FLEXIBLE METASURFACE
14^{40}-14^{50}	Kunanjambi MUPURUA Ateeq RAHMAN Hilja NDAKOLA	*University of Namibia, Namibia*	DETERMINING THE VARIABILITY IN GROUNDWATER QUALITY AROUND THE NUBUAMIS HAZARDOUS WASTE DUMPSITE, WINDHOEK
14^{50}-15^{00}	Pavithra L. Ragavi B.	*Nandha College of Technology, India* *Dr.NGP Institute of Technology, Coimbatore, India*	AN INTELLIGENT HEALTHCARE SYSTEM USING IOT IN WIRELESS SENSOR
15^{00}-15^{10}	Reguia BOUDRAA Djahida Talantikite-TOUATI Sarah BALIT Lotfi MOUNI	*University of Bejaia, Algeria*	COUPLING ADSORPTION-PHOTOCATALYTIC DEGRADATION OF SAFRANINE O DYE BY TERNARY NANOCOMPOSITE SUPPORTED ON NATURAL CLAY
15^{10}-15^{20}	Davina HIJAM Niketa ASHEM	*Regional Institute of Medical, India*	SFLT-1/PLGF AS A BIOMARKER OF PREECLAMPSIA (PE)
15^{20}-15^{30}	Ravinder SHARMA Anchal ARORA Vikas GUPTA	*The ICFAI University, India* *All India Institute of Medical Sciences, India* *Baba Farid University of Health Sciences, India*	A THERAPEUTIC JOURNEY OF FURAN DERIVATIVES AS A VERSATILE SCAFFOLD
15^{30}-15^{40}	Olatunji ONI	*University of Louisiana at Lafayette, United States of America*	EVALUATION OF SUSTAINABLE COMPOSITES OF SUGARCANE BAGASSE WITH MIXED ALGAE-SOY PROTEIN BINDERS
15^{40}-15^{50}	Moazam NIAZ	*Wichita State University, United States of America*	GREEN LOGISTICS PRACTICES: INTEGRATING RENEWABLE ENERGY AND SUSTAINABLE TRANSPORTATION ACROSS SUPPLY CHAINS
15^{50}-16^{00}	Kerimov Camal	*Azerbaycan Müasir İnnovasiyalar Lisesi, Azerbaijan*	QARABAĞIN FLORA VƏ FAUNASI
16^{00}-16^{10}	Hüseyn İMANOV	*Nakhchivan State University, Azerbaijan*	YAŞIL ENERJI NƏDIR? AZƏRBAYCANDA BU SAHƏDƏ GÖRÜLƏN IŞLƏR HANSILARDIR?
16^{10}-16^{20}	Hüseyn İMANOV	*Nakhchivan State University, Azerbaijan*	QARABAĞDA EKOSİD

16^{20}-16^{30}	RIYA	*Ranchi University, India*	NATURAL BIOACTIVE COMPOUNDS FROM WILD EDIBLE PLANT LEEA MACROPHYLLA ROXB. EX HORNEM
16^{30}-16^{40}	Endrit HASANI Afrim HAMIDI	*University of Prishtina, Kosovo* *Hungarian University, Hungary*	DETERMINATION OF COLIFORM BACTERIA IN MEAT PRODUCTS MARKETED IN KOSOVO
16^{40}-16^{50}	Endrit HASANI Livia DARNAY István DALMADI György KENESEI	*University of Prishtina, Kosovo* *University of Veterinary Medicine Budapest, Hungary* *University of Prishtina, Kosovo* *University of Prishtina, Kosovo*	COMBINED EFFECT OF SOUS VIDE AND FROZEN STORAGE ON TEXTURE ATTRIBUTES OF CHICKEN BREAST
16^{40}-16^{50}	Ermin C REVILLEZA	*REAMD Electric Power Industry Management Bureau, Philippines*	ASSESSMENT ON THE IMPLEMENTATION OF SECTION 59 OF THE ELECTRIC POWER INDUSTRY REFORM ACT OF 2001 TOWARDS POLICY ENHANCEMENT
16^{50}-17^{00}	Yousra MDARHRI Mohamed CHABBI Fakhita TOUHAMI Ahmed TOUHAMI	*Abdelmalek Essaadi University* *Abdelmalek Essaadi University, M* *Abdelmalek Essaadi University, Morocco* *University of Texas Rio Grande Valley, United States of America*	CHITIN AND CHITOSAN PRODUCTION FROM LOCAL SQUID PEN
17^{00}-17^{10}	Javed ALİ	*Mehran University, Pakistan*	PRETREATMENT OF MELANOIDINS USING ADVANCED TECHNIQUES TO ENHANCE DECOLORIZATION AND ANAEROBIC DIGESTION

OTURUM (1) | GÜN (1) | SALON (7) – SESSION (1) | DAY (1) | HALL (7)

Şişhane Salonu | Şişhane Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Javid NURMMADOV* *COORDINATOR* *Nurhkah SEYIDOV*
	Authors	**Affiliation**	**Topic title**
14^{00}-14^{10}	Mokhtari NARJISSE	*University Abdelmalek Essaadi, Morocco*	MINIMIZING AFLATOXIN CONTAMINATION IN PEANUT PROCESSING CHAIN THROUGH GOOD AGRICULTURAL, HYGIENIC, AND MANUFACTURING PRACTICES
14^{10}-14^{20}	A Y ABDULAZEEZ M I DABO F H MASANAWA	*College Of Science and Technology Kaduna Polytechnic, Nigeria*	EFFECT OF FILLER LOADING ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF YAM PEEL POWDER WITH UNSATURATED POLYESTER RESIN COMPISITE
14^{20}-14^{30}	Sana SAEED Naveed AHMED	*Mehran University of Science and Technology, Pakistan*	REMOVAL OF EMERGING CONTAMINANTS BY ADVANCED OXIDATION COUPLED DENITRIFICATION FROM WASTEWATER
14^{30}-14^{40}	Elnura SAFAROVA Zarifa ISMAYILOVA	*Azerbaijan State Pedagogical University, Azerbaijan*	FOR CLASSES VI-VII ON THE CONTENT LINE ANIMALS AND ENVIRONMENTOPPORTUNITIES FOR IMPARTING ENVIRONMENTAL KNOWLEDGE
14^{40}-14^{50}	Abubakar BALARABE Rabi MUSTAPHA Sanni Naseer AJOGE	*College of Science and Technology, Nigeria* *Kaduna State University, Nigeria* *College of Science and Technology, Nigeria*	AN EXPLAINABLE A.I FOR INTEGRATION OF KNOWLEDGE MANAGEMENT SYSTEMS AND INDUSTRIAL REVOLUTION 4.0. (IR4.0) TECHNOLOGIES
14^{50}-15^{00}	Javid NURMAMMADOV	*Baku State University, Azerbaijan*	LEVERAGİNG BALAKAN'S BİODİVERSİTY FOR SUSTAİNABLE TOURİSM OPPORTUNİTİES
15^{00}-15^{10}	Javid NURMAMMADOV	*Baku State University, Azerbaijan*	LEVERAGİNG BALAKAN'S BİODİVERSİTY FOR SUSTAİNABLE TOURİSM OPPORTUNİTİES
15^{10}-15^{20}	Gular MİRZAYEVA	*Baku State University, Azerbaijan*	ECOTOURİSM POTENTİAL OF SHUSHA'S NATURAL LANDSCAPES
15^{20}-15^{30}	Gizachew DIGA	*Jimma University, Ethiopia*	MONITORING EDDY CURRENT DENSITY FLUCTUATION AND POWER MANAGEMENT IN DOPED AL2O3 NANOWIRE

OTURUM (1) | GÜN (1) | SALON (8) – SESSION (1) | DAY (1) | HALL (8)

Karaköy Salonu | Karaköy Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Tim S BABU* *COORDINATOR* *Niyameddin SHUKUROV*
	Authors	**Affiliation**	**Topic title**
14^{00}-14^{10}	Yahaya M N Zumaru Z A Halilu A Bande A M	*Federal University Birnin Kebbi, Nigeria*	ASSESSING WIND POTENTIAL AS A PANACEA FOR SUSTAINABLE RURAL AND URBAN POWER USAGE
14^{10}-14^{20}	Tım S BABU	*Central University of Rajasthan, India*	ANALYSIS OF KNEE ANGLES IN INSTEP AND OUTSIDE KICKING TECHNIQUES IN FOOTBALL
14^{20}-14^{30}	Tım S BABU	*Central University of Rajasthan, India*	THE IMPACT OF SURYA NAMASKAR EXERCISE ON AGILITY PERFORMANCE AMONG RESIDENTIAL JUNIOR FOOTBALL
14^{30}-14^{40}	Tım S BABU	*Central University of Rajasthan, India*	COMPARATIVE ANALYSIS OF SPORTS COMPETITION ANXIETY: A STUDY OF UNIVERSITY-LEVEL FOOTBALL PLAYERS AT TWO DIFFERENT UNIVERSITIES IN INDIA
14^{40}-14^{50}	S K SHAKSHOOKI R M ALAEB F A AKARI Salima M EL-HAMRONI Amina M ELHAMMADY	*University of Tripoli, Libya*	CRYSTALLINE CERIUM PHOSPHATE-GLASSY ZIRCONIUM TITANIUM TELLURATES COMPOSITES SELF-DOPED AND SELF-SUPPORT POLYMERIZATION OF BENZIMIDAZOLE-CO-ANILINE, BENZIMIDAZOLE-CO-PYRROLE
14^{50}-15^{00}	RIYA	*Ranchi University, India*	PHARMACOGNOSTIC ACTIVITIES OF A WILD EDIBLE MEDICINAL PLANT LEEA MACROPHYLLA ROXB. EX HORNEM
15^{00}-15^{10}	Laraib SAEED	*Hohai University Nanjing, China*	EFFICIENCY OF WHEAT STRAW BIOCHAR IN COMBINATION WITH COMPOST AND BIOGAS SLURRY FOR ENHANCING NUTRITIONAL STATUS AND PRODUCTIVITY OF SOIL AND PLANT
15^{10}-15^{20}	Sania SAEED	*Hohai University Nanjing, China*	BIOCHAR IMPROVES PHOSPHORUS USE EFFICIENCY OF ORGANIC-INORGANIC FERTILIZERS, MAIZE-WHEAT PRODUCTIVITY AND SOIL QUALITY IN A LOW FERTILITY ALKALINE SOIL
15^{20}-15^{30}	Idowu W Akinde S T Aruwayo A	*Federal University Dutsin-Ma, Nigeria* *Federal Polytechnic Ayede, Nigeria* *Federal University Dutsin-Ma, Nigera*	PROXIMATE COMPOSITION OF BRACHIARIA RUZIZIENSIS AS AFFECTED BY COW DUNG AND CUTTING STAGES IN THE SAHEL SAVANNAH ZONE OF NIGERIA
15^{30}-15^{40}	K THAMIZHMARAN C Angala BHARATHI	*Government Engineering College, India*	INFRASTRUCTURE LESS SUPPORT BASED SECURE REACTIVE ROUTING PROTOCOL FOR MANETS
15^{40}-15^{50}	K THAMIZHMARAN P Latha MANGESHWARI	*Government Engineering College, India*	SECURE ROUTING FOR MOBILE AD HOC NETWORKS USING CRYPTOGRAPHY
15^{50}-16^{00}	K THAMIZHMARAN P Latha MANGESHWARI	*Government Engineering College, India*	SERVICE ORIENTATED DISTRIBUTED IN QUALITY OF SERVICE FOR MOBILE AD HOC NETWORKS
16^{00}-16^{10}	K THAMIZHMARAN Nithya K	*Government Engineering College, India*	COMPARISON OF DSDV AND OLSR WITH ATTACKS USING DCFM IN MANET

16^{10}-16^{20}	K THAMIZHMARAN Sanjana S	*Government Engineering College, India*	COMPARISON VARIOUS MODULATION METHODS USING INTER SATELLITE COMMUNICATION
16^{20}-16^{30}	B MADHUMITHA	*Government Engineering College, India*	SECURE ON-DEMAND DYNAMIC ROUTING PROTOCOL IN MOBILE AD HOC NETWORKS
16^{30}-16^{40}	N PRIYADHARSHINI	*Government Engineering College, India*	FUZZY LOGIC CONTROLLER USING MANET
16^{40}-16^{50}	Sindhupriya G	*Government Engineering College, India*	WEIGHTED FAIR QUEUING BASED SCHEDULING ALGORITHM IN WIRELESS NETWORK
16^{40}-16^{50}	B MADHUMITHA	*Government Engineering College, India*	ELIMINATE OF ACTIVE ATTACK FOR MANET USING HYBRID ROUTING PROTOCOL
16^{50}-17^{00}	Sindhupriya G	*Government Engineering College, India*	PRIORITY QUEUING IN SCHEDULING ALGORITHM IN INFRASTRUCTURELESS WIRELESS NETWORK
17^{00}-17^{10}	Preethy V	*Government Engineering College, India*	MANET ATTACKS USING FUZZY APPROACH

OTURUM (1) | GÜN (1) | SALON (9) – SESSION (1) | DAY (1) | HALL (9)

Eminönü Salonu | Eminönü Hall

MEETING ID: 831 4835 9437
PASSWORD: 841730

	20.02.2026	Time: 14^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Ramiz HUSEYNOV* *COORDINATOR* *Farahila BABAYEVA*
	Authors	**Affiliation**	**Topic title**
14^{00}-14^{10}	Yagubova SELIGA	*Azerbaijan State Petrol and Industrial University, Azerbaijan*	MODERN RADIOECOLOGICAL SITUATION AT ABSHERON OGED ENTERPRISE
14^{10}-14^{20}	Sevil SULEYMANOVA	*Ministry of Agriculture of Azerbaijan Republic, Azerbaijan*	PAULOWNIA (PAULÓWNIA): POSSIBILITIES OF APPLICATION IN SOLVING ENVIRONMENTAL PROBLEMS
14^{20}-14^{30}	Khayala YUNUSOVA	*Ministry of Agriculture of Azerbaijan Republic, Azerbaijan*	ECOLOGICAL CHARACTERISTICS OF CHERRY VARIETIES
14^{30}-14^{40}	Musayeva AYGUN Mustafayeva SEMAYE Memmedova ZEYNEB Huseynli ZEHRA Aytac ASKEROVA Melek EHMEDOVA	*Ministry of Agriculture of Azerbaijan Republic, Azerbaijan*	STUDY OF BIOREGIONAL CHARACTERISTICS OF LOCAL HAZELNUT CULTIVARS
14^{40}-14^{50}	Hajıyev ABBAS	*Ministry of Agriculture of Azerbaijan Republic, Azerbaijan*	THE TECHNOLOGY OF GROWING VEGETATIVE APPLE TREES WITH WOODED FENCES
14^{50}-15^{00}	Aynur ARABZADE	*Ministry of Agriculture of the Republic of Azerbaijan Scientific, Azerbaijan*	MORPHO-ANATOMICAL FEATURES OF MALUS NIEDZWETKYANA DIECK. SPECIES INTRODUCED IN ABSHERON
15^{00}-15^{10}	Musayeva AYGUN Mustafayeva SEMAYE Memmedova ZEYNEB Huseynli ZEHRA Askerova AYTAC Ehmedova MELEK	*Ministry of Science and Education of Azerbaijan, Azerbaijan*	STUDY OF BIOREGIONAL CHARACTERISTICS OF LOCAL NUT CULTIVARS
15^{10}-15^{20}	Mammadli Gultaj JOSHGUN	*Azerbaijan State Agrarian University, Azerbaijan*	ASSESSMENT OF THE TOURISM AND RECREATION POTENTIAL OF GAKH DISTRICT AND ITS DEVELOPMENT PROSPECTS
15^{20}-15^{30}	K THAMIZHMARAN	*Annamalai University, India*	A REVIEW OF SATELLITE INTERNET ' STAR LINK FOR LOW EARTH ORBIT
15^{30}-15^{40}	K THAMIZHMARAN	*Annamalai University, India*	MINI PROJECTOR COUPLED CAMERA FOR SIXTH SENSE TECHNOLOGY
15^{40}-15^{50}	NIYAMA ABDULLA	*Government College of Engineering, India*	A STUDY OF FUZZY LOGIC CONTROLLER
15^{50}-16^{00}	NIYAMA ABDULLA	*Government College of Engineering, India*	SECURE WIRELESS MOBILE AD HOC NETWORKS USING REACTIVE DYNAMIC ROUTING
16^{00}-16^{10}	NIYAMA ABDULLA	*Government College of Engineering, India*	A REVIEW OF SHORTEST PATH NETWORK
16^{10}-16^{20}	NIYAMA ABDULLA	*Government College of Engineering, India*	PERFORMANCE COMPARISON OF FUZZY LOGIC CONTROLLER – A STUDY
16^{20}-16^{30}	NIYAMA ABDULLA	*Government College of Engineering, India*	EFFECTIVE COMMUNICATION VARYING PARAMETERS FOR MOBILE AD HOC NETWORKS
16^{30}-16^{40}			

16^{40}-16^{50}	**Ramiz HUSEYNOV**	***Ministry of Agriculture of Azerbaijan Republic, Azerbaijan***	**ADVANCED STRUCTURAL DESIGN AND SEISMIC PERFORMANCE OPTIMIZATION IN MODERN URBAN INFRASTRUCTURE**
16^{40}-16^{50}	**Ramiz HUSEYNOV**	***Ministry of Agriculture of Azerbaijan Republic, Azerbaijan***	**ARTIFICIAL INTELLIGENCE DRIVEN PREDICTIVE MAINTENANCE SYSTEMS IN INDUSTRIAL ENGINEERING**
16^{50}-17^{00}	**Ramiz HUSEYNOV**	***Ministry of Agriculture of Azerbaijan Republic, Azerbaijan***	**SUSTAINABLE ENERGY STORAGE SOLUTIONS FOR NEXT GENERATION SMART GRIDS**
17^{00}-17^{10}	**Ramiz HUSEYNOV**	***Ministry of Agriculture of Azerbaijan Republic, Azerbaijan***	**AUTONOMOUS ROBOTICS AND HUMAN MACHINE COLLABORATION IN ADVANCED MANUFACTURING**

OTURUM (1) | GÜN (2) | SALON (1) – SESSION (1) | DAY (2) | HALL (1)

Taksim Salonu | Taksim Hall

MEETING ID: 869 4231 3188
PASSWORD: 217426

	21.02.2026	Time: 12^{00}-15^{00} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Oguzhan ÖZTÜRK* *COORDINATOR* *Berfin İpek SAKAOĞLU*
	Authors	**Affiliation**	**Topic title**
12^{00}-12^{15}	Miraç Umut KARA Safiye Nur ÖZDEMİR	*Sakarya University, Türkiye*	CFD-BASED THERMAL ANALYSIS OF LITHIUM ION BATTERY SYSTEMS
12^{15}-12^{30}	Ali ÇAKIR Mert Sinan TURGUT	*İzmir Demokrasi University, Türkiye*	EXPERIMENTAL AND THEORETICAL INVESTIGATION OF A REFRIGERATION SYSTEM USING R134A REFRIGERANT
12^{30}-12^{45}	Yaşar Seccat KESİCİ Evren Meltem TOYGAR	*Dokuz Eylul University, Türkiye*	TAGUCHI-BASED ANALYSIS OF THE EFFECTS OF INJECTION MOLDING PARAMETERS ON DIMENSIONAL SHRINKAGE IN VIRGIN, RECYCLED, AND HYBRID POLYPROPYLENE COMPOSITES
12^{45}-13^{00}	Oguzhan ÖZTÜRK Cemal MERAN Ömer EREN	*Nexans Turkey Industry, Türkiye* *Pamukkale University, Türkiye* *Nexans Turkey Industry, Türkiye*	INVESTIGATION AND COMPARISON OF CAPACITANCE IN MEDIUM VOLTAGE CABLES
13^{00}-13^{15}	Ömer Faruk ERTURUN Adem ÇİÇEK	*Ankara Yildirim Beyazit University, Türkiye*	INVESTIGATION OF THE EFFECTS OF CUTTING CONDITIONS ON GRINDING BURNS IN GEAR GRINDING PROCESS
13^{15}-13^{30}	Figen TAŞCI DURGUT	*Tekirdağ Namık Kemal University, Türkiye*	TURKISH AGRICULTURAL TECHNOLOGY ECOSYSTEM: LEVEL AND STRUCTURAL PROBLEMS OF AGRICULTURAL MECHANIZATION, R&D/INNOVATION DYNAMICS, ANALYSIS OF INCENTIVE ARCHITECTURE AND ROADMAP
13^{30}-13^{45}	Hüseyin KÖSE İsmail BAYAR	*Batman University, Türkiye*	EXPERIMENTAL INVESTIGATION OF THE EFFECT OF MICRO- AND NANO-SIO 2 PARTICLE REINFORCEMENT ON THE MECHANICAL AND TRIBOLOGICAL PROPERTIES OF EPOXY RESIN
13^{45}-14^{00}	Oğuzhan BOZOĞLU Mehmet ITİK Denis STOGL Mert Sinan TURGUT	*Izmir Demokrasi University, Türkiye* *B»robotized GmbH, Türkiye* *Izmir Dokuz Eylul University, Türkiye* *Izmir Demokrasi University, Türkiye*	LLM-ORCHESTRATED TOOL PIPELINE FOR AUTOMATED BEHAVIOR TREE EXECUTION IN ROBOT MANIPULATION
14^{00}-14^{15}	Muhammet Melih MEMİŞ Gökhan KÜÇÜKTÜRK	*Gazi University, Türkiye*	DEVELOPMENT OF A COMPOSITE PARTIALLY BIODEGRADABLE IMPLANT
14^{15}-14^{30}	Eda Nur İRİS Yasin SARIKAVAK	*Ankara Yıldırım Beyazıt University, Türkiye*	EFFECT OF SHOT PEENING PRESSURE AND IMPINGEMENT ANGLE ON THE SURFACE ROUGHNESS OF AA7075-T6
14^{30}-14^{45}	Sakine KIRATLI	*Cankiri Karatekin University, Türkiye*	EXPERIMENTAL INVESTIGATION OF SURFACE WETTABILITY IN GRAPHENE NANOPLATELETS-REINFORCED E- GLASS/CARBON-EPOXY HYBRID COMPOSITES
14^{45}-15^{00}	Selin KAPTAN İbrahim ÖZKOL	*Istanbul Technical University, Türkiye*	FREE VIBRATION ANALYSIS OF STEEL CANTILEVER BEAM CONSIDERING TEMPERATURE-DEPENDENT MATERIAL PROPERTIES

OTURUM (1) | GÜN (2) | SALON (2) – SESSION (1) | DAY (2) | HALL (2)

İstiklal Salonu | İstiklal Hall

MEETING ID: 869 4231 3188
PASSWORD: 217426

	21.02.2026	Time: 12^{00}-15^{00} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Emirhan YILMAZKAYA* *COORDINATOR* *Ufuk EZGİN*
	Authors	**Affiliation**	**Topic title**
12^{00}-12^{15}	Ahmet YAPMAZ Akay DELİHASAN Barış DOĞRU	*Istanbul Technical University, Türkiye*	A NUMERICAL INVESTIGATION ON UNBURNED HYDROCARBON EMISSION ELIMINATION OF AN SI ENGINE WITH A SHIFTED VALVE TIMING STRATEGY
12^{15}-12^{30}	Enes Levent KALKAN Şefik Ömer TURAN	*Kocaeli University, Türkiye*	INVESTIGATION OF THE EFFECT OF EPS HONEYCOMB STRUCTURE ON REDUCING SIDE IMPACT LOADS IN AUTOMOTIVE SEAT LATERAL SUPPORTS
12^{30}-12^{45}	Amar HASSAN Yasin VAROL Ş. Melih ŞENOCAK	*Fırat University, Türkiye* *Fırat University, Türkiye* *Osmaniye Korkut Ata University, Türkiye*	NUMERICAL INVESTIGATION OF THERMAL MANAGEMENT STRATEGIES FOR PRISMATIC NMC811 LITHIUM-ION BATTERY PACKS IN ELECTRIC VEHICLES
12^{45}-13^{00}	Murat AYDIN Tuğba YILMAZ AYDIN	*Isparta University of Applied Sciences, Türkiye*	DIGITAL FABRICATION OF EASY-TO-MANUFACTURE HYBRID CHAIR CONNECTORS
13^{00}-13^{15}	Faruk GÜMÜŞ Ahmet ÖZCAN	*Transportation Domestic and Foreign Trade Inc., Türkiye*	ROOT CAUSE ANALYSIS OF MAINTENANCE HATCH OPENING–CLOSING SAFETY IN URBAN PUBLIC TRANSPORTATION VEHICLES USING THE FISHBONE METHOD
13^{15}-13^{30}	Ömer AKMAN Mehmet İhsan KARAMANGİL Ahmet ÖZCAN	*Transportation Domestic and Foreign Trade Inc., Türkiye* *Bursa Uludağ University, Türkiye* *Transportation Domestic and Foreign Trade Inc., Türkiye*	STRUCTURAL VALIDATION AND WEIGHT OPTIMIZATION OF THE LE8 URBAN BUS BODY USING FINITE ELEMENT ANALYSIS
13^{30}-13^{45}	Yusuf AYAN	*Karabuk University, Türkiye*	IN-SITU ALLOYING PROCESS OF ER70S-6 LOW ALLOY STEEL WITH ER309L AUSTENITIC STAINLESS STEEL VIA WAAM
13^{45}-14^{00}	Emirhan YILMAZKAYA Bekir AKSOY	*Isparta University of Applied Sciences, Türkiye*	A SURVEY OF KNOWLEDGE RETRIEVAL, RELIABILITY CHALLENGES, AND MONITORING TECHNIQUES IN LARGE LANGUAGE MODELS
14^{00}-14^{15}	Emirhan YILMAZKAYA Bekir AKSOY	*Isparta University of Applied Sciences, Türkiye*	EXPLAINABLE ARTIFICIAL INTELLIGENCE: A SYSTEMATIC REVIEW ON INTERPRETABILITY, EXPLANATION METHODS, AND MODEL RELIABILITY
14^{15}-14^{30}	Ezgi ZENGİN Parvina IRGASHEVA	*Dokuz Eylül University, Türkiye*	EFFECTS OF ALLOYING A356 ALLOY WITH CU ON MICROSTRUCTURE, CORROSION BEHAVIOR AND MECHANICAL BEHAVIOR
14^{30}-14^{45}	Bahtiyar ÖZDEMİR Nimet KARDEŞ SEVER	*Pamukkale University, Türkiye*	THE IMPACT OF CLIMATE CHANGE ON THE POWER OUTAGE PERFORMANCE, INVESTMENT STRATEGIES, AND MAINTENANCE PLANNING OF ELECTRICITY DISTRIBUTION COMPANIES
14^{45}-15^{00}	Evren EREN Ahmet Baha İNAL	*Transportation Domestic and Foreign Trade Inc., Türkiye*	CONTROL OF PRODUCT TREE REVISIONS IN BUS DESIGN USING AN EXCEL MAKRO

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Kadıköy Salonu | Kadıköy Hall

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	21.02.2026	Time: 12^{00}-15^{00} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Hülya SAYGILI* *COORDINATOR* *Nigar EMECEN*
	Authors	**Affiliation**	**Topic title**
12^{00}-12^{15}	Adedoyin A. HUSSAIN	*Cyprus West University, Northern Cyprus*	A TASK SCHEDULING PROCESS IN THE CLOUD
12^{15}-12^{30}	Adedoyin A. HUSSAIN	*Cyprus West University, Northern Cyprus*	APPLICATION OF IMAGE PROCESSING AND MACHINE LEARNING IN ANALYSING AND PREDICTING FLOWERS IN THE FLORIST INDUSTRY: HET-NET AND BIG DATA ERA
12^{30}-12^{45}	Adedoyin A. HUSSAIN	*Cyprus West University, Northern Cyprus*	IMAGE ENHANCEMENT FOR DIGITAL IMAGES USING MACHINE LEARNING AND IMAGE PROCESSING
12^{45}-13^{00}	Adedoyin A. HUSSAIN	*Cyprus West University, Northern Cyprus*	TEXT SUMMARIZATION: COMPARISON OF EXTRACTIVE AND ABSTRACTIVE APPROACH
13^{00}-13^{15}	Pınar ERSOY Mustafa ERŞAHİN	*Commencis, Türkiye*	LEARNING-GATED ROBUST ESTIMATION AND SAFETY-PRESERVING CONTROL FOR CYBER–PHYSICAL ATTACK RESILIENCE IN CONNECTED WHITE APPLIANCES
13^{15}-13^{30}	Birkan BÜYÜKARIKAN Caner KARA	*Isparta University of Applied Sciences, Türkiye*	HYPERTENSIVE RETINOPATHY CLASSIFICATION WITH DINOV2 BASED SELF-SUPERVISED LEARNING AND SUPPORT VECTOR MACHINES
13^{30}-13^{45}	Hülya SAYGILI Meral KARAKURT	*Highways 8th Regional Directorate, Türkiye* *Osmaniye Korkut Ata University, Türkiye*	AUTOENCODER-BASED DIMENSIONALITY REDUCTION APPROACH AND COMPARATIVE DATA VISUALIZATION WITH PCA
13^{45}-14^{00}	Koray OĞUZ Volkan YAMAÇLI	*Mersin University, Türkiye*	PERFORMANCE ANALYSIS OF YOLOv8 AND FASTER R-CNN FOR DETECTING UNWANTED WORKPLACE BEHAVIOR WITH LIMITED DATASET
14^{00}-14^{15}	Ebutalib ÇELİK	*Çanakkale Onsekiz Mart University, Türkiye*	BIFURCATION OF SYMMETRIC FLOWS IN A DOUBLE-LID T-SHAPED CAVITY
14^{15}-14^{30}	Gülizar ALTINTAŞ Eren ÖZER Hasibe CANDAN KADEM Mustafa Özgür CİNGİZ	*Bursa Technical University, Türkiye*	ROBUST IOT INTRUSION DETECTION VIA OVERSAMPLING AND GRAPH LEARNING
14^{30}-14^{45}	Ali GÜNDÜZ İsmail AKGÜL	*Erzincan Binali Yıldırım University, Türkiye*	A COMPARATIVE SPEECH ENHANCEMENT ANALYSIS ON TURKISH AND ENGLISH LANGUAGES USING ATTENTION- BASED WAVE-U-NET ARCHITECTURE
14^{45}-15^{00}	Meral KARAKURT Hülya SAYGILI	*Osmaniye Korkut Ata University, Türkiye*	CANCER DIAGNOSIS WITH KARCIFANN METHOD

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Beylikdüzü Salonu | Beylikdüzü Hall

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	21.02.2026	Time: 12^{00}-15^{00} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Muhsin Zahid UĞUR* *COORDINATOR* *Baha Ahmet YILMAZ*
	Authors	**Affiliation**	**Topic title**
12^{00}-12^{15}	Fatih KOŞAR Müge EREL ÖZÇEVİK	*Manisa Celal Bayar University, Türkiye*	A COMPARATIVE ANALYSIS OF LEARNING MODELS AND REINFORCEMENT LEARNING FINE TUNING STRATEGIES FOR ENHANCING GENERALIZATION IN INDUSTRIAL DEXTEROUS MANIPULATION
12^{15}-12^{30}	Muhammet ALKAN Müge EREL ÖZÇEVİK	*Manisa Celal Bayar University, Türkiye*	COMPARATIVE ANALYSIS OF MICROSERVICES AND MONOLITHIC ARCHITECTURES IN CLOUD ENVIRONMENTS: A PRACTICAL IMPLEMENTATION WITH JAVA AND SPRING BOOT
12^{30}-12^{45}	Muhammed GİDER Müge EREL ÖZÇEVİK	*Manisa Celal Bayar University, Türkiye*	A NOVEL QUEUING THEORY BASED TRIAGE MANAGEMENT: A CASE STUDY PERFORMED IN MATLAB SIMULINK
12^{45}-13^{00}	Alev ATEŞ ÇOBANOĞLU İlkim Benay ÖZENBAY Eralp ALTUN Bahadır NAMDAR	*Ege University, Türkiye* *Buca Kozağaç Abdülhamit Han Secondary School, Türkiye* *Ege University, Türkiye* *Ege University, Türkiye*	TURKISH PRESERVICE SCIENCE TEACHERS' USE OF GENERATIVE ARTIFICIAL INTELLIGENCE AND THEIR PERCEIVED COMPETENCIES
13^{00}-13^{15}	Ali Atia Ali KOUNDI İsmail Hakkı CEDİMOĞLU	*Sakarya University, Türkiye*	APPLIED EVALUATION OF A POLICY-SENSITIVE TEXT-TO-SQL AGENT WITH POSTGRESQL ROW-LEVEL SECURITY (RLS) FOR DETERMINISTIC ACCESS CONTROL
13^{15}-13^{30}	Zehra Begüm AKTOLGA İsmail Hakkı CEDİMOĞLU	*Sakarya University, Türkiye*	BALANCING PRIVACY AND UTILITY IN MACHINE LEARNING: A STUDY ON DATA ANONYMIZATION AND MODEL PERFORMANCE
13^{30}-13^{45}	Reyhan METİN Büşra TEKİN Yunus Nusret ŞAHİN	*Turkish Technology, Türkiye*	GENERATIVE AI AS A FORCE MULTIPLIER FOR SOCIAL ENGINEERING
13^{45}-14^{00}	Muhsin Zahid UĞUR	*University of Health Sciences, Türkiye*	CROSS-PLATFORM FRAMEWORKS AND MOBILE ACCESSIBILITY: A COMPARATIVE ANALYSIS OF TOUCH TARGET COMPLIANCE IN NATIVE, REACT NATIVE, AND FLUTTER ANDROID APPLICATIONS
14^{00}-14^{15}	Muhsin Zahid UĞUR	*University of Health Sciences, Türkiye*	THE REASONING PARADOX: WHEN EXTENDED THINKING LEADS TO ARCHITECTURAL OVER-ENGINEERING IN MOBILE UIS
14^{15}-14^{30}	Rahaf Abou BAKAR Mustafa YILMAZ	*Gaziantep University, Türkiye*	ENHANCING EARLY RETINAL DISEASE DETECTION THROUGH CONVOLUTIONAL NEURAL NETWORK (CNN) AS AN ARTIFICIAL INTELLIGENCE (AI) APPLICATION IN MEDICINE
14^{30}-14^{45}	Seyhan PULLUKÇU Betül ÇINAR Haynunnisa DEĞİRMENCİ	*Fatih Islam Secen Science and Art Center, Türkiye*	THE TIMELINE OF MATHEMATICS: AN INTERACTIVE ATLAS OF THE HISTORY OF SCIENCE ENRICHED WITH ARTIFICIAL INTELLIGENCE AND WEB2 TOOLS
14^{45}-15^{00}	Volkan EFECAN	*Mersin University, Türkiye*	CYBERSECURITY RISKS IN DIGITAL MARITIME APPLICATIONS: CURRENT SITUATION AND FUTURE PROJECTIONS

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	21.02.2026	Time: 15^{00}-17^{45} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Selim BÜYÜKPOYRAZ* *COORDINATOR* *Berfin İpek SAKAOĞLU*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{15}	Muhammet ÇİL	*Düzce University, Türkiye*	A STUDY ON FACTORS AFFECTING OCCUPATIONAL STRESS AMONG WORKERS IN THE FOREST PRODUCTS SECTOR
15^{15}-15^{30}	Melike Büşra BAYRAMOĞLU KARŞI	*Bolu Abant Izzet Baysal University, Türkiye*	TRAFFIC-RELATED LEAD (PB) POLLUTION: A CONCEPTUAL EVALUATION OF TRANSPORT PATHWAYS FROM ROAD DUST TO AGRICULTURAL SOILS AND PLANT PRODUCTS
15^{30}-15^{45}	Sinan ACUN Hakan PEKEY Mesud DURDU Soner AKGÜN	*Kocaeli University, Türkiye* *Kocaeli University, Türkiye* *Kocaeli Water and Sewerage Administration General Directorate, Türkiye* *Kocaeli Water and Sewerage Administration General Directorate, Türkiye*	REMOVAL OF MANGANESE AND COLIFORM FROM GROUNDWATER IN A PILOT-SCALE DRINKING WATER TREATMENT SYSTEM
15^{45}-16^{00}	N. Kamil SALİHOĞLU Selim BÜYÜKPOYRAZ	*Bursa Uludağ University, Türkiye*	ASSESSMENT OF ENVIRONMENTAL IMPACTS IN POLYESTER YARN PRODUCTION PROCESSES AND ECO- EFFICIENCY-BASED IMPROVEMENT APPROACHES
16^{00}-16^{15}	Aleyna ŞENEL Ceyhun AKARSU Nüket SİVRİ	*Istanbul Cerrahpasa-University, Türkiye*	MICRO-SCALE CARBON FOOTPRINT ASSESSMENT AND CARBON NEUTRAL TRANSITION SCENARIO FOR A UNIVERSITY CLASSROOM
16^{15}-16^{30}	Ayşe Şevval MERMER Ceyhun AKARSU Nüket SİVRİ	*Istanbul Cerrahpasa-University, Türkiye*	ASSESSING CARBON FOOTPRINTS IN DRINKING WATER TREATMENT: COMPARATIVE ANALYSIS OF ARSENIC AND MANGANESE REMOVAL PLANTS
16^{30}-16^{45}	Mustafa Burak HIZ Ceyhun AKARSU Nüket SİVRİ	*Istanbul Cerrahpasa-University, Türkiye*	PIPE AGING AS A POTENTIAL DRIVER OF SECONDARY MICROPLASTIC CONTAMINATION IN DRINKING WATER DISTRIBUTION SYSTEMS: A CASE STUDY FROM ERGENE DISTRICT, TEKİRDAĞ PROVINCE, TÜRKİYE
16^{45}-17^{00}	Ayşenur TURAN BEKİR Ceyhun AKARSU Nüket SİVRİ	*Istanbul Cerrahpasa-University, Türkiye*	PLASTIC PELLET POLLUTION AS A SYSTEMIC RISK IN GLOBAL MARITIME TRANSPORT
17^{00}-17^{15}	Nevin YILDIRIM Mustafa ALTINOK Hakan KESKİN	*Gazi University, Türkiye* *Konya Karatay University, Türkiye* *Gazi University, Türkiye*	DETERMINATION OF HEAT TRANSFER AND TEMPERATURE CONDUCTIVITY PROPERTIES OF WOODEN PANELS PRODUCED FROM SUNFLOWER STALK AND WOOD SHAVINGS
17^{15}-17^{30}	İrem DEMİRCİ Neslihan TOP	*Gazi University, Türkiye*	CORE ARCHITECTURE EFFECTS ON THE STRUCTURAL PERFORMANCE OF HYBRID

			SANDWICH COMPOSITES FOR AEROSPACE APPLICATIONS
17^{30}-17^{45}	**Sami KAYA Okan YAZICIOĞLU**	***Kırşehir Ahi Evran University, Türkiye***	**LENGTH-WEIGHT AND LENGTH-LENGTH RELATIONSHIPS OF YELLOWSTRIPE BARRACUDA (SPHYRAENA CHRYSOTAENIA KLUNZINGER, 1884) IN İSKENDERUN BAY**
17^{45}-18^{00}	**Müşerref YÜCE Ece YAĞMUR**	***Konya Technical University, Türkiye***	**SUITABILITY ANALYSIS OF EMERGENCY ASSEMBLY AREAS USING MULTI CRITERIA DECISION MAKING (MCDM) METHODS: A CASE STUDY OF KONYA**

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	21.02.2026	Time: 15^{00}-17^{45} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Makbule KAPLAN ÖZEKES* *COORDINATOR* *Nigar EMECEN*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{15}	Yasemin KARABABA	*Bilecik Şeyh Edebali University, Türkiye*	METALLIC–PARACONTACT CORRESPONDENCE VIA ALMOST PRODUCT STRUCTURES
15^{15}-15^{30}	Makbule KAPLAN ÖZEKES	*Sinop University, Türkiye*	A GEODESIC FOUR-STEP ITERATIVE SCHEME FOR MULTIVALUED GENERALIZED A-NONEXPANSIVE MAPPINGS IN CAT(0) SPACES
15^{30}-15^{45}	Nilay Nurcan ŞENHALLI Sebahattin BEKTAŞ	*Ondokuz Mayis University, Türkiye*	A COMPARISON OF TRAVERSE ADJUSTMENT METHODS
15^{45}-16^{00}	Havva ÇALIŞKAN Hülya OLMUŞ	*Gazi University, Türkiye*	ORDERED LOGISTIC REGRESSION ANALYSIS WITH MACHINE LEARNING-BASED VARIABLE SELECTION
16^{00}-16^{15}	Selime Beyza ÖZÇEVİK Abdullah DERTLİ Savaş KARAAHMETOĞLU	*Yüksek Ihtisas University, Türkiye* *Ondokuz Mayis University, Türkiye* *Göl Adeka Multi Program Anatolian High School, Türkiye*	ON PROPERTIES HYBRID NUMBERS WITH COMPLEX FIBONACCI COEFFICIENTS
16^{15}-16^{30}	Anıl ALTINKAYA	*Gazi University, Türkiye*	TUBULAR SURFACES IN THE 3-DIMENSIONAL LIE GROUP
16^{30}-16^{45}	Tuğba DİKER	*Dicle University, Türkiye*	RELATIONSHIP BETWEEN ARTIFICIAL INTELLIGENCE AND MATHEMATICS
16^{45}-17^{00}	Asuman YILMAZ	*Van Yüzüncü Yıl University, Türkiye*	STATISTICAL INFERENCE FOR ALPHA POWER EXPONENTIAL DISTRIBUTION
17^{00}-17^{15}	Alı Nashwan Jameel ALDULAIMI Sebahattin BEKTAŞ	*Ondokuz Mayis University, Türkiye*	COMPARATIVE ANALYSIS OF UAV PHOTOGRAMMETRY AND TRADITIONAL TERRESTRIAL SURVEYING TECHNIQUES FOR LANDSLIDE MONITORING: A CASE STUDY IN SAMSUN
17^{15}-17^{30}	Flora Namenya OUNDO Sedat SERT	*Sakarya University, Türkiye*	A STUDY ON THE USE OF FİNE-GRAİNED POULTRY WASTE ASH İN SOİL IMPROVEMENT
17^{30}-17^{45}	Ahmet GÜZEL	*Batman University, Türkiye*	ANALYSIS OF THE HIGHER-ORDER ROBERT-ASSELIN-WILLIAMS (HORAW) TIME FILTER FOR IMEX DISCRETIZATIONS IN EVOLUTION EQUATIONS

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	21.02.2026	Time: 15^{00}-17^{45} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Aybüke BERK* *COORDINATOR* *Ufuk EZGİN*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{15}	Hatice ÜSTÜNER Hüseyin SERVİ Muhittin DİNÇ Mustafa YAVUZ Timur Hakan BARAK	*Konyaaltı Science and Art Center, Türkiye* *İstanbul Yeni Yüzyıl University, Türkiye* *Necmettin Erbakan University, Türkiye* *Akdeniz University, Türkiye* *Acıbadem Mehmet Ali Aydınlar University, Türkiye*	IN VITRO PROPAGATION OF ENDEMIC STACHYS EUADENIA P.H. DAVIS, PHYTOCHEMICAL COMPARISON OF WILD AND CULTURED PLANTS
15^{15}-15^{30}	Fatma Beyza AKIN Nurcihan HACIOĞLU DOĞRU	*Çanakkale Onsekiz Mart University, Türkiye*	HEAVY METAL BIOREMEDIATION WITH NATIVE SOIL BACTERIA
15^{30}-15^{45}	Anıl CEBECİ Halil Erhan EROĞLU	*Yozgat Bozok University, Türkiye*	GREEN SYNTHESIS OF IRON OXIDE NANOPARTICLES USING AQUEOUS EXTRACT OF RUMEX ACETOSELLA
15^{45}-16^{00}	Anıl CEBECİ Halil Erhan EROĞLU	*Yozgat Bozok University, Türkiye*	KARYOLOGICAL VARIATIONS AND KARYOTYPE ASYMMETRY IN MORUS ALBA (MORACEAE)
16^{00}-16^{15}	Fatih TAŞTAN Emine Tuğçe SARAÇ CEBECİ Hatice BAŞ	*Yozgat Bozok University, Türkiye*	THYMUS ARGAEUS BOISSIER BALANSA (LAMIACEAE): INSECTICIDAL ACTIVITY AGAINST GALLERIA MELLONELLA (L.) (LEPIDOPTERA:PYRALIDAE)
16^{15}-16^{30}	Emine Tuğçe SARAÇ CEBECİ Fatih TAŞTAN Hatice BAŞ	*Yozgat Bozok University, Türkiye*	ASSESSMENT OF MEDICAGO SATIVA L. (FABACEAE) AS A NATURAL ANTIBACTERIAL AGENT
16^{30}-16^{45}	Aybüke BERK Mehmet Gökhan HALICI Mithat GÜLLÜ	*Erciyes University, Türkiye*	ANTIMICROBIAL EFFECTS OF METHANOLIC EXTRACTS OBTAINED FROM COPRINELLUS SP. AND AMANITA SP. COLLECTED FROM THE IHLARA VALLEY ON ESCHERICHIA COLI AND CORYNEBACTERIUM RENALE
16^{45}-17^{00}	Mithat GÜLLÜ Fatma ÖZTÜRK KÜP Mehmet Gökhan HALICI	*Erciyes University, Türkiye*	CHEMOTAXONOMIC SIGNIFICANCE OF C AND K SPOT TEST REACTIONS IN SELECTED ACAROSPORA SPECIES AND A β-TUBULIN-BASED PHYLOGENETIC APPROACH
17^{00}-17^{15}	Ahsen KARAGÜZEL Pınar GOC RASGELE Serpil UĞRAŞ	*Duzce University, Türkiye*	ANTIBACTERIAL EFFICACY AND CYTOGENETIC ASSESSMENT OF ZINC PYRITHIONE (ZnPT)
17^{15}-17^{30}	Nihal DURMAZ Pınar GOC RASGELE Serpil UĞRAŞ	*Duzce University, Türkiye*	A STUDY ON INVESTIGATING THE CYTOGENOTOXICITY AND PROTECTIVE EFFECT OF QUERCETIN AGAINST ALUMINUM TOXICITY IN THE ALLIUM CEPA L. MODEL
17^{30}-17^{45}	Samet KOCABAY	*Inonu University, Türkiye*	NATURAL PRODUCT-BASED MANAGEMENT OF HYPERGLYCEMIA: COMPUTATIONAL AND EXPERIMENTAL ANALYSIS OF CAFFEIC ACID AND PEITC

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	21.02.2026	Time: 15^{00}-17^{00} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Muhammed Yusuf ÇAĞLAR* *COORDINATOR* *Baha Ahmet YILMAZ*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{15}	Nurbanu DOĞRU Güliz HASKARACA	*Sakarya University, Türkiye*	VITAMIN C ENCAPSULATION FOR FUNCTIONAL FOOD APPLICATIONS: CARRIER SYSTEMS AND TECHNOLOGICAL APPROACHES
15^{15}-15^{30}	Büşra ÇELIK Güliz HASKARACA	*Sakarya University, Türkiye*	MODIFICATION OF COLLAGEN PEPTIDES AND IMPROVEMENT OF THEIR FUNCTIONAL PROPERTIES
15^{30}-15^{45}	Zeynep AKÇA Güliz HASKARACA	*Sakarya University, Türkiye*	EDIBLE COATING APPLICATIONS IN RED MEAT PRESERVATION
15^{45}-16^{00}	Sevde BAYRAKTAROĞLU Görkem ÖZÜLKÜ	*Yıldız Technical University, Türkiye*	EFFECTS OF AMYLOLYTIC ENZYMES ON DOUGH AND BREAD QUALITY IN CONVENTIONAL AND FROZEN DOUGH PROCESSES
16^{00}-16^{15}	Eda ADAL	*Çukurova University, Türkiye*	RECENT TRENDS IN FUNCTIONAL FOODS IN TURKEY AND GLOBAL MARKETS
16^{15}-16^{30}	Eda ADAL	*Çukurova University, Türkiye*	FUNCTIONAL COMPONENTS ENHANCING IMMUNE SYSTEM: NUTRITION AND MICROBIOTA PERSPECTIVE
16^{30}-16^{45}	Muhammed Yusuf ÇAĞLAR	*Ağrı İbrahim Çeçen University, Türkiye*	ARTIFICIAL INTELLIGENCE–BASED RISK ASSESSMENT MODELS IN HALAL FOOD CERTIFICATION: A CONCEPTUAL FRAMEWORK FOR DIGITAL DECISION SUPPORT SYSTEMS
16^{45}-17^{00}	Muhammed Yusuf ÇAĞLAR	*Ağrı İbrahim Çeçen University, Türkiye*	PACKAGING MATERIALS AND MIGRATION ISSUES IN HALAL FOODS: HIDDEN RISKS IN HALAL COMPLIANCE

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	21.02.2026	Time: 15^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *K THAMIZHMARAN*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{10}	Katia BENYAKOUB Mourad KEDDAM Brahim BOUMAALI Michał KULKA	*Huari Boumedien University of Science and Technology, Algeria* *Huari Boumedien University of Science and Technology, Algeria* *Huari Boumedien University of Science and Technology, Algeria* *Poznan University of Technology, Poland*	KINETIC MODELLING OF POWDER-PACK BORONIZED 4CR5MOSIV1 STEEL BY THE BILAYER MODEL
15^{10}-15^{20}	G ROSHINI	*Government College of Engineering, India*	NOVEL DISPLAY DESIGN
15^{20}-15^{30}	G ROSHINI	*Government College of Engineering, India*	SMART FARMING FOR IOT
15^{30}-15^{40}	M SABITHA K THAMIZHMARAN	*Government College of Engineering, India*	WIRELESS MEDIUM TECHNOLOGY
15^{40}-15^{50}	P DEVADHARSHINI K THAMIZHMARAN	*Government College of Engineering, India*	IMAGE TECHNOLOGY
15^{50}-16^{00}	B MADHUMITHA K THAMIZHMARAN	*Government College of Engineering, India*	SECURE APPROACH FOR MOBILE AD HOC NETWORKS
16^{00}-16^{10}	P DEVADHARSHINI K THAMIZHMARAN	*Government College of Engineering, India*	FLYING AD HOC NETWORKS
15^{10}-15^{20}	K THAMIZHMARAN B MADHUMITHA	*Government College of Engineering, India*	SCHEDULING ALGORITHM IN INFRASTRUCTURELESS WIRELESS NETWORKS
15^{20}-15^{30}	S PRIYADHARSINI K THAMIZHMARAN	*Government College of Engineering, India*	A STUDY OF DATA SECURITY
15^{30}-15^{40}	S PRIYADHARSINI K THAMIZHMARAN	*Government College of Engineering, India*	BUSINESS ORGANIZATION
15^{40}-15^{50}	S PRIYADHARSINI K THAMIZHMARAN	*Government College of Engineering, India*	HYBRID LINK STATE FOR MOBILE AD HOC NETWORKS
15^{50}-16^{00}	S PRIYADHARSINI K THAMIZHMARAN	*Government College of Engineering, India*	SENSOR NODE LIFETIME USING MULTI-GEOGRAPHICAL ROUTING PROTOCOL
16^{00}-16^{10}	K THAMIZHMARAN	*Government College of Engineering, India*	SATELLITE COMMUNICATION LINKS
16^{10}-16^{20}	S PRIYADHARSINI K THAMIZHMARAN	*Government College of Engineering, India*	ACKNOWLEDGEMENTS WITH CRYPTOGRAPHY FOR MANET
16^{20}-16^{30}	V PREETHY K THAMIZHMARAN	*Government College of Engineering, India*	SIMULATION ANALYSIS OF ALGORITHM IN MANETS
16^{30}-16^{40}	V PREETHY K THAMIZHMARAN	*Government College of Engineering, India*	WIRELESS COMMUNICATION
16^{40}-16^{50}	B MADHUMITHA K THAMIZHMARAN	*Government College of Engineering, India*	HYBRID ROUTING PROTOCOL

16^{40}-16^{50}	Govinda PAL Amit BISWAS Nimai Das BAIRAGYA Ankita BANERJEE	*Haldia Institute of Technology, India*	A HOLISTIC APPROACH TO HAND TOOL AND MACHINERY DEVELOPMENT: PHYSIOLOGY AND PSYCHOLOGY INTEGRATION
16^{50}-17^{00}	Rahmani MAHSA Babalar MESBAH Mahsa RAHMANI	*University of Tehran, Iran*	EFFECT OF RATE NH 4 + /NO 3 - +NH 4 + TO K + , IONS UPTAKE ON PEACH TREES (PRUNUS PERSICA (L.) BATSCH. CVS. ALBERTA & ZAFERANI)
17^{00}-17^{10}	Rahmani MAHSA Babalar MESBAH Mahsa RAHMANI	*University of Tehran, Iran*	EFFECT OF NUTRIENT SOLUTION ON VEGETATIVE TRAITS , CHLOROPHYLLS AND CAROTENOID OF PEACH TREES

OTURUM (2) | GÜN (2) | SALON (6) – SESSION (2) | DAY (2) | HALL (6)

Karaköy Salonu | Karaköy Hall

MEETING ID: 869 4231 3188
PASSWORD: 217426

	21.02.2026	Time: 15^{00}-16^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Raul D.S.G. CAMPILHO*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{10}	Ağabalayev Qafqaz MƏHƏMMƏDHƏSƏN Qarayev Elvin MAHIR	*AMEA, Şəki Regional Elmi Mərkəzi, Azerbaijan*	İQTİSADİYYATIN ƏSAS SAHƏLƏRİ ÜZRƏ MƏHSUL BURAXILIŞININ DİNAMİKASI VƏ STRUKTUR TƏHLİLİ (2018–2023-CÜ İLLƏR) (BALAKƏN RAYONU ÜZRƏ)
15^{10}-15^{20}	Auwal IBRAHIM Ibrahim Lawal KANKARA Muktar BABAGANA	*Kaduna Polytechnic, Nigeria*	ASSESSMENT OF HEAVY METAL CONTAMINATION IN COMMERCIAL FLOUR BRANDS FROM KADUNA METROPOLIS, NIGERIA: A HEALTH RISK ASSESSMENT STUDY
15^{20}-15^{30}	Shubhangi BHARADWAJ	*OFK Government College, India*	ARTIFICIAL INTELLIGENCE AND HUMAN RESOURCE MANAGEMENT: TRANSFORMING THE FUTURE OF WORK
15^{30}-15^{40}	Shubhangi BHARADWAJ	*OFK Government College, India*	RIGID HIERARCHIES TO DYNAMIC, HUMAN-AI SYMBIOTIC FRAMEWORKS
15^{40}-15^{50}	Fatima ABUBAKAR Jamila Bashir YAKASAI Mukhtar YUSUF	*Kaduna Polytechnic, Nigeria* *National Water Resources Institute, Nigeria* *Kaduna Polytechnic, Nigeria*	GREEN SYNTHESIS AND CHARACTERIZATION OF NANO FERTILIZER USING DAMAGI PLANT EXTRACT (Chrozophora Senegalensis)
15^{50}-16^{00}	Fatima ABUBAKAR Jamila Bashir YAKASAI Mukhtar YUSUF	*Kaduna Polytechnic, Nigeria* *National Water Resources Institute, Nigeria* *Kaduna Polytechnic, Nigeria*	PROXIMATE AND HEAVY METALS DETERMINATION OF GOAT ORGANS SOLD IN ZANGO ABATTOIR MARKET KADUNA, NIGERIA
16^{00}-16^{10}	Rafael R. ROCHA Raul D. F. MOREIRA Raul D.S.G. CAMPILHO	*Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal* *University of Porto, Portugal* *Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal*	ANALYSIS OF WOOD/PLYWOOD JOINTS IN LARGE PALLETS USING NUMERICAL FINITE ELEMENT ANALYSIS
15^{10}-15^{20}	Hajar CHAHI Said HAKIMI	*University of Sultan Moulay Slimane, Morocco*	EXISTENCE OF NONNEGATIVE SOLUTIONS FOR A CLASS OF SEMIPOSITONE PROBLEMS IN A BALL
15^{20}-15^{30}	Raul D.S.G. CAMPILHO Raul D. F. MOREIRA	*Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal* *University of Porto, Portugal*	LUBRICATION EFFICIENCY ASSESSMENT IN AUTOMATED AUTOMOTIVE COMPONENT FABRICATION
15^{30}-15^{40}	Lucas L. SILVA Raul D.S.G. CAMPILHO	*Institute of Science and Innovation in Mechanical and Industrial Engineering, Portugal*	NUMERICAL MODELLING OF A ROBUST STEEL PALLET FOR OVERSIZED SHAFT TRANSPORT
15^{40}-15^{50}	Ramesh R Seenivasan M Kannan M. Jagatheesan R.	*Arignar Anna Government Arts College, India* *DDE Annamalai University, India* *Arignar Anna Government Arts College*	ANALYSIS OF FUZZY PREEMPTIVE REPEAT PRIORITY QUEUE WITH RESAMPLING

	Gunasekar. T.	***Salem Sowdeswari College, India*** ***Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, India***	
15^{50}-16^{00}	**Ramesh R** **Seenivasan M** **Rajasekar S P** **Hari Ganesh A** **Pattabiraman. K**	***Arignar Anna Government Arts College, India*** ***DDE Annamalai University, India*** ***Arignar Anna Government Arts College, India*** ***Poombuhar College, India*** ***Government Arts College, India***	**SIMULATION ON FUZZY M/M/1 QUEUEING MODELS IN FUZZY ENVIRONMENT**
16^{00}-16^{10}	**Ramesh R** **Nathiya. R** **Seenivasan M** **Syamala. P** **Sakthivel K**	***Arignar Anna Government Arts College, India*** ***Affiliated to Bharathidasan University, India*** ***DDE Annamalai University, India*** ***AVVM Sri Pushpam College, India*** ***Arignar Anna Government Arts College, India***	**FUZZY ANALYSIS IN INTERVAL DATA BASED GAME THEORETICAL PROBLEM**

OTURUM (2) | GÜN (2) | SALON (7) – SESSION (2) | DAY (2) | HALL (7)

Beylikdüzü Salonu | Beylikdüzü Hall

MEETING ID: 869 4231 3188
PASSWORD: 217426

	21.02.2026	Time: 15^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Raja Muhammad LATIF* *COORDINATOR* *Niyameddin SHUKUROV*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{10}	F.F. MAMMADOV F.R. KALBALIYEV	*Azerbaijan National Aerospace Agency, Azerbaijan* *UNEC Research Center, Azerbaijan*	ANALYSIS OF SOLAR ENERGY AND ITS VARIOUS TECHNIQUES FOR ELECTRICITY GENERATION
15^{10}-15^{20}	L V SHAHMAROVA R O NAZAROV	*Cadastre and Geospatial Design-Research Center, Azerbaijan*	STUDY OF CHANGES IN THE FERTILITY PROPERTIES OF GRAY-MEADOW SOILS UNDER THE INFLUENCE OF ANTHROPOGENIC FACTORS
15^{20}-15^{30}	Gular MIRZAYEVA	*Baku State University, Azerbaijan*	CORRECT PLANTING METHOD
15^{30}-15^{40}	Mammadova U F	*Ministry of Science and Education of Azerbaijan, Azerbaijan*	ECOTOURISM POTENTIAL OF LAHIJ SETTLEMENT (ISMAYILLI DISTRICT)
15^{40}-15^{50}	Qani QASIMOV	*Ministry of Science and Education of Azerbaijan, Azerbaijan*	EROSION IN KURMUKCHAY BASIN AND ITS PREVENTIVE METHODS
15^{50}-16^{00}	Zakaria Guebli Rafik Benrabaa Houria Djediai Laâldja Meddour-Boukhobza	*Université Mohamed Chérif Messaadia, Algeria* *University of Science and Technology Houari Boumedien Algeria* *Université des Sciences et de la Technologie M-B d'Oran* *University of Science and Technology Houari Boumediene, Algeria*	SYNTHESIS AND CHARACTERIZATION OF A TITANIUM-BASED CATALYST FOR THE PRODUCTION OF HYDROGEN BY PHOTOCATALYSIS
16^{00}-16^{10}	Dr. Ganesha K S Sachin SB	*Dayananda Sagar College of Engineering, India*	A STUDY ON IMPACT OF DIGITAL MARKETING ON THE CONSUMER DECISION MAKING FOR INTERIOR DESIGN PRODUCTS
15^{10}-15^{20}	G BALAJI M KAVASKAR	*Annamalai University, India*	ROLE OF NGO IN TRANSFER OF FARM TECHNOLOGIES TO EMPOWER THE LIVELIHOOD SECURITY OF SMALL AND MARGINAL FARMING COMMUNITIES
15^{20}-15^{30}	Chethana V CHALAPATHY Shruti AWASTHI	*Garden City University, India*	GREEN SYNTHESIS, CHARACTERIZATION OF IRON-BASED NANO FERTILIZER FOR SUSTAINABLE RELEASE AND EFFICIENT USE OF NUTRIENTS OF IRON NANOPARTICLES USING GREEN TEA EXTRACT.
15^{30}-15^{40}	Shefali RAIZADA Shruti AWASTHI Keerthana R Chandralekha	*Garden City University, India*	THE EFFECTS OF FHUMAN FOOD ADDITIVES ON DROSOPHILA MELANOGASTER- A DIETARY EXPOSURE EXPERIMENT
15^{40}-15^{50}	Chethana V CHALAPATHY Shruti AWASTHI	*Garden City University, India*	MOSQUITO REPELLENT SPRAY
15^{50}-16^{00}	Ismail MUHAMMAD Muinat ABDULLAHI ABUBAKAR Rejoice Asher Abdulmalik Bala SHUAIBU	*Gombe State University, Nigeria*	INVITRO ASSESSMENT OF THE LARVICIDAL ACTIVITY OF VECTOBAC 12AS FORMULATION (BACILLUS THURINGIENSIS VAR. ISRAELIENSIS) ON ANOPHELES MOSQUITO LARVA

16^{00}-16^{10}	I. O. Raheem	*Federal University of Kashere, Gombe State, Nigeria*	DETERMINATION OF INCREMENT IN CARBON-DIOXIDE (CO2) EMISSION PRODUCED FROM AUTOMOBILE ON SELECTED HIGHWAYS IN BAUCHI STATE BY SPEED BUMPS
16^{10}-16^{20}	Meriem AZIEZ Noureddine BRIBI	*University of Bejaia, Algeria*	ANTIOXIDANT ACTIVITY OF SPIRULINA EXTRACT
16^{20}-16^{30}	B SAMAILA	*Federal University Birnin Kebbi, Nigeria*	EXPOSURE TO NATURAL BACKGROUND RADIATION IN NIGERIA'S OILFIELDS: A SYSTEMATIC REVIEW
16^{30}-16^{40}	Magashi M A Jamilu H	*Bayero University, Nigeria*	PRODUCTION PLANNING STRATEGIES AND BIOPROCESS OF LIPASES: A REVIEW
16^{40}-16^{50}	Raja Mohammad LATIF	*Prince Mohammad Bin Fahd University, Saudi Arabia*	GZ IRRESOLUTE MAPPINGS INTOPOLOGICAL SPACES
16^{40}-16^{50}	Raja Mohammad LATIF	*Prince Mohammad Bin Fahd University, Saudi Arabia*	Zs CONTINUOUS MAPPINGS INTOPOLOGICAL SPACES
16^{50}-17^{00}	Raja Mohammad LATIF	*Prince Mohammad Bin Fahd University, Saudi Arabia*	GZ LINDELOF TOPOLOGICAL SPACES
17^{00}-17^{10}	Raja Mohammad LATIF	*Prince Mohammad Bin Fahd University, Saudi Arabia*	ZsCOMPACT TOPOLOGICAL SPACES

OTURUM (2) | GÜN (2) | SALON (8) – SESSION (2) | DAY (2) | HALL (8)

Şişhane Salonu | Şişhane Hall

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PASSWORD: 217426

	21.02.2026	Time: 15^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Malahat ABDULLAYEVA* *COORDINATOR* *Nigar MUSTAFAYEVA*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{10}	Rey Avila MANGARIN Felinita II R VILLACURA Marilou P CUBERO	*UM Panabo College, Philippines*	ACTION RESEARCH COMPETENCE AND TEACHING PERFORMANCE
15^{10}-15^{20}	Rey Avila MANGARIN Myla A. MATO Rey Avila MANGARIN Zerlyn A. GONZALO	*UM Panabo College, Philippines*	CYBERBULLYING AND SELF-ESTEEM OF GRADE 11 STUDENTS
15^{20}-15^{30}	Rey Avila MANGARIN Zerlyn A. GONZALO	*UM Panabo College, Philippines*	SOCIAL INTELLIGENCE AND MATH ANXIETY OF GRADE 10 STUDENTS
15^{30}-15^{40}	Marcela CHIOCCARELLO Carlos CORDEIRO	*Prime Research Centre, Portugal*	BIBLIOMETRIC ANALYSIS OF STREAMING SERVICES' IMPACT ON THE CINEMATOGRAPHIC INDUSTRY
15^{40}-15^{50}	Alina KORETSKA Carlos CORDEIRO	*Prime Research Centre, Portugal*	CYBERSECURITY STATE OF THE ART: A BIBLIOMETRIC ANALYSIS FROM 2021 TO 2024
15^{50}-16^{00}	Malahat ABDULLAYEVA	*Azerbaijan State Pedagogical University, Azerbaijan*	ON THE ACTIVITY OF STUDENTS IN MATHEMATICS LESSONS THE EFFECT OF PYGMALION EFFECT
16^{00}-16^{10}	Blerina BOÇI Aurora SIMONI	*Aleksandër Moisiu University, Albania* *University of Tirana, Albania*	ENHANCING PORTFOLIO OPTIMIZATION THROUGH BAYESIAN OPTIMIZATION AND PARTICLE SWARM OPTIMIZATION FOR PARAMETER TUNING
15^{10}-15^{20}	Umar Danjuma MAIWADA Aminu Aminu MUAZU Abubakar Danjuma MAIWADA	*Umaru Musa Yaradua University, Nigeria* *Umaru Musa Yaradua University, Nigeria* *Bayero University, Nigeria*	ENHANCING 5G SYSTEM EFFICIENCY THROUGH IMPROVED HANDOVER DELAYS WITH INTELLIGENT CONTEXT HANDOVER SERVICES
15^{20}-15^{30}	Aldo CANI Aurora SIMONI	*The Directorate of Information Technology, Albania* *University of Tirana, Albania*	CYBER SECURITY CHALLENGES IN HIGHER EDUCATION INSTITUTIONS
15^{30}-15^{40}	Rey Avila MANGARIN Leavic M. TAJON	*UM Panabo College, Philippines*	PUBLIC LEADERSHIP BEHAVIOR AND COMPETENCE OF STUDENT LEADERS
15^{40}-15^{50}	Zohaib Hassan SAIN	*Superior University, Pakistan*	BLENDED LEARNING: NAVIGATING CHALLENGES, FUTURE TRAJECTORIES, AND RECOMMENDATIONS
15^{50}-16^{00}	Zohaib Hassan SAIN	*Superior University, Pakistan*	THE INTEGRATION OF ARTIFICIAL INTELLIGENCE FOR HIGHER EDUCATION ADVANCEMENT IN PAKISTAN
16^{00}-16^{10}	Rey Avila MANGARIN Geraldine J. MISOLES Medardo Abellana JR	*UM Panabo College, Philippines*	THE INFLUENCE OF SOCIAL MEDIA EXPOSURE TO FAMILY RELATIONSHIP OF SPA STUDENTS
16^{10}-16^{20}	Rey Avila MANGARIN Janice V. JALBUNA	*UM Panabo College, Philippines*	THE INFLUENCE OF COMPUTER LITERACY TO PERCEIVED ACADEMIC PERFORMANCE OF GRADE 11 STUDENTS
16^{20}-16^{30}	Rey Avila MANGARIN Jeffrey SOLIDARIOS Donnabelle CANTEROS	*UM Panabo College, Philippines*	THE USE OF L+S IN IMPROVING THE PERFORMANCE OF SHS STUDENTS IN STATISTICS AND PROBABILITY

16^{30}-16^{40}	Rey Avila MANGARIN Jenny Fe PIO	*UM Panabo College, Philippines*	PREFERENCES AND BEHAVIOR IN BUYING SMARTPHONES AMONG PUBLIC SCHOOL TEACHERS
16^{40}-16^{50}	Rey Avila MANGARIN Graciella O. ABUCAYON Arra E. Delos SANTOS Cyres Angel J. GURADILLO Princess Dyan B. MARILLA Yvonne Kaye D. VERGARA Jovanny Gleen ALLAWAN	*UM Panabo College, Philippines*	GOOSE GRASS (ELEUCINE INDICA) AND HEAVENLY ELIXIR (TINOSPORA RUMPHII) EXTRACT AS BOTANICAL PESTICIDE FOR HOUSEFLY (MUSCA DOMESTICA)
16^{40}-16^{50}	Rey Avila MANGARIN Graciella O. ABUCAYON Arra E. Delos SANTOS Cyres Angel J. GURADILLO Princess Dyan B. MARILLA Yvonne Kaye D. VERGARA Jovanny Gleen ALLAWAN	*UM Panabo College, Philippines*	PREDICTING WATER CONSUMPTION: A REGRESSION ANALYSIS ON NUMBER OF HOUSEHOLD CONSUMERS
16^{50}-17^{00}	Rey Avila MANGARIN Koolleen Jean P. AVIRA Christel Joy C. TAGAILO Angela Jarn S. DALISAY Arianne Xandrea H PAGTACONAN Faith Claire L. SALE Ira Mae O. BAUTISTA Jovanny Gleen ALLAWAN	*UM Panabo College, Philippines*	THE EFFECTIVENESS OF CAVENDISH BANANA (MUSA ACUMINATA) AND EGGSHELLS AS FOLIAR FERTILIZER
17^{00}-17^{10}	Rey Avila MANGARIN Angelie GALOS Kriselle Mae GARIANDO Richel Jane BACERDO Joshua MESIA Ryan YBAÑEZ Jay Marvin GAVIA Aldrin JAYA Jovanny Gleen ALLAWAN	*UM Panabo College, Philippines*	BICYCLE AS CELLPHONE CHARGER

OTURUM (2) | GÜN (2) | SALON (9) – SESSION (2) | DAY (2) | HALL (9)

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	21.02.2026	Time: 15^{00}-17^{10} (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *Aminur RAHMAN* *COORDINATOR* *Farahila BABAYEVA*
	Authors	**Affiliation**	**Topic title**
15^{00}-15^{10}	Muhammad SHOAIB Dilawar KHAN	*Kohat University of Science and Technology, Pakistan*	THE IMPACT OF ENERGY AND WATER USE EFFICIENCY ON SUSTAINABLE AGRICULTURE IN SOUTH ASIA; 2000 TO 2023
15^{10}-15^{20}	Paola ÁNEZ Natalia GALINDO María SABATER Ariadna BARGIELA Rubén ARTERO	*University of Valencia, Spain* *University of Valencia, Spain* *Health Research Institute La Fe* *Biomedical Research Institute INCLIVA, Spain* *Biomedical Research Center on Rare Diseases, Spain*	MSI2 EXPRESSION IN LGMDD2: EFFECTS OF DIFFERENTIATION AND CELL SEEDING DENSITY
15^{20}-15^{30}	Ahmed Ali MUSTAFA Bnona Izzalddein ABDELRAHMAN Deyeen Almahdi DEYEEN Maaza Hussein ALMUBARAK Rowyda Abdelrahman HAMED	*Gezira University, Sudan*	BIOLOGICAL ACTIVITIES AND CHEMICAL CHARACTERIZATION OF PROPOLIS MINI-REVIEW
15^{30}-15^{40}	İlqar V. ƏLIYEV	*Azerbaijan University, Azerbaijan*	COP 29 (TƏRƏFLƏRIN KONFRANSI)
15^{40}-15^{50}	Yusufova Kh.J.	*Azerbaijan Medical University, Azerbaijan*	GENETIC FACTORS IN HUMAN OBESITY
15^{50}-16^{00}	Suleymanova L.M.	*Azerbaijan Medical University, Azerbaijan*	IMPORTANCE OF GENETIC COUNSELING FOR PATIENTS WITH GM1 GANGLIOSIDOSIS
16^{00}-16^{10}	Mammadova N.Ch.	*Azerbaijan Medical University, Azerbaijan*	GENETIC DIAGNOSIS OF MONOGENIC DIABETES
15^{10}-15^{20}	Valiyeva G. A.	*Azerbaijan Medical University, Azerbaijan*	FREQUENCY OF THE G6PD-DEFICIENT IN AZERBAIJAN POPULATION
15^{20}-15^{30}	Mammadova S. N.	*Azerbaijan Medical University, Azerbaijan*	IDENTIFICATION OF D442G MUTATION IN THE CETP GENE
15^{30}-15^{40}	Malahat ABDULLAYEVA	*Azerbaijan State Pedagogical University, Azerbaijan*	INNOVATIVE APPROACH TO TEACHING: PROBLEM-BASED LEARNING IN MATHEMATICS
15^{40}-15^{50}	İsmayılov Şahismayıl Namaz OĞLU	*Azerbaijan University of Languages, Azerbaijan*	AZƏRBAYCAN-TÜRKIYƏ MÜNASIBƏTLƏRINƏ IQTISADI ƏLAQƏLƏR ÇƏRÇIVƏSINDƏ BAXIŞ
15^{50}-16^{00}	Majid GURBANOV Gulnar GURBANOVA Gumru MIKAYILI Toghrul MUSTAFALI Mohlat KARIMZADE	*Institute of Control Systems, Azerbaijan* *Azerbaijan Technical University, Azerbaijan* *Zagatala State College, Azerbaijan* *Azerbaijan Technical University, Azerbaijan* *Azerbaijan Technical University, Azerbaijan*	AI FOR OSINT: CHALLENGES, OPPORTUNITIES, AND FUTURE DIRECTIONS
16^{00}-16^{10}	Imane AKKARI Mohamed Mehdi KACI Zahra GRABA Nacer BEZZİ Marta PAZOS	*Université de Bejaia, Algeria* *Université de Bejaia, Algeria* *Université de Bejaia, Algeria* *Université de Bejaia, Algeria* *University of Vigo, Spain*	ISOTHERM, KINETIC AND THERMODYNAMIC STUDIES OF AZO DYE ADSORPTION BY PHOSPHORIC ACID-ACTIVATED HYDROCHAR

16^{10}-16^{20}	Akinde Toyin EMMANUEL Ayodele OTONYE Eyinade ADEDAPO Ayinmode Stephen AYODELE	*Ladoke Akintola University of Technology, Nigeria* *University of Lagos, Nigeria* *Emmanuel Alayande University of Education, Nigeria* *Tai Solarin University, Nigeria*	REVAMPING NIGERIAN CERAMIC ARTISTRY THROUGH MODERNIZED COMMERCE
16^{20}-16^{30}	Aminur RAHMAN	*Leading University, Bangladesh*	ANALYZING THREAT INTELLIGENCE FRAMEWORK FOR ENHANCE CYBER SECURITY IN NETWORK ENVIRONMENT
16^{30}-16^{40}	Aminu Aminu MUAZU Ahmad Sobri HASHIM	*Umaru Musa Yar'adua University, Nigeria* *Universiti Teknologi Petronas, Malaysia*	CHARACTERIZING THE BEHAVIOR OF ONE-PARAMETER-AT-A-TIME APPROACH IN COMBINATORIAL T-WAY TESTING FOR EFFICIENT TEST SUITE GENERATION
16^{40}-16^{50}	Rey Avila MANGARIN Mariesel A LAUREL Wendie D CUTILLON	*UM Panabo College, Philippines*	BILINGUALISM IN THE PERSPECTIVES OF TEACHERS
16^{40}-16^{50}	Rey Avila MANGARIN Janice V. JALBUNA Wendie D CUTILLON	*UM Panabo College, Philippines*	LAVENDER LANGUAGE: EXPLORING THE COLORS OF GAY LINGO IN THE ACADEME
16^{50}-17^{00}	Rey Avila MANGARIN Angelyn CUIZON Forreli TRESFUENTES Kyle FLORES Ma. Elaisa BAUGBOG Raquel ABAQUITA Angel Cris ERMITA Frazer Axel RASUCAY Jovanny Gleen ALLAWAN	*UM Panabo College, Philippines*	COCONUT (COCOS NUCIFERA) SAP AND CALAMANSI (CITROFORTUNELLA X MICROCARPA) EXTRACT AS AN ALTERNATIVE CONTACT WEED KILLER
17^{00}-17^{10}	Rey Avila MANGARIN ChariseRouxwayne A. ROMEO Xyleemay G. MANGLIGOT Lucille Mae F. MAGNO Jolamae S. PEÑALOSA Jezzel M. PONTILLAS Blessy P. BAYA Jovanny Gleen ALLAWAN	*UM Panabo College, Philippines*	THE POTENTIAL OF CAVENDISH (MUSA ACUMINATA) BANANA STALKS FOR PAPER MAKING

OTURUM (2) | GÜN (2) | SALON (10) – SESSION (2) | DAY (2) | HALL (10)

Beşiktaş Salonu | Beşiktaş Hall

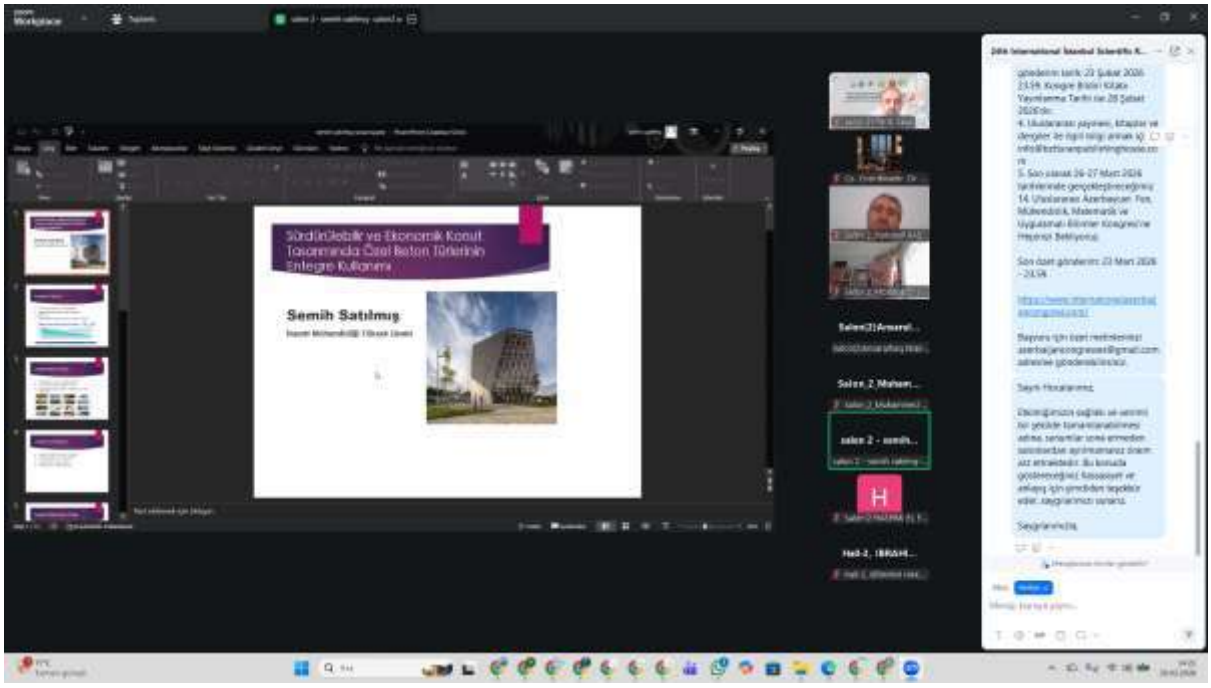
MEETING ID: 869 4231 3188
PASSWORD: 217426

	21.02.2026	Time: 15⁰⁰-17¹⁰ (Turkey Local time GMT+3)	MODERATOR & HEAD OF SESSION: *RIYA* *COORDINATOR* *Rasul DADASHOV*
	Authors	**Affiliation**	**Topic title**
15⁰⁰-15¹⁰	Bouazdia KARIM Araar SALAH Menaceur OLAYA	*Echahid Cheikh Larbi Tebessi University, Algeria*	TOXICITY AND SUB-LETHAL EFFECT OF PYRETHROID INSECTICIDE TO AN ENDOGEIC EARTHWORM
15¹⁰-15²⁰	Riya	*Ranchi University, India*	AN INDISPENSABLE PHARMACOGNOSTIC ACTIVITIES OF A MEDICINAL PLANT LEEA MACROPHYLLA ROXB. EX HORNEM. (HASTIKARNAPALASA)
15²⁰-15³⁰	Abusalam MUKHTAROV Fuad MAMMADOV	*Azerbaijan State Oil and Industry University, Azerbaijan* *Azerbaijan Technical University, Azerbaijan*	COMPREHENSIVE ANALYSIS OF GEOTHERMAL ENERGY POTENTIAL AND APPLICABLE GEOTHERMAL SYSTEMS IN AZERBAIJAN: AN IN-DEPTH OVERVIEW
15³⁰-15⁴⁰	Mohd Izamudin Itam AHMED Ahmad Firdaus Mohamad MOHSIN Muhammad Asrul Affendi Mat NOR	*Pasir Salak Community College, Malaysia*	EFFECTIVENESS STUDY OF THE' MAGNETIC WORKLIGHT' INNOVATION AS A PRACTICAL AID FOR AUTOMOTIVE STUDENTS LAB WORKS
15⁴⁰-15⁵⁰	Ahmad Firdaus Mohamad MOHSIN Mohd Izamudin Itam AHMED Muhammad Asrul Affendi Mat NOR	*Pasir Salak Community College, Malaysia*	ENHANCING ACADEMIC PERFORMANCE IN AUTOMOTIVE ENGINEERING: A STUDY ON THE IMPACT OF INTERACTIVE LAB SHEETS IN THE SAU20103 COURSE AT PASIR SALAK COMMUNITY COLLEGE
15⁵⁰-16⁰⁰	Yousra MDARHRI Mohamed CHABBI	*Abdelmalek Essaadi University, Morocco*	A COMPREHENSIVE EXPLORATION OF EMULSION STABILIZATION TECHNIQUES
16⁰⁰-16¹⁰	Ramesh R Seenivasan M Sakthivel K	*Arignar Anna Government Arts College, India* *DDE Annamalai University, India* *Arignar Anna Government Arts College, India*	FUZZY MULTI SERVER QUEUING MODEL BY DSW ALGORITHM TECHNIQUE
15¹⁰-15²⁰	Ramesh R Seenivasan M Kannan M Jagatheesan R	*Arignar Anna Government Arts College, India* *DDE Annamalai University, India* *Arignar Anna Government Arts College, India* *Arignar Anna Government Arts College, India*	PERFORMANCE EXPEDIENTS ON A FUZZY NON-PARAMETRIC BATCH ARRIVAL QUEUEING SYSTEM
15²⁰-15³⁰	Ramesh R Seenivasan M Rajasekar S P Hari Ganesh A	*Arignar Anna Government Arts College, India* *DDE Annamalai University, India* *Government Arts College for Women Poombuhar College, India*	PERFORMANCE ANALYSIS ON FUZZY M X /M/1 QUEUEING SYSTEM WITH MULTIPLE WORKING VACATION
15³⁰-15⁴⁰	Mammadova Saadat ABBAS Guliyeva Lala SHAHIN Mamedova Ulviya MUBARIZ Tagirli Gilal MURADKHANLY Verdiyev Suleyman CHILINGIR	*Institute of the Ministry of Science and Education of the Republic of Azerbaijan, Azerbaijan*	DIFFUSION CARBIDE COATINGS

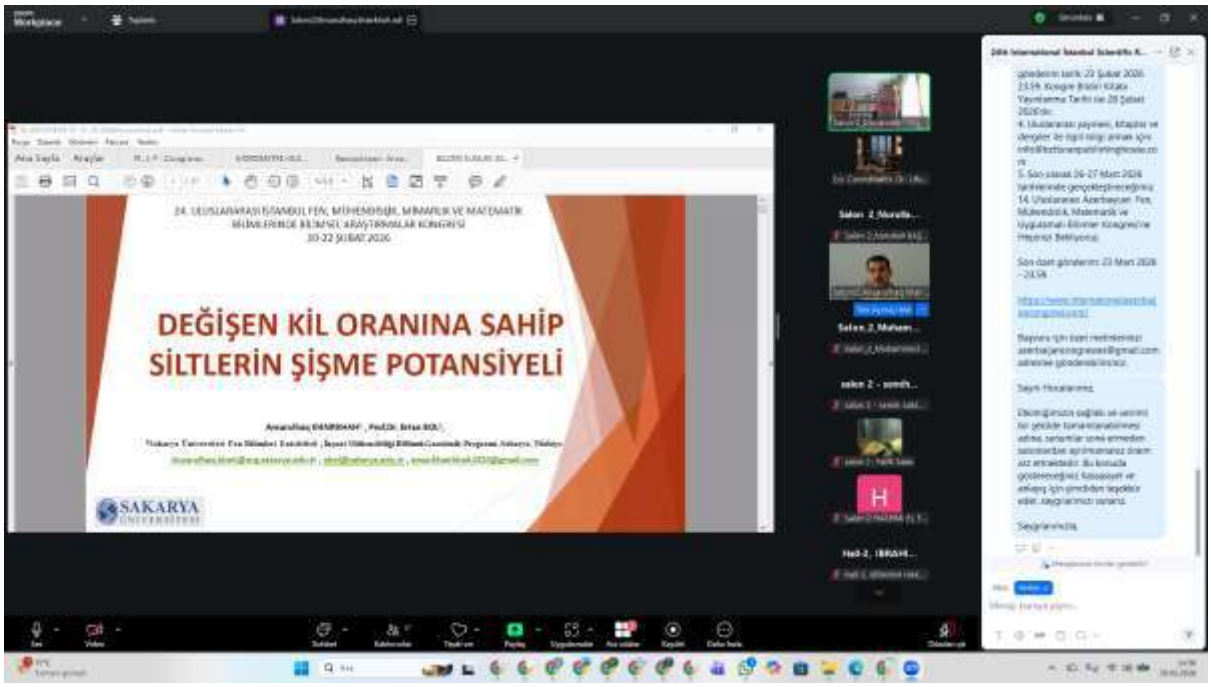
	Adigozelova Mehriban NAMIK Huseynova Afag SABIR		
15^{40}-15^{50}	**Mikayil ISMAYILOV**	***Baku State University, Azerbaijan***	**ESTIMATION OF AGRO ECOTOURISM POTENTIAL IN DASHKASAN DISTRICT, AZERBAIJAN**
15^{50}-16^{00}	**Sevda TALIBOVA Mammad MAMMADOV Aynura AHMADOVA**	***Ministry Science and Education, Azerbaijan***	**REGULATION OF THE EFFECT OF ORGANIC FERTILIZERS ON SOIL FERTILITY INDICATORS**
16^{00}-16^{10}	**Fuad MAMMADOV Nurlan NAJAFZADE**	***Azerbaijan National Aerospace Agency, Azerbaijan***	**UNLOCKING SUSTAINABLE ILLUMINATION: THE COMMERCIAL ADVANTAGES OF SOLAR ROAD LIGHTS OVER TRADITIONAL LIGHTING SOLUTIONS**
16^{10}-16^{20}	**Mohammad Mahboob Hussain KHAN**	***Jahangirnagar University, Bangladesh***	**TREND ANALYSIS OF THUNDERSTORM DURING PRE-MONSOON (MARCH TO MAY) AND MONSOON (JUNE-SEP) SEASONS IN BANGLADESH**
16^{20}-16^{30}	**Javid NURMAMMADOV**	***Baku State University, Azerbaijan***	**BALAKAN LAND RESOURCES AND THEIR EFFICIENT USE**
16^{30}-16^{40}	**Samia RANI Abid HUSSANAN Amir ABBAS Aamir SHAHZAD**	***University of Education, Pakistan University of Education, Pakistan Baba Guru Nanak University, Pakistan Baba Guru Nanak University, Pakistan***	**HEAT TRANSFER IN MICROPOLAR CASSON NANOFLUIDS CONTAINING CU NANOPARTICLES OF DIFFERENT GEOMETRIES IN THE PRESENCE OF TRANSVERSE MAGNETIC FIELD**
16^{40}-16^{50}	**N. M. SHEHU G. BABAJI M. H. ALI**	***Bayero University, Nigeria***	**THE IMPACT OF VARIATION OF CHANNEL DOPING CONCENTRATION ON SHORT CHANNEL EFFECTS IN NANOSCALE DOUBLE GATE FINFETS: A COMPARATIVE STUDY**
16^{40}-16^{50}	**Asif Raza JARWAR Guo SU**	***Hohai University, China***	**ADVANCING SUSTAINABLE ENERGY: A COMPREHENSIVE REVIEW OF RENEWABLE ENERGY SOURCES, TECHNOLOGIES, AND PUBLIC PERCEPTIONS.**
16^{50}-17^{00}	**Manasa GOWDA**	***Garden City University, India***	**MARIGOLD'S ESSENCE: EXPLORING MEDIA NARRATIVES AND THEIR IMPACT ON BEAUTY, HEALTH, AND CULTURAL HERITAGE PRESERVATION**
17^{00}-17^{10}	**Afar IQBAL**	***Kohat University of Science and Technology, Pakistan***	**DAY-AHEAD FORECASTING OF HUMIDITY WITH TIME SERIES AND MACHINE LEARNING MODELS**

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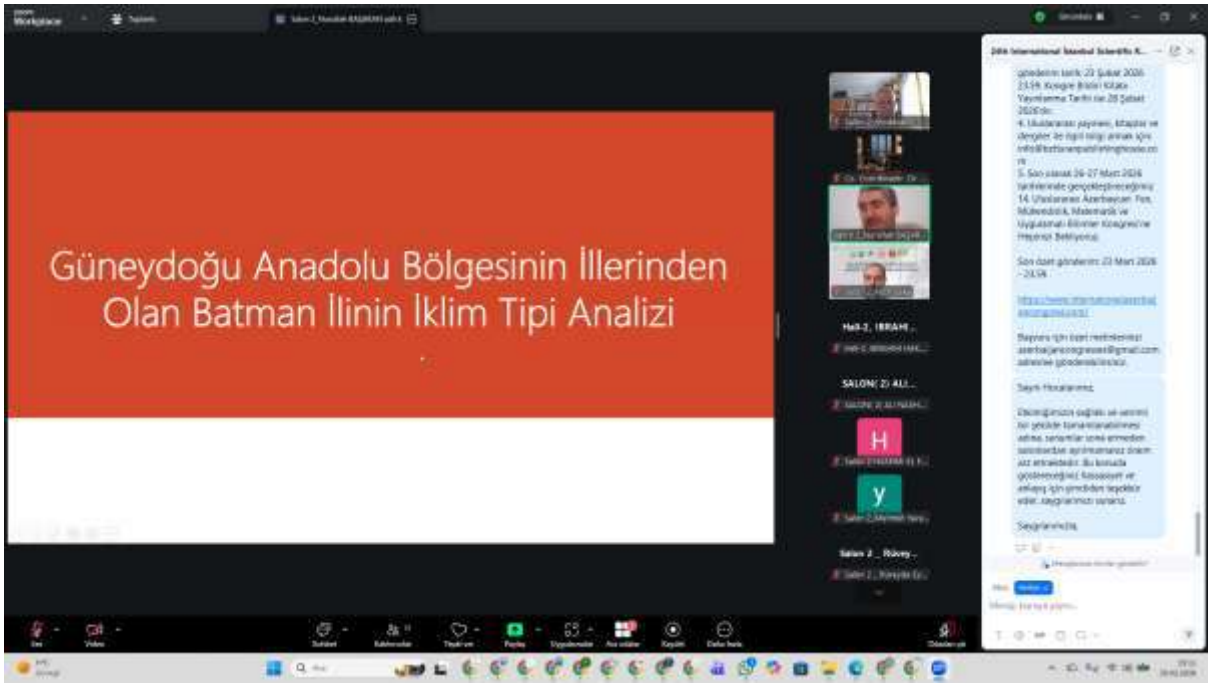
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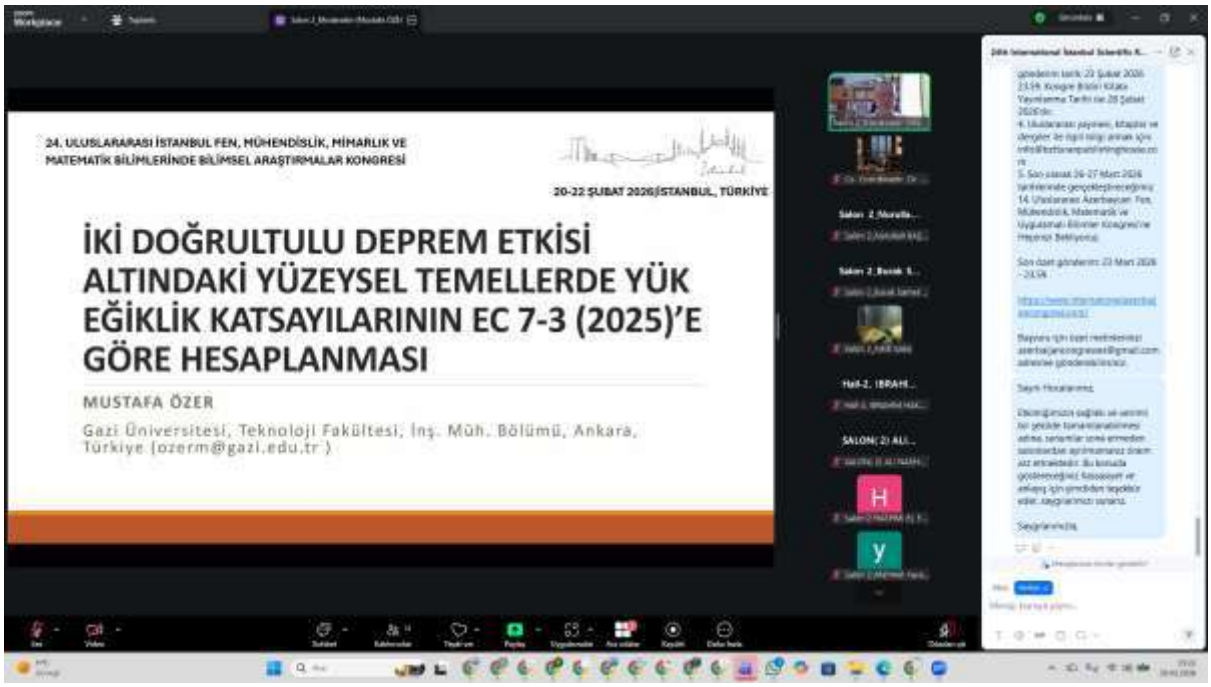


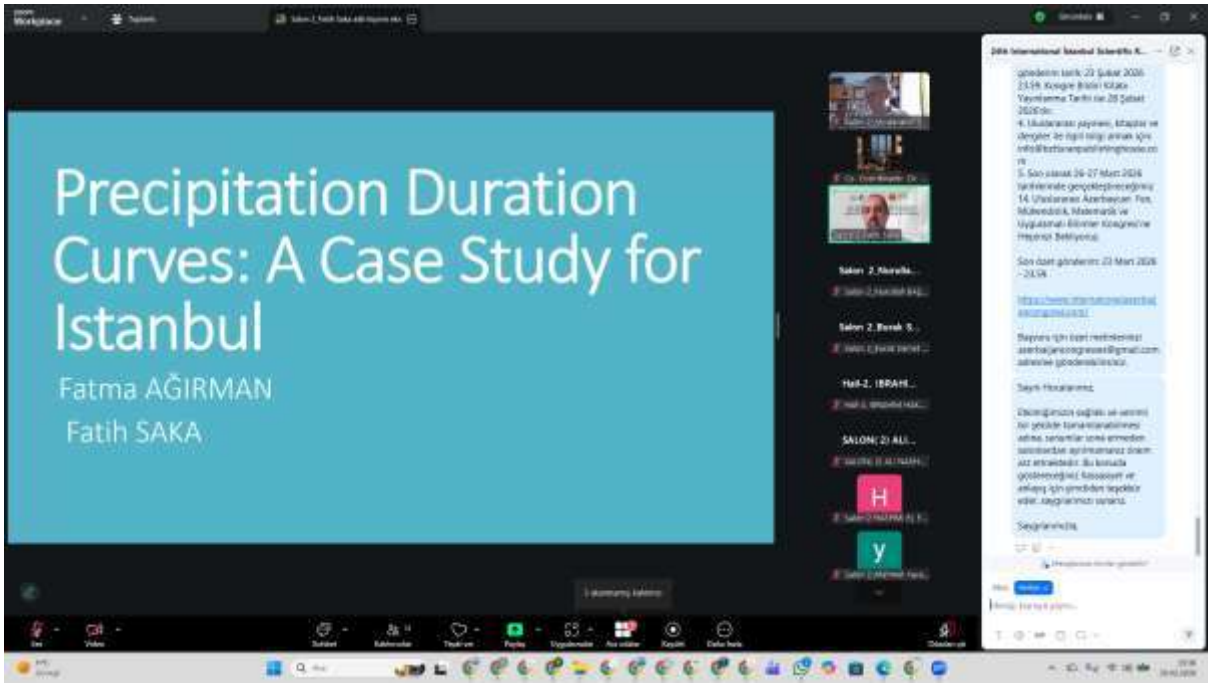
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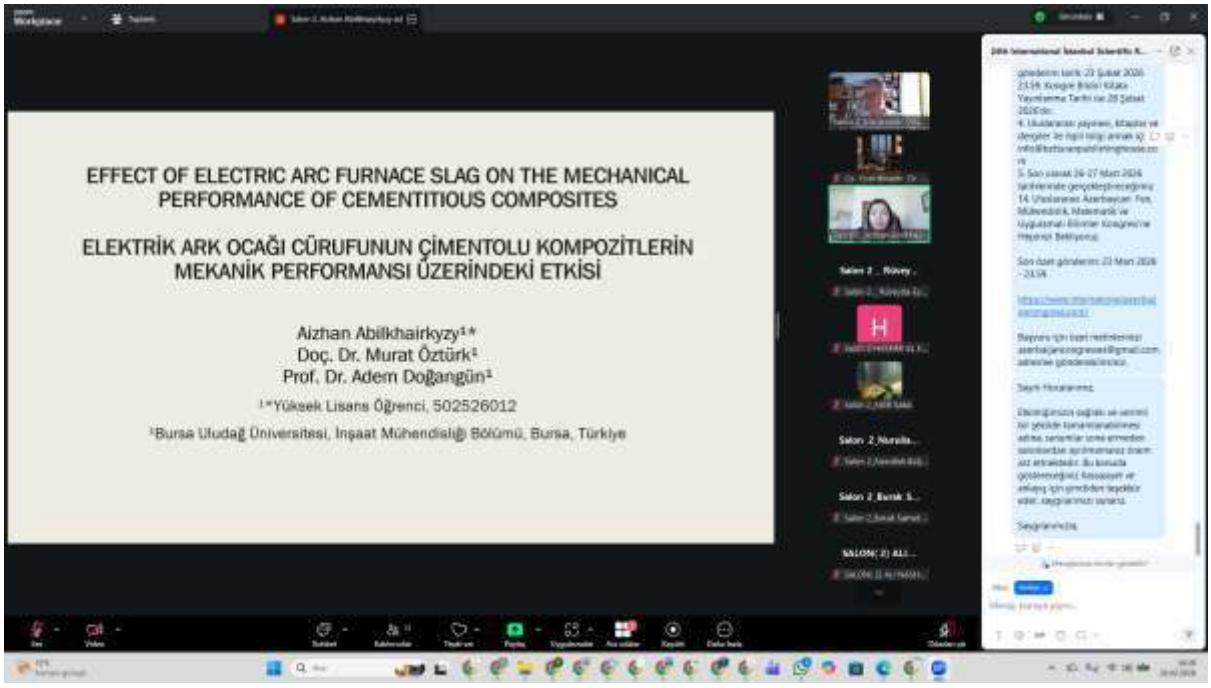
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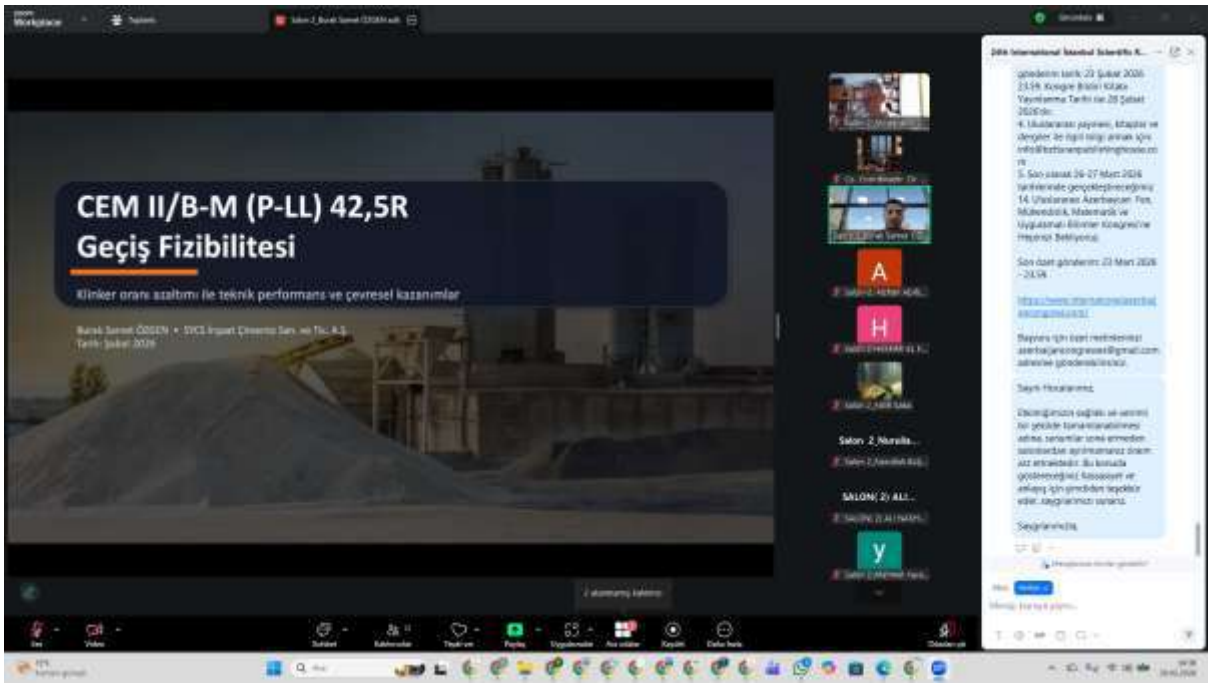


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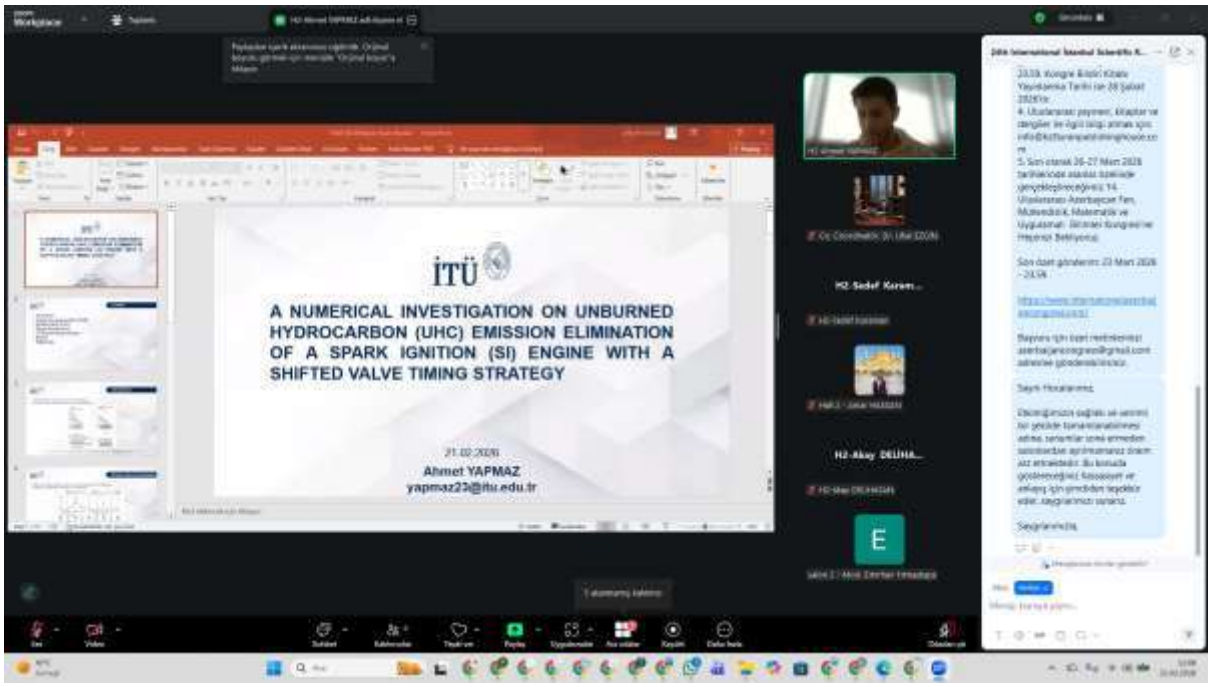


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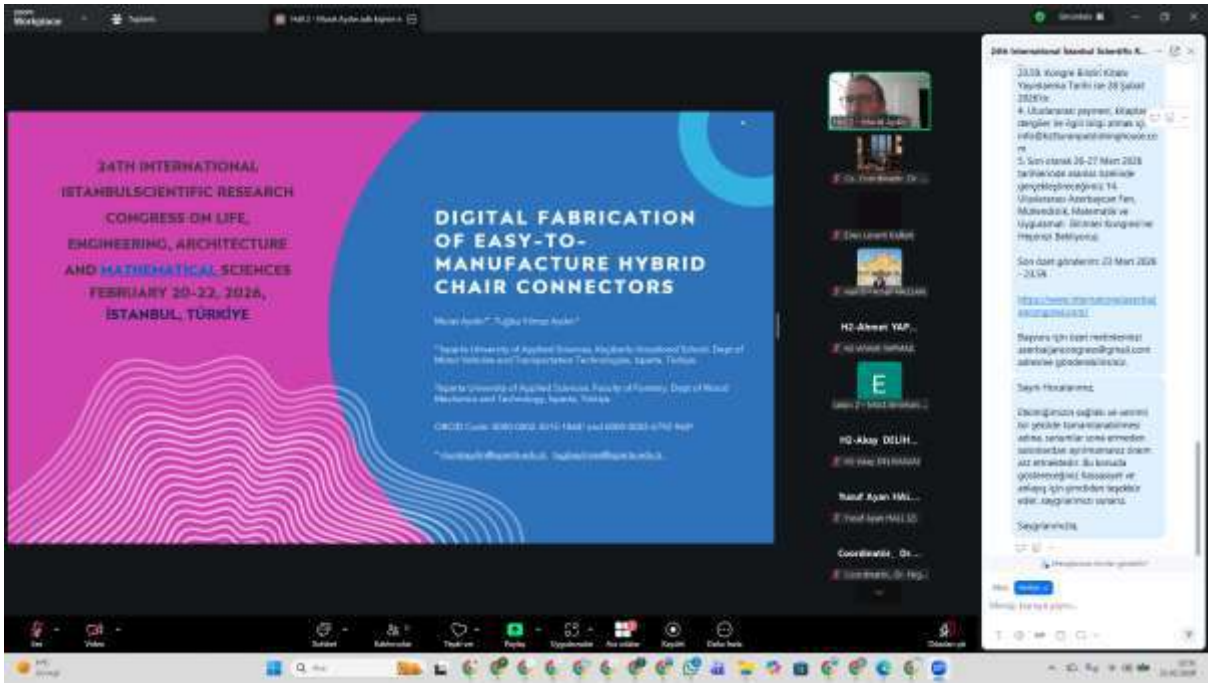
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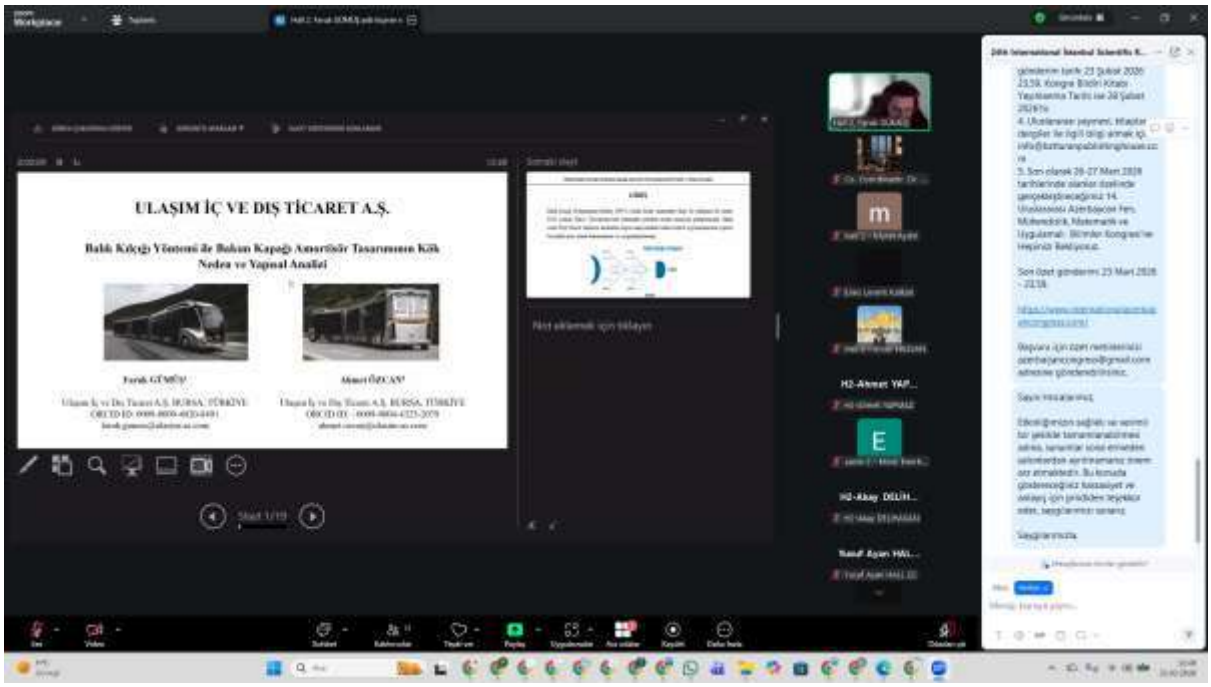


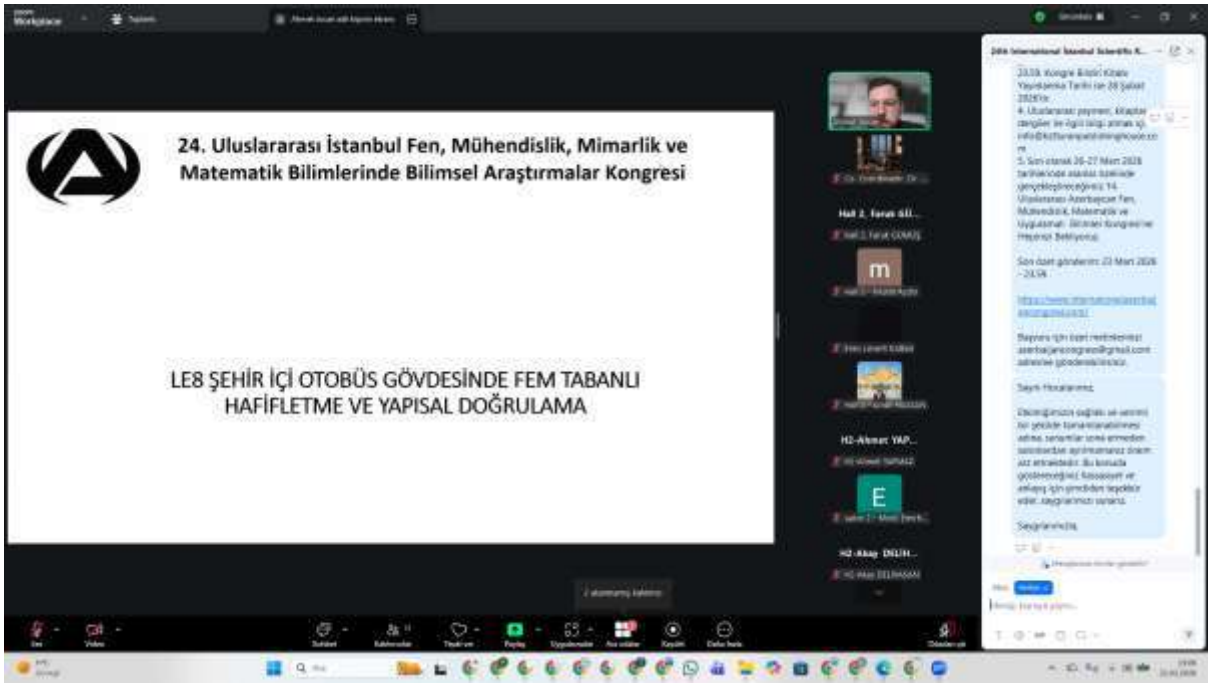
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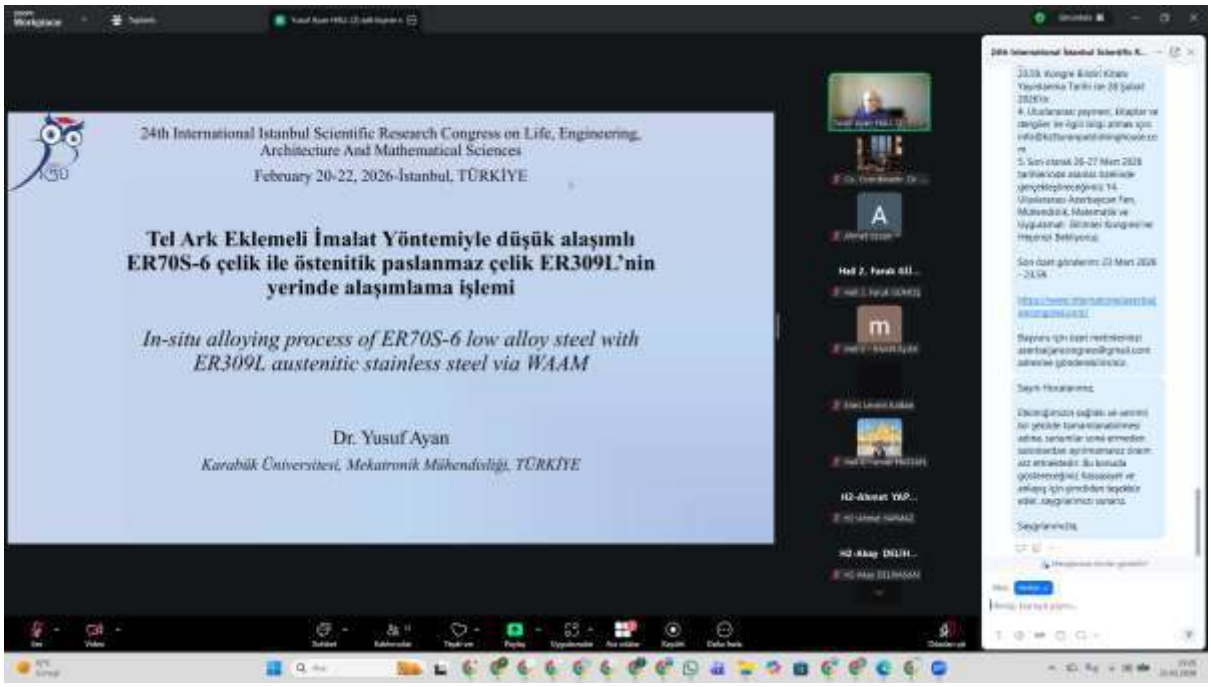


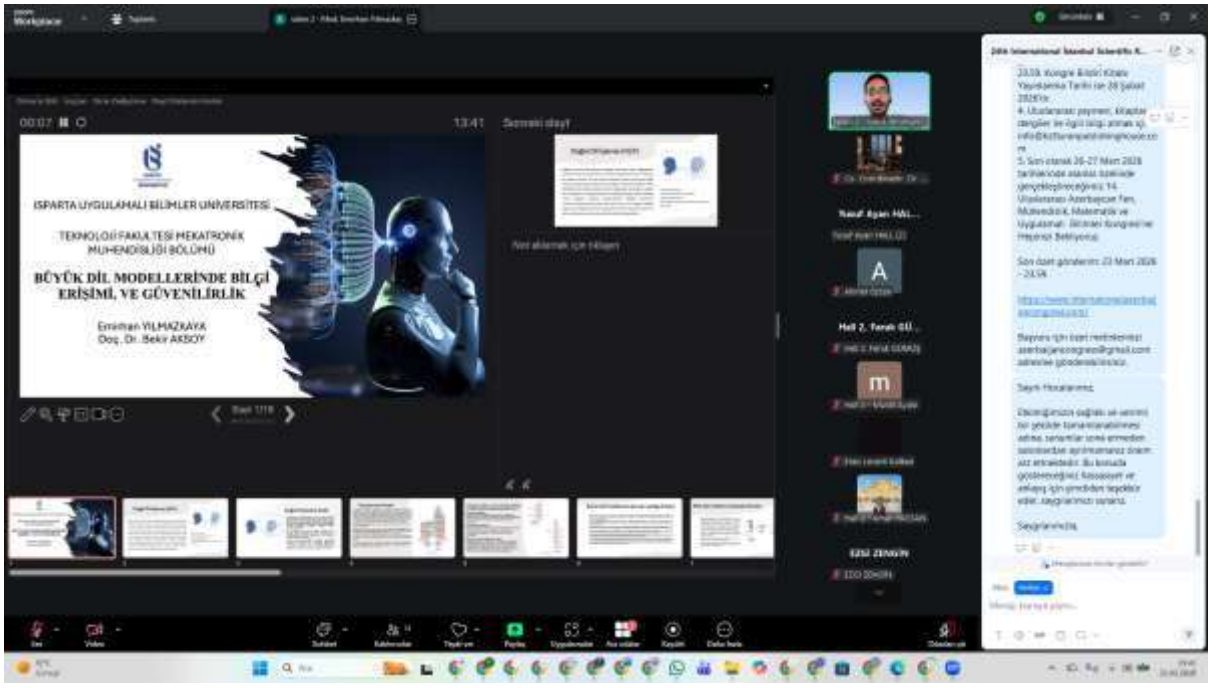
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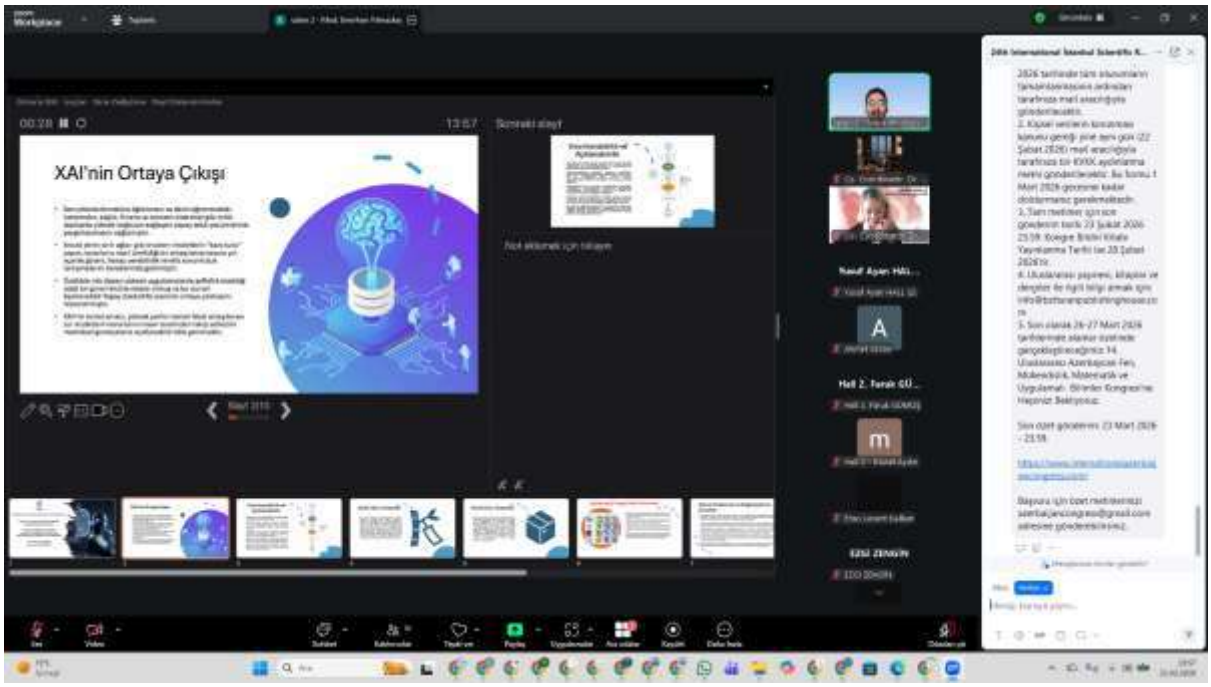


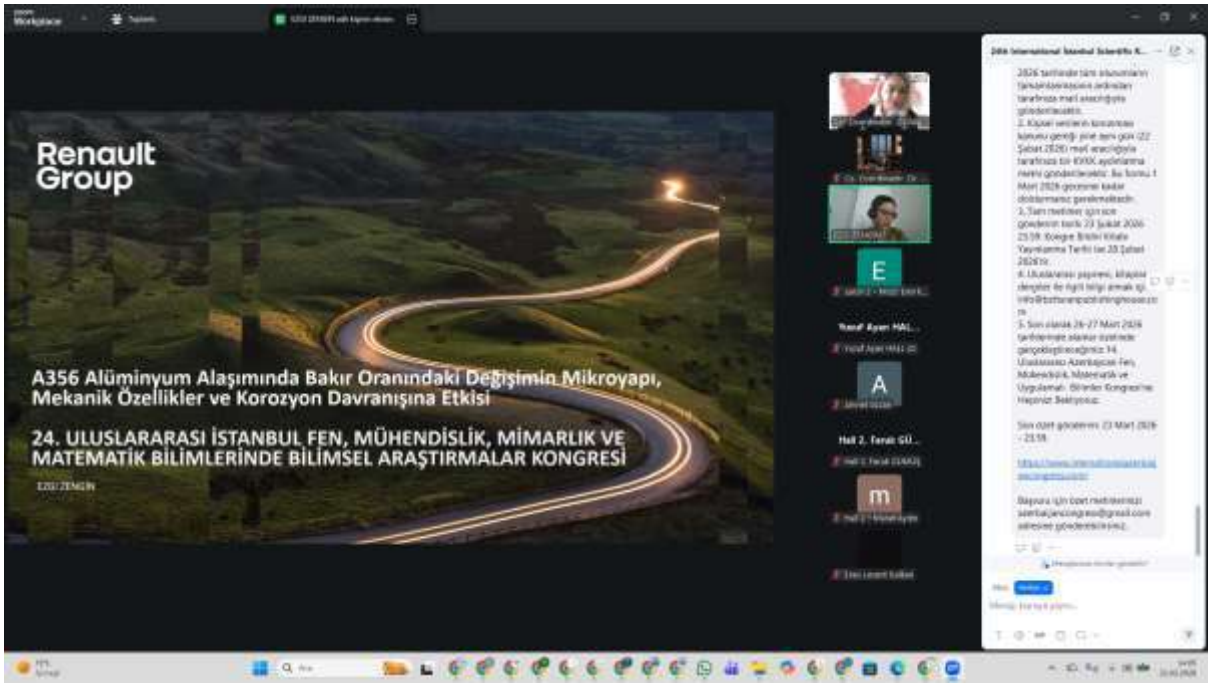
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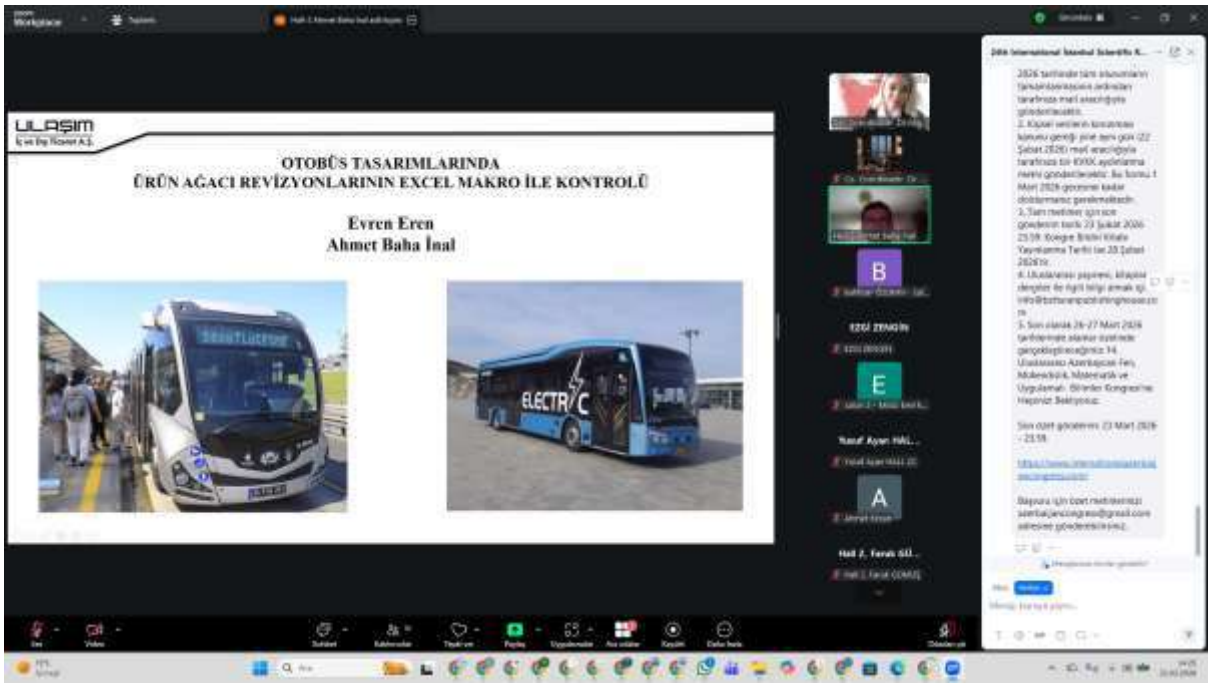


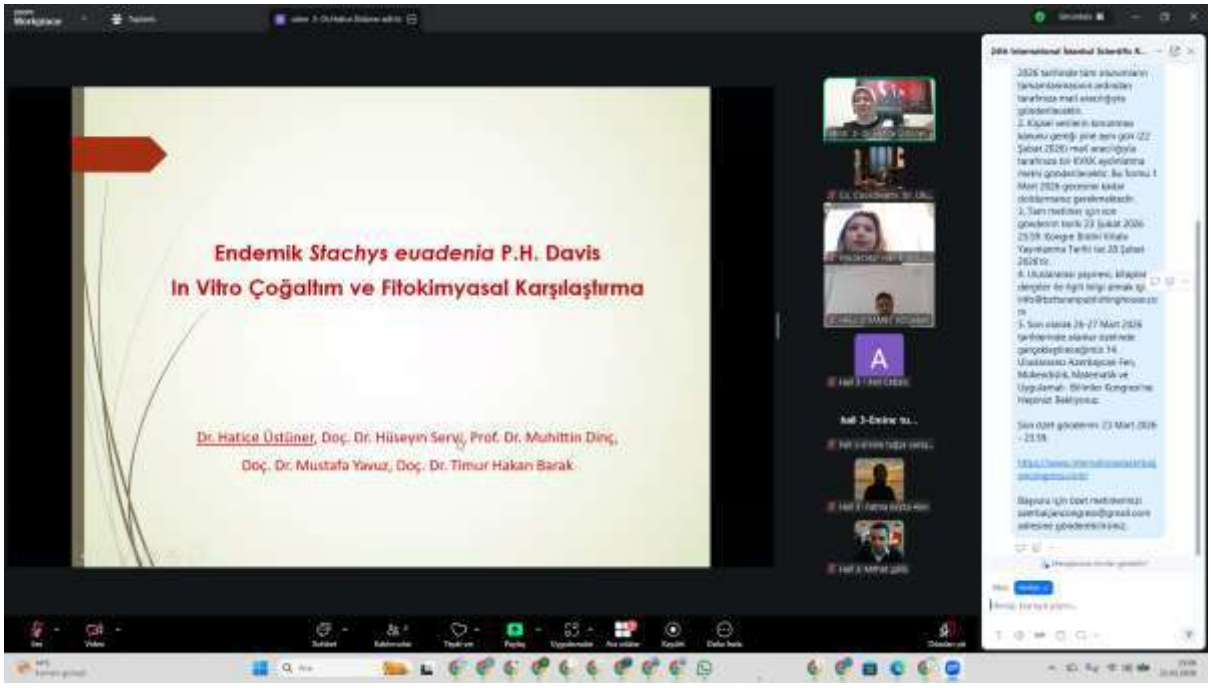
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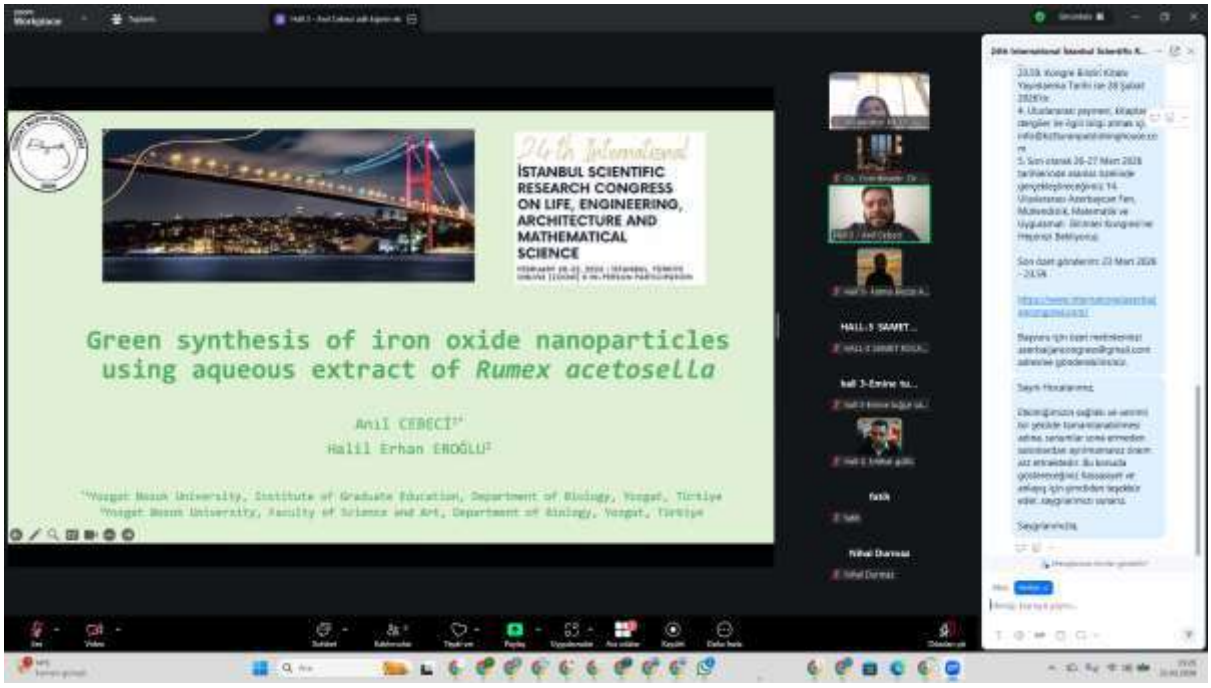
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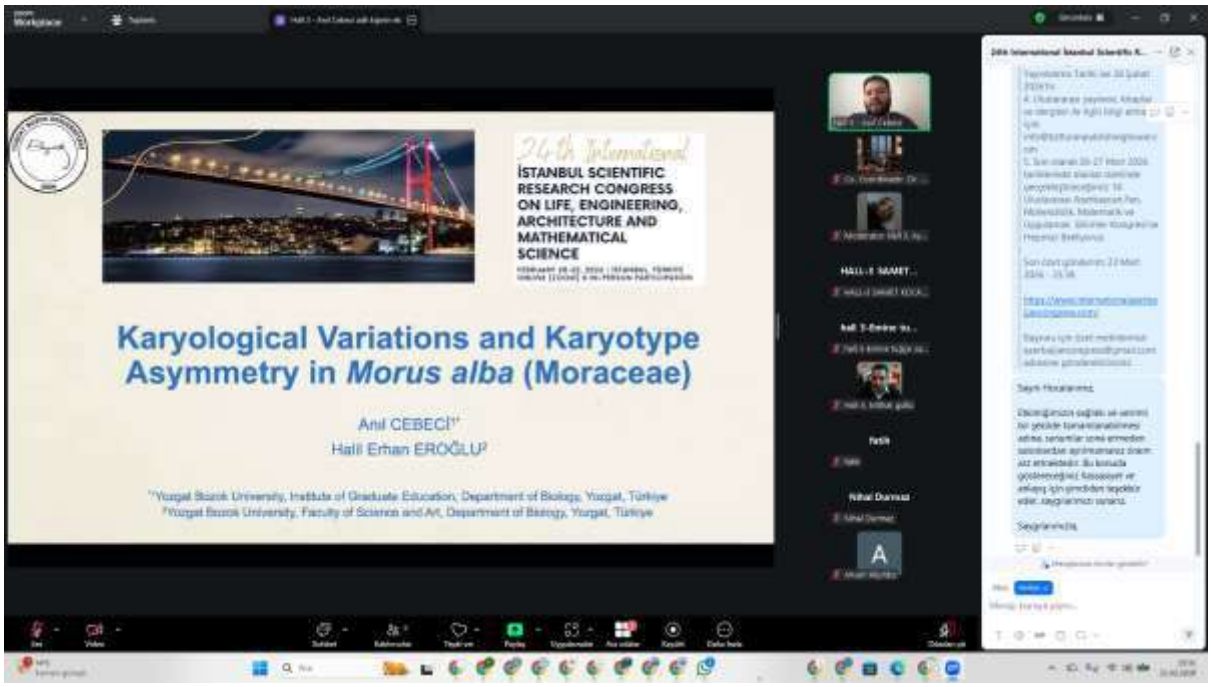


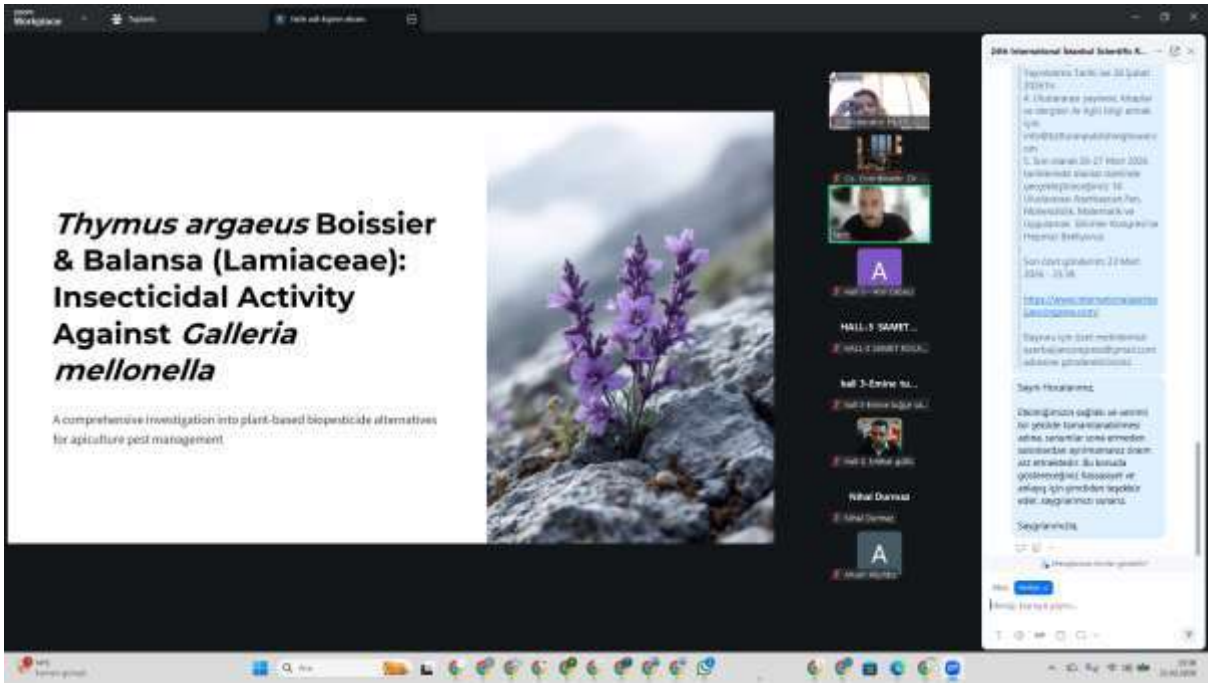
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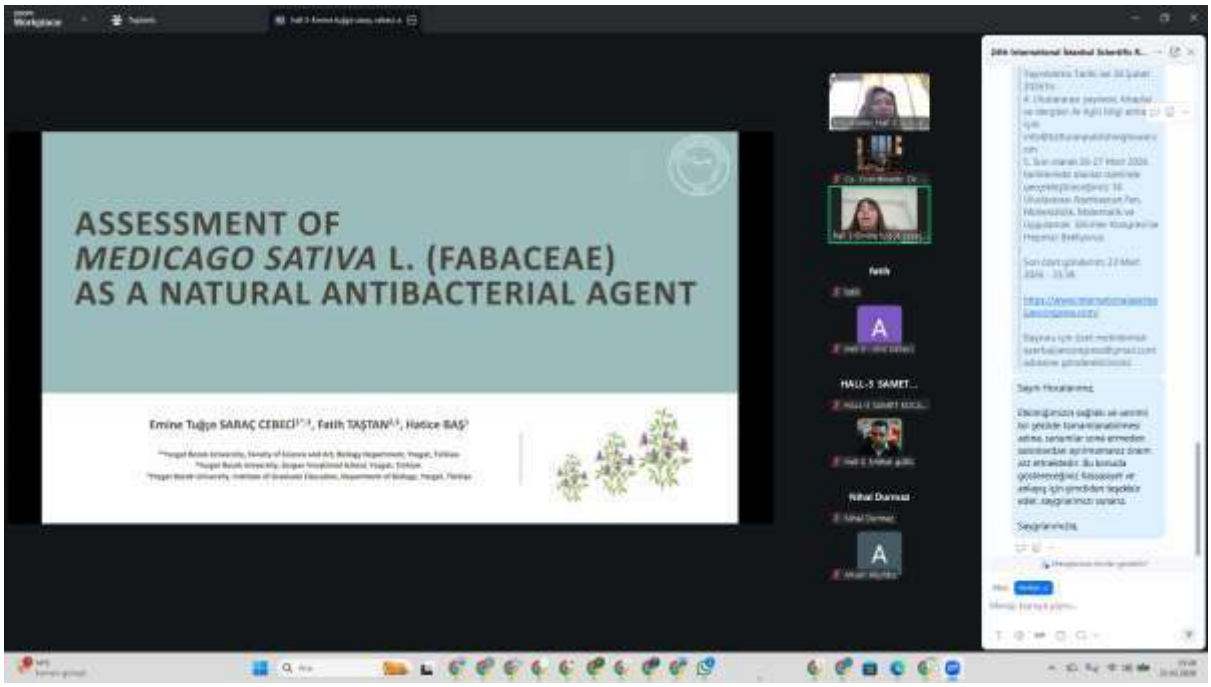


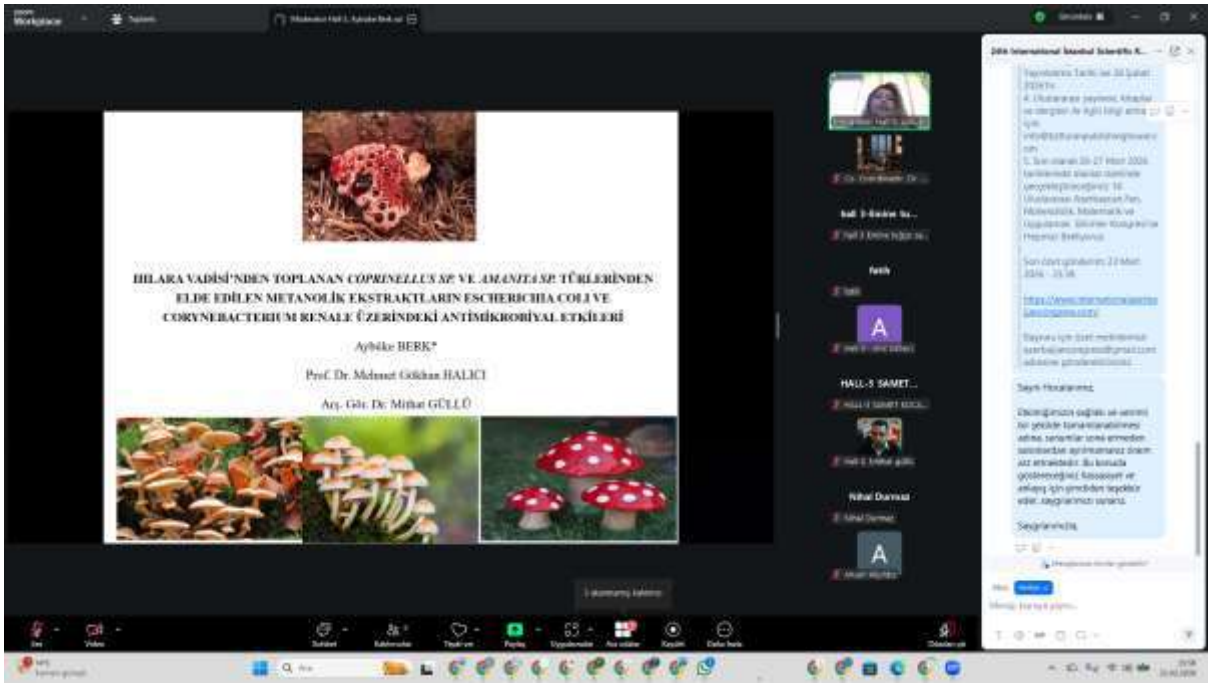
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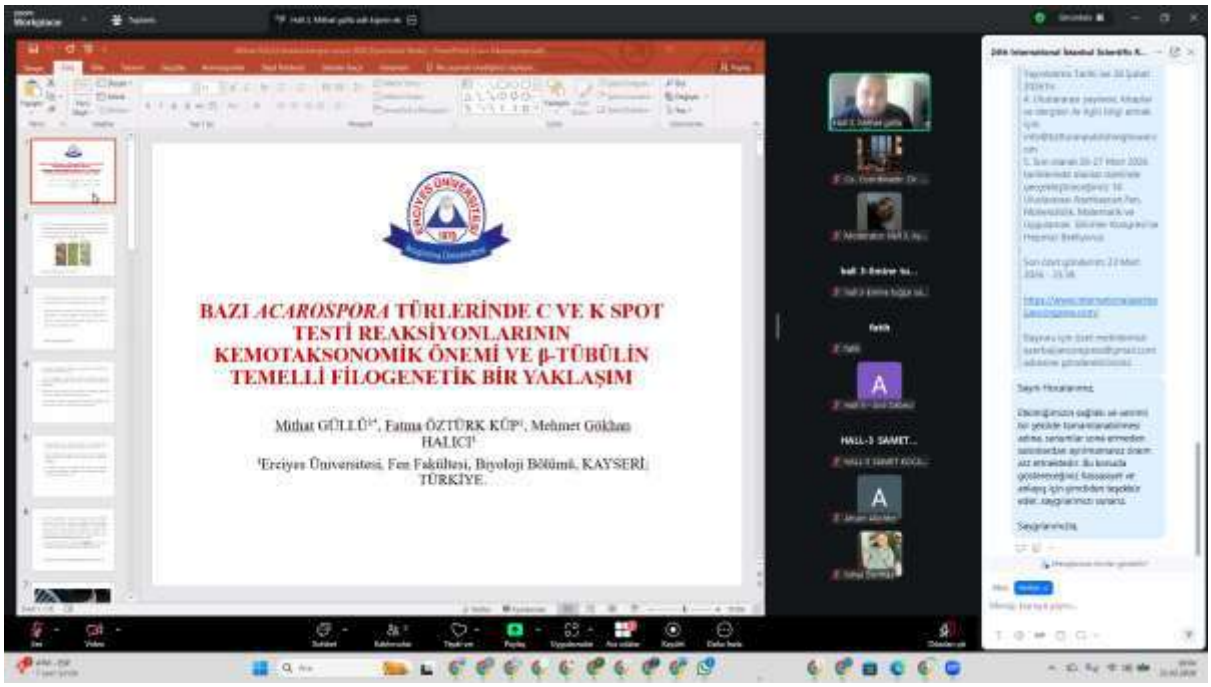


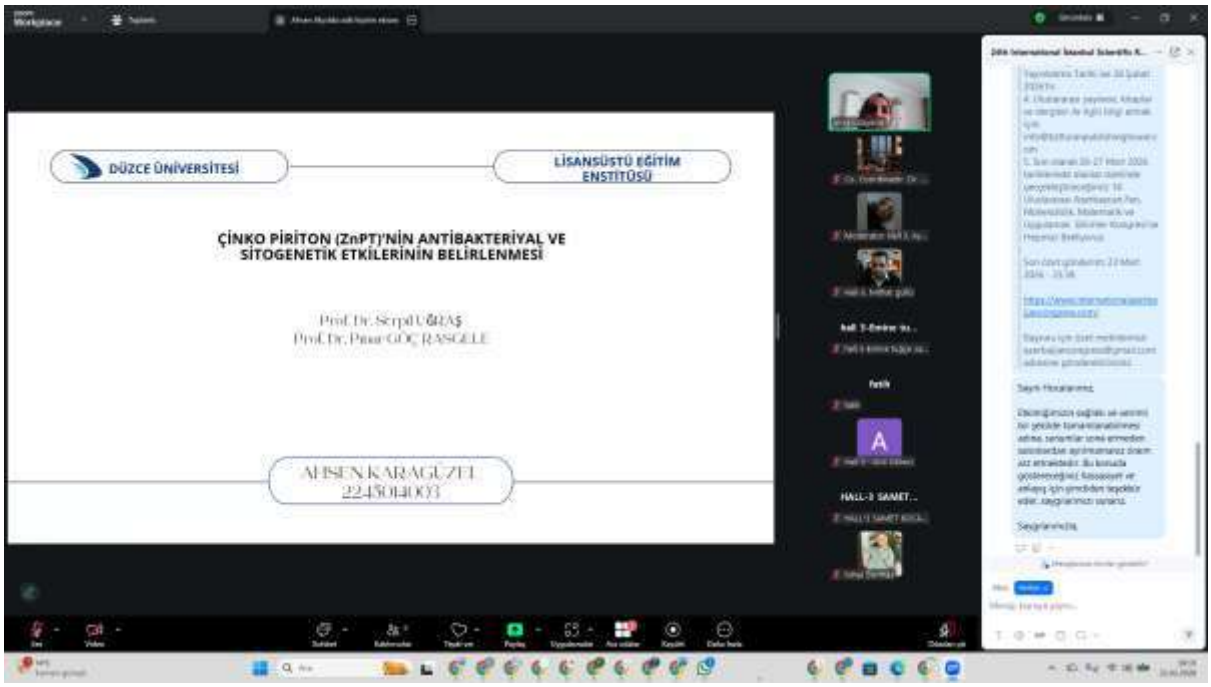
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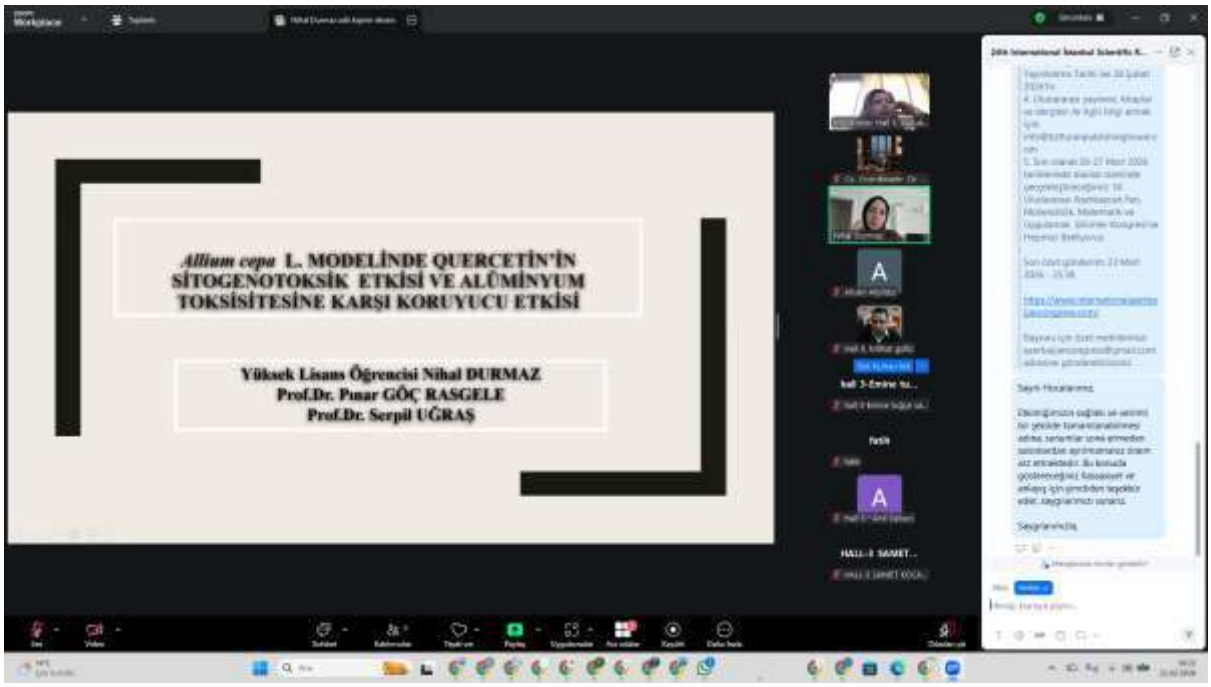


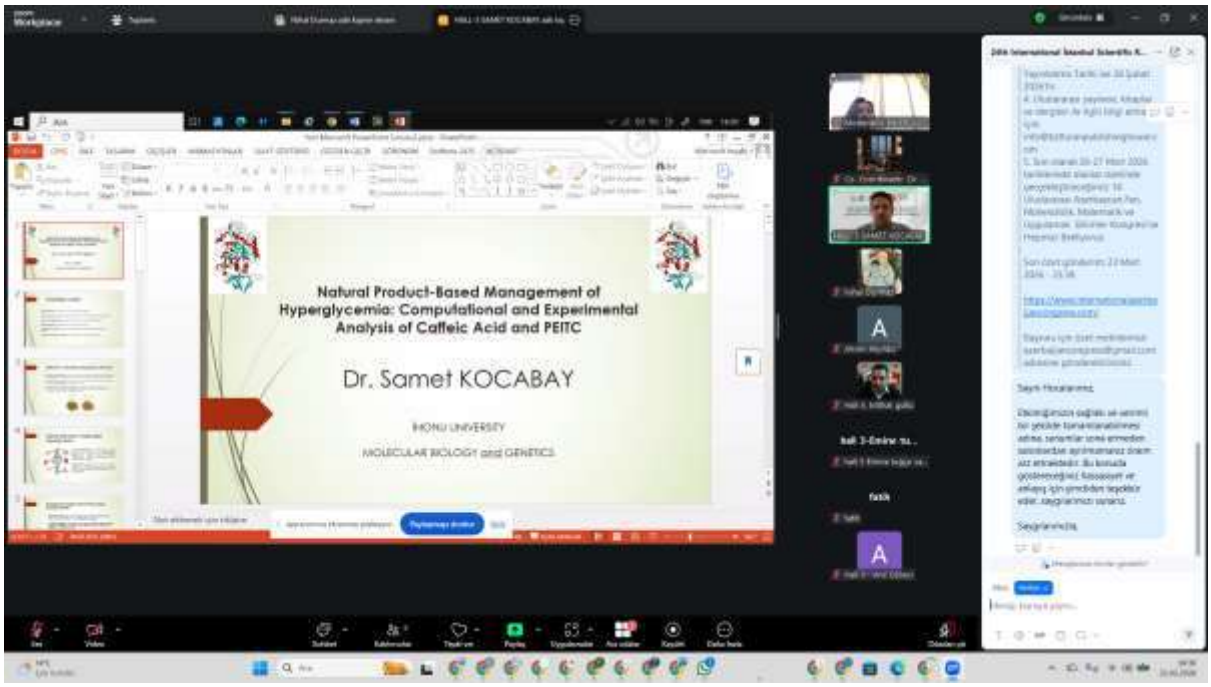
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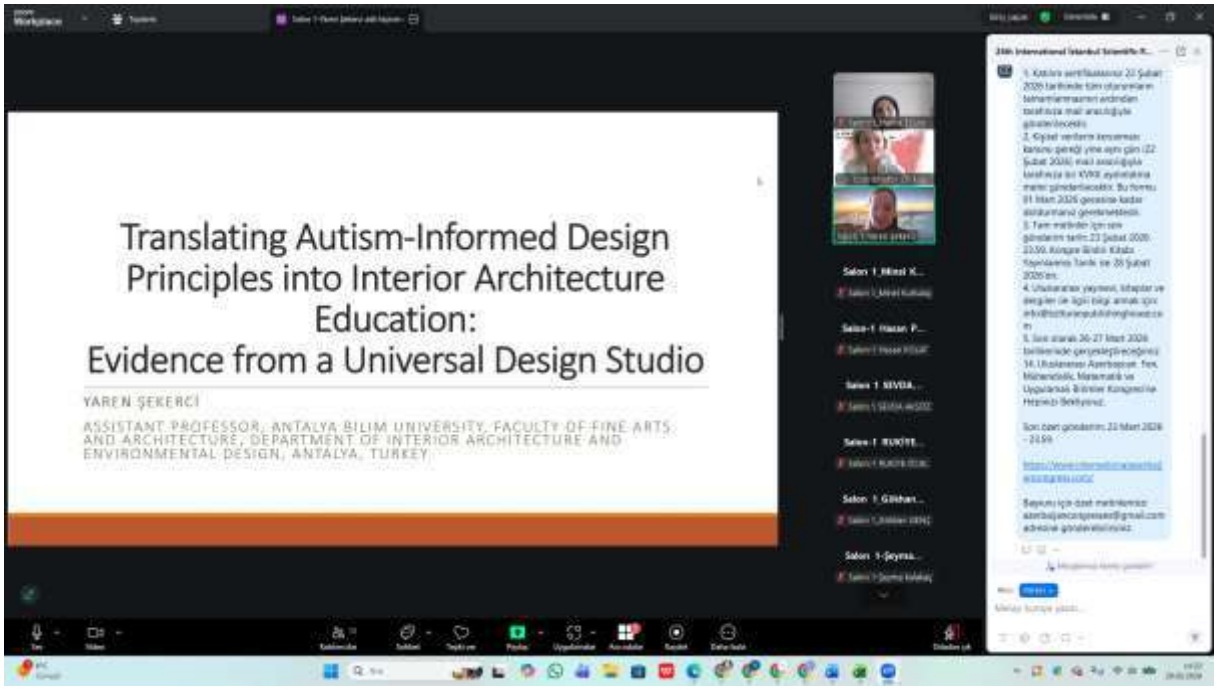
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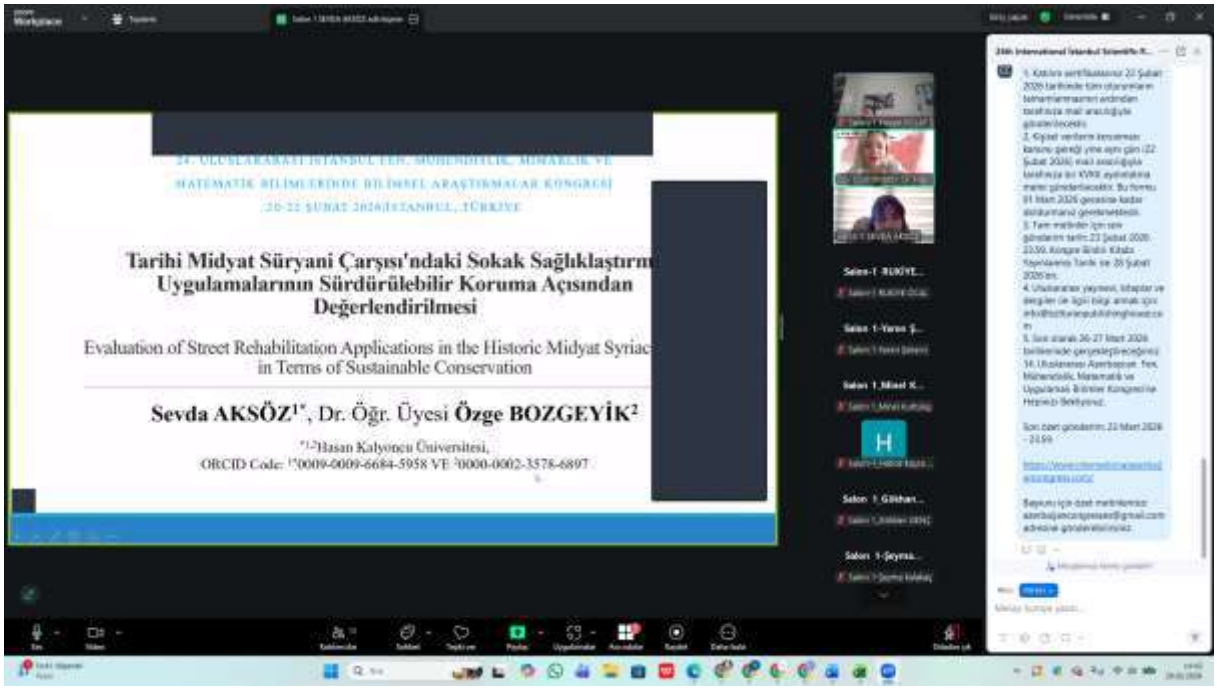
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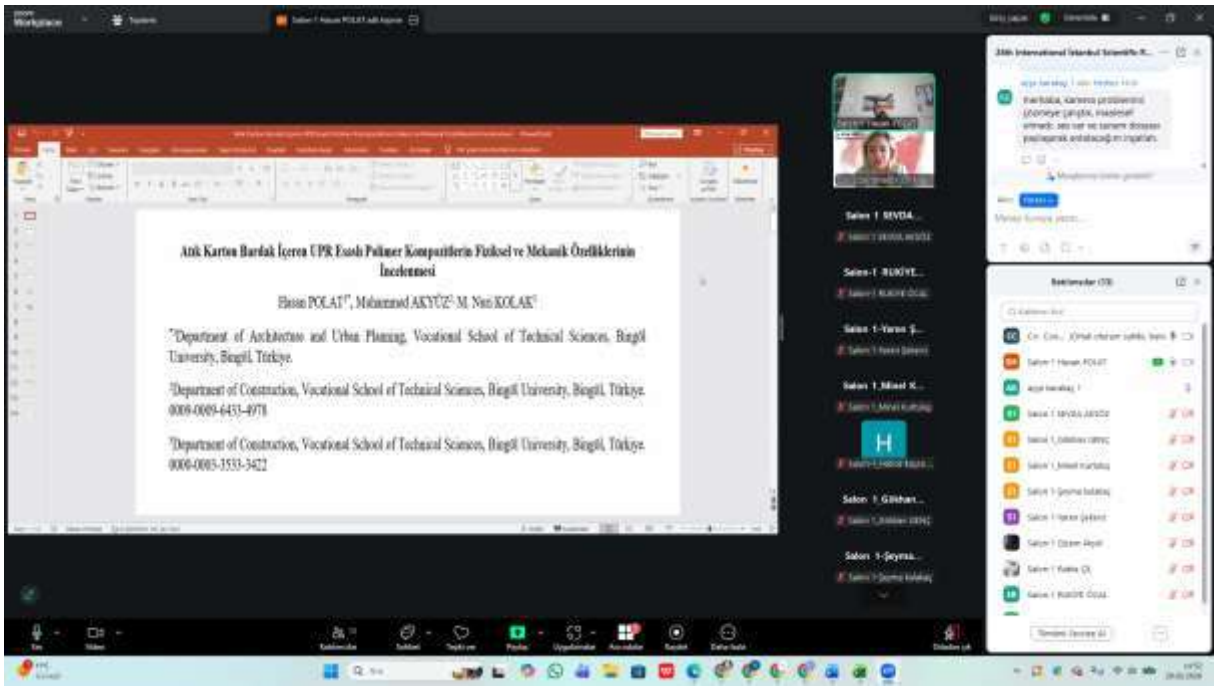


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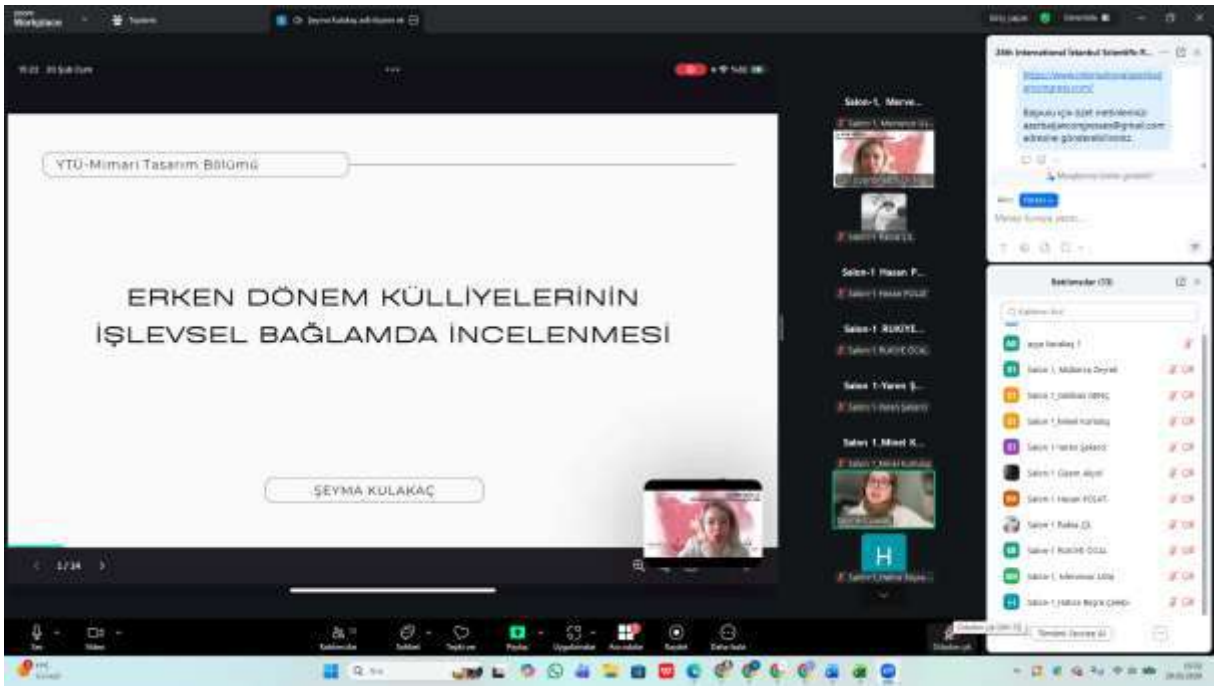


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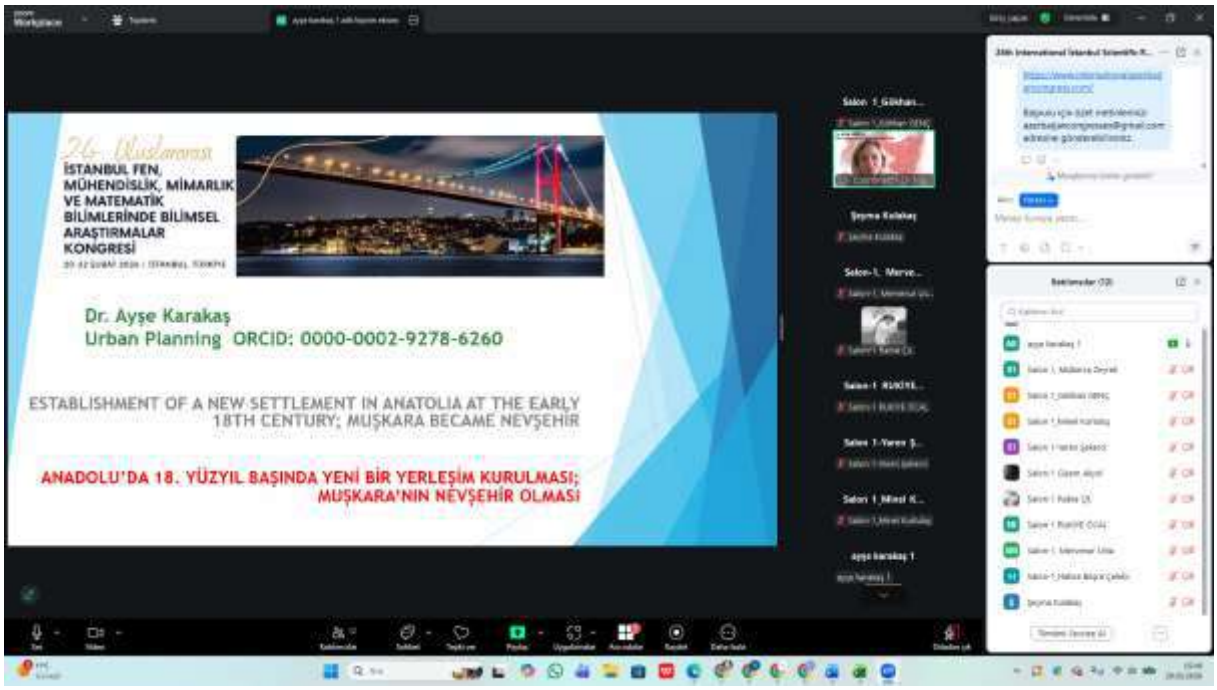


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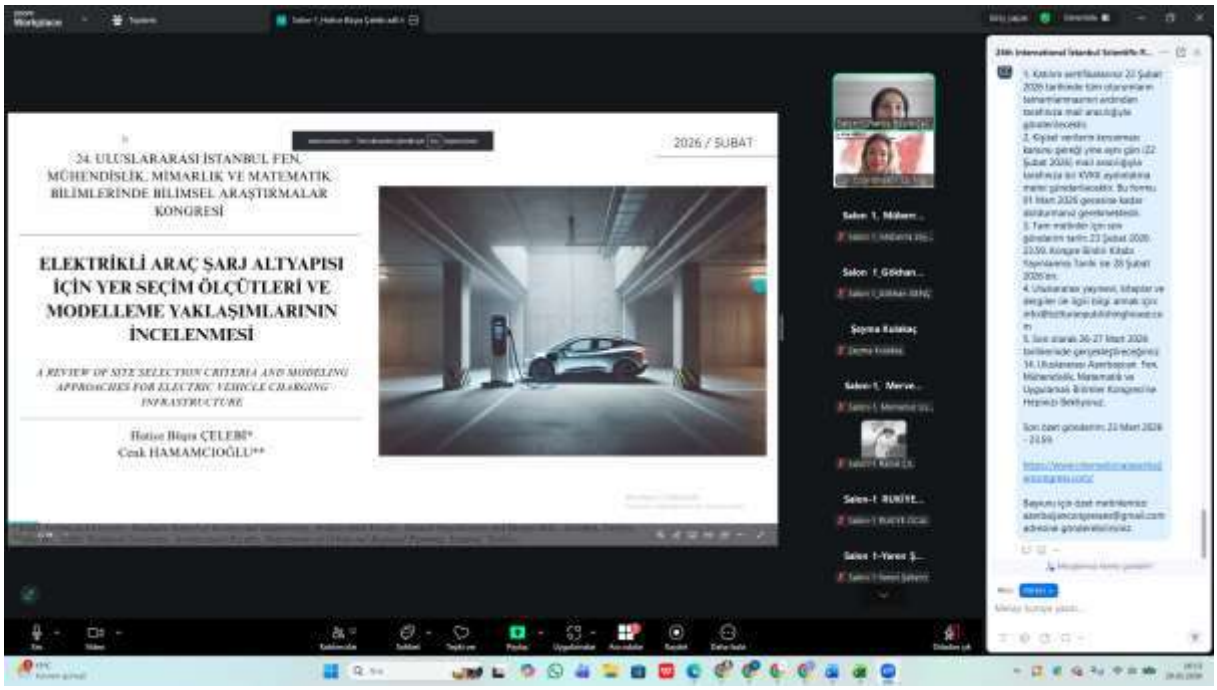


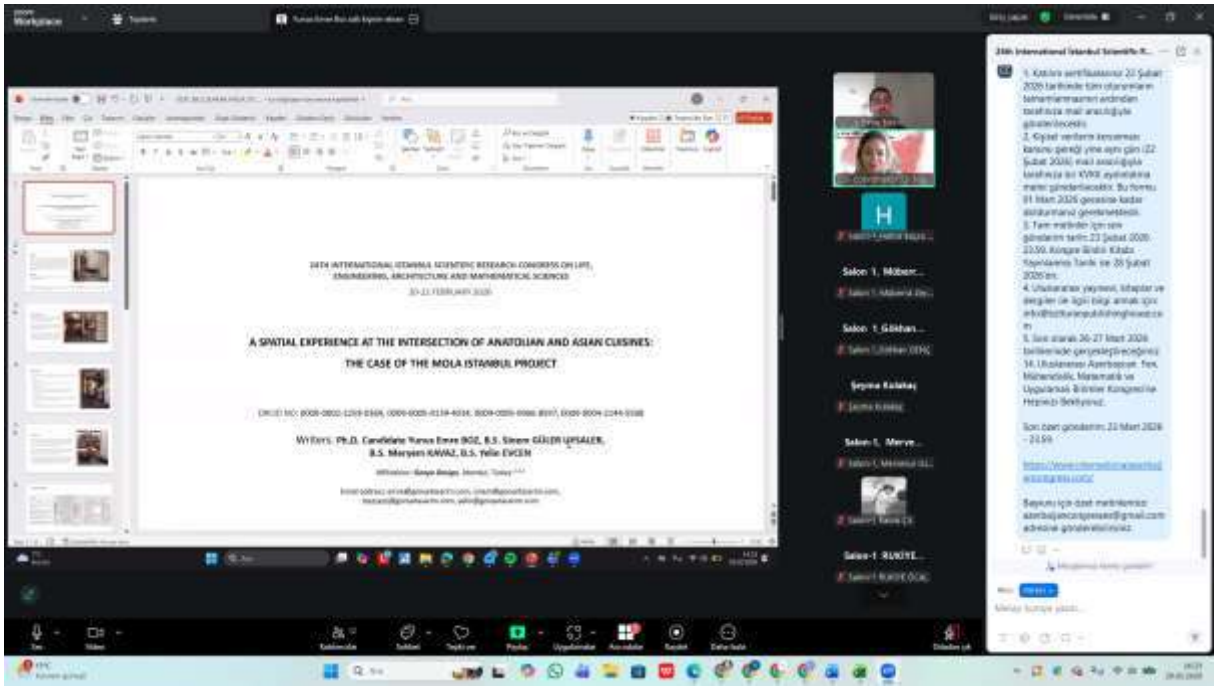
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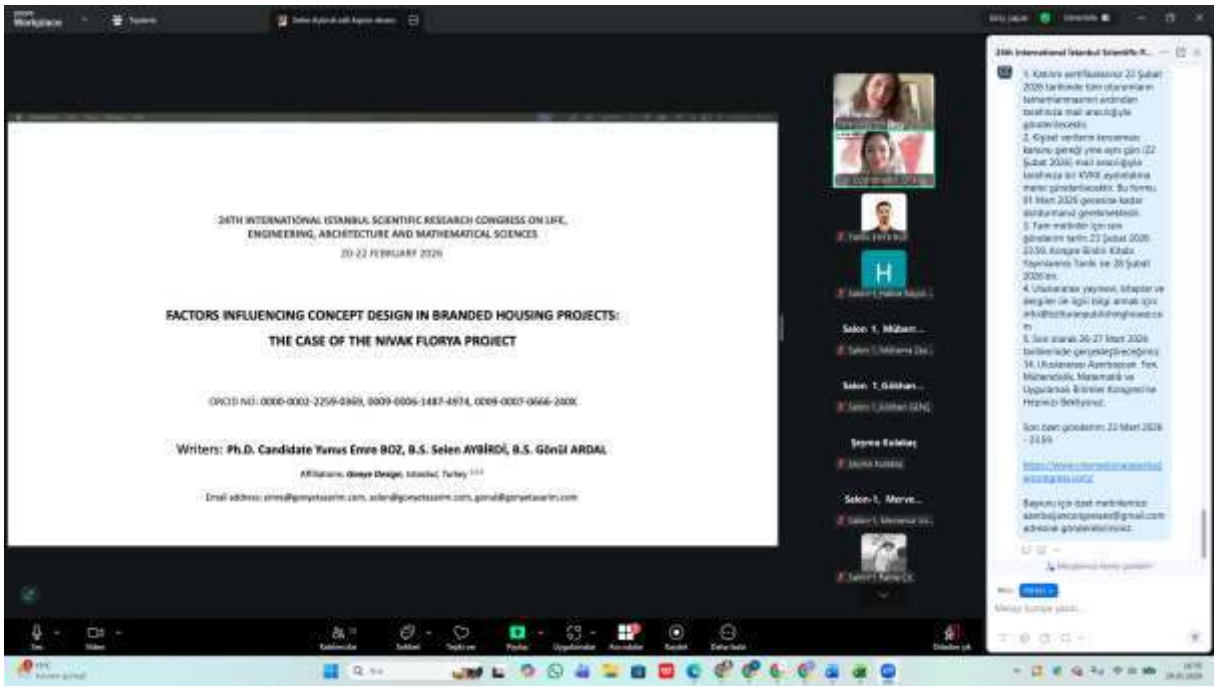


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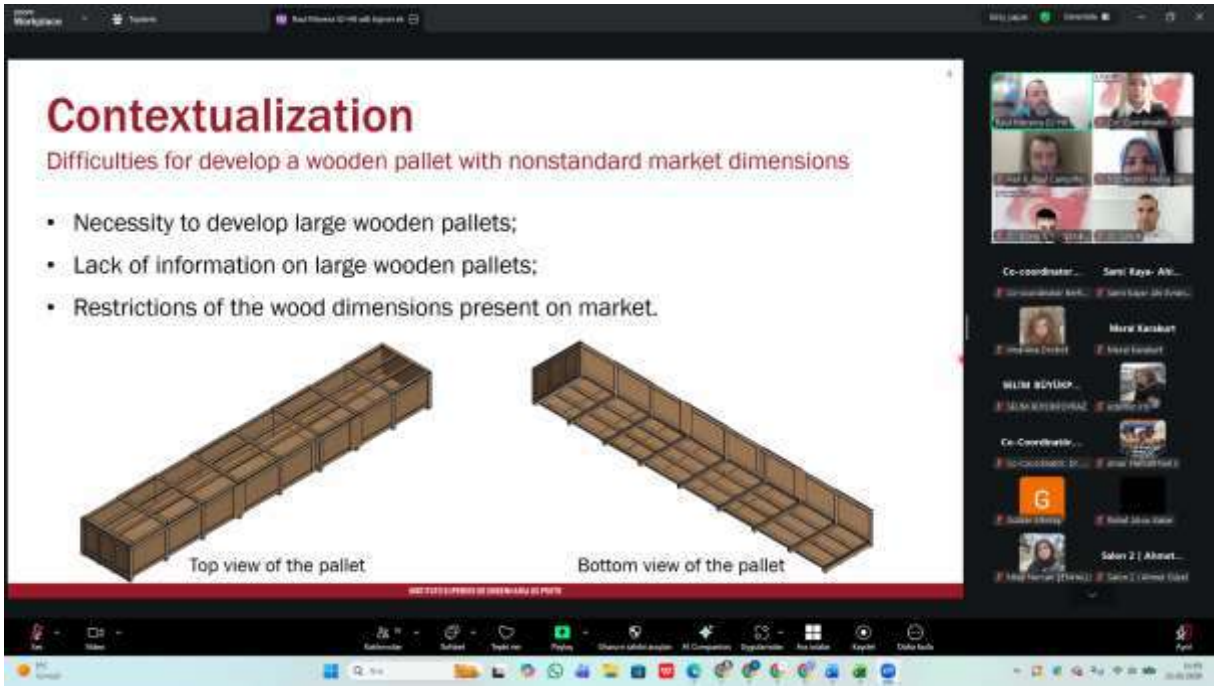
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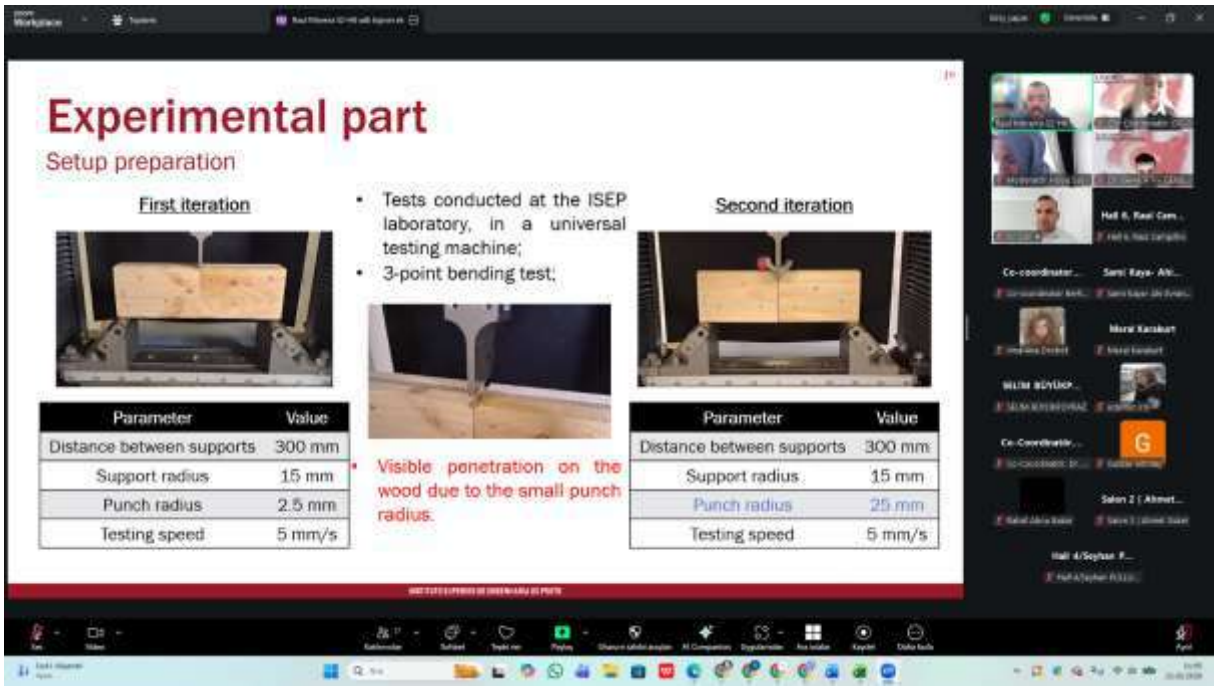


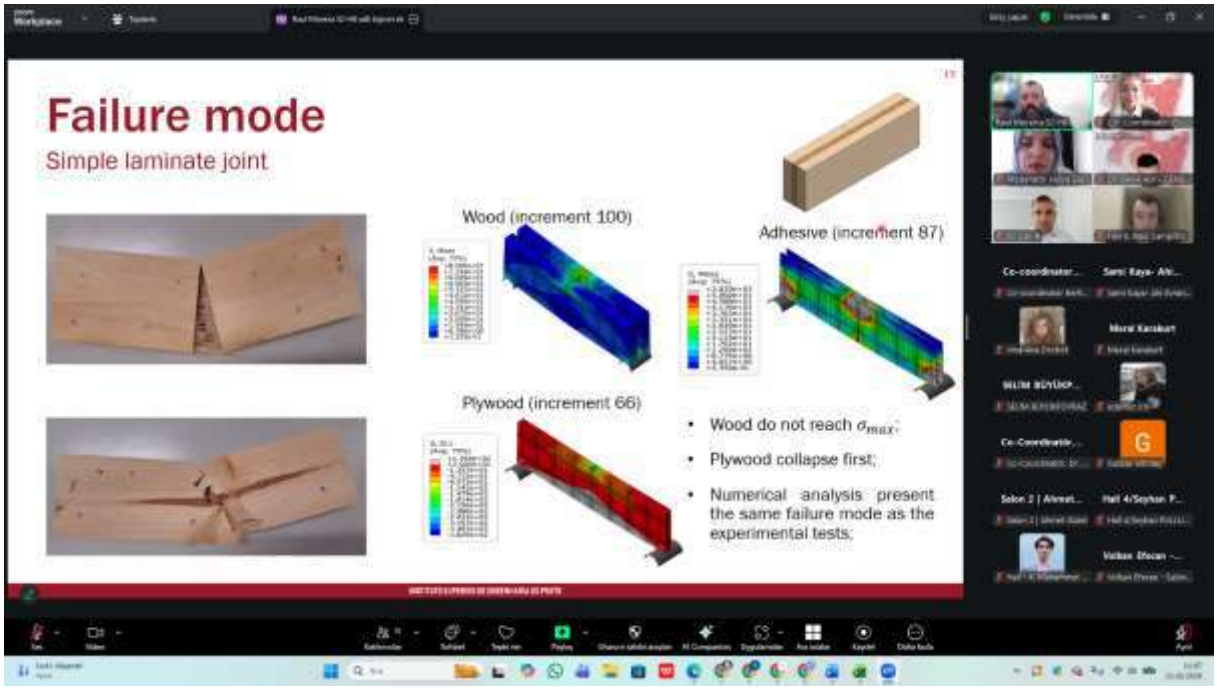
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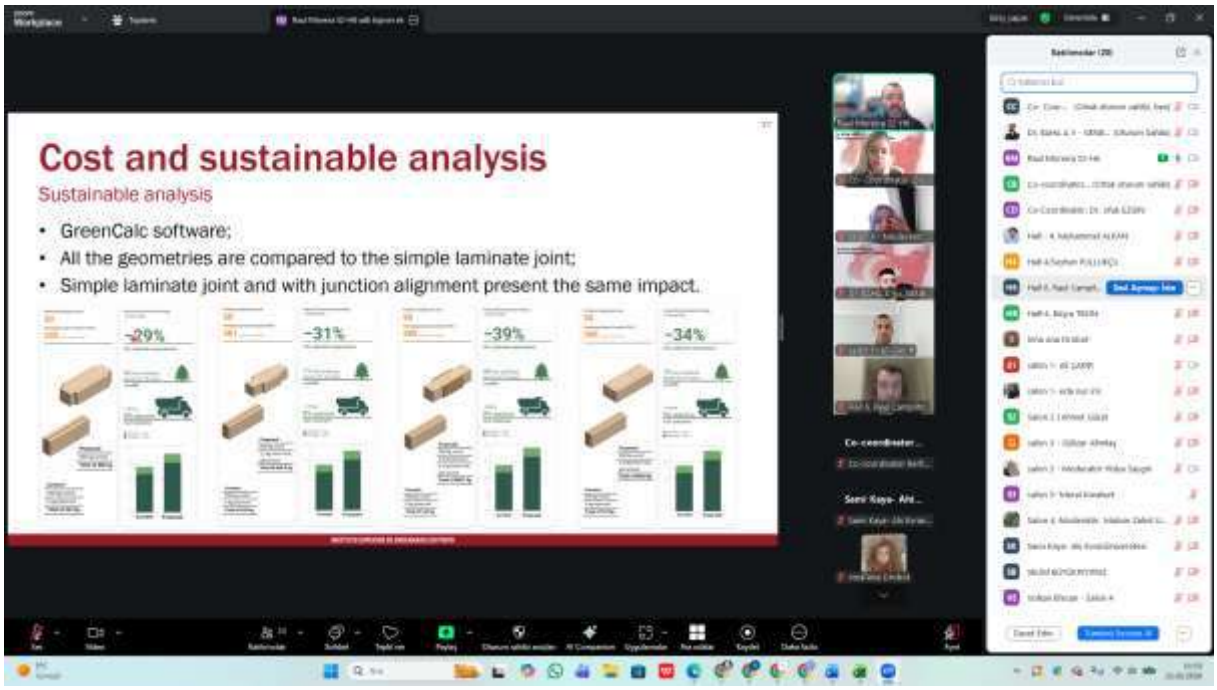


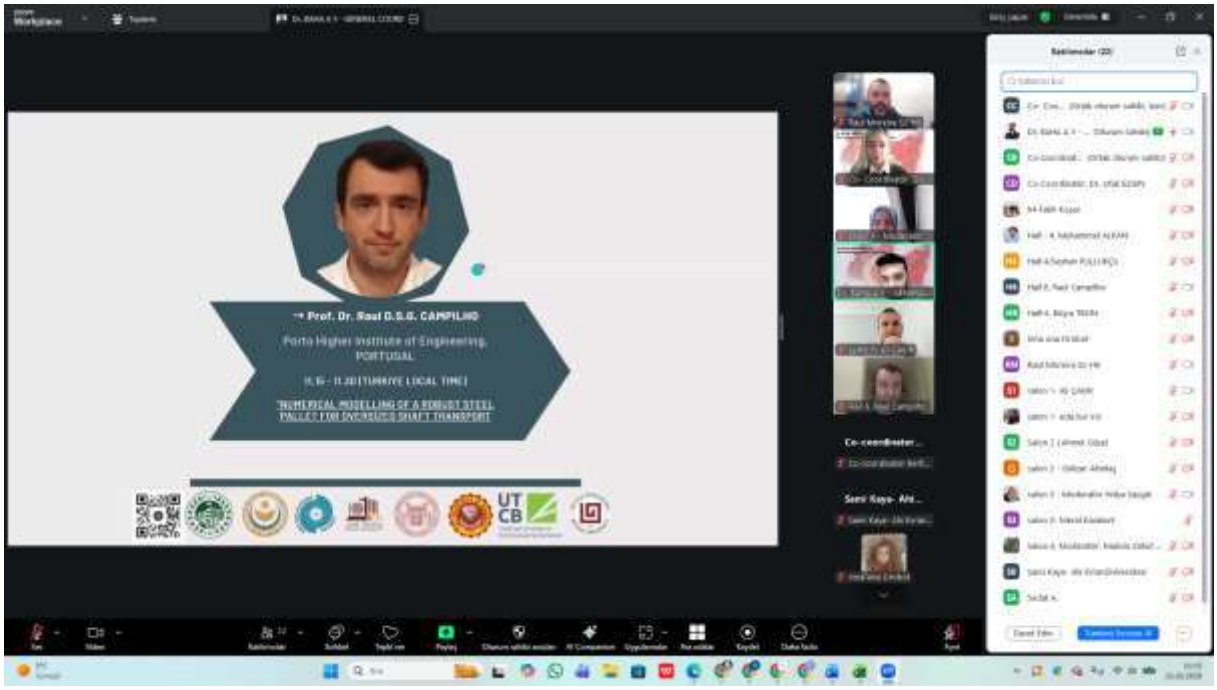
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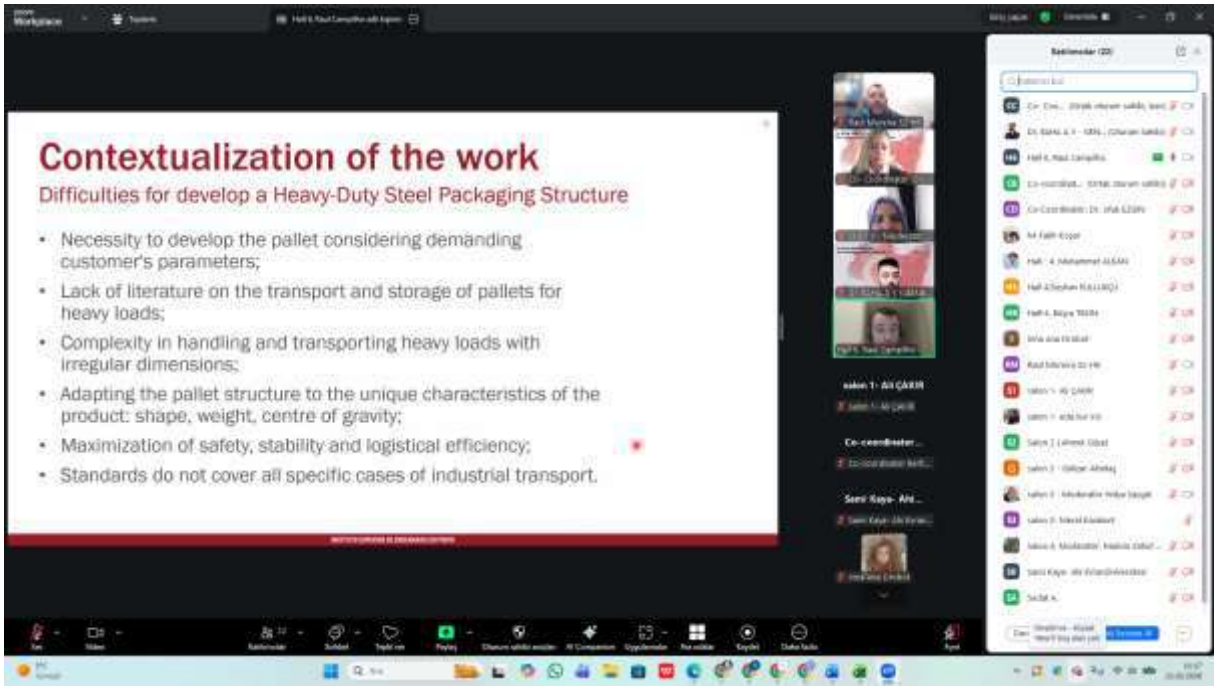
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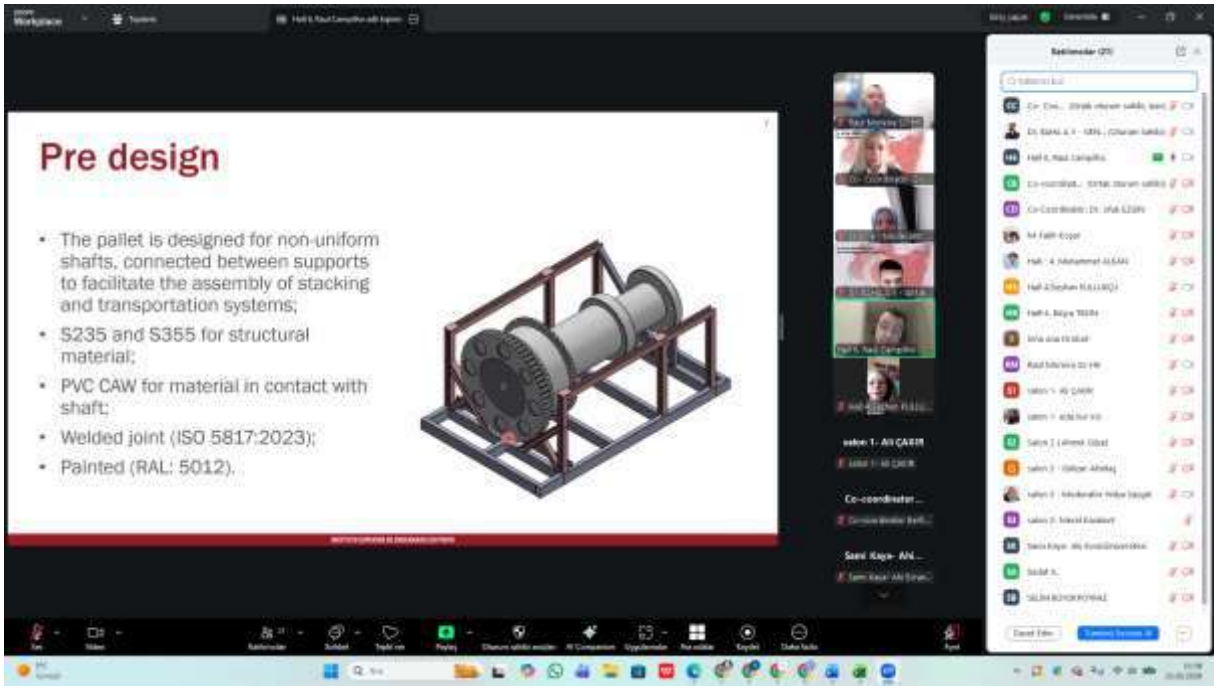
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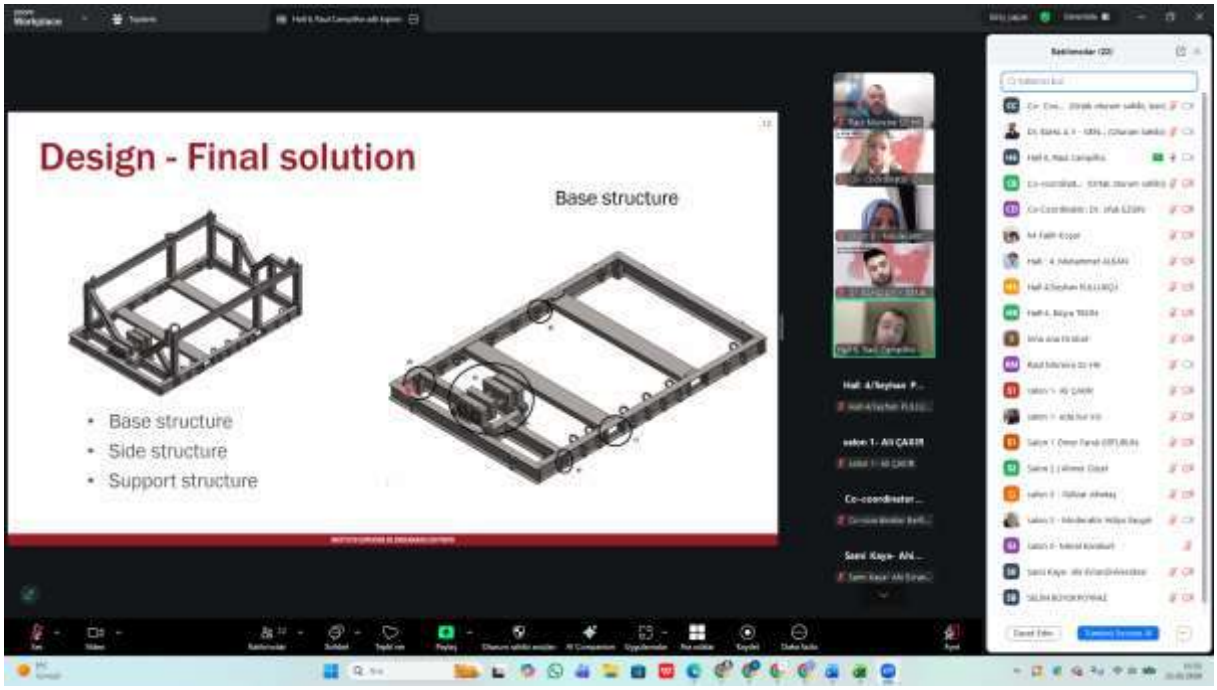
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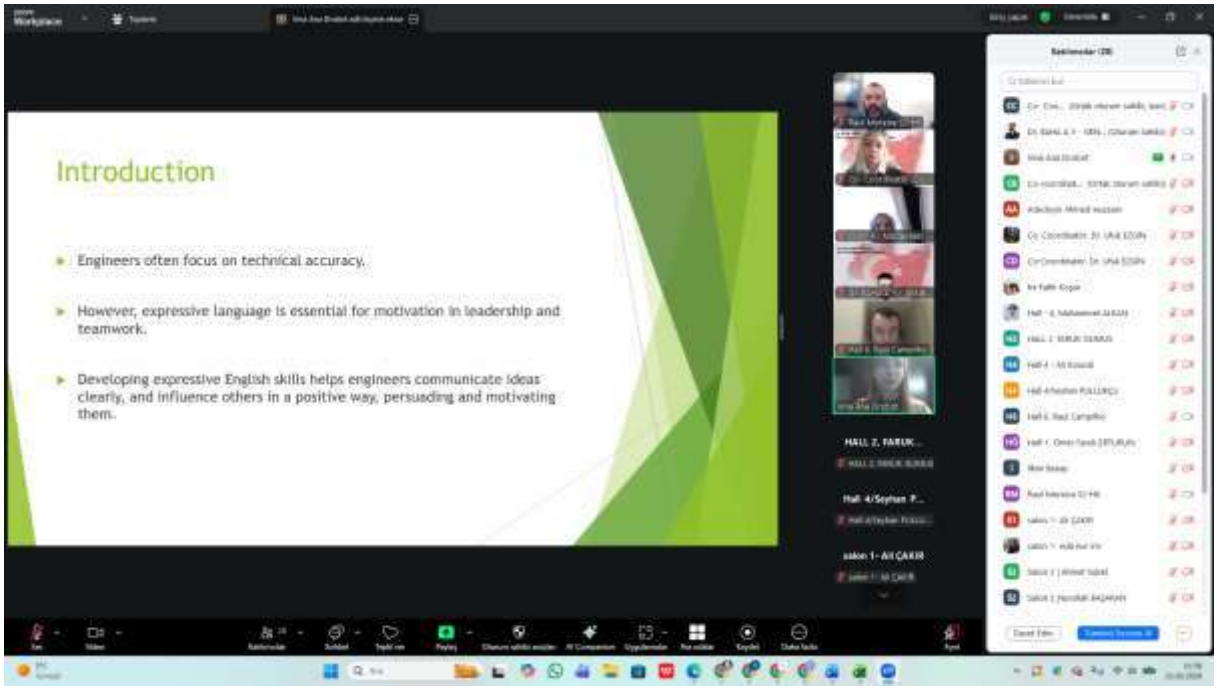
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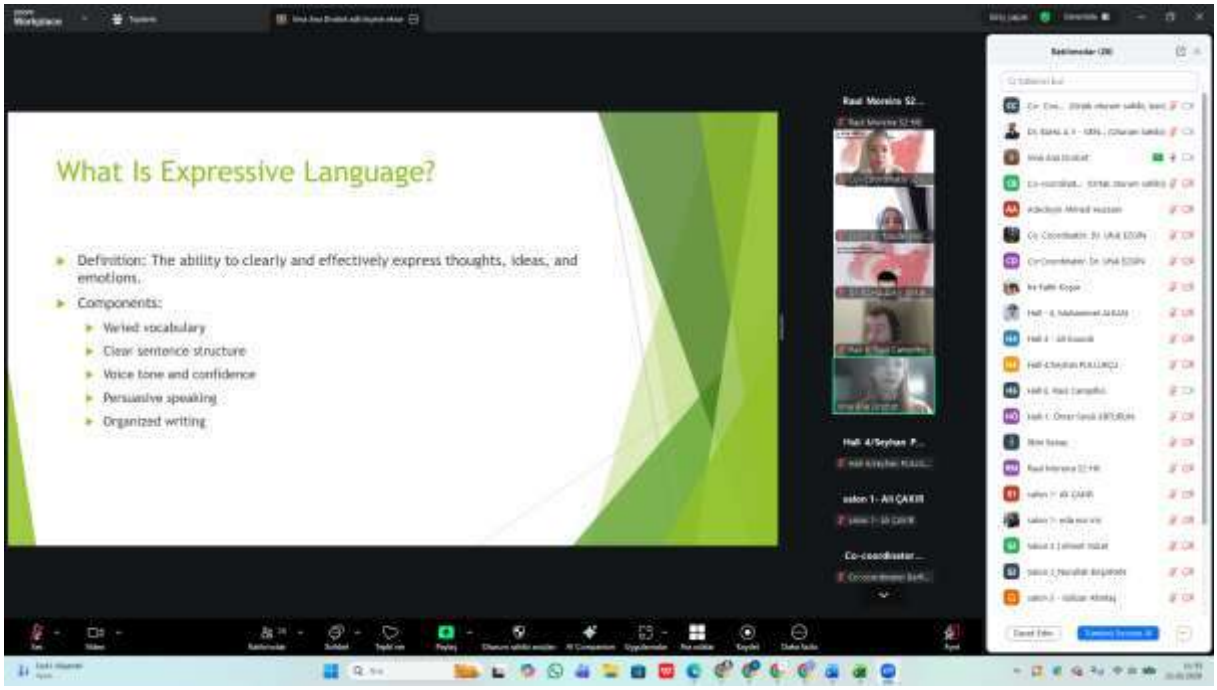
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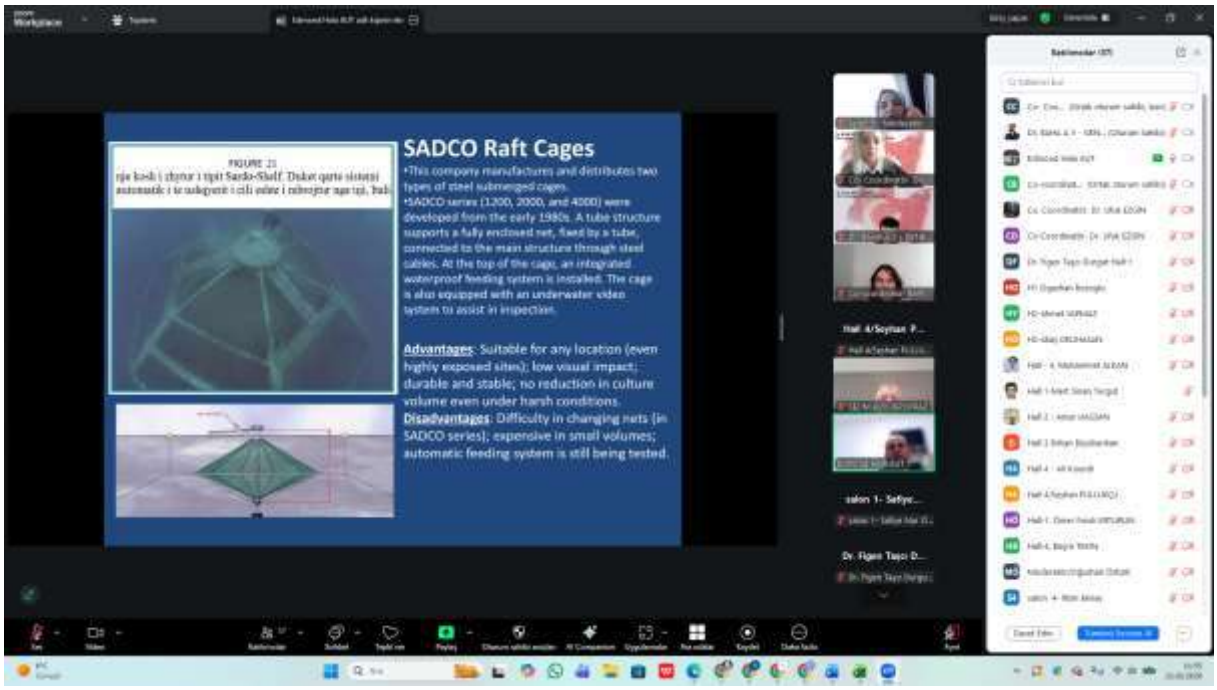


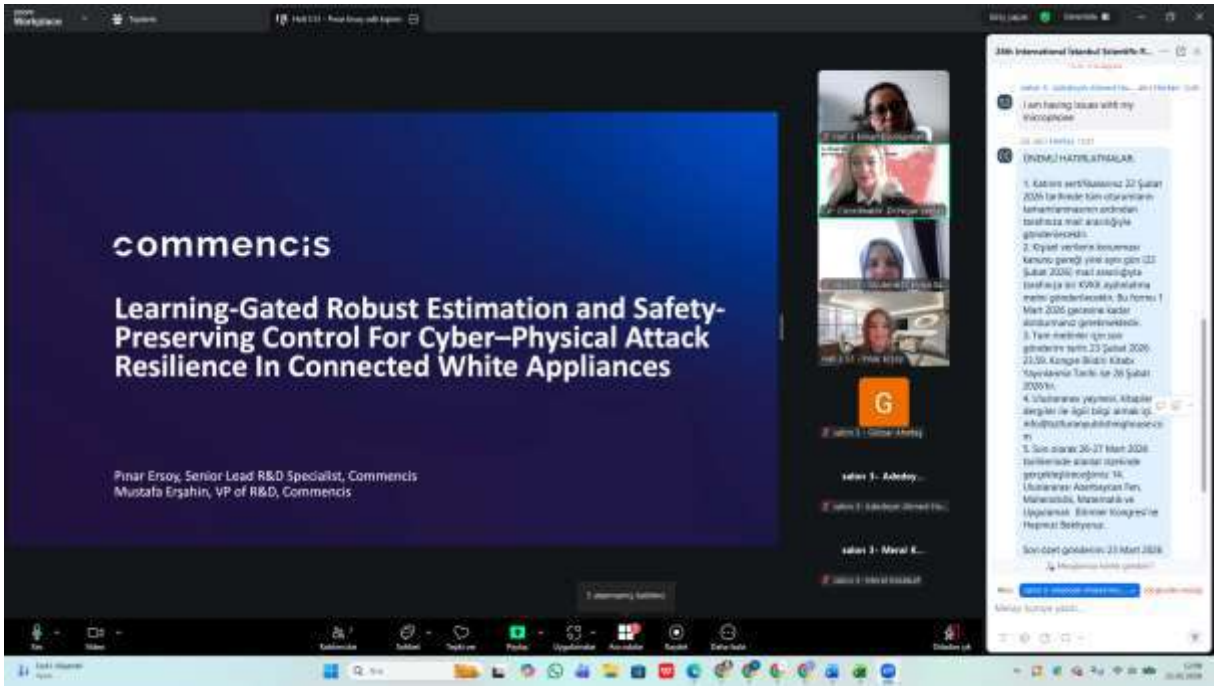
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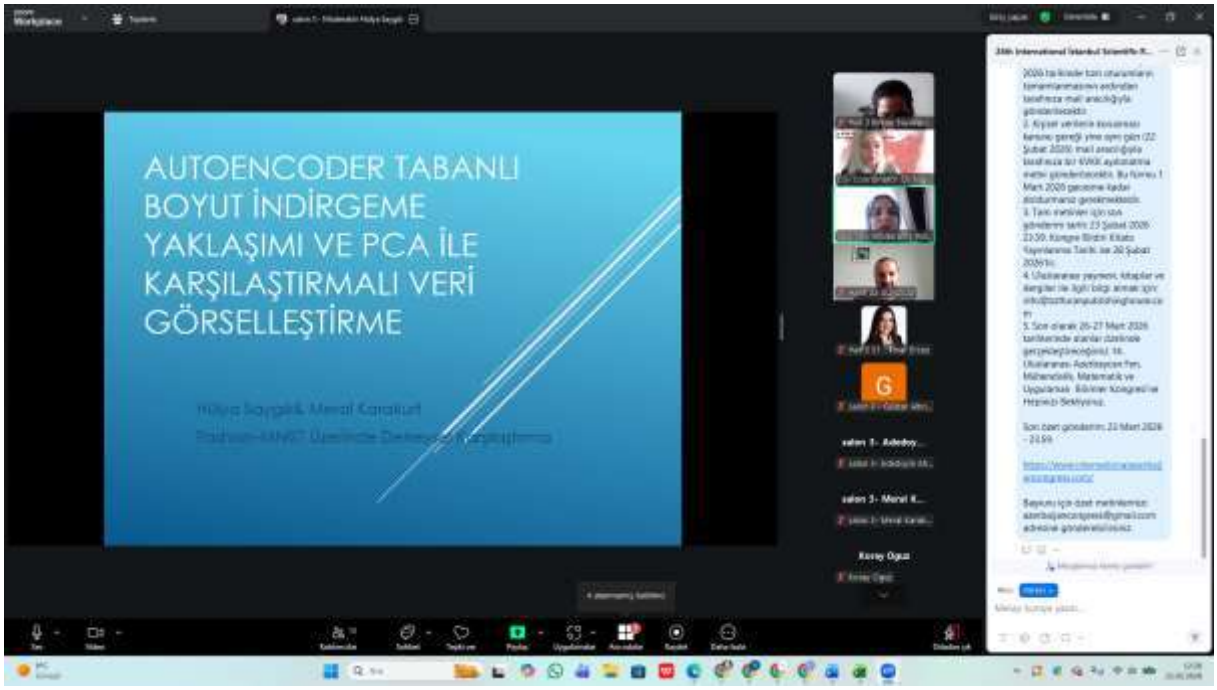
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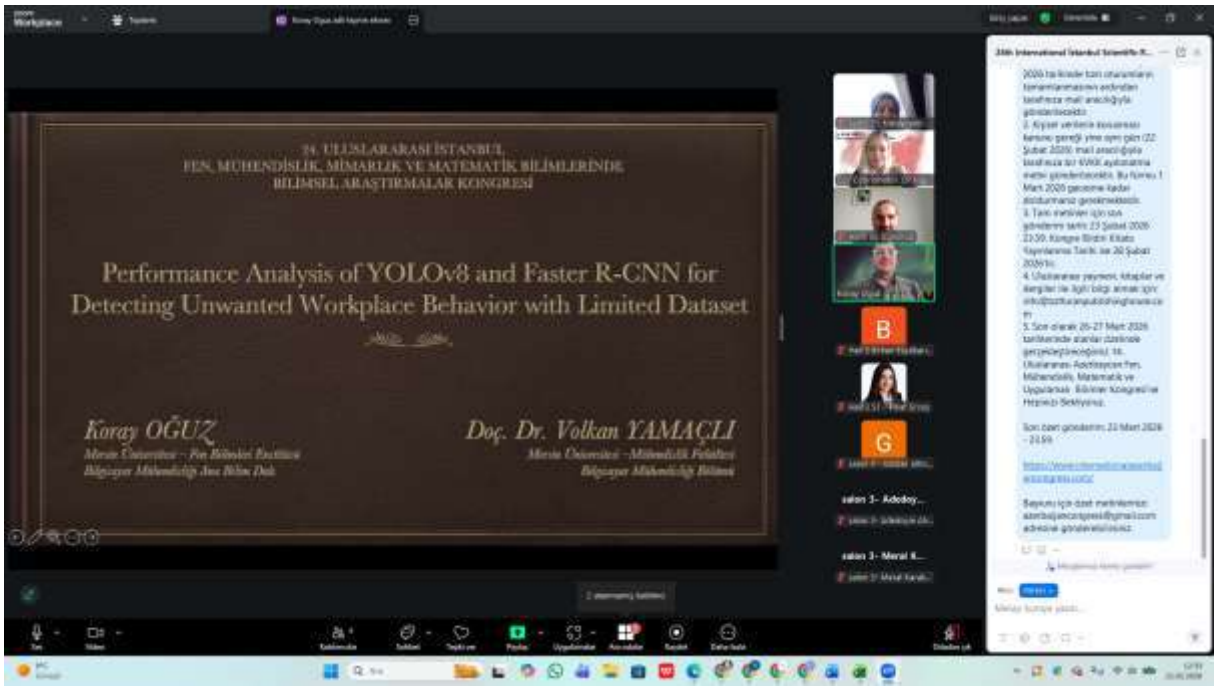


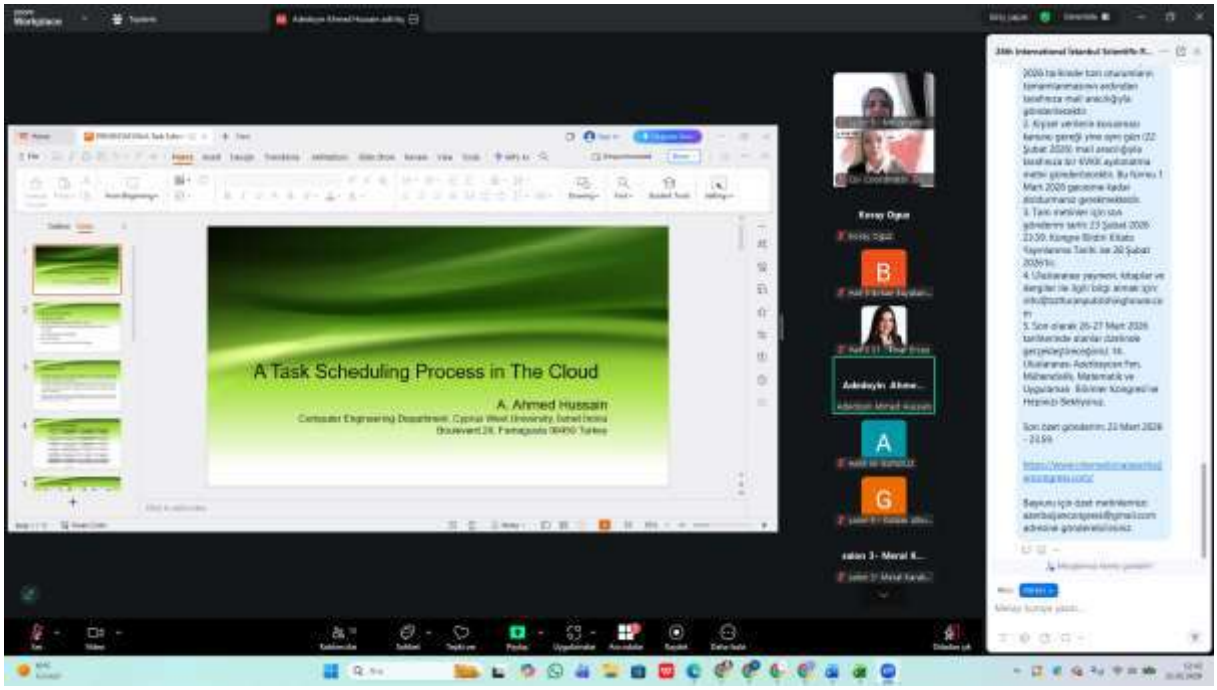
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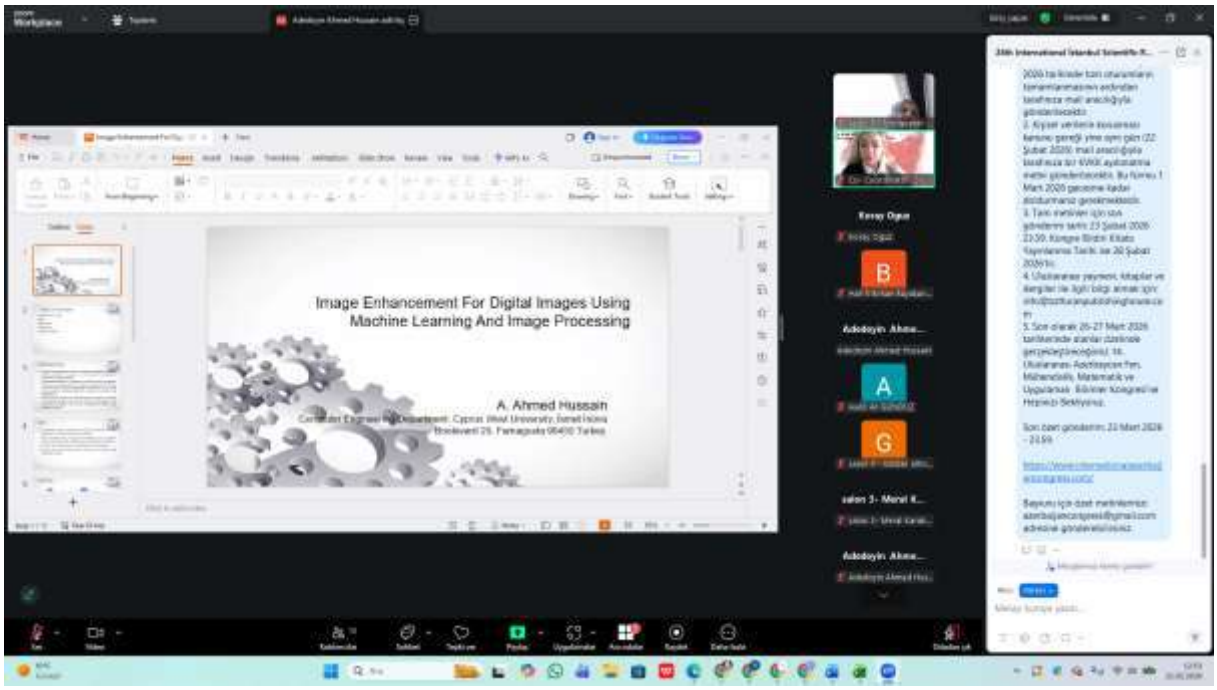


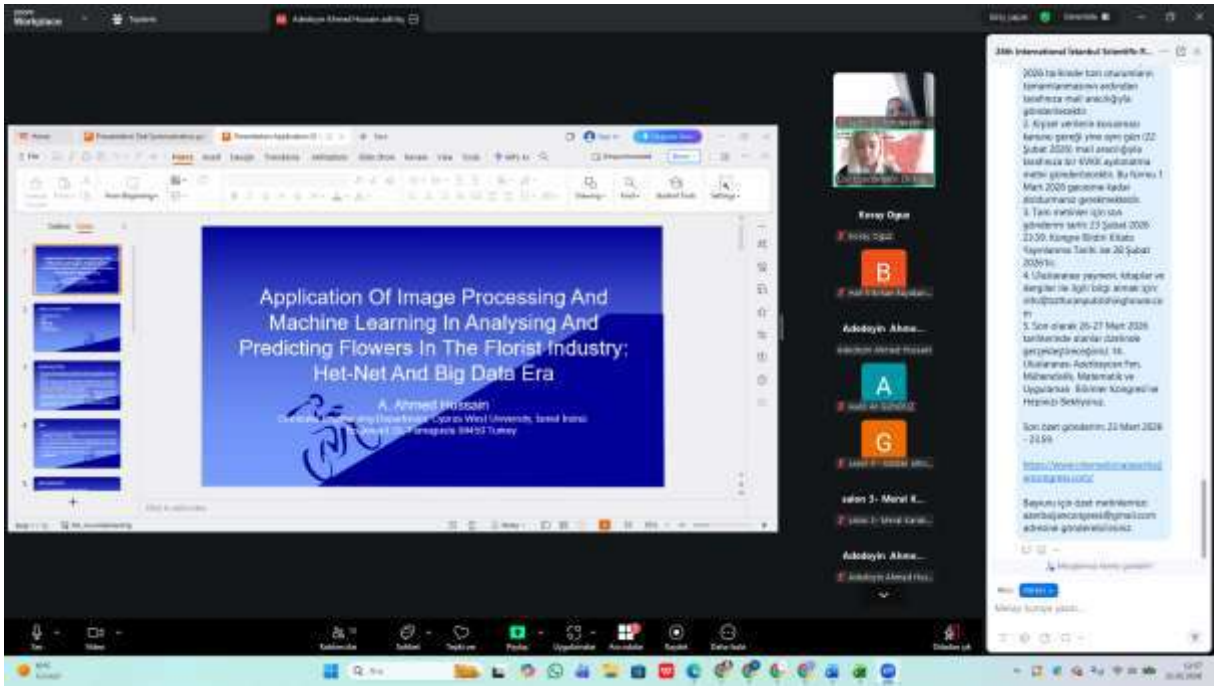
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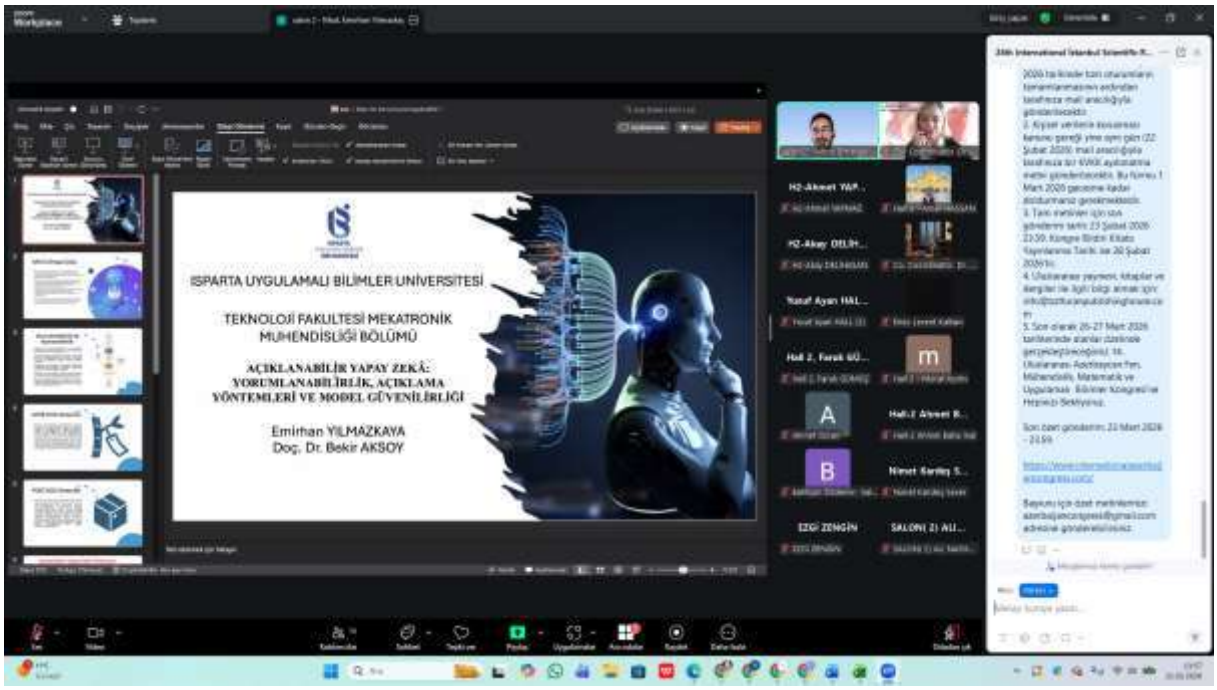


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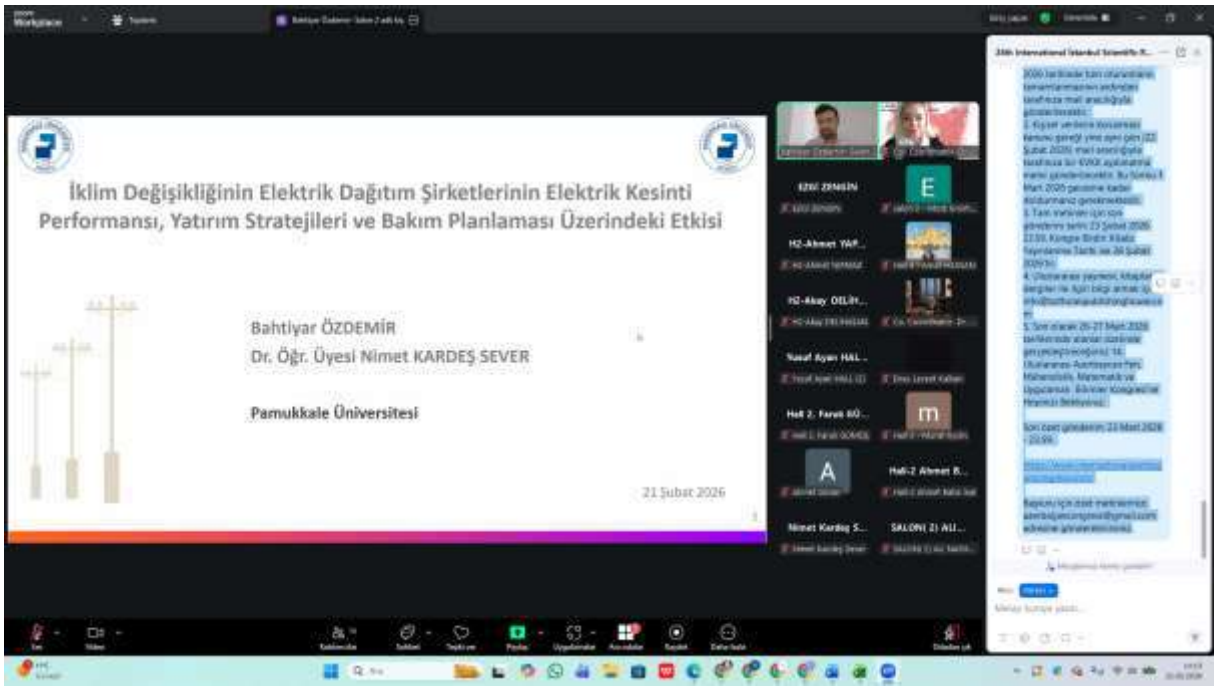


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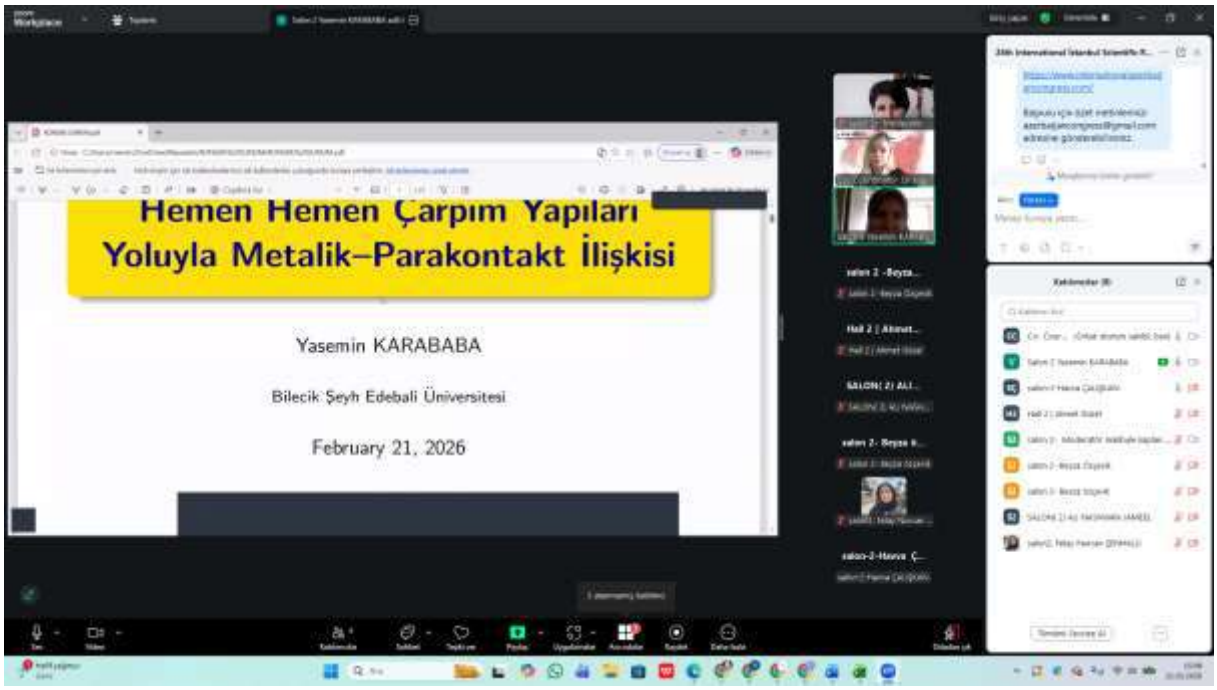


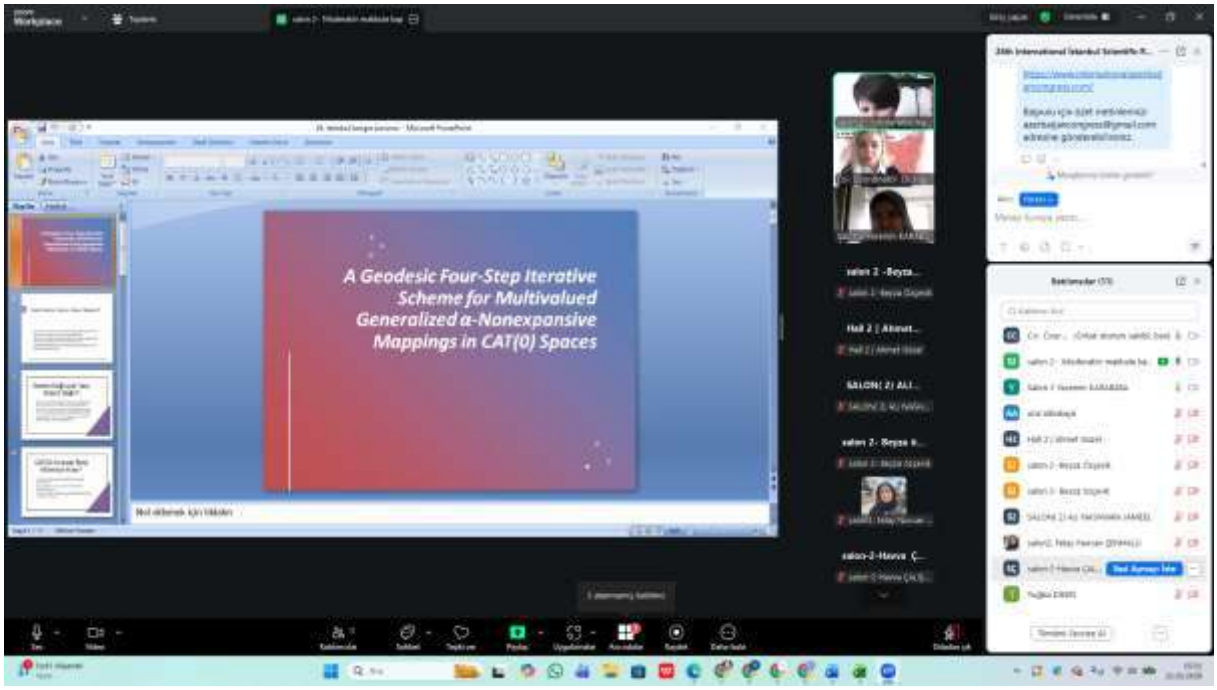
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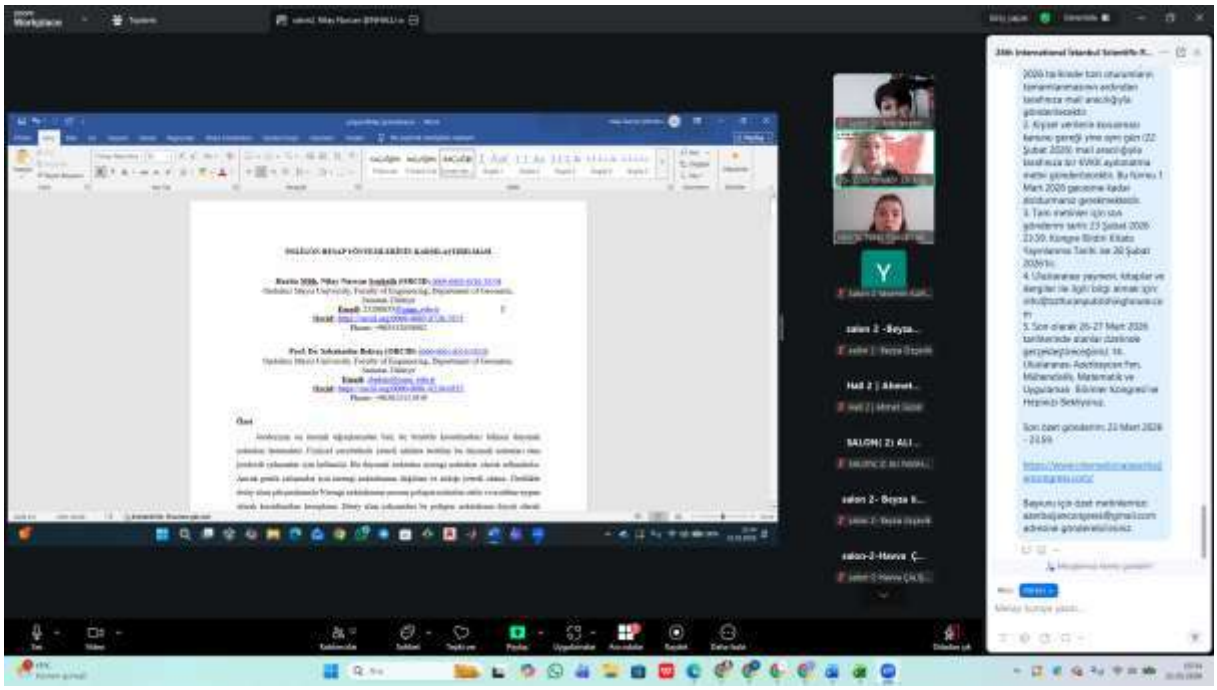


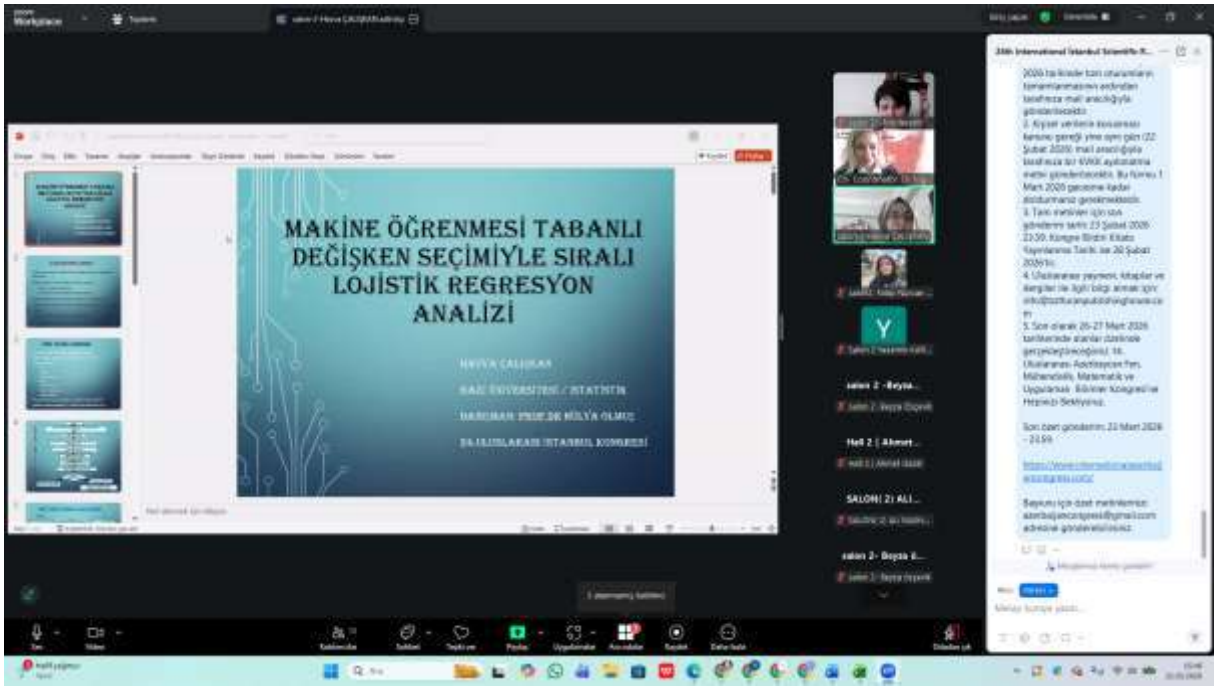
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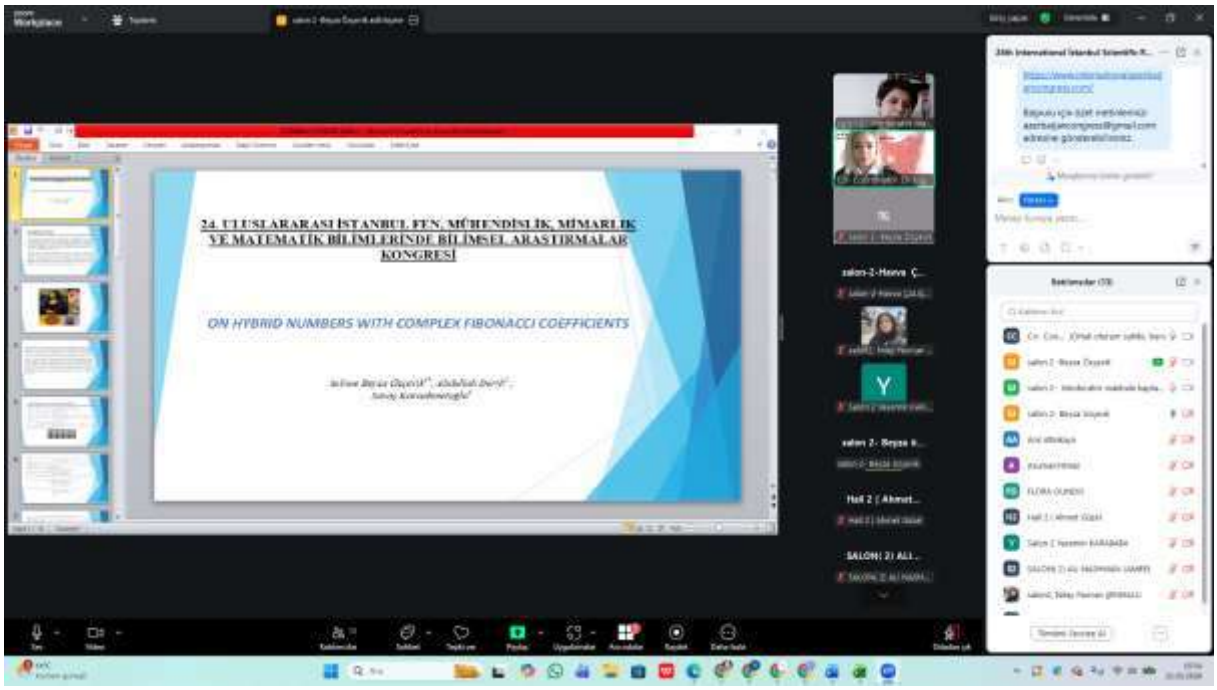


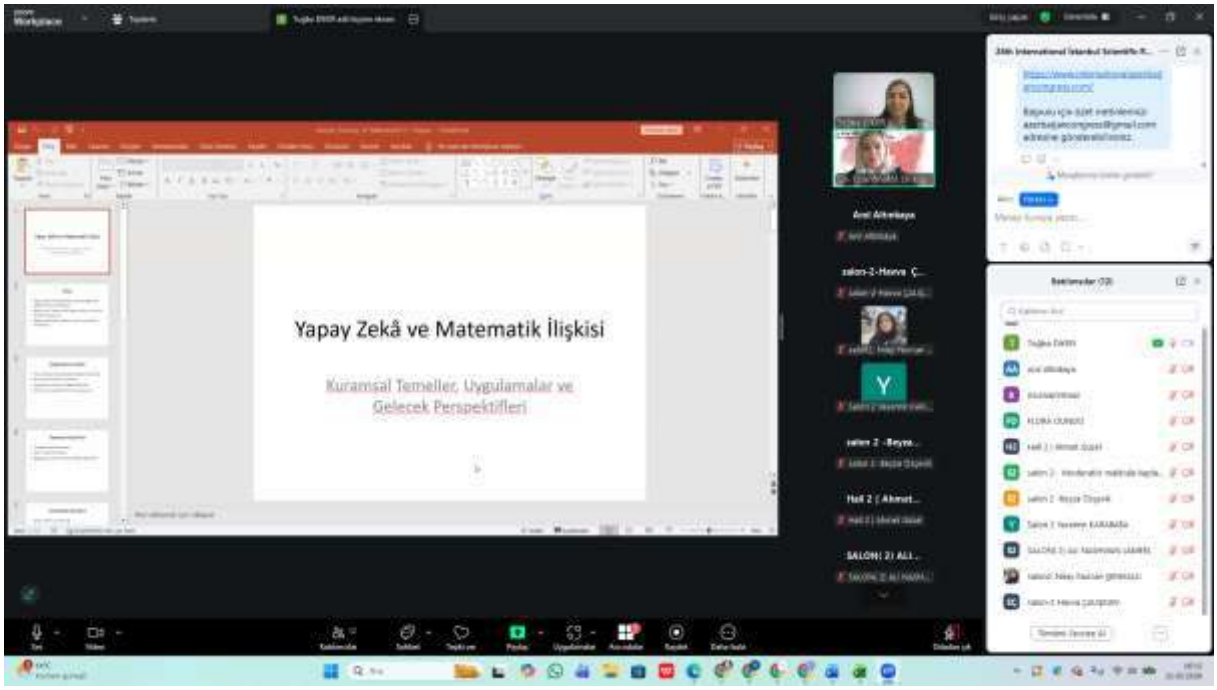
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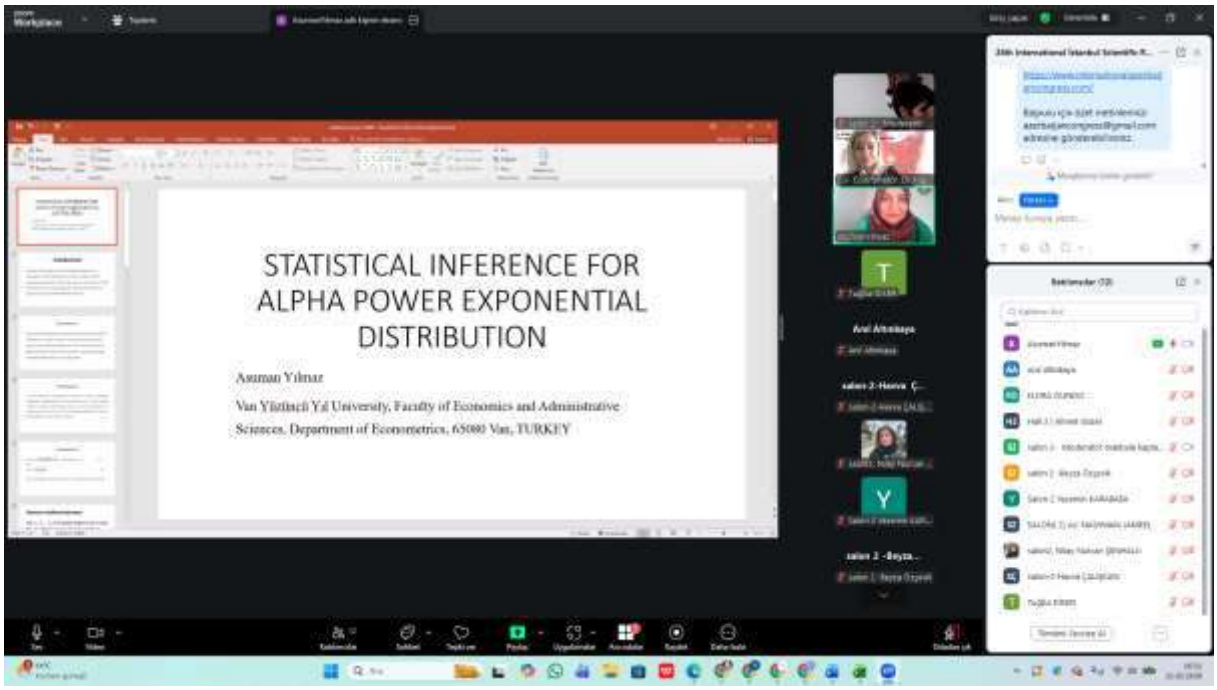


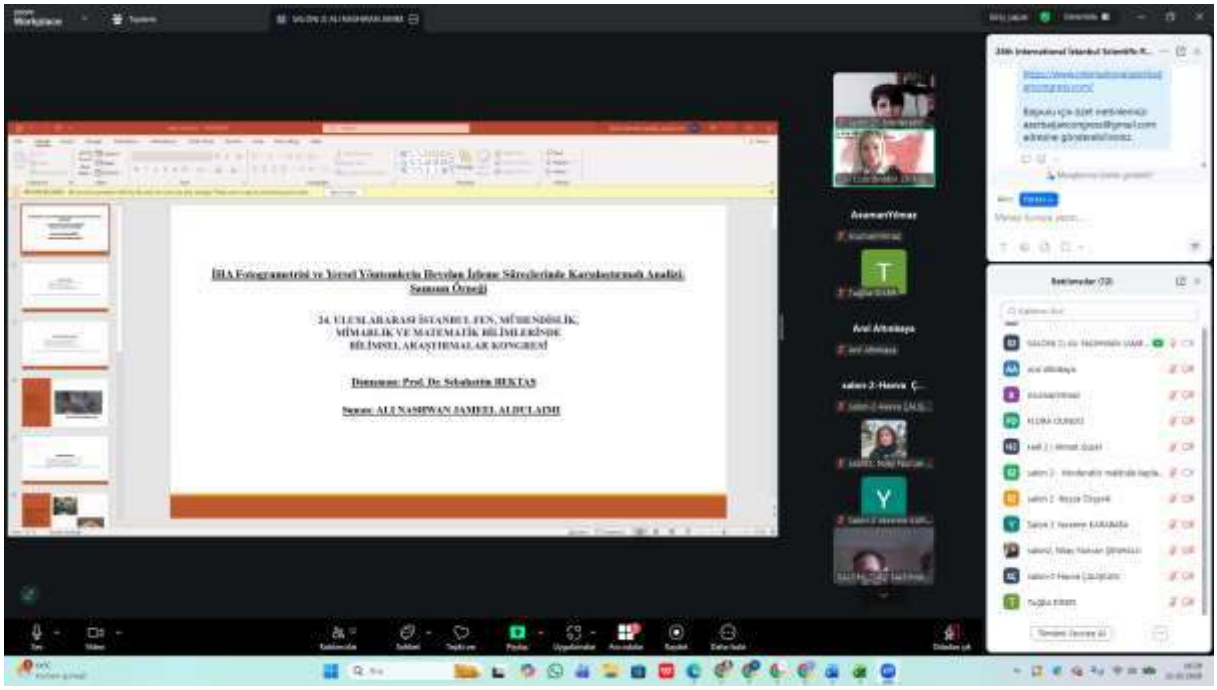
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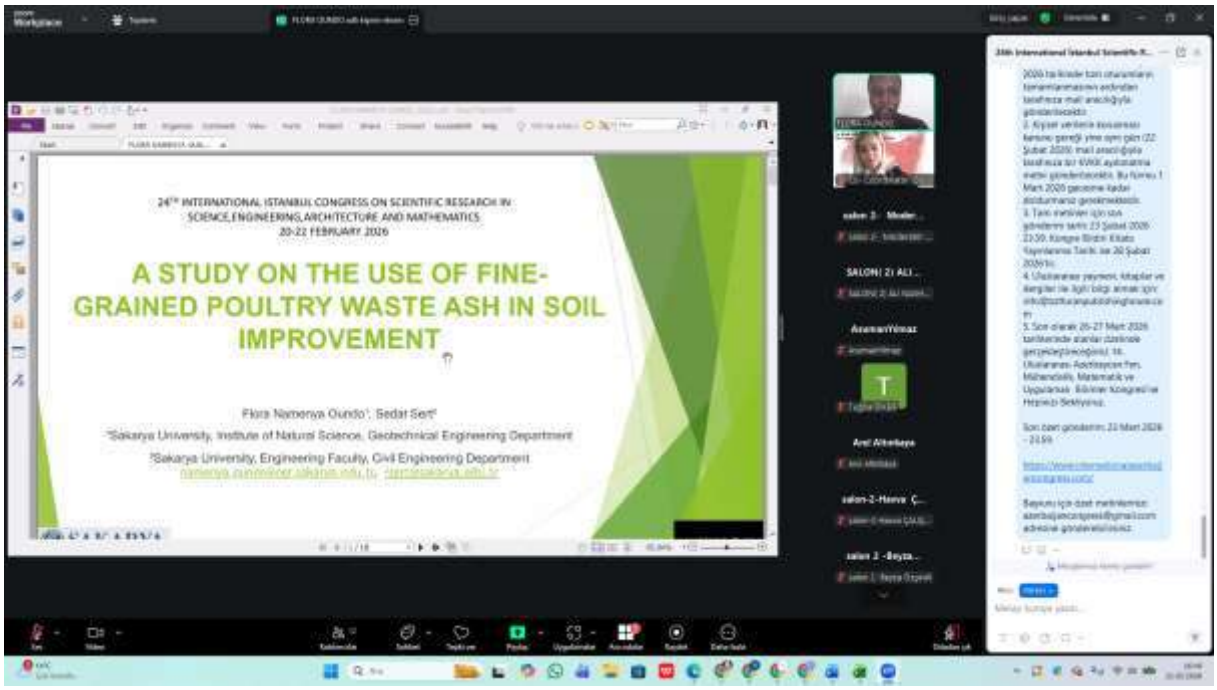


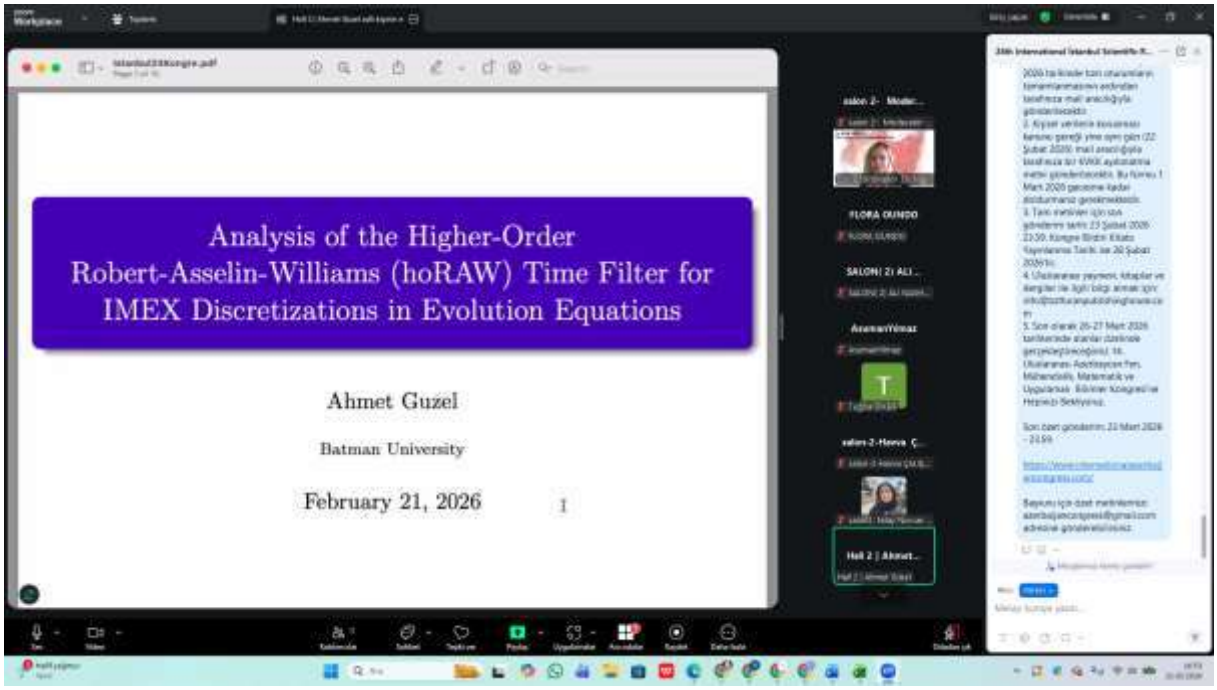
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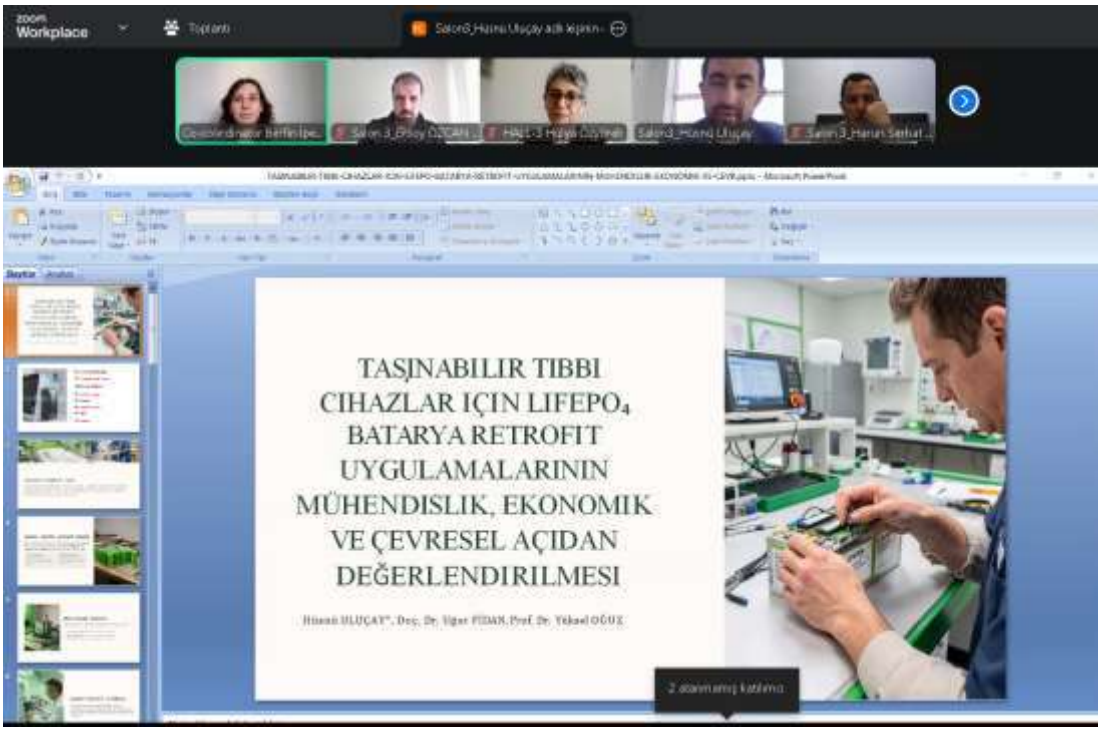


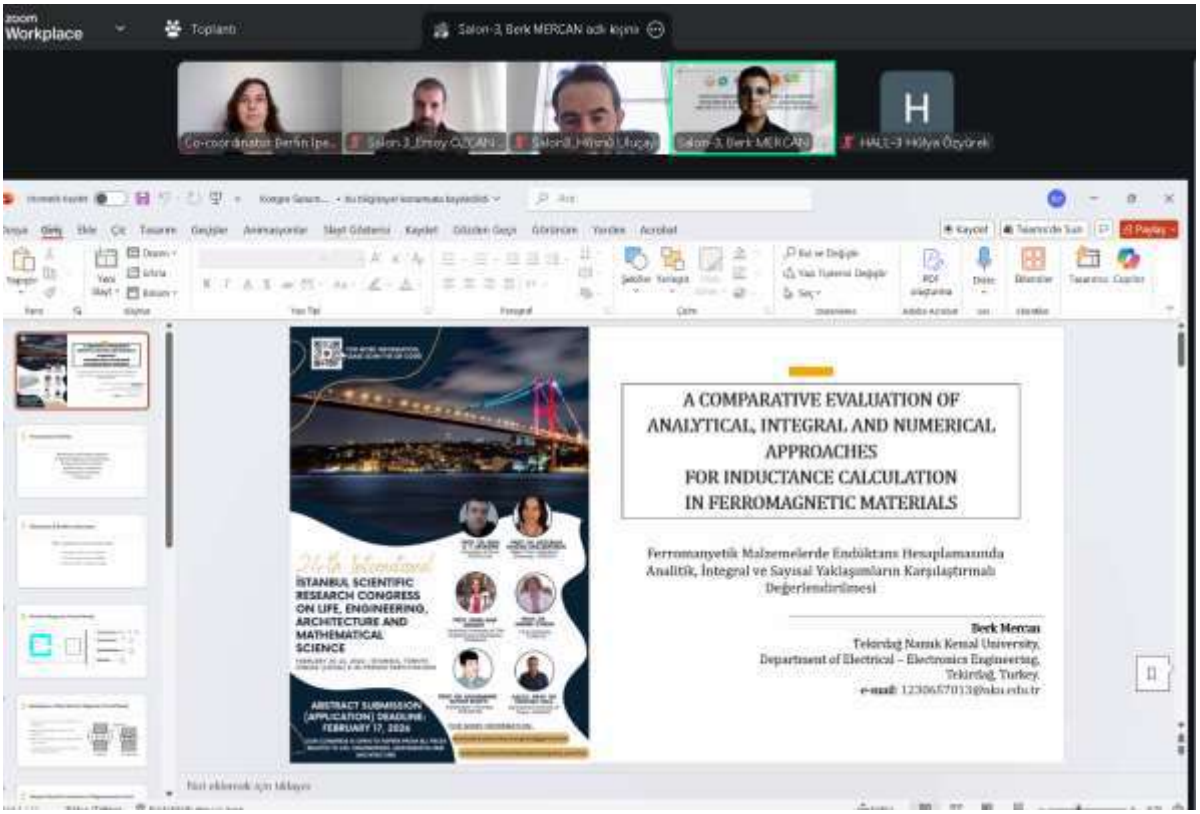
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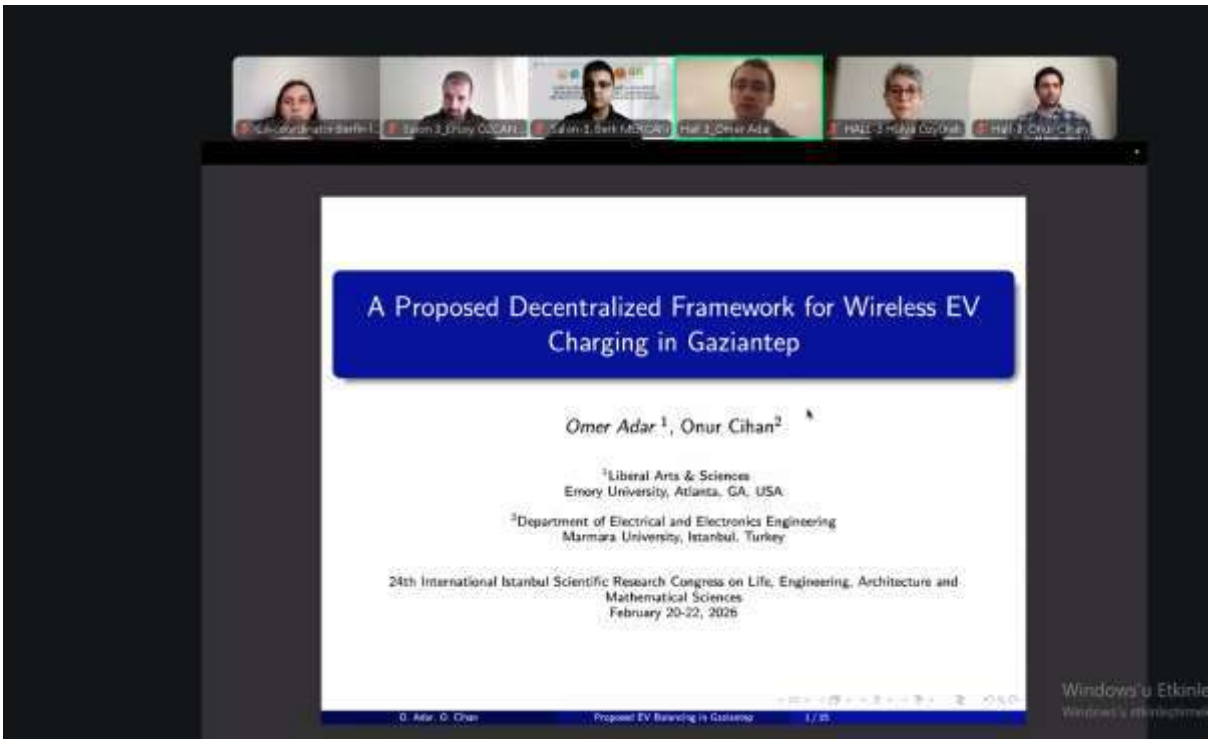


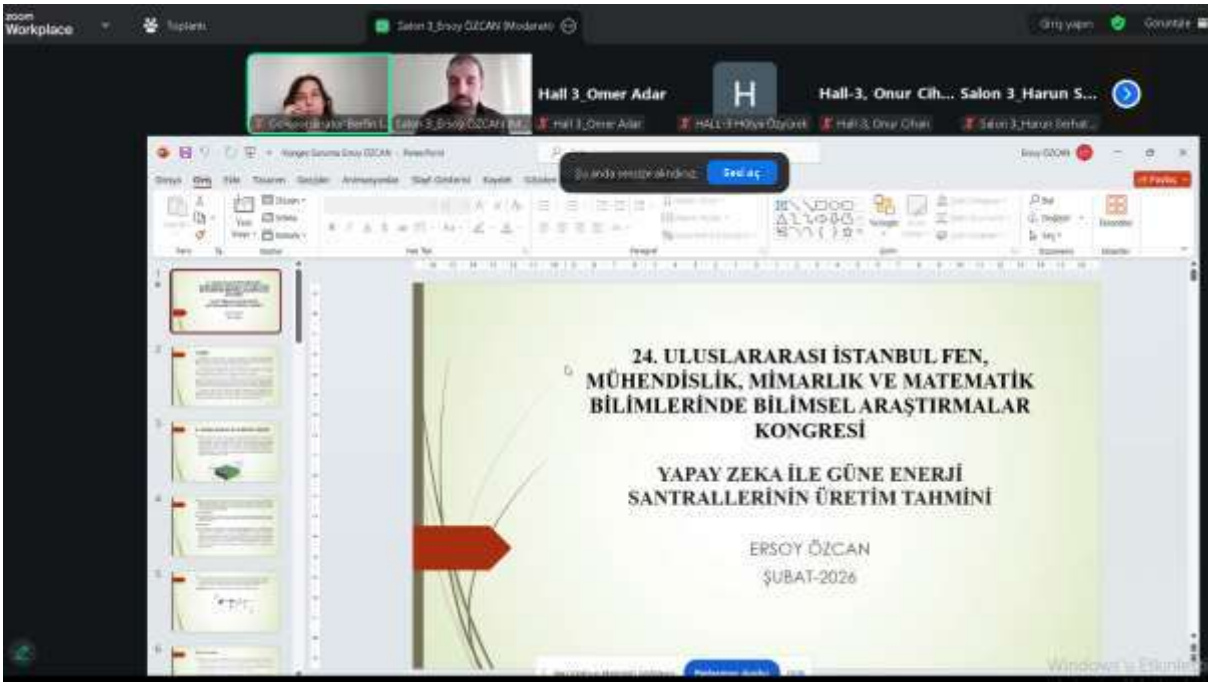
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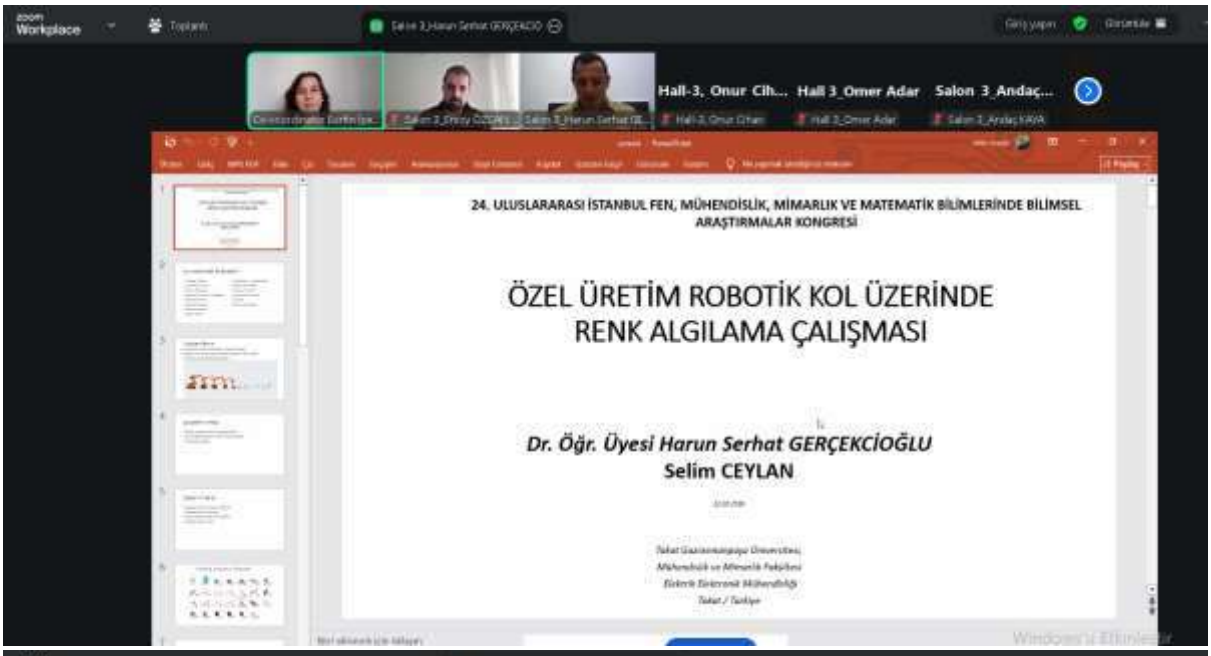


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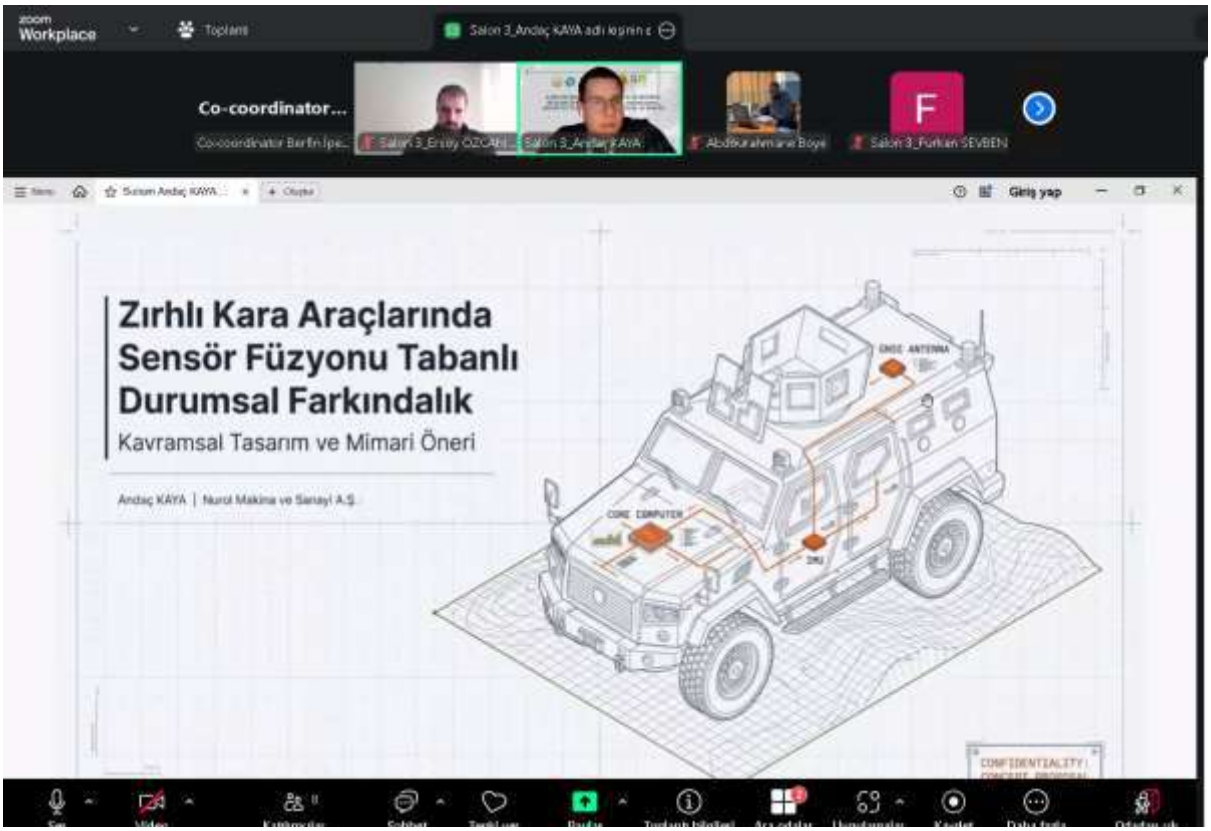
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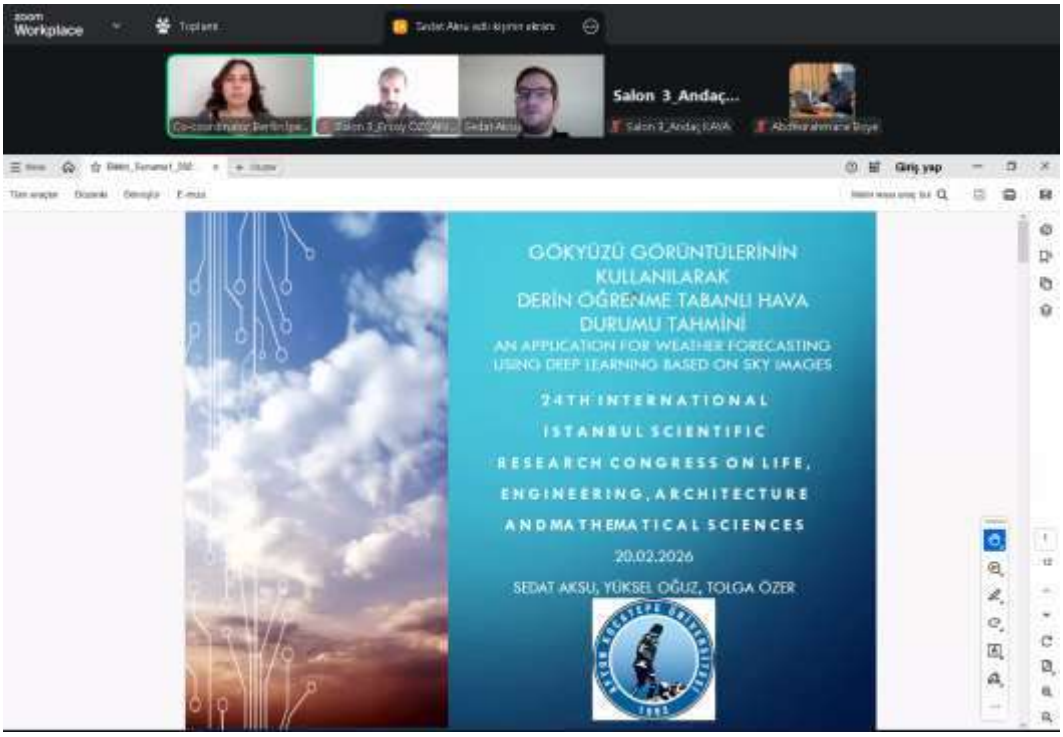
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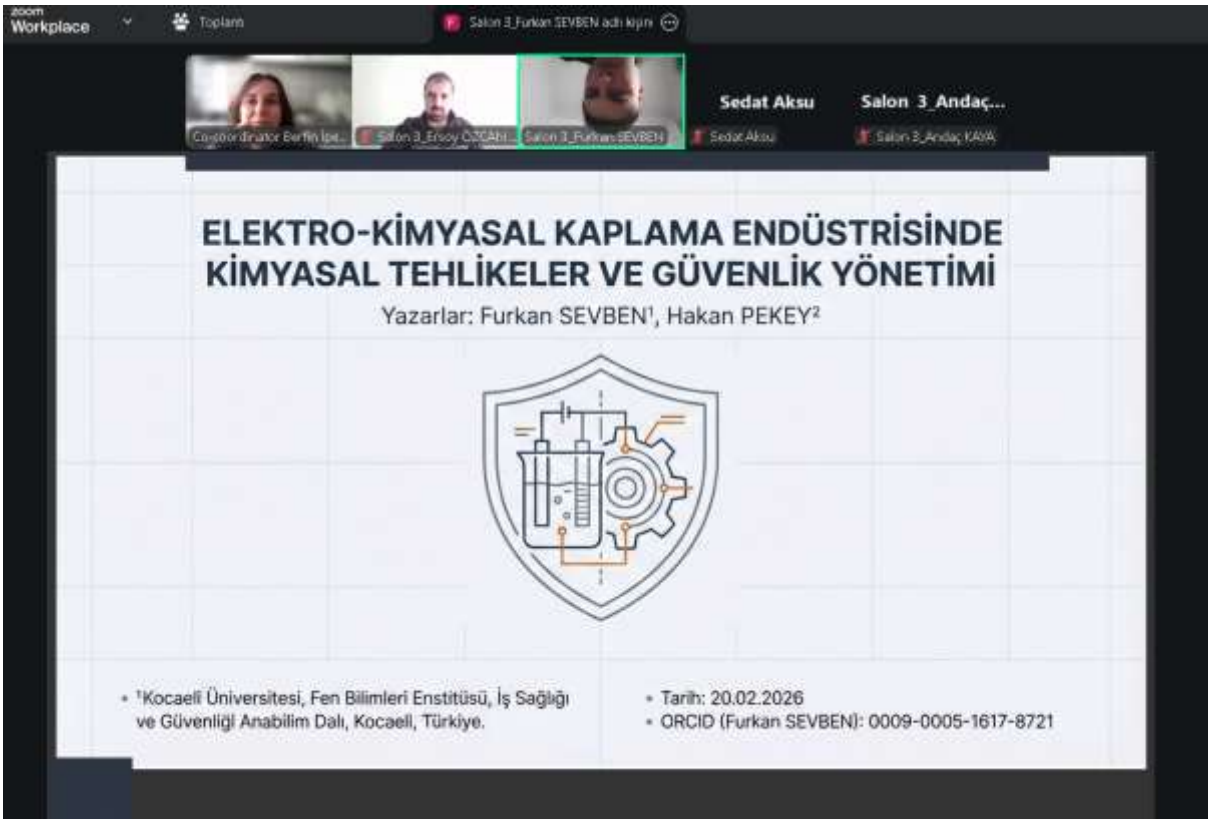
TOKAT GAZİOSMANPAŞA ÜNİVERSİTESİ • 1992 •

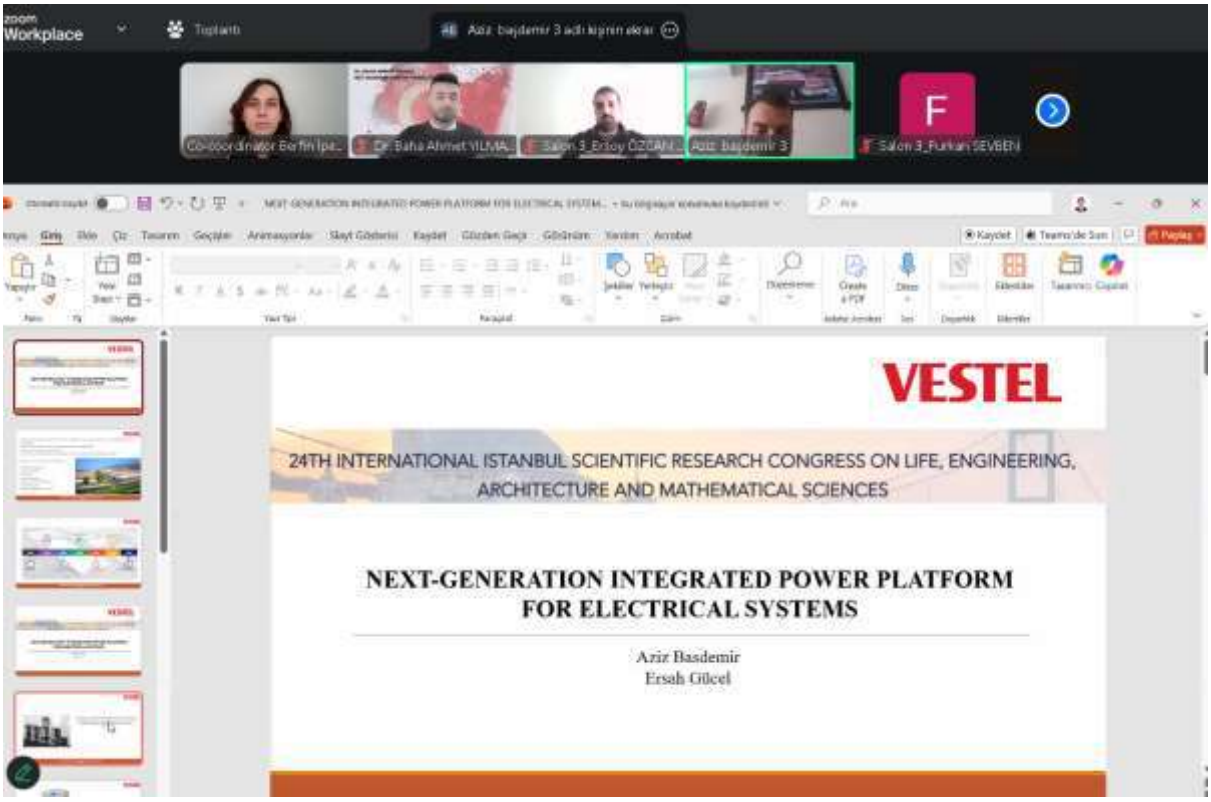
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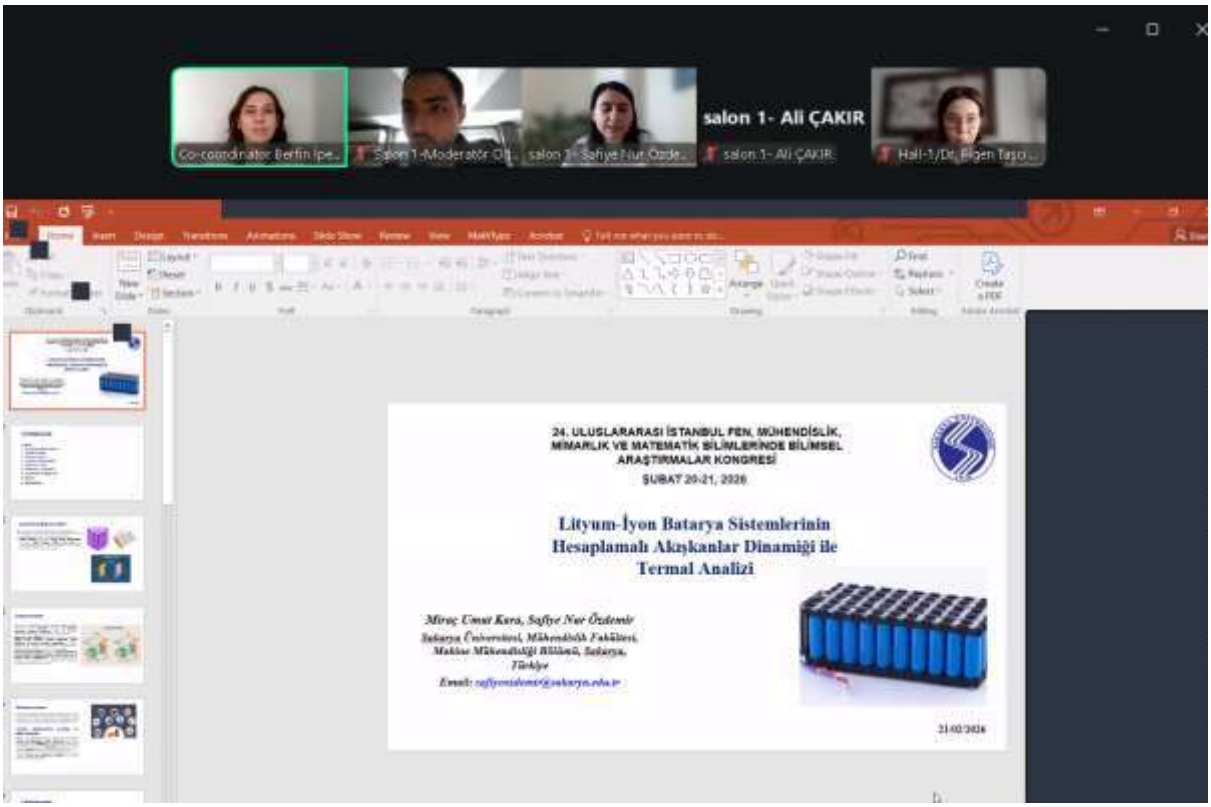


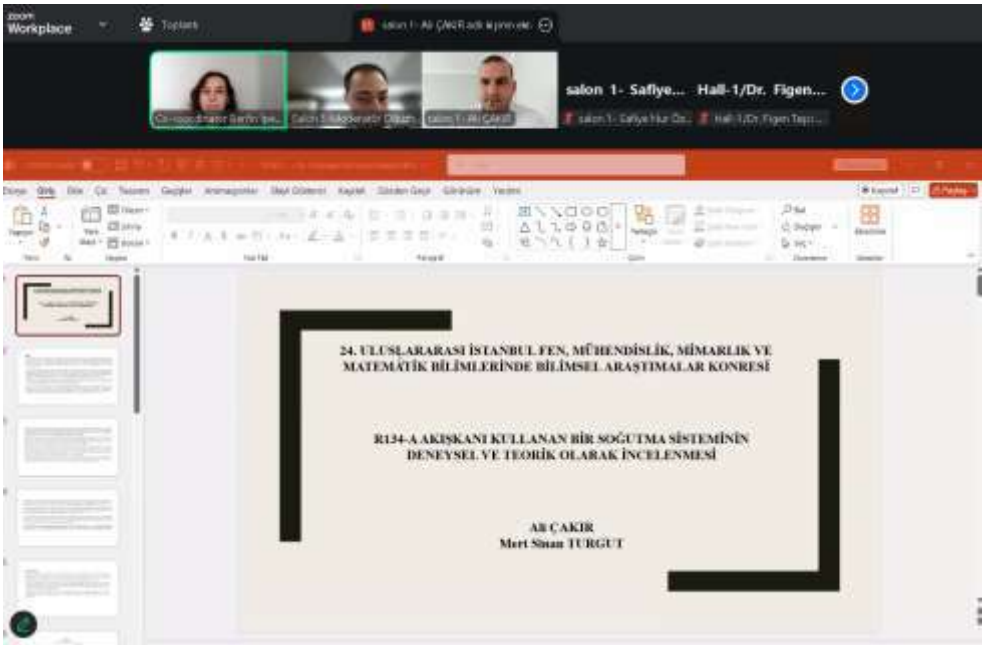
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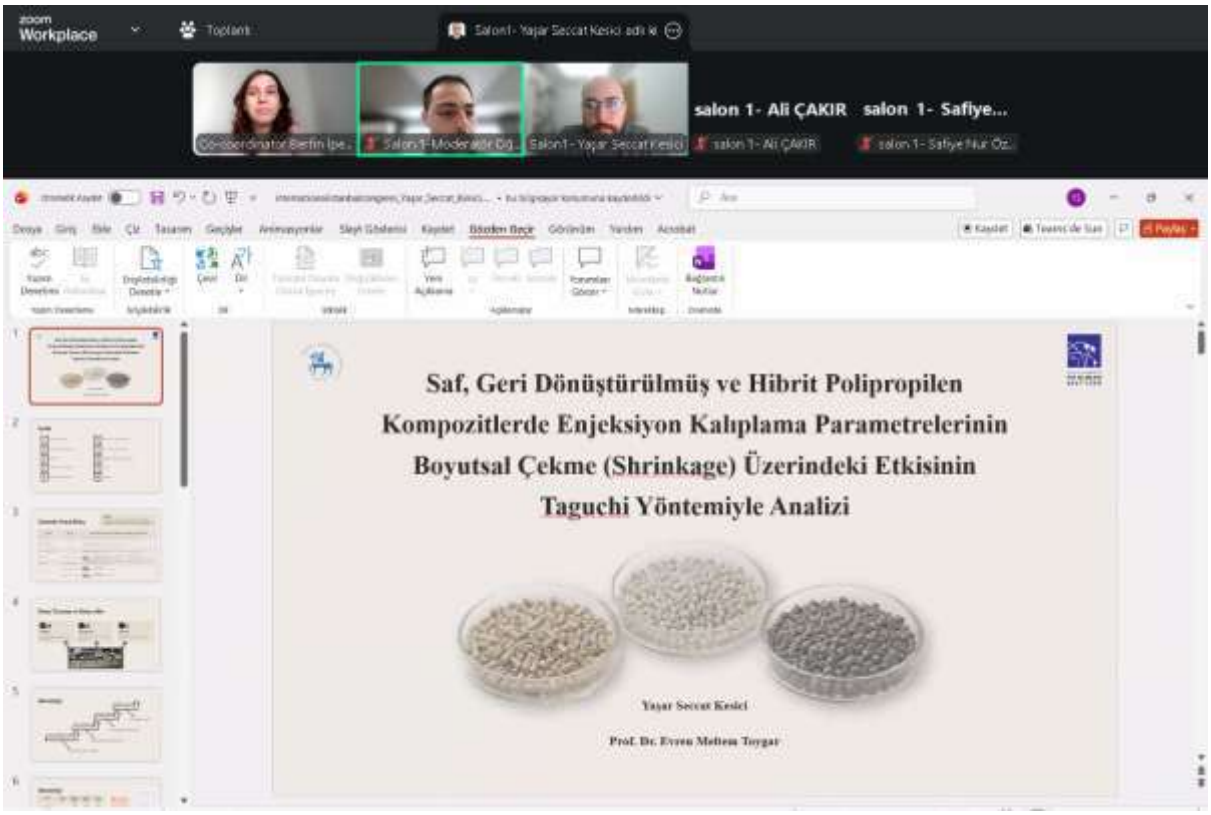


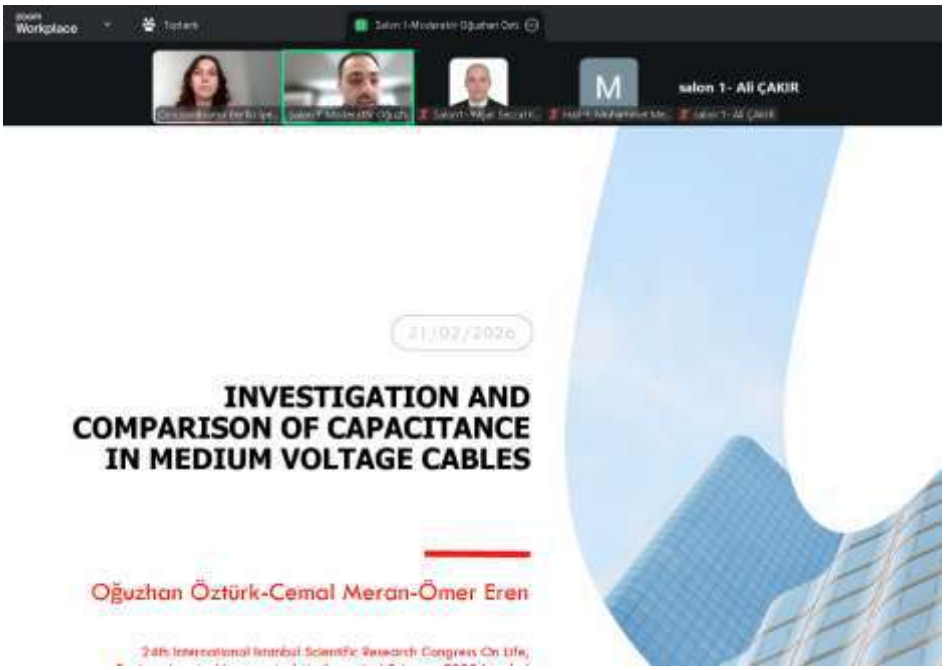
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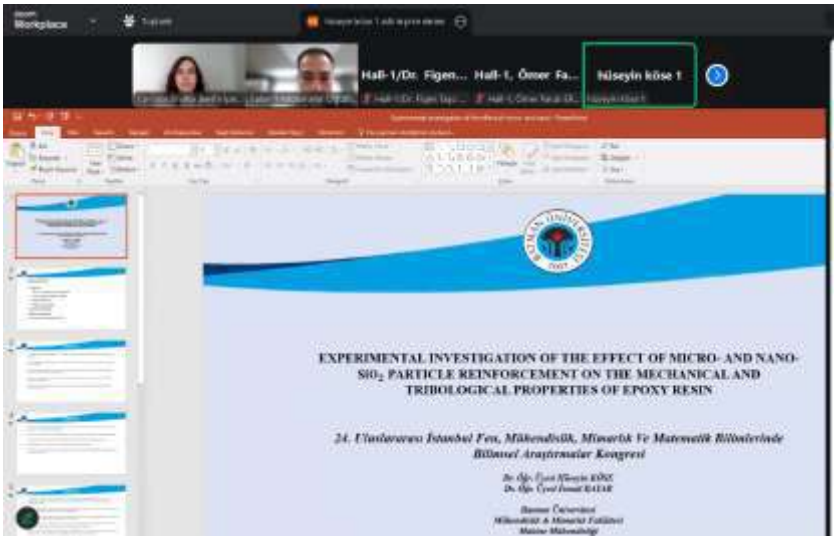
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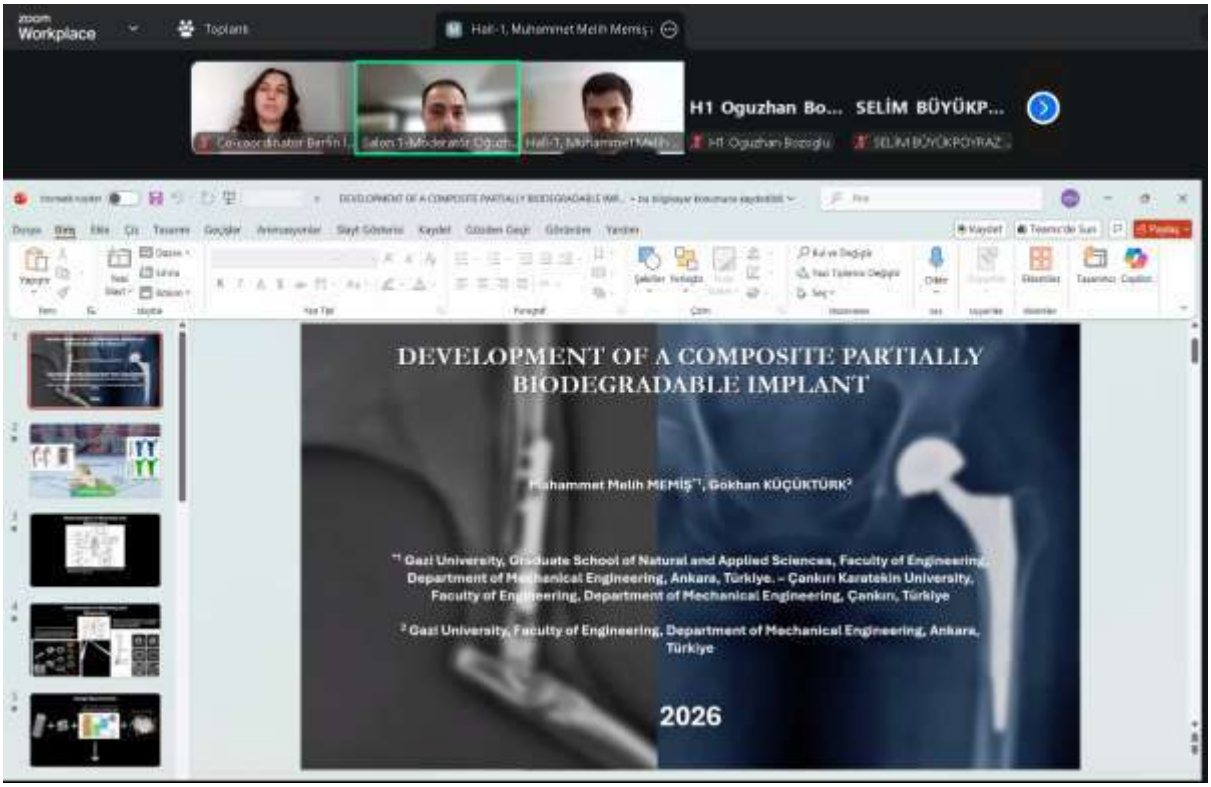
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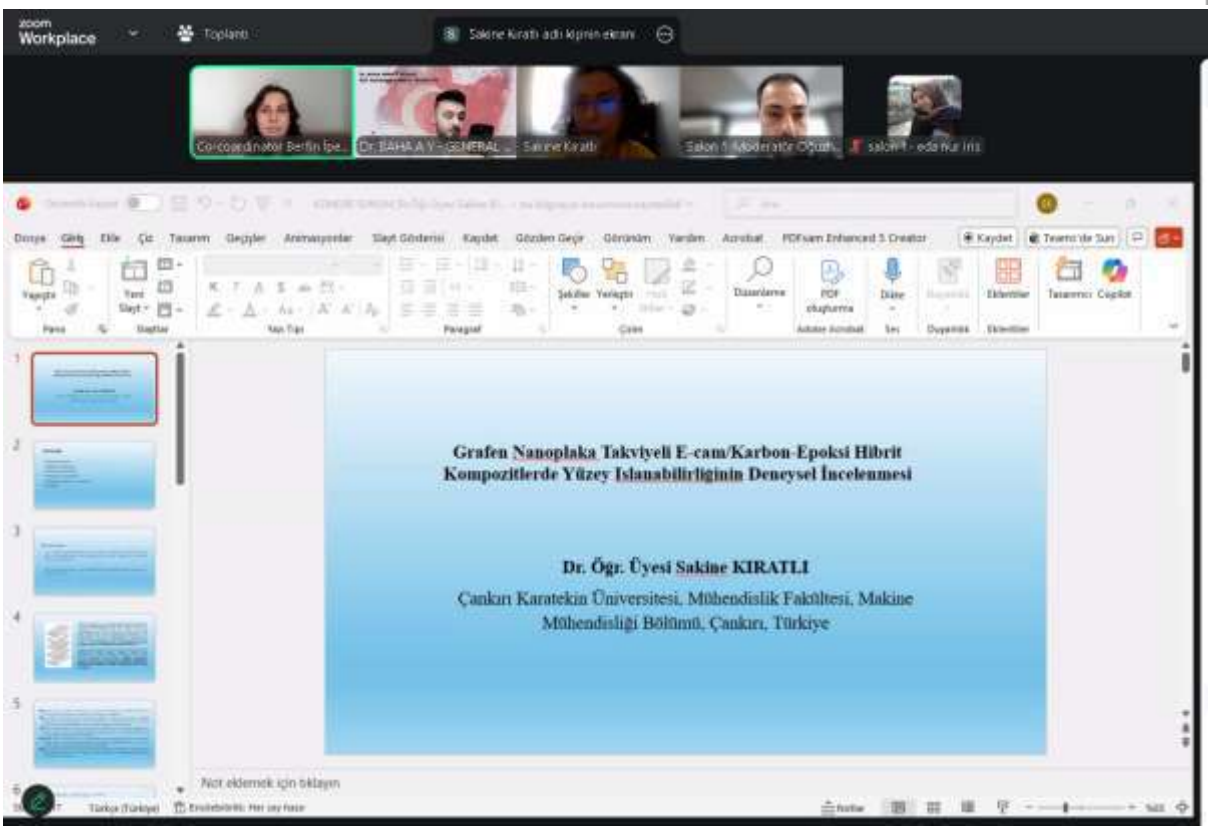
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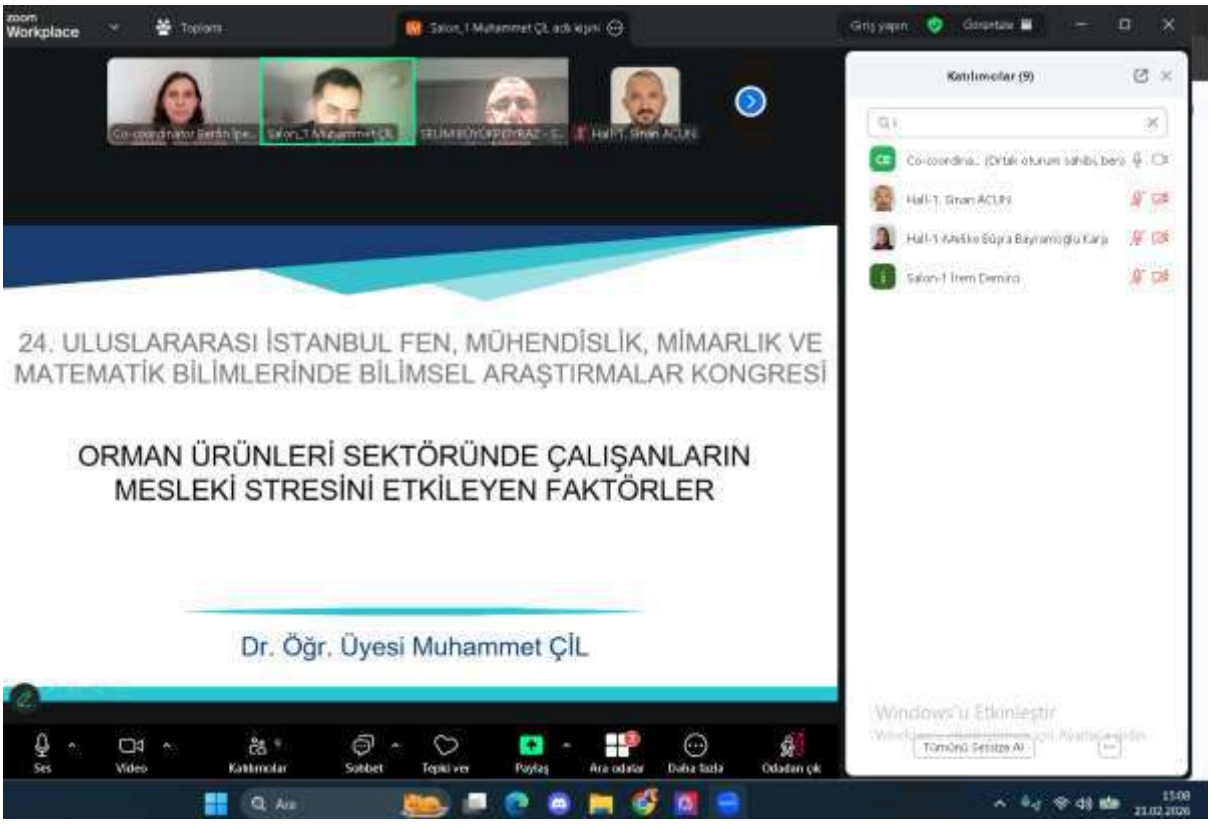
İSTANBUL SCIENTIFIC RESEARCH CONGRESS ON LIFE, ENGINEERING, ARCHITECTURE AND MATHEMATICAL SCIENCE

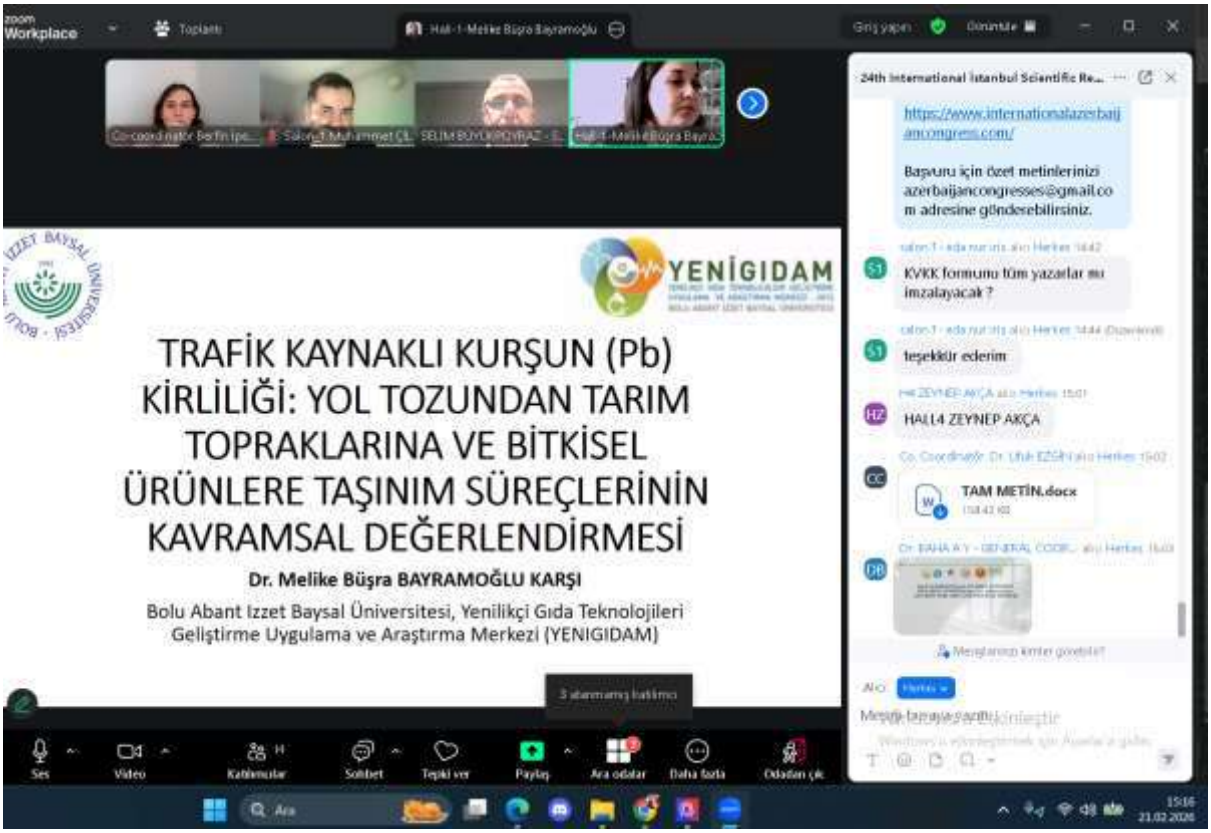
EFFECT OF SHOT PEENING PRESSURE AND IMPINGEMENT ANGLE ON THE SURFACE ROUGHNESS OF AA7075-T6

Eda Nur İRİS
Master Student, Ankara Yıldırım Beyazıt University
Yasin SARIKAVAK
Associate Professor, Ankara Yıldırım Beyazıt University

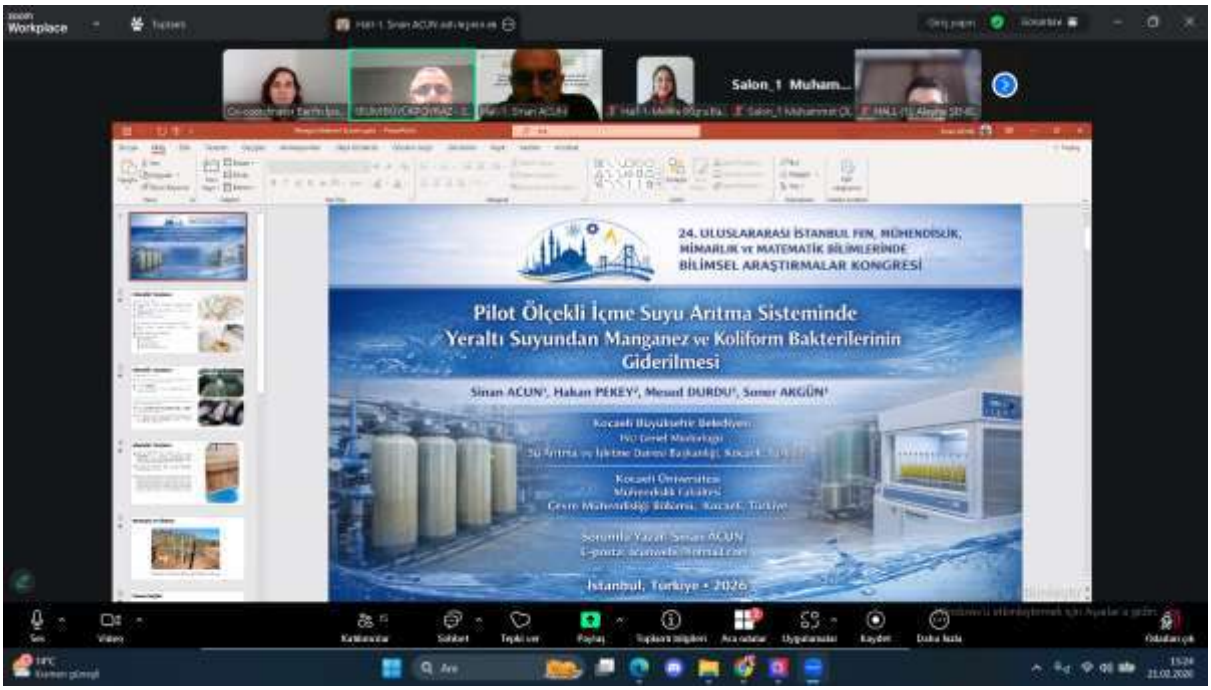


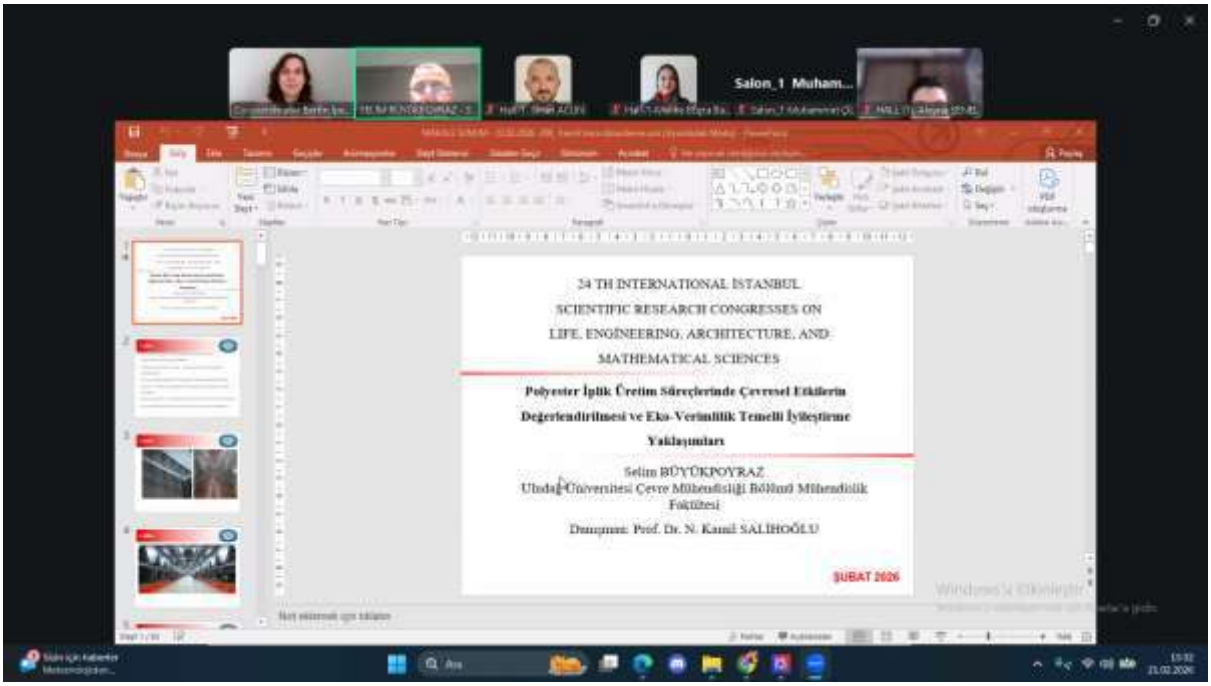
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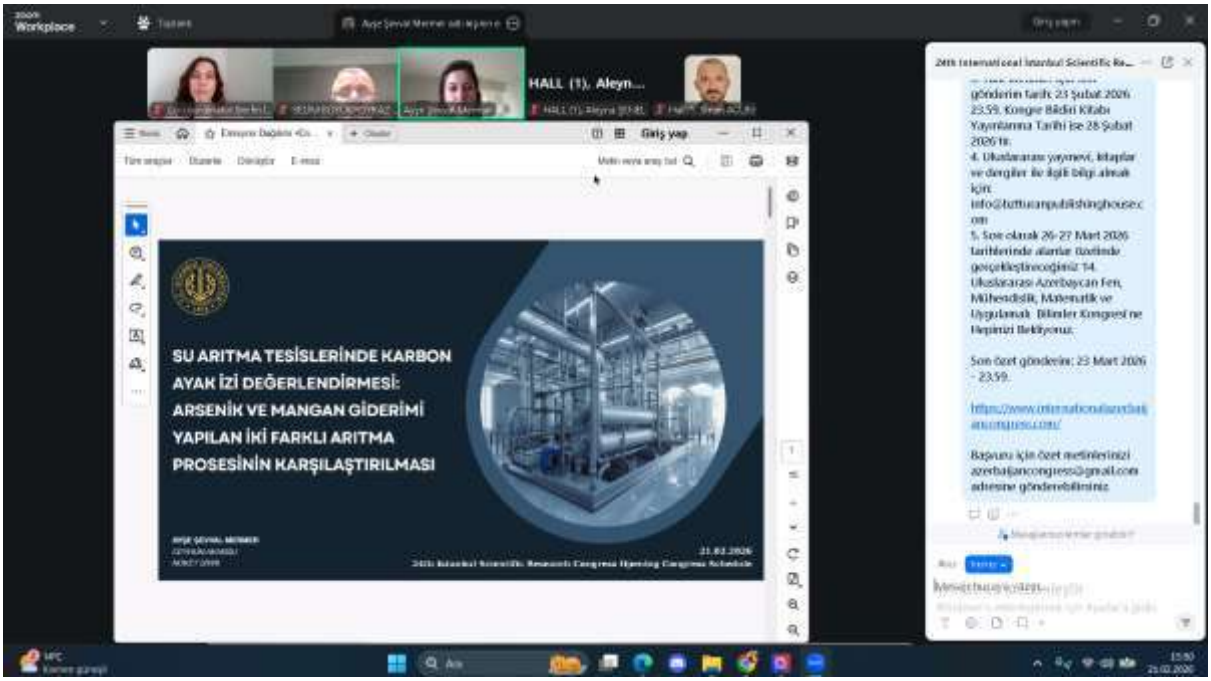
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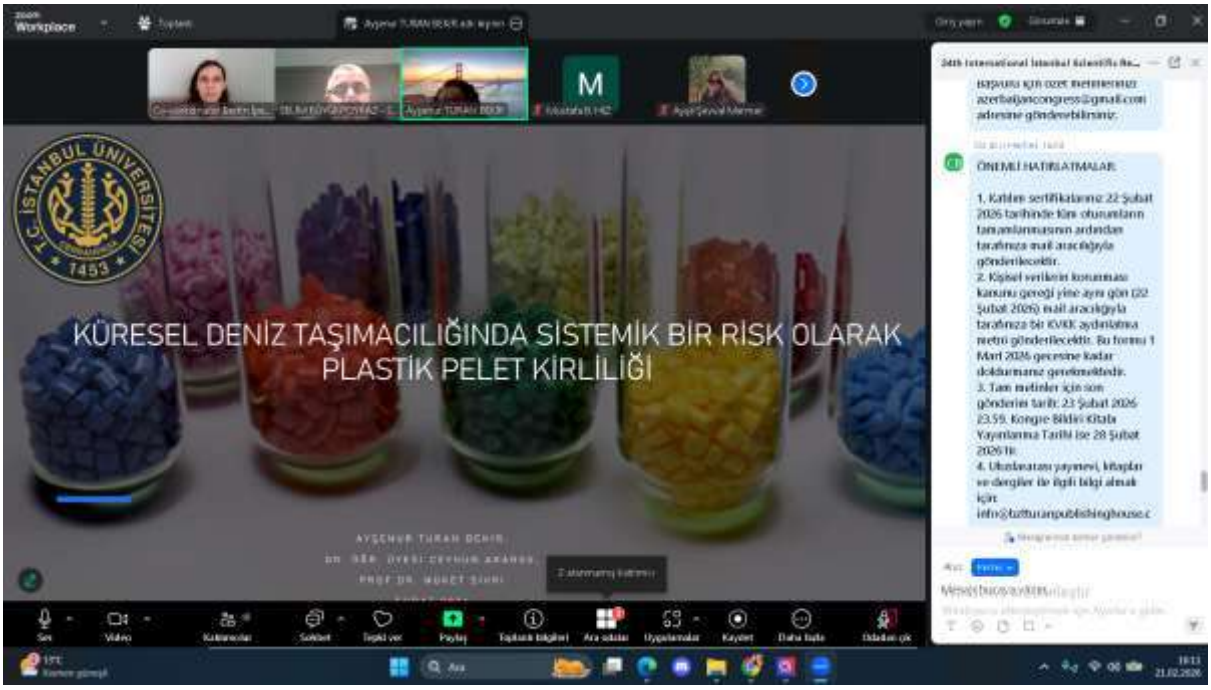
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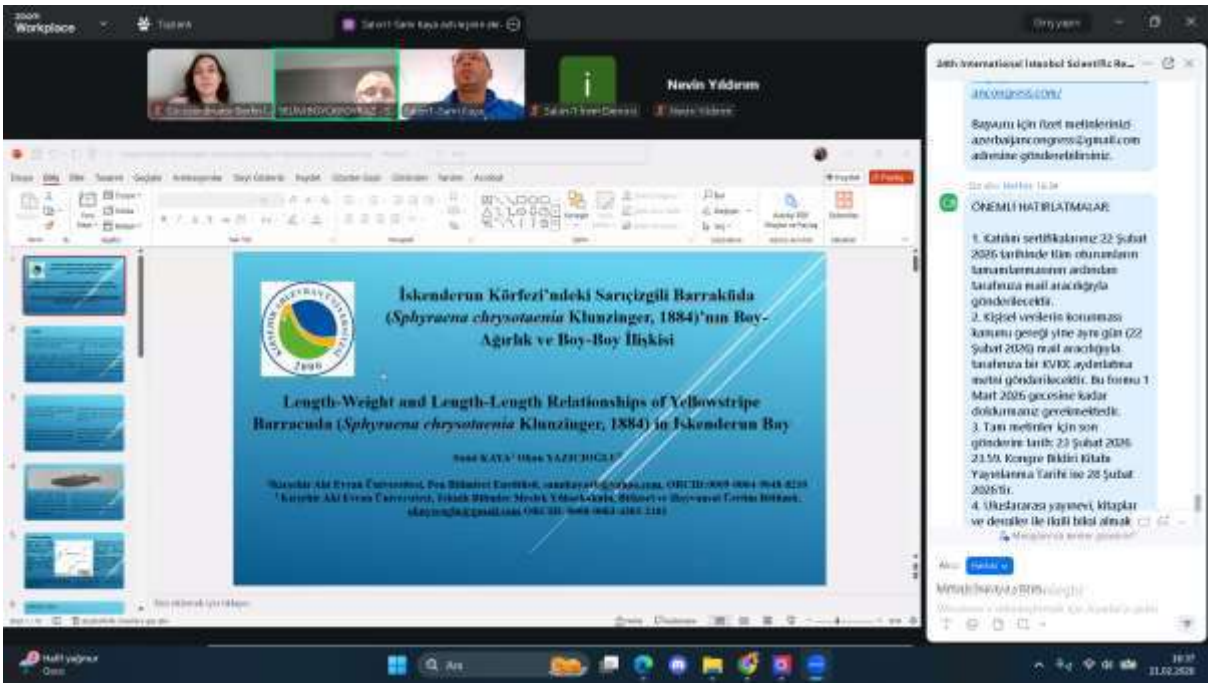


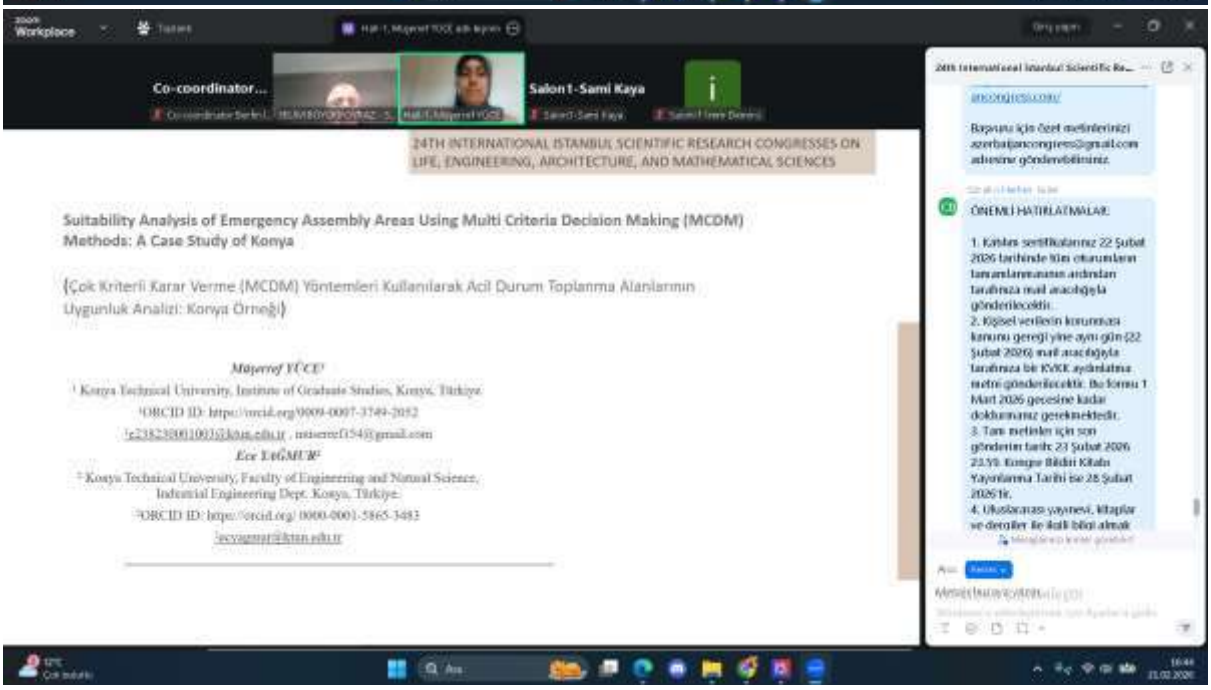
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DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AN EXPLORATORY STUDY OF INTERIOR ARCHITECTURE STUDENTS' DESIGN PARADIGMS IN FUTURE-ORIENTED FURNITURE DESIGN USING QUALITATIVE AND VISUAL ANALYSIS METHODS

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ABSTRACT

This study investigates how third-year interior architecture students, who are at a critical transition point between academic training and professional practice, conceptualize and articulate their design paradigms for future furniture. The research focuses on how students envision future-oriented furniture designs in relation to key design parameters, including material selection, formal characteristics, scale, technological integration, and color preferences. By examining these dimensions, the study aims to reveal emerging tendencies in students' design thinking and their perceptions of future living environments.

The research was conducted with third-year students enrolled in the Department of Interior Architecture at Istanbul Gelişim University. These students were selected due to their advanced level of design education and their increasing exposure to professional design contexts. The study was implemented over a total duration of six hours within a studio-based setting. During this process, students were asked to develop conceptual furniture designs under the theme of "future furniture," with a specific focus on essential domestic activities such as sitting, dining, and sleeping. This thematic framework enabled students to address everyday living needs while reinterpreting them through future-oriented perspectives.

Participants were encouraged to express their design ideas both visually and verbally. Visual representations were produced through freehand drawings, while written statements accompanied each design to explain decisions related to material, form, scale, color, usage scenarios, and the anticipated functional and symbolic roles of the furniture in future contexts. This dual data structure allowed for a comprehensive examination of both visual imagination and conceptual reasoning.

The collected visual and textual data were analyzed using qualitative visual content analysis. The analysis process was supported by the MAXQDA Analytics Pro software, utilizing the code matrix browser tool to systematically identify patterns and relationships within the data. During the coding

phase, detailed sub-codes were developed under broader analytical categories, including design approach, material, form, scale, and color. This coding structure enabled a nuanced interpretation of students' design paradigms and recurring conceptual tendencies.

The findings reveal that students predominantly conceptualized future furniture through themes of technological advancement, adaptability, personalization, and scenario-based use. Furniture designs were frequently associated with flexible functions and interactive user experiences. In terms of visual characteristics, blue and gray color palettes emerged as dominant, reflecting associations with technology and neutrality. Additionally, oval, fluid, and organic forms were repeatedly emphasized, suggesting a departure from rigid geometries toward more dynamic and ergonomic spatial expressions.

Overall, the study provides a qualitative framework for understanding how interior architecture students construct future-oriented design visions. By revealing students' emerging paradigms, the research contributes to discussions on design education, future living concepts, and the role of speculative thinking within interior architecture curricula.

Keywords: Future furniture, interior architecture education, furniture design, qualitative visual analysis, student designs

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ISBN: 978-9952-610-30-7

TURKISH PRESERVICE SCIENCE TEACHERS' USE OF GENERATIVE ARTIFICIAL INTELLIGENCE AND THEIR PERCEIVED COMPETENCIES[1]

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ABSTRACT

The use of artificial intelligence (AI) in education assists students' understanding of intensive, complex, and abstract topics by providing personalized learning in science education. The purpose of this study is to examine Turkish preservice science teachers' use of generative AI and their perceived competencies according to demographic variables. The sample consists of 187 undergraduate students enrolled in the Science Education Departments at Ege University (n=80) and Aydın Adnan Menderes University (n=107). This study, which is the first phase of a scientific research project, employed a descriptive survey method. The findings indicated that the majority of teacher candidates has no prior training in AI, but they are partially familiar with it. They frequently used AI tools, preferred ChatGPT, and used it mostly for assignments, projects, and course material studies. Additionally, the participants exhibit a moderate-to-high level of perceived competency and usage of generative AI. Furthermore, their perceived competency and utilization of generative AI exhibit significant variations based on their perceived level of knowledge and prior training in AI. This preliminary study suggests that fostering awareness and competence on generative AI in the early stages of teacher training

[1] This work was supported by Ege University Scientific Research Projects Coordination Unit. Project Number: 33085.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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contributes to the future development of teachers who integrate AI pedagogically, think critically, and feel responsible to ethical values.

Keywords: Artificial Intelligence, Science Education, STEM, Teacher Training

INTRODUCTION

Generative artificial intelligence (GenAI) is an AI technology that can generate original content such as text, images, audio, or code by responding to commands given in natural language, and has rapidly gained traction in the field of education in recent years (Miao & Holmes, 2023). GenAI-based tools such as ChatGPT, Gemini, and Claude have become the focus of educators and researchers due to their potential for content creation, feedback provision, and learning support in teaching processes (Baidoo-Anu & Owusu Ansah, 2023; Michel-Villarreal et al., 2023; Su et al., 2023). Current assessments of the increasing use of AI in higher education reveal that these technologies bring new requirements in terms of ethics, reliability, and application, along with the opportunities they offer from a pedagogical perspective (Crompton & Burke, 2023).

In the context of science education, GenAI is considered a tool that can support STEM learning and teaching processes; however, it is emphasized that teacher guidance is critically important due to the potential for misinformation, information pollution, and ethical risks (Baidoo-Anu & Owusu Ansah, 2023; Verma et al., 2023). Therefore, the ability of teachers, and especially teacher candidates, to integrate AI into classroom applications is related not only to their level of familiarity with the tools, but also to their perceived competence in using these tools for pedagogical purposes and their capacity to translate this into practice. Indeed, the technology integration literature indicates that perceived usefulness and ease of use (Technology Acceptance Model) and self-efficacy beliefs are decisive in the adoption of new technologies (Davis, 1989; Bandura, 1977). Prospective teachers' perceptions of their competence regarding GenAI are a prerequisite for the effective and responsible integration of these technologies into teaching processes.

Recent studies discussing the potential contribution of large language models (LLMs) to learning processes have shown that the realization of this potential is closely linked to users' competencies, usage experiences, and opportunities for guided application (Kasneci et al., 2023). Therefore, revealing the level of science teacher candidates' perceptions for GenAI usage and proficiency and examining whether these perceptions differ according to demographic characteristics can provide an evidence-based foundation for how teacher training programs can be structured in terms of content, educational interventions, and application-based support. Furthermore, comparing the perceptions of GenAI proficiency among teacher candidates studying at universities in different provinces is also important in terms of revealing the relationship between teacher education and the institutional context.

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In this context, the current study aims to describe science teacher candidates' perceptions of their use and competence regarding AI technologies and to examine whether these perceptions differ significantly according to demographic variables. Within this scope, the study seeks to answer the following research questions:

(1) What are science teacher candidates' perceptions of their use and competence regarding AI technologies?

(2) Do science teacher candidates' perceptions of GenAI technology use and competence differ significantly according to their demographic characteristics?

This study describes science teacher candidates' perceptions of GenAI use and competence, providing original data within the Turkish context to the limited quantitative literature in this field. The findings are expected to contribute to the planning of educational content on GenAI in teacher training programs and the development of applications for integrating AI into science education.

MATERIALS AND METHODS

This study, which examines science teacher candidates' perceptions of the use and proficiency of GenAI technologies, as well as how these perceptions vary according to demographic variables, adopts a quantitative research approach and a descriptive survey model. This model was chosen to accurately reflect the participants' current situation (Creswell & Creswell, 2021). The sample consisted of 187 undergraduate students enrolled in the Science Education departments at Ege University and Adnan Menderes University.

The data were collected through convenient sampling method as a purposive sampling technique and via an online survey. In the power analysis performed with G*Power, the minimum sample size required for a 95% confidence level, 80% power, and a medium effect size (d = 0.30) was calculated as 175; sufficient representativeness was achieved by reaching a total of 187 participants from Adnan Menderes University (n=107) and Ege University (n=80). The data collection tools were as follow:

1- Generative AI Usage and Competence Scale (GenAIUCS): This scale is developed by Arslankara and Usta (2024), it is a five-point Likert-type scale consisting of 19 items and two factors.

2- Demographic Information Form: This form is developed by the authors in line with the related literature. It is a form consisting of three sections and 16 questions. The first two sections of the form (demographic characteristics and technology use) were included in the analysis process.

Following descriptive statistics in the analysis process, the normal distribution characteristics of the data were examined; appropriate parametric or non-parametric tests were applied to determine differences based on demographic variables. A significance level of $p < 0.05$ was accepted in all analyses.

RESULTS

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1. Findings Regarding Science Teacher Candidates' Perceptions of Using and Competence in Generative AI Technologies

To answer the first research question, "What are science teacher candidates' perceptions of their use and competence in GenAI technologies?", data obtained from the GenAIUCS was analyzed. The analysis results are presented in Table 1.

Table 1. Descriptive Statistics for the GenAI Usage and Proficiency Scale

Scale	*n*	$\bar{x}$	*SS*	*Median*
GenAI Usage and Competence Scale	187	63.28	12.78	64.00

When the data obtained was examined, it was determined that the mean score of the 187 science teacher candidates participating in the study was 63.28, the standard deviation was 12.78, and the median value was 64.00. The fact that the mean and median values are close to each other indicates that the scale scores show a similar distribution across the sample. The standard deviation value of 12.78 indicates that the scores show a certain spread around the mean and that there are score differences among participants in terms of their perceptions of GenAI use and competence.

2. Findings on the Science Teacher Candidates' Perceptions of GenAI Technology Use and Competence According to Their Demographics

To answer the second research question, "Do science teacher candidates' perceptions of their use and competence in GenAI technologies differ significantly according to their demographic characteristics?", comparative analyses of GenAIUCS scores were conducted according to various demographic variables. In this regard, the distribution characteristics of the GenAIUCS scores were first evaluated; considering the sufficient sample size (n = 187), parametric tests were used as the basis for the analyses. To support the consistency of the analysis results, additional checks were performed using non-parametric tests when necessary. The findings obtained are presented below.

2.a. *The Perceptions of GenAI Use and Competence by University*

To examine whether science teacher candidates' perceptions of GenAI use and competence differ according to the university where they study, GenAIUCS scores were compared in terms of the university variable. Due to differences in sample sizes between groups and the lack of homogeneity of variance, Welch's t-test was used for comparisons. The findings are presented in Table 2.

Table 2. The Results for the Perceptions of GenAI Use and Competence by University

Scale	University	*n*	$\bar{x}$	*SS*	*t*	*p*
GenAI Usage and	Adnan Menderes	107	61.95	11.48		

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Competence Scale	Ege	80	64.25	14.33	1.18	0.241

Table 2 shows that there is no statistically significant difference between the average GenAIUCS scores of universities (t = 1.18, p = .241).

2.b. *The Perceptions of GenAI Use and Competence by Grade Level*

To examine whether science teacher candidates' perceptions of GenAI use and competence differ according to grade level, GenAIUCS scores were compared in terms of the grade level variable. Due to the comparison of multiple groups and the number of groups being greater than two, one-way analysis of variance (ANOVA) was used in the analyses. The findings are presented in Table 3.

Table 3. The Results for the Perceptions of GenAI Use and Competence by Level

Scale	Grade Level	*n*	$\bar{x}$	*SS*	*F*	*p*
GenAI Usage and Competence Scale	1	26	48.04	16.89	1.30	0.276
	2	63	47.63	16.65		
	3	56	52.46	15.44		
	4	42	45.95	21.26		

Table 3 presents the findings regarding the scale scores of science teacher candidates according to grade levels. Accordingly, the mean and standard deviation values for each grade level are shown in the table. The results of the one-way analysis of variance show that there is no statistically significant difference in scale scores according to the grade level variable (F = 1.30, p = .276).

2.c. *The Perceptions of GenAI Use and Competence by AI Knowledge*

To examine whether science teacher candidates' perceptions of AI usage and competence differ according to their perceived level of knowledge about AI, their GenAIUCS scores were compared in terms of the reported knowledge level variable. Due to the presence of more than two groups, one-way analysis of variance (ANOVA) was used in the analyses. The findings are presented in Table 4.

Table 4. The Results for the Perceptions of GenAI Use and Competence by Perceived AI knowledge

Scale	Perceived AI knowledge	*n*	$\bar{x}$	*SS*	*F*	*p*	η^2
GenAI Usage and Competence	Yes, I know it somewhat and use it.	107	62.27	10.67	13.78	0.000	*0.184*
	Yes, I have basic knowledge of it.	47	58.81	10.15			

Scale	Yes, I know it very well and use it.	30	75.03	14.49			
	No, I've heard of it but haven't used it.	3	51.67	30.73			

Table 4 shows findings regarding GenAIUCS scores according to perceived AI knowledge level. The results of the one-way analysis of variance indicate statistically significant differences between groups ($F(3,183)=13.78$, $p<.001$, $\eta^2=.184$). When examining the means, it is seen that the Perceived AI score mean of the "Yes, I know and use it very well" group is higher than that of the other knowledge level groups.

2.d. *The Perceptions of GenAI Use and Competence by AI Prior training*

To examine whether science teacher candidates' perceptions of AI usage and competence differ based on whether they have received AI prior training, AI usage and competence scores were compared according to the training status variable. Due to the comparison of two independent groups and the lack of homogeneity of variances, Welch's independent samples t-test was used in the analyses. The findings are presented in Table 5.

Table 5. *The Results for the Perceptions of GenAI Use and Competence by AI Prior training*

Scale	AI prior training	*n*	$\bar{x}$	*SS*	*t*	*sd*	*p*	*Hedges g*
GenAI Usage and Competence Scale	Yes	31	68.94	11.00	2.998	47.28	0.004	0.53
	No	159	62.28	12.79				

Table 5 displays the findings regarding the scale scores of science teacher candidates based on whether they received training in AI. Welch t-test results indicate that pre-service teachers who received prior training in AI had significantly higher GenAIUCS scores than those who did not receive training ($t = 2.998$, $p = .004$). The calculated effect size (*Hedges* $g = 0.53$) indicates that this difference corresponds to a medium-sized effect. Also it is notable that few of the student teachers had prior training in AI.

2.e. *The Perceptions of GenAI Use and Competence by AI Usage Frequency*

To examine whether science teacher candidates' perceptions of GenAI usage and competence differ based on their frequency of using GenAI technologies, their GenAIUCS scores were compared in terms of the usage frequency variable. Due to the group size exceeding two, one-way analysis of variance (ANOVA) was used in the analyses. The findings are presented in Table 6.

Table 6. *The Results for the Perceptions of GenAI Use and Competence by AI Usage Frequency*

Scale	*AI Usage Frequency*	*n*	$\bar{x}$	*SS*	*F*	*p*	η^2

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GenAI Usage and Competence Scale	Yes, I use it frequently.	107	70.78	12.74	8.25	<0.001	0.119
	Yes, I use it occasionally.	74	63.00	9.92			
	I've tried it a few times.	4	56.25	20.89			
	No, I've never used it.	2	54.50	0.71			

The results of the one-way analysis of variance conducted according to Table 6 indicate that there is a statistically significant difference between the frequency of use groups ($F = 8.25$, $p < .001$, $\eta^2 = .119$). Upon examining the findings, it is observed that the mean GenAIUCS score of the frequently AI using group is higher than that of the other groups. Also, it is notable that most of the students mentioned that they use AI frequently.

2.f. *Science Teacher Candidates' Preferred GenAI Tools*

The data obtained to determine the AI tools preferred by science teacher candidates were analyzed using frequency (f) and percentage (%) values. Since participants could use more than one AI tool, frequency and percentage values were calculated taking multiple responses into account. The findings are presented in Table 7.

Preferred GenAI	*f*	*%*
ChatGPT	173	92.5
Gemini	82	43.9
Copilot	41	21.9
Other	18	9.6

Table 7. *Science Teacher Candidates' Preferred GenAI Tools*

Table 7 presents that the vast majority of science teacher candidates use ChatGPT (92.5%). ChatGPT is followed by Gemini (43.9%) and Copilot (21.9%). The percentage of participants who stated that they use other AI tools is 9.6%. These findings indicate that teacher candidates concentrate their use of generative AI around specific tools and that their usage preferences are concentrated on a limited number of platforms.

2.g. *Science Teacher Candidates' Purposes for Using GenAI*

The data obtained to determine the purposes for which science teacher candidates use GenAI tools were analyzed based on frequency (f) and percentage (%) values. Since participants could indicate

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

more than one purpose of use, the analyses were conducted taking multiple responses into account. The findings are presented in Table 8.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Table 8. Science Teacher Candidates' Purposes for Using GenAI

Purpose of Using GenAI	*f*	*%*
Homework and project work	165	88.2
Preparing course materials	151	80.7
Gaining knowledge in my daily life	140	74.9
Supporting my own learning	135	72.2
Getting coding or technical support	32	16.8
I haven't used it	1	0.5
Other	4	2.1

Table 8 displays that science teacher candidates most commonly use GenAI tools for homework and project work (88.2%) and preparing teaching materials (80.7%). In addition, acquiring information in daily life (74.9%) and supporting their own learning processes (72.2%) are also prominent areas of use. The usage rate for coding or technical support purposes (16.8%) is relatively lower, while the percentage of participants who stated they never use generative AI tools remains quite limited (0.5%).

DISCUSSION

In the current study, the finding that science teacher candidates' perceptions of their AI competence were at a moderate level is consistent with other findings in the literature. Mustafaoğlu and Alkan (2025) reported that despite teacher candidates' positive attitudes toward AI, their competence perceptions remained cautious and moderate; He et al. (2025) reported that students' literacy and competence levels were below the expected level. Similarly, Katsantonis and Katsantonis (2024) emphasized that high awareness does not directly translate into high perceived competence. When these findings are considered together, it can be said that despite students and teacher candidates in different disciplines recognizing AI, they do not yet fully consider themselves competent in effectively using these technologies.

The lack of a significant difference in science teacher candidates' perceptions of AI literacy based on the university they attend can be discussed through two fundamental perspectives in the literature. According to the first approach, He et al. (2025) argue that AI literacy is shaped by individual usage practices and direct experiences rather than the institutional context. Similarly, Katsantonis and Katsantonis (2024) emphasize that the university effect is secondary due to the widespread exposure to digital technologies at the societal level and that high awareness does not always translate into high

competency perceptions. On the other hand, there are also studies in the literature that point to the importance of institutional infrastructure and policy differences. Zawacki-Richter et al. (2019) reported that institutions with strong technological infrastructure positively influenced student perceptions, while Holmes et al. (2022) reported that universities that systematically integrated AI into their curricula did the same. When these two approaches are considered together, the fact that no difference was found between universities in this study indicates that there are not yet any distinctive, structured, and institutionalized differences in the implementation of AI education in the institutions examined.

The finding that teacher candidates' perceptions of AI usage and competence do not differ significantly across grade levels is consistent with evidence showing that AI competence does not develop automatically with academic progress. Ng et al. (2021) and Akgun and Greenhow (2022) emphasized that students' awareness of AI increases as they progress through grade levels; however, structured educational experiences are necessary for this awareness to translate into perceived competence. In this context, the absence of differences between grade levels in the current study suggests that universities do not offer systematic and gradual education on GenAI. Similarly, Crompton and Burke (2023) stated that competence and readiness regarding AI in higher education are related to institutional-level education, curriculum integration, and application opportunities rather than grade level or academic seniority. In this context, the fact that no significant differences were found based on grade level indicates that systematic and gradual training on GenAI has not yet been provided in the examined process and that the perception of competence remains independent of academic seniority.

It is revealed that science teacher candidates' perceptions of AI usage and competence vary significantly based on their perceived level of knowledge on AI. This indicates that competence perception is closely related to individuals' awareness and personal experience with AI. The knowledge level variable reflects a structure that reflects participants' individual assessments and trials of AI rather than a planned educational intervention. In this context, the fact that teacher candidates in the “I know and use it very well” group have a higher perception of competence indicates that GenAI competencies are strengthened not only by technical knowledge but also by active use and experience. Studies conducted with different samples in the literature also reveal that as the level of knowledge about AI increases, individuals perceive themselves as more competent in using and evaluating these technologies. He et al. (2025) stated that participants with low AI literacy had limited perceptions of competence, and that perceived competence increased as the level of knowledge increased. Similarly, studies conducted with teacher candidates indicate that individuals with a high level of knowledge about AI develop more confident and competent perceptions of the educational potential of these technologies (Demir, 2024; Mustafaoğlu & Alkan, 2025). The difference in perceived competence based on the level of AI knowledge reveals that GenAI competencies are not random, but rather shaped by individual experience and cognitive awareness.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Besides, another finding suggest that science teacher candidates who received training on AI had statistically significantly higher perceptions of generative AI usage and competence compared to those who did not receive training. This finding suggests that AI competencies have a structure directly related to education. Quantitative studies conducted with teacher candidates report that receiving training on AI significantly increases participants' perceptions of self-efficacy in using AI and evaluating it in a pedagogical context (Demir, 2024). Similarly, a comprehensive review study conducted in the higher education context emphasizes that AI competence and readiness develop not only through individuals' exposure to technology but also through structured education and guided practice opportunities (Crompton & Burke, 2023). Furthermore, studies conducted with experimental and quasi-experimental designs show that training involving the use of AI significantly strengthens teacher candidates' perceptions of self-efficacy (Kitcharoen et al., 2024; Lademann et al., 2026; Mevlüt, 2024). In this context, the fact that teacher candidates who received prior AI training had higher GenAIUCS scores supports the idea that GenAI competencies can be developed through planned, guided, and intervention-based training rather than as a self-developed trait.

Also, the study revealed that science teacher candidates who use GenAI technologies more frequently have significantly higher perceptions of usage and competence, demonstrating that competence perception is a structure that is directly strengthened by experience. Frequency of use, unlike knowledge level, refers to the individual's continuous interaction with generative AI tools and experiencing feedback, trial and error, and self-regulation processes through this interaction. The literature emphasizes that regular use of AI tools contributes to individuals using these technologies more effectively, critically, and appropriately; this process increases perceived competence over time (Kasneci et al., 2023). Similarly, recent assessments of AI use in higher education reveal that individuals who interact with AI tools on a regular basis perceive these technologies not only technically but also pedagogically and cognitively more proficiently (Crompton & Burke, 2023). In this context, increasing competence perception with frequency of use supports the notion that GenAI competencies are reinforced through repeated use and experience.

Moreover, science teacher candidates were found to use generative AI tools primarily through a limited number of platforms, mainly ChatGPT, and to prefer these tools mainly for homework and project work, preparing teaching materials, and supporting individual learning. Similarly, the literature reports that teacher candidates and university students primarily use generative AI to increase academic productivity, create content, and facilitate learning processes (Baidoo-Anu & Owusu Ansah, 2023; Crompton & Burke, 2023; Söğüt, 2024). However, the limited use of GenAI in more advanced areas such as coding or technical support indicates that teacher candidates have not yet progressed to the stage of using these technologies in-depth from a pedagogical and technical perspective. This finding aligns with studies emphasizing the need for structured training to support a more conscious,

multifaceted, and pedagogically grounded use of generative AI in education (Crompton & Burke, 2023; Searson et al., 2024).

In this study, perceived AI knowledge level reflects individual awareness and experience regarding AI; the status of receiving prior training in AI represents the effect of planned and structured learning processes on the perception of competence, while frequency of AI use represents the reinforcement of these competencies through experience. In sum, the findings indicated that science teacher candidates' perceptions of GenAI use and competence are shaped by a multidimensional process that is strengthened not only by awareness but also by knowledge structured through education and regular use. Therefore, structured learning environments incorporating planned training and regular usage opportunities, in addition to awareness-based approaches, could be beneficial for supporting the perception of competence regarding GenAI in teacher training programs.

CONCLUSION

The present study revealed that science teacher candidates' perceptions of their use and competence in GenAI are generally moderate. It was observed that their perceptions of competence did not differ significantly based on university or class level; however, significant differences were found based on their level of knowledge about AI, whether they had received training on AI, and frequency of use. Specifically, it was determined that teacher candidates who received structured training on AI and utilized GenAI technologies more frequently exhibited heightened perceptions of competence.

In sum, these findings suggest that GenAI competencies are shaped through a process that is knowledge-based, supported by education, and strengthened through experience, rather than developing spontaneously. In light of these results, it is suggested that evaluating structured educational content and practice-based learning opportunities related to GenAI in teacher education has the potential to contribute to teacher candidates' ability to use these technologies effectively and ethically.

AI Usage Disclosure: This document was translated with assistance of DeepL Translate on-line tool. The content has been reviewed and edited by the researchers.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to Prof. Dr. Burak Feyzioğlu for his invaluable contributions to the data collection process.

This work was supported by Ege University Scientific Research Projects Coordination Unit. Project Number: 33085.

REFERENCES

Akgun, S., & Greenhow, C. (2022). Artificial intelligence in education: Addressing ethical challenges in K-12 settings. *AI and Ethics*, *2*(3), 431-440.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Arslankara, V. B., & Usta, E. (2024). Generative artificial intelligence as a lifelong learning self efficacy: Usage and Competence Scale. *Journal of Teacher Education and Lifelong Learning*, *6*(2), 288-302. https://doi.org/10.51535/tell.1489304

Baidoo-anu, D. ve Ansah, L. O. (2023). Education in the Era of Generative Artificial Intelligence (AI): Understanding the Potential Benefits of ChatGPT in Promoting Teaching and Learning. *Journal of AI*, *7*(1), 52–62. doi:10.61969/JAI.1337500

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*(2), 191–215. doi:10.1037/0033-295X.84.2.191

Creswell, J. W., & Creswell, J. D. (2021). Araştırma tasarımı. *Nobel Yayıncılık*.

Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: the state of the field. *International journal of educational technology in higher education*, *20*(1), 22.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly: Management Information Systems*, *13*(3), 319–339. doi:10.2307/249008

He, T., Huang, J., Li, Y., Wang, L., Liu, J., Zhang, F., Fu, S., & Gong, S. (2025). The mediation effect of AI self-efficacy between AI literacy and learning engagement in college nursing students: A cross-sectional study. *Nurse education in practice*, *87*, 104499. https://doi.org/10.1016/j.nepr.2025.104499

Holmes, W., & Tuomi, I. (2022). State of the art and practice in AI in education. *European journal of education*, *57*(4), 542-570.

Kasneci, E., Seßler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., ... & Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education. *Learning and individual differences*, *103*, 102274.

Katsantonis, A., & Katsantonis, I. G. (2024). University Students' Attitudes toward Artificial Intelligence: An Exploratory Study of the Cognitive, Emotional, and Behavioural Dimensions of AI Attitudes. *Education Sciences*, *14*(9), 988. https://doi.org/10.3390/educsci14090988

Kitcharoen, P., Howimanporn, S., & Chookaew, S. (2024). Enhancing Teachers' AI Competencies through Artificial Intelligence of Things Professional Development Training. *International Journal of Interactive Mobile Technologies*, *18*(2).

Lademann, J., Henze, J., Honke, N., Wollny, C., & Becker-Genschow, S. (2026, January). Teacher training in the age of AI: impact on AI literacy and teachers' attitudes. In *Frontiers in Education* (Vol. 10, p. 1671306). Frontiers.

Mevlüt, K. (2024). Geleceğin eğitimini şekillendirmek: Öğretmen yardımcısı yapay zeka. *PEARSON JOURNAL, 8*(29), 1555–1578. https://doi.org/10.5281/zenodo.13384238

Michel-Villarreal, R., Vilalta-Perdomo, E., Salinas-Navarro, D. E., Thierry-Aguilera, R. ve Gerardou, F. S. (2023). Challenges and Opportunities of Generative AI for Higher Education as Explained by ChatGPT. *Education Sciences 2023, Vol. 13, Page 856*, *13*(9), 856. doi:10.3390/EDUCSCI13090856

Mustafaoglu, F. M., & Alkan, F. (2025). Artificial Intelligence in Education: Attitudes and Perceptions of Pre-service Teachers. *Information Technologies and Learning Tools*, *110*(6), 120-134. https://doi.org/10.33407/itlt.v110i6.6341

Ng, D. T. K., Leung, J. K. L., Su, J., Ng, R. C. W., & Chu, S. K. W. (2023). Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. *Educational technology research and development*, *71*(1), 137-161.

Searson, M., Langran, E. ve Trumble, J. (2024). *Exploring New Horizons: Generative Artificial Intelligence and Teacher Education AACE-Association for the Advancement of Computing in Education*. https://designer.microsoft.com/ adresinden erişildi.

Söğüt, S. (2024). Generative artificial intelligence in EFL writing: A pedagogical stance of pre-service teachers and teacher trainers. *Focus on ELT Journal*, *6*(1), 58–73. doi:10.14744/FELT.6.1.5

Su, X., Yang, X. ve Xu, Y. (2023). Fuzzy adaptive terminal sliding mode control based on recurrent neural network compensation for a maglev system. *Engineering Applications of Artificial Intelligence*, *124*, 106588. doi:10.1016/J.ENGAPPAI.2023.106588

Verma, G., Campbell, T., Melville, W. ve Park, B. Y. (2023). Navigating Opportunities and Challenges of Artificial Intelligence: ChatGPT and Generative Models in Science Teacher Education. *Journal of Science Teacher Education*, *34*(8), 793–798. doi: https://doi.org/10.1080/1046560X.2023.2263251

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education–where are the educators?. *International journal of educational technology in higher education*, *16*(1), 1-27.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CFD-BASED THERMAL ANALYSIS OF LITHIUM ION BATTERY SYSTEMS

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ABSTRACT

This study provides a numerical investigation of the effectiveness of air cooling for the thermal management of lithium-ion battery packs, focusing on 2×2, 4×4, and 6×6 cell configurations. Computational Fluid Dynamics (CFD) simulations were performed using ANSYS Fluent to assess the impact of several factors, including discharge rates (1C, 2C, and 3C), inlet air velocities (0.5, 1, and 2 m/s), and ambient temperatures (5, 15, and 25 °C) on the thermal performance of the battery systems. The results reveal that a 2×2 configuration demonstrates effective heat dissipation; however, in the 6×6 configuration, the central cells do not adequately benefit from the cooling provided by the peripherals. Across all configurations, temperature increases cumulatively along the flow direction, with peak temperatures occurring in the upper regions of the cells. Despite airflow velocities in the inter-cell channels reaching up to 3.813 m/s, the presence of low-velocity regions behind the cells considerably restricts local heat dissipation. In scenarios involving high discharge rates (3C) and elevated ambient temperatures (25 °C), the maximum battery temperature in the 6×6 configuration approaches the critical operating limit of 60 °C. Moreover, the maximum temperature difference between the cells (ΔT) is observed to range between 10 and 14 °C, suggesting the potential for thermal gradients that may adversely affect battery longevity and operational safety. In conclusion, the findings indicate that conventional air cooling can provide adequate thermal management for small- and medium-sized battery packs under lower ambient temperatures.

Keywords: Lithium-ion battery, CFD modelling, Thermal management

INTRODUCTION

The combustion of fossil fuels releases carbon dioxide (CO_2) and other greenhouse gases into the atmosphere, significantly contributing to climate change and global warming. As a result, the need to address the environmental crisis has become increasingly urgent. Within this context, the search for new energy sources has intensified, aiming to achieve the goal of "zero emissions". Since approximately one-quarter of global carbon emissions come from the transportation sector, one of the most effective strategies for mitigation is the widespread adoption of electric vehicles (Sciatti et al.,

2026). Electric vehicles represent a promising solution for sustainability and energy efficiency. Lithium-ion batteries are crucial enabling technologies for this transition. Lithium-ion batteries have gained popularity due to their low self-discharge rates and long cycle life, without experiencing the memory effect common in other battery technologies (Khan et al., 2023). Despite the advantages of lithium-ion technology, its thermal stability limitations cannot be overlooked. Thermal stability refers to a battery's ability to endure high temperatures without undergoing structural degradation or triggering unsafe reactions, such as thermal runaway. This issue poses a critical challenge that significantly impacts the performance and safety of lithium-ion batteries. Research indicates that these batteries should ideally be operated within a temperature range of 15 °C to 35 °C to ensure safe and efficient functioning. Moreover, the temperature difference across the battery module should not exceed 5 °C. When thermal limits are exceeded, batteries face significant risks that affect both performance and safety. Elevated temperatures can lead to uncontrolled heat generation, triggering thermal runaway and potentially causing hazardous events such as fires and explosions. On the other hand, low temperatures decrease ionic conductivity, negatively affecting battery performance. This situation increases internal resistance, reduces power capability, and can cause metallic lithium to deposit on the anode surface, ultimately leading to irreversible damage to the cell (Magri et al., 2023). Given these considerations, it is evident that the efficiency and reliability of electric vehicles depend heavily on the implementation of an effective Battery Thermal Management System (BTMS) to optimize battery pack thermal loads across various driving and climatic conditions. BTMS's primary goal is to maintain the battery's optimal temperature range, prevent overheating, and ensure even thermal distribution throughout the pack (Luo et al., 2024). Yang et al. developed a passive thermal management model for a T-shaped battery pack containing six prismatic cells. The model utilizes phase change material (PCM) and air cooling to improve thermal uniformity. The thermal behavior of the PCM and laminar airflow was analyzed numerically using COMSOL. They identified the optimal configuration by comparing various inlet and outlet arrangements based on temperature distribution (Yang et al., 2024). Du et al. proposed a novel design for phase change materials (PCMs) with spiral fins to enhance the thermal management of lithium-ion batteries by improving heat transfer. This study conducted a numerical investigation into how the number of fins and their rotation angle affect the temperature distribution within the batteries. The results were compared to those from conventional flat-finned structures. The findings revealed that spiral fins significantly improved natural convection, resulting in greater temperature uniformity and a reduction in the maximum battery temperature by approximately 2.7 °C (Du et al., 2025). Li et al. developed a three-dimensional electrothermal model integrated with CFD to analyze the temperature distribution of battery packs. The model was validated under natural ventilation and ambient-temperature conditions, and optimal battery placement was determined using an ANN, resulting in 1.9% and 4.5% improvements in maximum temperature and temperature difference, respectively (Li et al. 2022). This study

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

investigates the effects of different operating conditions on the thermal performance of an air-cooled lithium-ion battery pack using CFD simulations.

MATERIALS AND METHODS

In this study, numerical simulations were conducted to analyze the influence of several key factors on the thermal performance of battery systems. The factors examined included discharge rates (1C, 2C, and 3C), inlet air velocities (0.5, 1, and 2 m/s), and ambient temperatures (5, 15, and 25 °C). The thermal behavior of a lithium-ion battery pack was analyzed using three configurations: 2×2, 4×4, and 6×6, with simulations conducted in ANSYS Fluent 2024 R2. The model geometry was developed using ANSYS DesignModeler, and the 2×2 lithium-ion battery cell configuration is illustrated in **Figure 1. Figure 2** shows the computational domain of the 4×4 lithium-ion battery pack. The mesh consists of 1,059,300 elements and 1,210,958 nodes. The turbulence effects were modeled using the standard k–ε turbulence model. The governing equations include the continuity, Navier–Stokes, and energy equations, which were solved fully coupled using the finite-volume method.

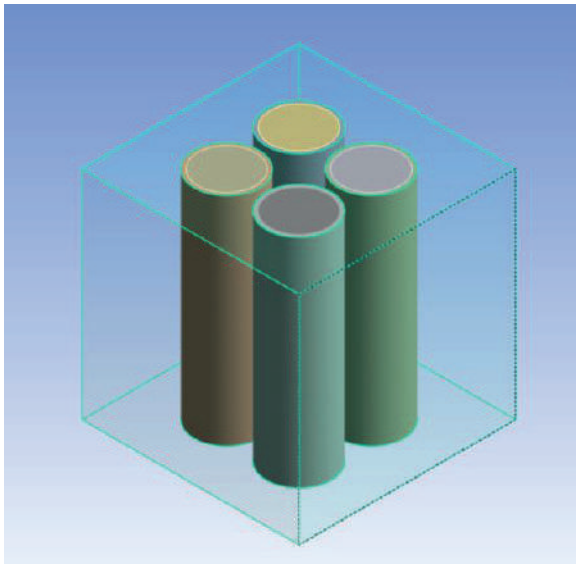
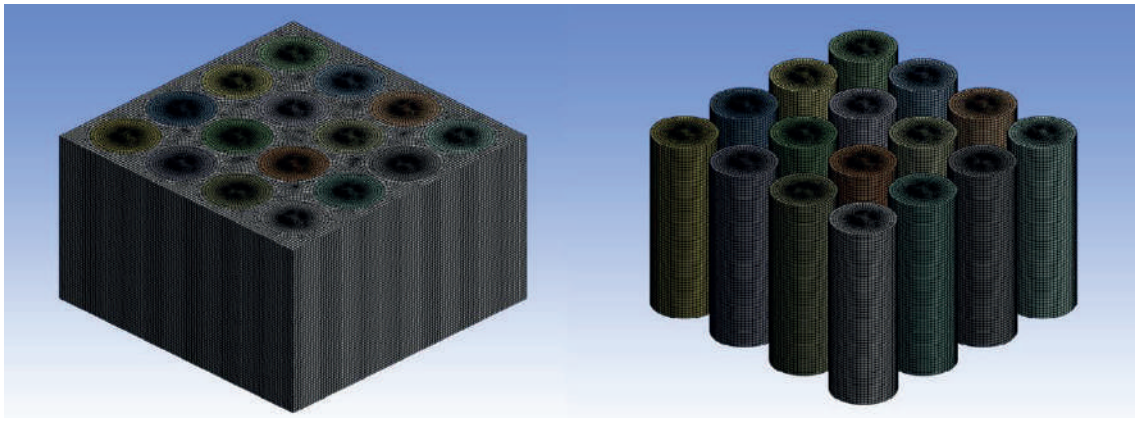


Figure 1. Computational domain of the lithium-ion battery pack for the 2×2 cell configuration.

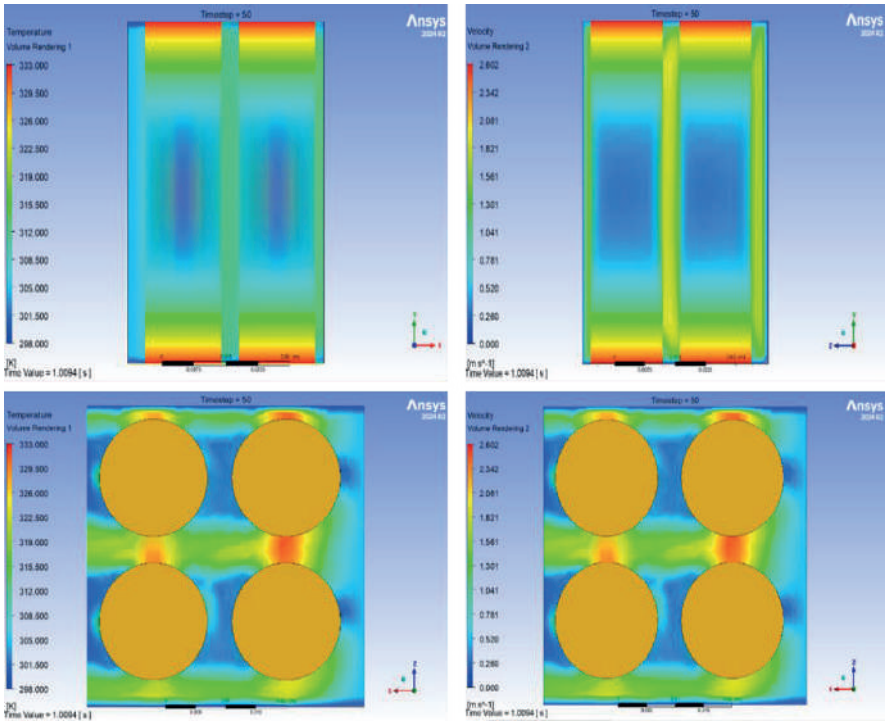


DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Figure 2. Computational domain of the lithium-ion battery pack for the 4×4 cell configuration.

RESULTS AND DISCUSSION

The sectional analyses presented in **Figure 3** illustrate the distributions of airflow velocity and temperature within the internal regions of the 2×2 battery pack. In the cross-section taken from the upper plane of the pack, it is observed that the temperature remains relatively stable in the central regions of the cells. However, local cooling occurs near the cell surfaces as the cooling air flows through the narrow channels between cells. In the wake regions, where the airflow does not directly interact with the cells, the temperature contours shift toward the orange-red range (326–333 K), indicating heat accumulation. The velocity contours indicate that the fluid accelerates in the gaps between the cells due to flow contraction, reaching a maximum value of 2.602 m/s. Low-velocity zones formed immediately behind the cells reduce the local convective heat transfer coefficient, thereby limiting heat dissipation in these areas. In the vertical side sections, heat accumulates from the lower part to the upper part of the cells. The coolant enters the system at 298 K and gradually absorbs heat as it flows through the cells, increasing the thermal gradient near the upper outlet region of the pack. The velocity profiles in the side sections indicate that the flow follows a relatively linear path along the cells; however, the velocity decreases near the cell walls due to the formation of a boundary layer.



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Figure 3. Temperature and velocity distributions of the lithium-ion battery pack for the 2×2 cell configuration.

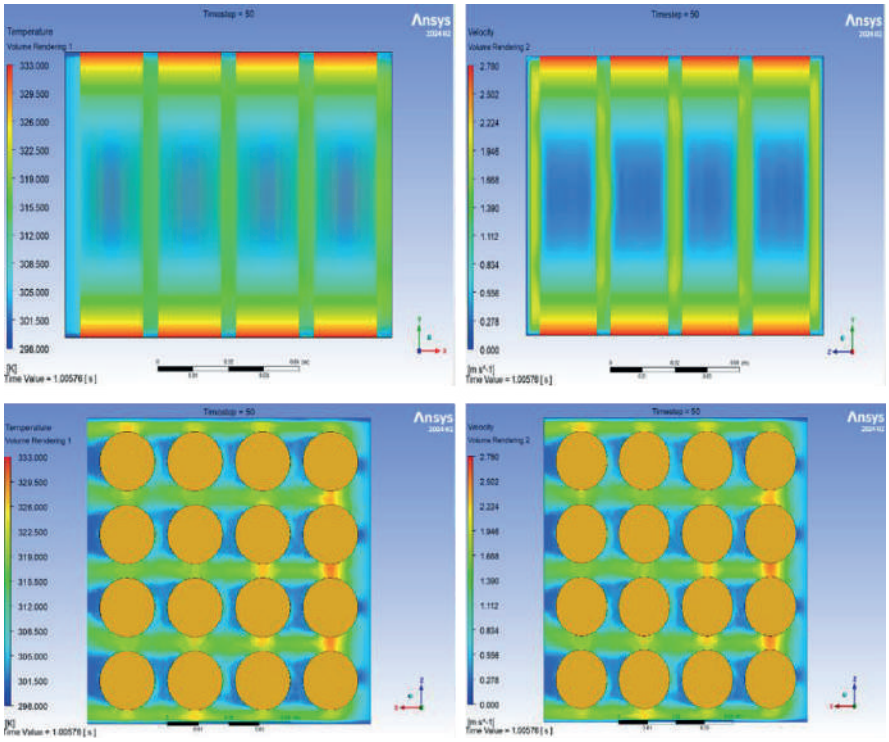


Figure 4. Temperature and velocity distributions of the lithium-ion battery pack for the 4×4 cell configuration.

The analyses in **Figure 4** show the airflow velocity and temperature distribution within a 4×4 battery pack with 16 cells. In the top view, the coolant reaches a maximum velocity of 2.780 m/s as it moves through the narrow channels between the cells. Effective cooling occurs where airflow interacts with the cells, but temperatures in the inner regions and behind the cells approach 333 K due to reduced airflow. In the side views, heat accumulation is observed to increase from the lower parts to the upper sections of the pack. The coolant enters at 298 K and absorbs heat as it flows, raising the thermal gradient near the upper outlet, where temperatures approach 333 K. The velocity decreases near the cell walls due to boundary layer formation, even though the maximum velocity is 2.780 m/s.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

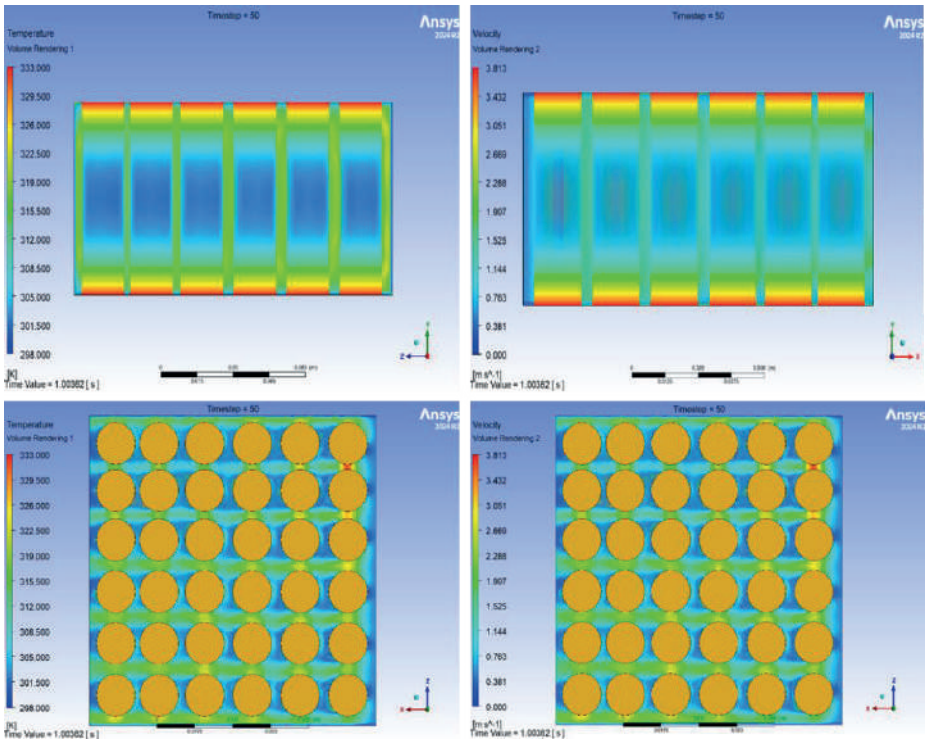


Figure 5. Temperature and velocity distributions of the lithium-ion battery pack for the 6×6 cell configuration.

The analysis presented in **Figure 5** provides detailed insights into the velocity and the resulting thermal gradients within the internal regions of a large-scale 6×6 battery pack comprising 36 cells. The findings confirm that cooling performance challenges increase with the number of cells in the pack. In the horizontal cross-section (top view), the coolant accelerates as it moves through the significantly narrowed channels between the cells, reaching a local maximum velocity of 3.813 m/s. The temperature contours indicate that, compared to the 2×2 and 4×4 configurations, airflow penetration into the pack's central cells is significantly reduced. This restriction leads to the formation of a large high-temperature region in the core of the pack. Vertical cross-sections show that heat accumulates more in the pack's depth and flow direction. The lower regions, exposed to cooling air, stay around 298 K, while the middle and upper cells reach approximately 333 K due to saturated thermal capacity. High cell density increases flow resistance, confining airflow to specific channels. Even though the maximum velocity reaches 3.813 m/s, the thicker boundary layer and flow separation near cell surfaces significantly reduce heat transfer efficiency. The analysis highlights that in the 6×6 configuration, centrally located cells gain little from convective cooling. This demonstrates that simply increasing airflow velocity is inadequate for large-scale battery packs, underscoring the need for additional cooling channels or hybrid thermal management strategies in design.

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CONCLUSION

This study examined the effectiveness of air-based thermal management in lithium-ion battery packs through transient CFD simulations across three different cell configurations: 2×2, 4×4, and 6×6, which represent increasing cell densities. The results showed that as the pack size increases, managing thermal conditions becomes more challenging. Heat accumulation intensifies in the upper and central regions due to the saturation of cooling air and a decrease in convective heat transfer. The 2×2 configuration demonstrated effective heat dissipation with minimal thermal trapping. In contrast, the 4×4 configuration revealed the development of central hot spots and increased temperature non-uniformity. In the larger 6×6 configuration, even with airflow velocities reaching up to 3.8 m/s, severe thermal trapping occurred, leading to central cell temperatures approaching the safety limit of 60 °C, particularly under high ambient temperatures (25 °C) and high discharge rates (3C).

REFERENCES

Du, J., Jia, S., Huang, X., Xie, T., Zhao, L., & Hong, Y. (2025). CFD assessment on thermal management behavior of lithium ion battery by employing phase change material and spiral fins. *Journal of Energy Storage*, *132*. https://doi.org/10.1016/j.est.2025.117707

Khan, F. M. N. U., Rasul, M. G., Sayem, A. S. M., & Mandal, N. (2023). Maximizing energy density of lithium-ion batteries for electric vehicles: A critical review. *Energy Reports*, *9*, 11–21. https://doi.org/10.1016/j.egyr.2023.08.069

Li, A., Yuen, A. C. Y., Wang, W., Chen, T. B. Y., Lai, C. S., Yang, W., Wu, W., Chan, Q. N., Kook, S., & Yeoh, G. H. (2022). Integration of Computational Fluid Dynamics and Artificial Neural Network for Optimization Design of Battery Thermal Management System. *Batteries*, *8*(7). https://doi.org/10.3390/batteries8070069

Luo, D., Zhao, Y., Cao, J., Wu, Z., Yang, X., & Chen, H. (2024). Effective temperature control of a thermoelectric-based battery thermal management system under extreme temperature conditions. *Journal of Energy Storage*, *103*. https://doi.org/10.1016/j.est.2024.114344

Magri, L., Sequino, L., & Ferrari, C. (2023). Simulating the Electrochemical-Thermal Behavior of a Prismatic Lithium-Ion Battery on the Market under Various Discharge Cycles. *Batteries*, *9*(8). https://doi.org/10.3390/batteries9080397

Sciatti, F., Tamburrano, P., Distaso, E., Amirante, R., Radogna, A. v., Morciano, A., & Grassi, G. (2026). A comprehensive overview of lithium-ion batteries for electric vehicles: Materials, performance, safety, recycling, and emerging technologies. In *Journal of Energy Storage* (Vol. 144). Elsevier Ltd. https://doi.org/10.1016/j.est.2025.119694

Yang, T., Li, J., Xin, Q., Zhang, H., Zeng, J., Agbossou, K., Du, C., & Xiao, J. (2024). Thermal Performance Analysis of a Prismatic Lithium-Ion Battery Module under Overheating Conditions. *Batteries*, *10*(3). https://doi.org/10.3390/batteries10030086

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A TASK SCHEDULING PROCESS IN THE CLOUD

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ABSTRACT

This paper discusses the task scheduling process in cloud computing. Cloud computing enables the delivery of various resources as metered services over the Internet, including hardware, software, and programming frameworks for users. Task scheduling involves mapping user requests to appropriate available resources. Due to the dynamic nature of cloud environments, challenges such as resource provisioning and efficient allocation must be addressed using effective task scheduling techniques. This study provides an overview of the task scheduling process in the cloud and summarizes the challenges and issues associated with task scheduling. In addition, various task scheduling techniques and optimization criteria are reviewed. The study adopts a literature-based methodology in which relevant research papers were systematically collected, screened, and analyzed to identify existing approaches, performance metrics, and limitations. The findings highlight the need to introduce optimization techniques in cloud scheduling, as traditional methods are often insufficient to produce optimal solutions within polynomial time. Finally, this paper presents a comparative analysis of different task scheduling approaches, which may be useful for researchers and professionals in the field.

Keywords: Task scheduling, Cloud computing, Resource processes, Optimization.

INTRODUCTION

IoT-Cloud technology is a well-known platform that is utilized in business resource arrangement and it grants customers to use computing assets from numerous resource service providers (Kim & Jo, 2014; Asghari & Navimipour, 2017; Aznoli & Navimipour, 2017). In the cloud, one of the client's main concerns is the cost which is identified with what they can manage (Zeng et al., 2015; Milani & Navimipour, 2016; Mohammadi & Navimipour, 2017; Sheikholeslami & Navimipour, 2017; Tabagchi Milan & Navimipour, 2017). Providing on-request benefits with high adaptability and accessibility in dispersed conditions is the primary thought behind the cloud (Rimal et al., 2011; Hajizadeh & Navimipour, 2017; Hazratzadeh & Navimipour, 2017). A representation of this IoT-cloud platform appears in Figure 1. The cloud comprises an assortment of assets and administrations, for example, virtual machines, stockpiling, memory, and data management (Navimipour et al., 2015; Fouladi & Navimipour, 2017; Navimipour, 2015). In this manner, numerous heuristic calculations have been

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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proposed to pick up a moderately ideal arrangement. The scheduling issue is a Nondeterministic Polynomial (NP)-hard issue (Ashouraie & Navimipour, 2015; Azad & Navimipour, 2017). Notwithstanding, various heuristic methods may be stuck in nearby local optima. As of late, Evolutionary Algorithms (EAs), for example, Particle Swarm Optimization (PSO), are joined with various calculations that perform searches to quicken search capacities (Padmavathi et al., 2012). While addressing this, the metaheuristic procedure is utilized to tackle issues related to scheduling (Akbari & Rashidi, 2016). The reason for the proposed heuristic calculation is to enhance the makespan by expanding the parallelization. At this point, PSO operators are mostly applied to upgrade these arrangements. In the proposed PSO calculation, first, the underlying populace is created randomly.

The cloud has grown as PC and organizational innovation improves, which is the result of combining virtual innovation with fast and current data processes. A suitable planning system is required to distribute the requests to the required resources. The fundamental standard of distributed computing system is that it breaks down requests by clients into other sub requests or tasks. Consequently, task scheduling or planning in the cloud is regarded to be one of the main developments of distributed computing, it influences the process of distributed computing. After preparing the subtasks, the processes initiate each resource to the clients by the scheduling methodology (Armbrust et al., 2010; Calheiros et al., 2011; Hussain et al., 2020; Hussain & Al-Turjman, 2020). Countless examinations show cloud task scheduling is associated with the NP-hard problem; it has been a major research point for numerous researchers. The PSO has been considered by various researchers because of the nature of the administration of clients. The outcomes in this area suggest more work have to be carried out regarding cloud task scheduling for logical processing. Writers like Zongbin and Zhongjun (2013) depicted an assignment scheduling calculation in distributed computing for finding a solution to this issue dependent on improved hereditary calculation, the outcome was to get a better timing factor compared to other research.

This study provides these clear contributions.

- An extensive understanding of cloud computing.
- The description and understanding of how the cloud performs scheduling.
- Optimization and task scheduling in the cloud environment.
- Assisting researchers in identifying suitable techniques and approaches for scheduling user applications for cloud computing.
- Finally, discussion of issues in the cloud.

The structure of this work is presented as follows. Understanding the cloud and its computing is presented in section 2. Section 3 profers task scheduling and its process. Section 4, 5, and 6, explains

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and puts forward the optimisation in the cloud and its criteria. Section 7 provides discussions and open challenges encountered in the research study. Lastly, section 8 concludes the paper by providing the conclusion and future works. Also, table 1 gives the used abbreviation and its meaning. The list of abbreviations is given in Table 1.

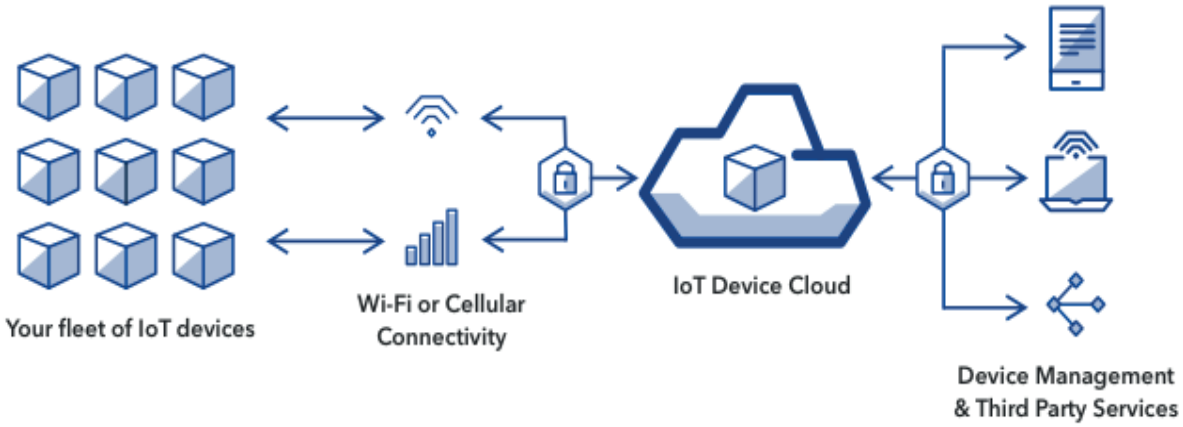


Figure 1. Cloud-IoT Platform Illustration

Table 1. Utilised Abbreviations

Terms	Meaning
ICT	Information and Communication Technologies
QoS	Quality of Service
NP	Nondeterministic Polynomial
PC	Personal Computer
IaaS	Infrastructure as a Service
PSO	Particle Swarm Optimization
PaaS	Platform as a Service
GA	Genetic Algorithm
ACO	Ant Colony Optimization
SaaS	Software as a Service

METHODS

This study followed a structured process to examine task scheduling in cloud computing environments. The approach involved collecting relevant publications from recognized computing and computer science databases, conducting an initial relevance screening, reviewing selected studies in detail, and summarizing the key findings. Task scheduling in the cloud is defined in this study as the methods and techniques used to allocate cloud resources efficiently to tasks in order to improve performance, reduce execution time, and optimize resource utilization.

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Search Strategy: A systematic search was conducted using keywords such as “cloud computing” and “task scheduling” across academic databases, focusing on literature published within the last five years. Additional studies were identified by reviewing the reference lists of initially selected papers. Each retrieved publication was evaluated against predefined inclusion criteria to ensure relevance to cloud-based task scheduling.

Selection of Studies: The selected studies were independently evaluated by authors with expertise in computer science and related fields. An initial screening phase eliminated clearly irrelevant publications based on titles, abstracts, keywords, and publication type. Studies unrelated to cloud task scheduling, such as those focusing on non-computing cloud concepts or unrelated application domains, were excluded. Only full-text, peer-reviewed articles written in English were retained, while editorials, letters, and non-scientific publications were removed to ensure academic rigor.

CLOUD COMPUTING

Utilizing the cloud reduces the expense of carrying out programming arrangements and the capacity of information management. Cloud computing addresses a pool of frameworks that are associated with an organization and gives a versatile foundation so programming frameworks and information can be utilized. To have a superior comprehension of what cloud computing addresses we need to contrast it with conventional ideas, for example, grid processing. Given these advances, the IoT-cloud arrangement can and should be a great subject of measure and needs for associations. There are a few fundamental innovations to guarantee effective IoT-cloud implementation, including distributed computing, standard cloud deployment models, cloud service models, and other valuing models (Bauer, 2018). It is perceived that IoT-cloud can offer types of assistance through models like Software as a Service (SaaS), and Infrastructure as a Service (IaaS), Platform as a Service (PaaS), these models can as well be utilized as a public, private, or hybrid cloud (Bellini et al., 2015).

Subsequently, an organization with the internet is needed for utilizing IoT administrations service through customers. The IoT-cloud model is utilized in an assortment of cloud resources, for example, IaaS gives source to frameworks and information management, and the SaaS application upheld by the PaaS model permits business clients to alter the IoT administration system or process (Chang et al., 2016). IoT applications incorporate web applications, internet providers, information management, and encryption models (Sahmim & Gharsellaoui, 2017). Considering the conversation of the IoT-cloud model and the acknowledgment of practical and specialized agreement, each cloud resource has its uses. Contingent upon the business needs of the association, the cloud administrations can be joined to meet determined prerequisites (Stergiou et al., 2018). In alternate ways, it includes specialized assets, cloud-based applications, accessibility, and security (Subramanian & Jeyaraj, 2018).

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A. Cloud Computing Deployment Models Perspectives

In the accompanying paragraph, more discussion will be provided on various cloud deployment models that can be utilized in IoT-cloud. These models will propel businesses to incorporate cloud technologies into organizations efficiently. Table 2 shows a comparison of the deployment models.

- Hybrid Cloud: It is a deployment model with a mix of private and public clouds. The major advantage of a hybrid cloud is that it diminishes costs. By implementing this, clients can determine what type of information lives on either open o private in the cloud. The information is accumulated from the two sources to give the outcomes that clients required. It can also be referred to as a deployment model with a mix of private cloud, premise, and a third-party public service with an orchestration among the two platforms. It also possesses great cloud-bursting capabilities, with the gain of both public and private environments. Their top vendors are those who provide both private and public cloud resources.

- Private Cloud: It is a deployment model that is used by a single entity/organization. It is profoundly safe because of its mode of implementation and is liked by most organizations since, once utilized remotely, assistance can be presented by the provider. It can be propagated whether within an organization or remotely. By doing this, the foundation is uniquely worked to offer incredible execution and soundness. One more benefit is the assets can be delegated in solitary to a customer. It can also be referred to as a deployment model in which a proprietary architecture is used by an enterprise and implements cloud servers on their data farms. This mode comprises on-premise hardware and single-tenant architecture. It also has direct control of the underlying cloud infrastructure. Their top vendors include Microsoft, Dell EMC, and VMware, among others.

- Public Cloud: In this model type information can be stored on it by users without the security that a safe organization has. Which by and large implies that it is open for public use. The principal concern is protection since suppliers don't promise it. This kind of Cloud can likewise be presented as free for everyone to utilize. It can also be referred a cloud model where a third-party provider makes available compute resources over the internet to the public. This model is an advantage in the sense that the enterprise does not have to set up and manage its cloud servers in-house. It also comprises a pay-as-you-servicing model and multitenant architecture. Their top providers are AWS, Microsoft Azure, and the google cloud.

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Table 2. Comparison of Cloud Deployment Models

	Hybrid Cloud	**Private Cloud**	**Public cloud**
Hardware	Medium/Variable.	Variable (can be both on site or through third-party).	Third-party.
Flexibility and scalability	Very high.	Medium (a stable capacity).	High.
Cost	Medium/Variable.	Relatively high.	Lowest.
Privacy and security	Varies from low to high.	High.	Low.
Overall reliability	Medium to high.	High.	Medium.
Control of data	Medium.	High.	Low.
Setup and use	Requires IT professionals.	Requires IT professionals.	Handle in-house.

B. *Cloud Computing Service Models Perspectives*

The providers of cloud computing offer assistance as per customer requests. Accordingly, cloud arrangements are financially dependable and savvy. Cloud computing is of three service models, more discussion is given on them below and its depiction of their services is given in Figure 2 and a comparison is given in Table 3.

I. Platform as a Service (PaaS)

This is presumably the most well-known kind of cloud that is utilized because it works with the execution and testing of programming arrangements. This service model provides currently an OS, a programming language, a web server, and so forth. The assets are consequently assigned so the client doesn't have to do that manually. Running applications are activated using assets provided by this service model. This model utilizes a third-party provider which enables them to host application development tools and platforms on their structure and it becomes available over the internet to users. Examples of these platforms include AWS elastic beanstalk, Heroku, and Google app engine.

II. Infrastructure as a Service (IaaS)

This model likewise provides various assets like firewalls, programming arrangements, load balancers, and so much more. The IaaS providers offer virtual or physical machines that can satisfy client requests to execute programming arrangements. It also gives them the security that they need. This sort of administration offers an incredible benefit to customers that need a strong and adaptable

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foundation. One more benefit of utilizing IaaS is that users can send and keep up with the working process of the framework. The model assists clients with conveying their products at decreased expenses. Generally, customers just pay for the resource dispensed for their executed request, without stressing for equipment assistance. Hence, the provider isn't constraining the customers to make use of one main OS. A third-party provider in this model hosts storage, servers, and other virtualized resources for computing and they become accessible over the internet to users. Examples of these platforms include Google's compute engine, AWS, and Microsoft Azure.

III. Software as a Service (SaaS)

To get to this, customers should pay a membership charge. The SaaS model is depicted as pay as you go system. Here the provider provides customers with a designed (equipment and programming) arrangement. The responsibility of the SaaS is for the maintenance of the customer without the customer worrying about resource maintenance. The advantage of using this model is that customers' stress is not needed over any equipment, upkeep, or programming. For this, a yearly or monthly membership cost will be paid by the organization that will rely solely on customization of the IoT equipment or possibly the resources assigned for that organization. For a superior agreement, SaaS can give admittance for businesses to an IoT arrangement. It can be referred to as a software distribution model. In this case, applications are hosted by the third-party provider and they become accessible over the Internet to customers. Examples of these platforms include NetSuite, salesforce, and Concur.

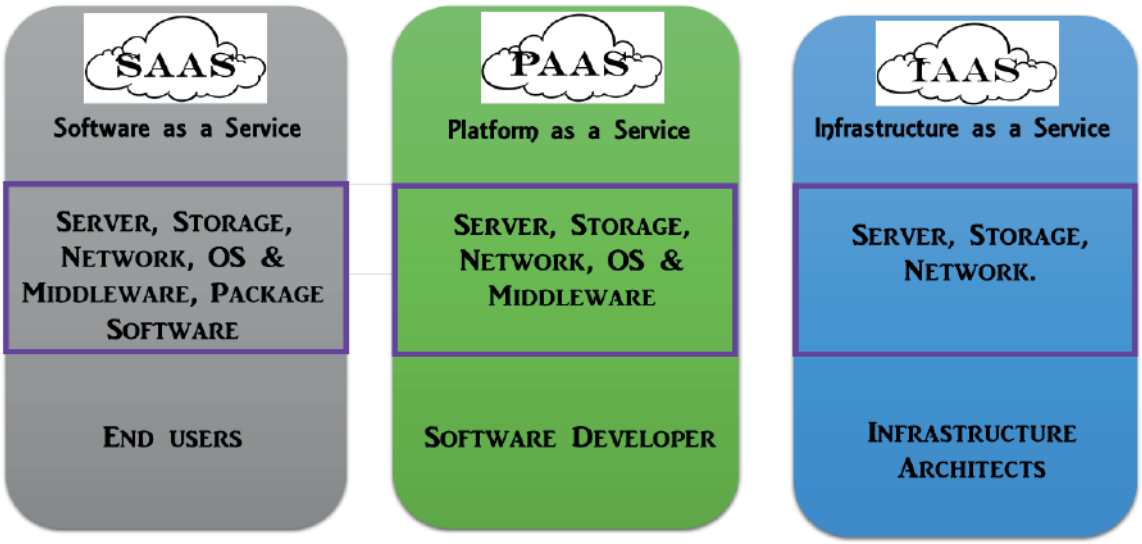


Figure 2. Illustration of the Cloud Service Models

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Table 3. Pros and Cons of the Cloud Service Models

Types	Advantages	Disadvantages
IaaS	Cloud computing model with the most flexibility. Networking, storage, processing power and server are easy to automate and deploy. Consumption can be used to purchase hardwares. Complete control is given to client based of their infrastructure. Purchases of resource can be done based on needs. Scalability is high.	Control over costs if scalability is unlimited. Security is multi-tenant. Internal training and resources. Operating legacy systems in the cloud. Security and data concerns. Technical issues.
PaaS	Scalable. Highly available. Simple, cost-effective development and deployment of applications. No need for maintaining software. Automation of business processes/policies. Reduction of coding is significantly required.	Security and data concerns. Dependency on vendor. Compatibility of existing infrastructure. Performance concerns (reliability, speed and support). Vendor lock-in. Lack of scalability.
SaaS	Accessibility. Scalability and integration. Lower up-front cost. Fast to realize benefits, quick set up and deployment. New releases (upgrade).	Connectivity requirements. Limited range of applications. Limited control. Upgrade and new features timelines are given by vendor. Concerns in data sovereignty and security.

TASK SCHEDULING IN THE CLOUD

The primary target of scheduling is the ideal designation of assets to explicit tasks in a restricted chance to accomplish a superior exhibition processing and helpful nature of the service. The simplest scheduling calculation is the first come first serve (FCFS) which chooses the initial request process for implementation from the prepared or queued line (Silberschatz et al., 2009). Hence, FCFS generally selects the first cycle whereas SJF chooses an interaction with the briefest execution time. The planning administrator should plan the given request for accessible assets subject to specific

imperatives to further develop at least one enhancement standard (Reuther et al., 2017). The downside of FCFS is that a cycle with a more modest execution time superfluous sits tight for the long term assuming the interaction with the longest execution time is chosen first. The Cooperative calculation which is the round robin utilizes the idea of time cutting known as quantum time. Planning calculations vary by the idea of assignments or requests in the application. Each cycle has an opportunity to execute for the same measure of time, known as quantum. Another scheduling calculation is the shortest job first (SJF), each time which chooses an interaction with the briefest execution time from the prepared line or queue. In cloud computing frameworks, the scheduling algorithm is liable for choosing the suitable assets for task execution thinking about a few dynamic and static task boundaries (Nallakumar et al., 2014). This SJF calculation is said to be more productive than FCFS as it guarantees the least normal holding-up time. The following prepared process is picked for execution. This cycle is rehashed till all cycles finish their execution.

At the point when an undertaking has a succession, the errand can be planned solely after its principal assignments have all been finished, this is called workflow scheduling. If the quantum is too little for the RR, every cycle executes for a modest quantity of time which causes regular setting exchanging. This calculation inclines toward the cycles with more modest execution time yet the cycles with larger execution time might finish last since each task is given a specific time to finish their processes. The productivity of RR effort is thoroughly reliant upon the quantum. The downside of SJF is that it requires information about central execution time ahead of time (Lingyun et al., 2003). At the point when the quantum for an ongoing cycle terminates its execution it is briefly stopped and it is set toward the prepared line with a new quantum. In another situation, when errands are autonomous of one another, it can also be planned for any request which is referred to as independent scheduling (Yu et al., 2008). In any case, assuming the quantum is too huge, the cycle executes for a long span which may increase the waiting time. In the accompanying section, we will discuss further scheduling optimization in the cloud platform.

A. The Task Scheduling Approach in The Cloud

The Cloud has various qualities with great advantages to users. The structure of scheduling in the cloud is a basic goal to lessen computational expenses. The significant highlights of the cloud are adaptability, self-redesigned, and customization. The key goal is to expect the best procedure for the scheduling system when required. The elements of cloud assets are crucial for totally designed clients' satisfaction. To accomplish this, we play out a determined evaluation for scheduling in the cloud environment. Certain bodies ought to be considered while fulfilling these objections like cloud suppliers, and clients of the cloud. The users request the resources, and the cloud provider is answerable for the assignment of the anticipated resource, so the client avoids the encroachment of the Service Level Agreement (SLA). For the techniques of scheduling in the cloud, the pattern of task scheduling helps to get tasks from the clients and get a solicitation from the cloud information service

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(CIS) for their properties and open resources. The cloud scheduler has to be skilled to appoint different virtual machines (VMs) to a different process. Thus, the scheduling structure in the cloud is shown in Figure 3.

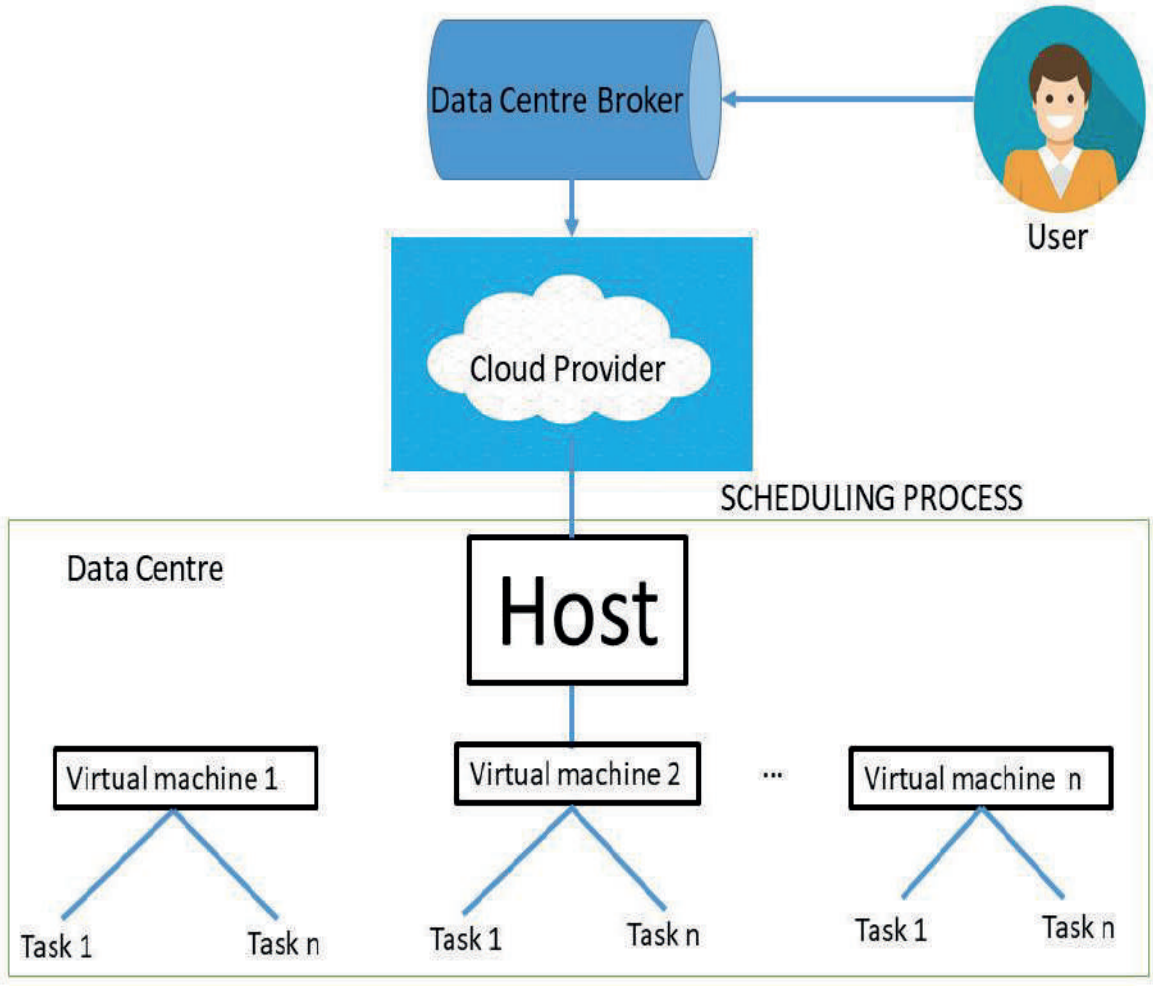


Figure 3. Description of the Task Scheduling System Structure

OPTIMIZATION

Optimization issues assist us with tracking down the ideal arrangement among a bunch of given solutions for instance the best return or the most reduced expense, and so on. In this study, we investigate one such improvement issue called task scheduling for the cloud. There are various sorts of optimization issues and various issues have various answers for them.

The objective of optimization is to track down the best incentive for every variable to accomplish palatable execution. Before the process of optimization can start, all issues to be streamlined ought to be planned as a framework with its status constrained by a couple of information factors and its exhibition indicated by an obvious objective capability or the fitness capability, which can be meant as f or f(x). A particular set of the input factors, position, is given by x, $x \in \mathbb{R}xD$, where D is the all-out number of input factors and can likewise be alluded to as a decision or set vector. The variables

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expected by the fitness capability are alluded to as the decision or the input factors. The arrangement of all plausible outcomes is known as the function space or search space. The factors could have straightforward imperatives or could have complex ones. The outcome assessed by the objective capability to give a specific position is known as the fitness value or the objective value. Both minima and maxima could be alluded to as the ideal for that objective capability. The most extreme worth arrived at by an objective capability is known as the maxima, comparatively the least worth by the objective capability is the minima. The optimum between neighbors is called the local optimum while the global optimum is the ideal among all neighborhood optima.

Figure 4 depicts a unimodal objective capability with a base 0.5 at x = 0 for f(x) = x2 + 0.5. Both a minima and a maxima can be referred to as an optimum. A local optimum is said to be ideal inside its neighborhood.

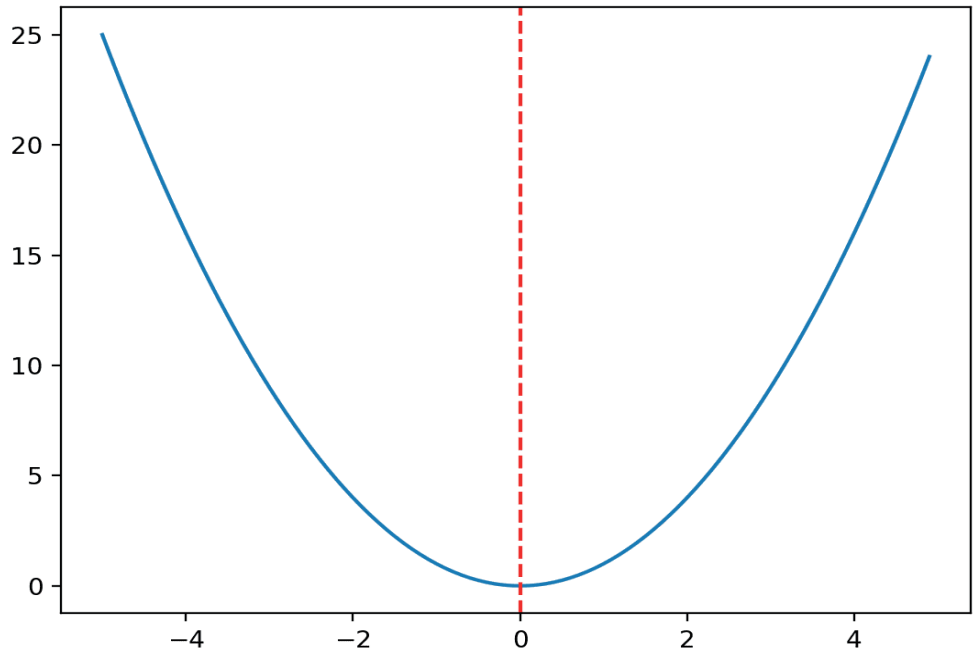


Figure 4. Illustration of Unimodal Objective Function

Figure 5 shows a global minimum of generally −1.8 found near x = 5 in the search space [−1, 8]. The minima are the ideal of all local optima; i.e., within the search space, it is optima. Figure 4 shows the multimodal objective capability f(x) = 1.4 sin(x) + x. The minimization issue is an issue of optimization for which the situation with the least objective value is to be found. While maximization issue is an issue of optimization for which the position (for example input factors) with the most noteworthy objective value is to be found. This issue can be changed over into a minimization issue by discrediting the objective capability.

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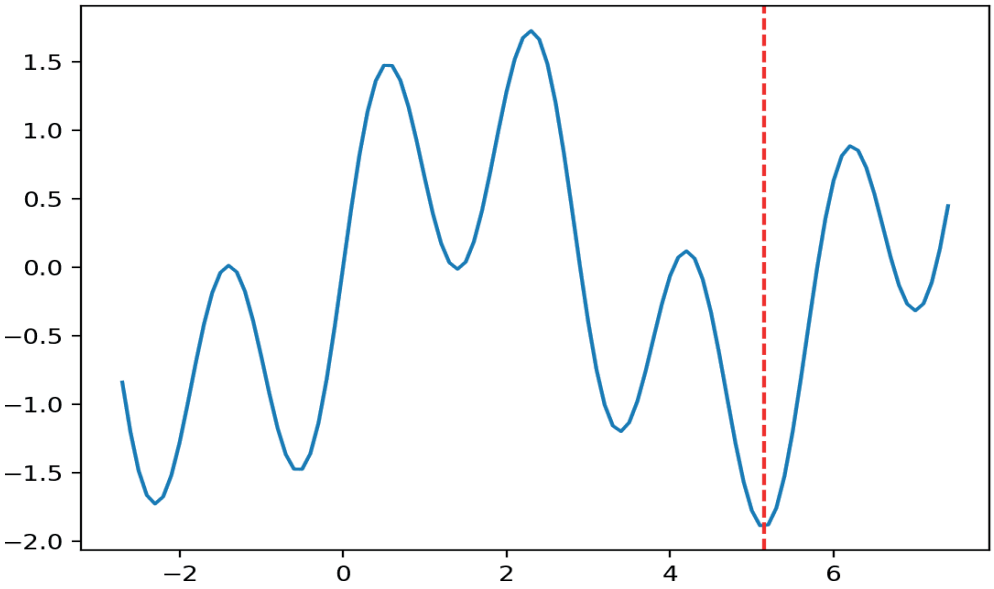


Figure 5. Illustration of Multimodal Objective Function

OPTIMIZATION SCHEDULING APPROACH IN THE CLOUD

Scheduling optimization in the cloud is of several kings. Figure 6 below shows the segmentation of the scheduling optimization in the cloud. The scheduling technique can be subjected to three main categories known as AI or meta-heuristic, heuristic, and finally the traditional optimization technique (Yang et al., 2013). More insight will be provided into this scheduling technique in the accompanying sub-paragraph and more emphasis will be given to the AI or meta-heuristic approach since it quantifies the majority use.

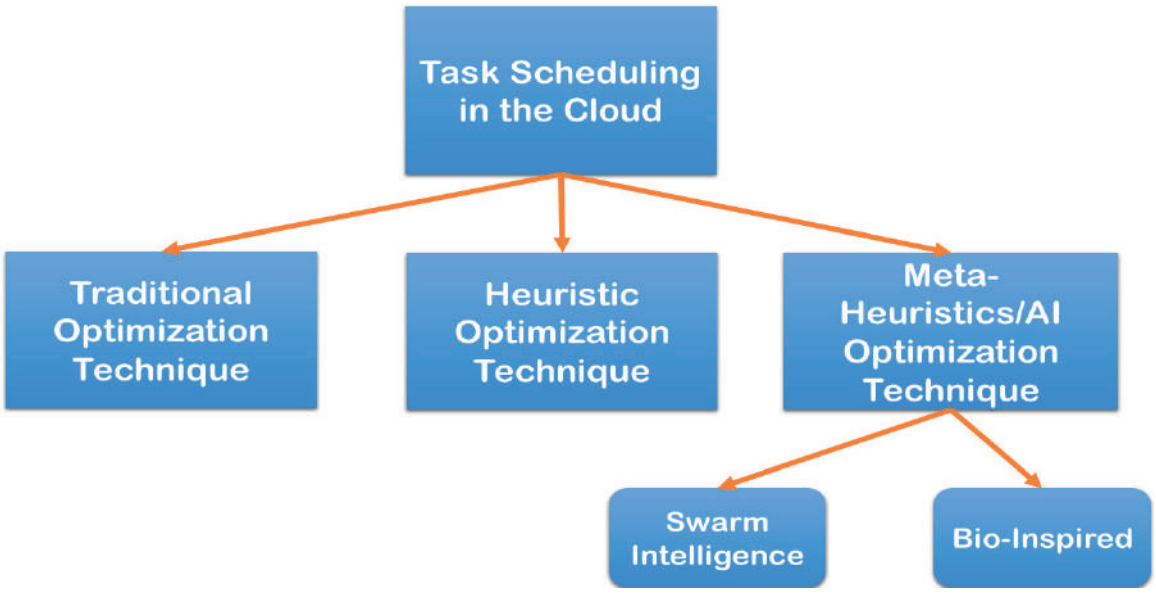


Figure 6. Classification of the Task Scheduling Optimization Techniques

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A. Traditional Optimization Techniques

Conventional or traditional procedures are the fundamental methods for scheduling optimization on various undertakings, examples of these techniques are Round Robin (RR), Shortest Job First (SJF), and First Come First Serve (FCFS). The FCFS calculation intends that a task that starts things out will be executed first. These procedures are quick, basic, deterministic, and acquire definite arrangements (Li & Guo, 2010). The SJF is a procedure that relies upon the execution circle of the undertaking. Yet, they are not proficient to grasp the optimality issue by and large (Singh et al., 2017). The assignments are lined given need, the most significant length of time is set last with the least need and the littlest time is put first with the most noteworthy need (Thakur & Mahajan, 2017). In this way, customary or traditional methods are not optimally practical in cloud scheduling (Kalra & Singh, 2015). Other traditional algorithm tends to diminish the holding up time and completion time profoundly contrasted with ordinary RR planning with no plan for a quantum time, as opposed to giving static time quantum in the central scheduling process. Many works have been done to work on the execution of the traditional methods (Nayak et al., 2012). Authors in Elmougy et al. (2017) proposed a mixed calculation of SJF and RR called SRDQ calculation. This calculation has a powerful factor in the task quantum time. The RR is a similar method that works utilizing a quantum time or time cut. Authors in Li et al. (2017) proposed a calculation for task planning in light of clustering fuzzy calculations to expand the asset usage and limit the process execution time. In this calculation, the computer processor is doled out to the errand with the least execution time. The proposed scheduling technique by Sangwan et al. (2017) depends on the RR technique, however, impacts the method of the planning estimations. The calculation of RR possesses a downside in that it uses static quantum time.

B. Heuristic Optimization Techniques

The heuristic methods are utilizing the test space of arbitrary answers to discover the ideal or close-to-ideal answers to a solution. The max-min is an example of the heuristic approach which designates an undertaking with normal execution time. Other numerous heuristic procedures exist, for example, max-min, priority-based min-min, min-min, and enhanced max-min (Sharma et al., 2017). This calculation builds the opportunity for simultaneous tasks of undertakings on assets. These strategies give improved results when contrasted with the conventional procedures, yet don't ensure to score high positioning in the cloud space (Raj & Prasad, 2016). The essential min-min calculation is a direct and powerful calculation that creates the ideal scheduling for lessening task consummation time. The solutions coming about because of heuristic methods frequently stall out in the issue of local minima. In any case, the greatest downside is load adjusting, which is viewed as one of the significant difficulties for cloud specialist co-ops. A better Max-min procedure utilizing the normal execution time for the determination premise rather than consummation time is proposed by Bhoi and Ramanuj (2013). LBIMM calculation is essentially planned in light of the Min-Min calculation to build the asset

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ISBN: 978-9952-610-30-7

use and lessen the culmination time. Authors in Chen et al. (2013) have further developed load adjusting by proposing a better Burden Equilibrium and Further developed Min (LBIMM) calculation.

C. Meta-heuristic/Artificial Intelligence Optimization Techniques

Meta-heuristic methods are arranged into two classes: Bio-inspired and swarm intelligence (SI). The issue of designating requests on assets in the cloud environment is termed an NP-hard issue. Bio-inspired has infiltrated into sciences practically in all areas of, biomedical designing, information mining, parallel processing, and control systems. Along these lines, the scheduling of tasks is explained by utilizing meta-heuristics and heuristics to get close to ideal or ideal arrangements in minimal time. Heuristic strategies are subsets of meta-heuristic procedures. There are numerous Bio-inspired calculations like GA, MA, and imperative competitive algorithms (ICA). Meta-heuristic methods are in many cases nature-roused by friendly ways of living things behavior or human intelligence like AI (Yang, 2010). Similarly, a swarm intelligence strategy is a new approach that is used to determine the issues of unconstrained improvement and it is roused based on insects colonies' social behavior and different living things like ACO, PSO, glowworm swarm algorithm (GSA), artificial bee colony (ABC), Firefly algorithm (FA), BA, cuckoo search (CS) and cat swarm optimization (CSO). The phrase meta-heuristic is expressed in 1986 by Fred Glover, the term meta signifies a more elevated level and heuristic signifies to find through experimentation. Analysts generally attempt to track down better calculations, particularly for scheduling problems in the cloud.

We embraced a reasonable meaning of the word metaheuristic from Sörensen and Glover (2013) a metaheuristic is a significant level issue-free algorithmic structure that gives a bunch of rules or techniques to foster heuristic enhancement calculations. We present here a clear investigation of these calculations given different streamlining rules that build up the strengthening of Search spaces. The term is likewise used to allude to an issue of explicit execution of a heuristic enhancement calculation as per the rules communicated in such structure. Authors in Pooranian et al. (2015) introduced a calculation for free task planning for framework processing by a combination of PSO with the gravitational emulation local search (GELS) to keep away from nearby minima issues. All meta-heuristic methods have two primary parts diversification and intensification. Authors in Sridhar and Babu (2015) introduced a better PSO known as (HPSO) which is a mixture of TS and PSO calculations. Considering optimization this technique produces arranged answers for investigation in search space all the more completely on the big scale, while escalation focuses on search in neighborhood spaces by involving the nearby data in the hunt cycle to create improved arrangements. HPSO gives the neighborhood search procedure by Tabu Search. Subsequently, the ongoing neighborhood data can be a subsidiary of the objective. HPSO upgrades arbitrarily created a populace by isolating it into halves. Since the heuristic procedures frequently stall out regarding the issue of neighborhood optima, the meta-heuristic methods were showing best to turn away this present circumstance as referenced in Al-maamari and Omara (2015); Tsai and Rodrigues (2014). Then, at

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

that point, blending them into one section to trade local and global best solutions. The HPSO limitation is that it limits the makespan and enhances the use of the assets.

The blend PSO-GELS calculation shows a huge decrease in Makespan time. The mixture PSOCS calculation accomplishes great asset use and makespan decrease for free errand planning for the cloud. An original PSO calculation was introduced by Aron et al. (2015) it depends on a hyper-heuristic calculation for secure task planning for a minimum climate. Authors in Raghavan et al. (2015) tackled work process planning issues for cloud environments utilizing bat calculation. It proffers improved aftereffects of cost handling contrasted and Best Resource Selection (BRS) calculation. The heuristic calculation diminishes both Makespan and cost. To upgrade the heightening of search space, a mixture of CS and PSO calculations was introduced. An undertaking planning calculation in light of twofold fitness versatile calculation work crossing time and load balancing genetic algorithm (JLGA) which was presented in Wang et al. (2014) for circulation of burden among VMs, energy decrease and decreasing the time of makespan. Authors in Xue and Wu (2012) diminish the PSO intelligent union and further develops nearby search capacity by utilizing hill climbing calculation after every cycle. This calculation utilizes a covetous calculation to introduce the populace. The GHPSO calculation works for discrete issues by utilizing mating pool methodologies of a hereditary calculation. GHPSO is utilized in limiting expenses. It takes hybrid and transformation for versatile probabilities rather than fixed esteem. Nevertheless, there are still limitations to these algorithms which this study will address.

OPTIMIZATION CRITERIA

The current works have tended to various types of criteria for optimization, for example, load balancing, makespan, budget, cost, resource utilization, deadline, energy efficiency, and throughput. The section here provides an understanding of the boundaries/criteria utilized to gauge the viability in the cloud for task scheduling. These optimization criteria are tended to from the vast majority of the surveyed works. For the most part, these criteria are arranged into two segments given cloud administration: cloud provider desired criteria and cloud user desired criteria (Laghari et al., 2017). Subsequently, this work attempts to exhibit how these measures are concentrated relatively.

- Provider Desire Criteria

Throughput: Throughput is a process that deals with finding how capable the scheduling approach is. It denotes the completed task for each resource per time unit (Pacini et al., 2015).

Resource utilization: the cloud provider has to maximize the use of this resource. This also implies utilizing most of the available resources and making it as occupied as it can be. This is helpful to providers to attain some gains for constant leaving on demand by the user (Lin et al., 2014).

Energy efficiency: This implies making sure the consumption of energy in the cloud is minimal (Bajaj, 2018).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Load balancing: This is a measure of load distribution between assessable VMs evenly in the cloud over each physical resource. Several balancing techniques have been introduced by authors in Jianfang et al. (2014).

- User Desire Criteria

Cost: This is the financial expense charged to the user based on the client, regarding the time spent on a specific resource (Latiff et al., 2018).

Makespan (total completion time): This is referred to as the completion time it takes the final request from the client to be completed and it is terminated when the stopping criteria is being met (Latiff et al., 2018).

Budget: This is the constraint given to a task to be completed within a budget (Yu & Buyya, 2006).

Deadline: This is stopping criteria given to a particular task based on a certain time (Poola et al., 2014).

DISCUSSION

In this part, we give an examination and open discussion and challenges on how the cloud environment performs task scheduling. These procedures are understood regarding the different optimizing models as referenced in the previous section. There are various factors to be considered while optimizing in the cloud for the scheduling process. Table 4 portrays various works that have been performed in the optimization of task scheduling in the cloud. A portion of these factors are considered based on the client and the suppliers. The table involves criteria for scheduling in the cloud with load balancing, makespan, cost, energy efficiency, and deadline. Little consideration is shown to throughput, budget, and resource use. Minimization of makespan is a significant criterion for cloud clients who want to accelerate the execution of their applications. Makespan, budget, and cost are liked by the clients. Moreover, asset usage, load balancing, throughput, and energy effectiveness are liked by the suppliers. Besides, Cost comes next to everyones advantage. Choices in cloud task scheduling are for the most part founded on the metric known as makespan for its applications. Subsequently, limiting the makespan is one of the main pressing issues of specialists to improve the efficiency of cloud task scheduling. Different sorts of constraints have been viewed in the study, for example, makespan and calculation costs. Other challenges in the cloud that need addressing include:

Resource allocation: It refers to the conservative dissemination of assets on the cloud among various applications through the web (Anuradha & Sumathi, 2014).

Resource provisioning: This is the most common way of dispensing the assets from the provider to the cloud clients with the assistance of quality affirmation not entirely set in stone in the service level agreement (SLA) (Nagesh, 2014).

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ISBN: 978-9952-610-30-7

Resource mapping: It is referred to as the consistency among assets accessible with a cloud provider and assets expected by cloud clients (Leivadeas et al., 2013).

Resource selection and discovery: This is the most common way of finding all assets introduced in the system and gathering the present status of assets then, settling on choices which target asset ought to be chosen in light of the data got from the discovery (Endo et al., 2011).

Resource adaptation: It is referred to as the capacity of this framework to powerfully change assets to meet client necessities (Manvi & Shyam, 2014).

Resource brokering: This is the course of discussion for the expected assets through a specialist to ensure that vital assets are accessible to finish the main aim (Parikh et al., 2017).

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ISBN: 978-9952-610-30-7

Table 4. Comparison with Similar Works

Author/Approach	Nature of Tasks	Optimization Criteria	User/Provider Desired Or Both	Experimental Scale	Simulation Environment
Pooranian, et al. (2015). PSO–GELS,	Independent	Makespan	User	Several Resources Varying on Workload	Java Simulation Environment
Aron, et al. (2015). A NOVEL PSO - Based Hyper-Heuristic	Independent	Makespan, Cost	User	150–250 Resources 700 Tasks	Gridsim
Sridhar & Babu, (2015). HPSO	Dependent	Budget	User	Two Resources 200, 400, 600, 800 And 1000 Tasks	Cloudsim
Raghavan, et al. (2015). Workflow Scheduling Based On A Bat Algorithm	Dependent	Makespan, Cost	User	Three Resources Four Tasks	Not Mentioned
Xue & Wu, (2012). GHPSO	Dependent	Cost, Deadline	User	Randomly Generated	Cloud Simulation Environment (Java)
Pandey, et al. (2010). PSO Based Heuristic	Dependent	Makespan, Cost	User	Amazon Cloudfront	Jswarm Package
Abdi, et al. (2014). Modified PSO Algorithm	Independent	Makespan	User	4 Resources 100 – 800 Tasks	Eucalyptus Cloud
Wang, et al. (2012). PSOTBM	Independent	Energy Efficiency	Provider	100 - 5000 Resources	Cloudsim
Joseph, et al. (2015). A Novel Family Genetic approach	VM Placement	Resource Utilization	Provider	Several Resources Varying on Workload	Cloudsim
Rouhi & Nejad, (2015). CSO-GA	Dependent	Makespan	User	7-25 Resources 50–100 Tasks	Java
Dam, et al. (2014). A Novel Ant Colony Based algorithm	Independent	Load Balancing	Provider	25, 50 And 75resources Online Tasks	Cloud Analyst
Hussain, & Al-Turjman, (2022). HGA	Independent	TWT, TFT, TET, Cost, Resource Utilization, Throughput	Both	25-100 Tasks, With Several Expansion Criteria.	Cloudsim

CONCLUSION

The discussed study proffers an understanding of task scheduling in the cloud environment. A comparative analysis was given on cloud computing and its environment, it includes the deployment

and service models. Emphasis was given to the optimization of task scheduling approaches in the cloud. Task scheduling optimization, criteria, and categories in the cloud environment are discussed. Following the literature deduced from this paper we can conclude that most authors were subjected to using meta-heuristic approaches after contrasting it with the traditional optimisation techniques. Some of the common algorithms include GA, ACO, and PSO. However, there include other algorithms that are rarely used like BT, CSO, and ICA. This research can be concluded by saying that makespan and cost are one of the main criteria to be considered when optimizing task scheduling in the cloud environment. Although the research still needs future directives like implementation and understanding of other algorithms to solve various criteria in polynomial time. This research will assist cloud specialists, students, and professionals understand task scheduling in the cloud at whatever point being considered.

REFERENCES

Abdi, S., Motamedi, S. A., & Sharifian, S. (2014, January 8-9). Task scheduling using Modified PSO Algorithm in cloud computing environment [Conference presentation]. International Conference on Machine Learning, Electrical and Mechanical Engineering, Tehran, Iran.

Akbari, M., & Rashidi, H. (2016). A multi-objectives scheduling algorithm based on cuckoo optimization for task allocation problem at compile time in heterogeneous systems. Expert Systems with Applications, 60, 234–248. https://doi.org/10.1016/j.eswa.2016.05.010

Al-maamari, A., & Omara, F. A. (2015). Task scheduling using hybrid algorithm in cloud computing environments. IOSR Journal of Computer Engineering, 17(3), 96–106.

Anuradha, V., & Sumathi, D. (2014). A survey on resource allocation strategies in cloud computing. In 2014 International Conference on Information Communication and Embedded Systems (ICICES) (pp. 1–7). IEEE.

Aron, R., Chana, I., & Abraham, A. (2015). A hyper-heuristic approach for resource provisioning-based scheduling in grid environment. The Journal of Supercomputing, 71(4), 1427–1450. https://doi.org/10.1007/s11227-014-1271-1

Armbrust, M., Fox, A., & Griffith, R. (2010). A view of cloud computing. Communications of the ACM, 53(4), 50–58. https://doi.org/10.1145/1721654.1721672

Asghari, S., & Navimipour, N. J. (2017). Cloud services composition using an inverted ant colony optimization algorithm. *International Journal of Bio-Inspired Computation, 9*(1), 11–23.

Ashouraie, M., & Navimipour, N. J. (2015). Priority-based task scheduling on heterogeneous resources in the expert cloud. Kybernetes, 44(10), 1455–1471. https://doi.org/10.1108/K-01-2015-0007

Azad, P., & Navimipour, N. J. (2017). An energy-aware task scheduling in cloud computing using a hybrid cultural and ant colony optimization algorithm. International Journal of Cloud Applications and Computing, 7(4), 14–21.

Aznoli, F., & Navimipour, N. J. (2017). Cloud services recommendation: Reviewing the recent advances and suggesting the future research directions. Journal of Network and Computer Applications, 77, 73–86. https://doi.org/10.1016/j.jnca.2016.10.001

Bajaj, S. (2018). Current Drift in Energy Efficiency Cloud Computing: New Provocations, Workload Prediction, Consolidation, and Resource Over Commitment. In Critical Research on Scalability and Security Issues in Virtual Cloud Environments (pp. 283–308). IGI Global.

Bauer, E. (2018). Cloud Automation and Economic Efficiency. IEEE Cloud Computing, 5(2), 26–32. https://doi.org/10.1109/MCC.2018.022171661

Bellini, P., Cenni, D., & Nesi, P. (2015). A Knowledge Base Driven Solution for Smart Cloud Management. In 2015 IEEE 8th International Conference on Cloud Computing (pp. 1066–1069). IEEE.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Bhoi, U., & Ramanuj, P. N. (2013). Enhanced max-min task scheduling algorithm in cloud computing. International Journal of Application or Innovation in Engineering and Management, 2(4), 259–264.

Calheiros, R. N., Ranjan, R., & Beloglazov, A. (2011). CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience, 41(1), 23–50. https://doi.org/10.1002/spe.995

Chang, V., Kuo, Y., & Ramachandran, M. (2016). Cloud computing adoption framework: A security framework for business clouds. Future Generation Computer Systems, 57, 24–41. https://doi.org/10.1016/j.future.2015.09.031

Chen, H., Wang, F., Helian, N., & Akanmu, G. (2013). User-priority guided Min-Min scheduling algorithm for load balancing in cloud computing. In 2013 National Conference on Parallel Computing Technologies (PARCOMPTECH) (pp. 1–8). IEEE.

Dam, S., Mandal, G., Dasgupta, K., & Dutta, P. (2014). An ant colony based load balancing strategy in cloud computing. In Advanced Computing, Networking and Informatics (Vol. 2, pp. 403–413). Springer.

Elmougy, S., Sarhan, S., & Joundy, M. (2017). A novel hybrid of Shortest job first and round Robin with dynamic variable quantum time task scheduling technique. Journal of Cloud Computing, 6(1), 12. https://doi.org/10.1186/s13677-017-0085-0

Endo, P. T., de Almeida Palhares, A. V., Pereira, N. N., Goncalves, G. E., Sadok, D., & Kelner, J. (2011). Resource allocation for distributed cloud: concepts and research challenges. IEEE Network, 25(4), 42–46. https://doi.org/10.1109/MNET.2011.5958006

Fouladi, P., & Navimipour, N. J. (2017). Human resources ranking in a cloud-based knowledge sharing framework using the quality control criteria. Kybernetes, 46(5), 876–889. https://doi.org/10.1108/K-04-2017-0134

Hajizadeh, R., & Navimipour, N. J. (2017). A method for trust evaluation in the cloud environments using a behavior graph and services grouping. Kybernetes, 46(7), 1245–1261. https://doi.org/10.1108/K-03-2017-0091

Hazratzadeh, S., & Navimipour, N. J. (2017). Colleague recommender system in the expert cloud using the features matrix. Kybernetes, 46(5), 790–804. https://doi.org/10.1108/K-10-2016-0293

Hussain, A. A., & Al-Turjman, F. (2020). Resource allocation in volunteered cloud computing and battling COVID-19. In Volunteered Cloud Computing: Technologies and Applications (pp. 23–45). CRC Press. https://doi.org/10.1201/9781003098881-2

Hussain, A. A., Bouachir, O., Al-Turjman, F., & Aloqaily, M. (2020). AI techniques for COVID-19. IEEE Access, 8, 128776–128795. https://doi.org/10.1109/ACCESS.2020.3007939

Hussain, A. A., & Al-Turjman, F. (2022). Hybrid Genetic Algorithm for IOMT-Cloud Task Scheduling. Wireless Communications and Mobile Computing, 2022, Article 6604286. https://doi.org/10.1155/2022/6604286

Jianfang, C., Junjie, C., & Qingshan, Z. (2014). An optimized scheduling algorithm on a cloud workflow using a discrete particle swarm. Cybernetics and Information Technologies, 14(1), 25–39.

Joseph, C. T., Chandrasekaran, K., & Cyriac, R. (2015). A novel family genetic approach for virtual machine allocation. Procedia Computer Science, 46, 558–565. https://doi.org/10.1016/j.procs.2015.02.095

Kalra, M., & Singh, S. (2015). A review of metaheuristic scheduling techniques in cloud computing. Egyptian Informatics Journal, 16(3), 275–295. https://doi.org/10.1016/j.eij.2015.07.001

Kim, W. C., & Jo, O. (2014). Cost-optimized configuration of computing instances for large sized cloud systems. ICT Express, 1(1), 24–33.

Laghari, A. A., He, H., Karim, S., Shah, H. A., & Karn, N. K. (2017). Quality of experience assessment of video quality in social clouds. Wireless Communications and Mobile Computing, 2017, Article 8319540. https://doi.org/10.1155/2017/8319540

Latiff, M. S. A., Madni, S. H. H., & Abdullahi, M. (2018). Fault tolerance aware scheduling technique for cloud computing environment using dynamic clustering algorithm. Neural Computing and Applications, 29(1), 279–293. https://doi.org/10.1007/s00521-016-2448-8

Leivadeas, A., Papagianni, C., & Papavassiliou, S. (2013). Efficient resource mapping framework over networked clouds via iterated local search-based request partitioning. IEEE Transactions on Parallel and Distributed Systems, 24(6), 1077–1086. https://doi.org/10.1109/TPDS.2012.184

Li, J., Ma, T., Tang, M., Shen, W., & Jin, Y. (2017). Improved FIFO scheduling algorithm based on fuzzy clustering in cloud computing. Information, 8(1), 25. https://doi.org/10.3390/info8010025

Li, Q., & Guo, Y. (2010). Optimization of resource scheduling in cloud computing. In 2010 12th International Symposium on Symbolic and Numeric Algorithms for Scientific Computing (pp. 315–320). IEEE.

Lin, J., Zhong, Y., Lin, X., Lin, H., & Zeng, Q. (2014). Hybrid ant colony algorithm clonal selection in the application of the cloud's resource scheduling. arXiv preprint arXiv:1411.2528.

Lingyun, Y., Jennifer, M. S., & Ian, F. (2003, November 15-21). Conservative Scheduling: Using predictive variance to improve scheduling decisions in Dynamic Environment [Conference presentation]. SC '03: Proceedings of the 2003 ACM/IEEE Conference on Supercomputing, Phoenix, AZ, USA.

Manvi, S. S., & Shyam, G. K. (2014). Resource management for Infrastructure as a Service (IaaS) in cloud computing: A survey. Journal of Network and Computer Applications, 41, 424–440. https://doi.org/10.1016/j.jnca.2013.10.004

Milani, A. S., & Navimipour, N. J. (2016). Load balancing mechanisms and techniques in the cloud environments: Systematic literature review and future trends. Journal of Network and Computer Applications, 71, 86–98. https://doi.org/10.1016/j.jnca.2016.06.003

Mohammadi, S. Z., & Navimipour, N. J. (2017). Invalid cloud providers' identification using the support vector machine. International Journal of Next Generation Computing, 8(1), 11–21.

Nagesh, B. B. (2014). Resource provisioning techniques in cloud computing environment-A survey. International Journal of Research in Computer and Communication Technology, 3(3), 395–401.

Nallakumar, R., Sengottaiyan, N., & Priya, K. S. (2014). A survey on scheduling and the attributes of task scheduling in the cloud. International Journal of Advanced Research in Computer and Communication Engineering, 3(5), 8167–8171.

Navimipour, N. J. (2015). A formal approach for the specification and verification of a trustworthy human resource discovery mechanism in the expert cloud. Expert Systems with Applications, 42(19), 6112–6131. https://doi.org/10.1016/j.eswa.2015.03.030

Navimipour, N. J., Habibizad Navin, A., Rahmani, A. M., & Hosseinzadeh, M. (2015). Behavioural modelling and automated verification of a cloud-based framework to share the knowledge and skills of human resources. Computers in Industry, 68, 65–77. https://doi.org/10.1016/j.compind.2014.12.007

Nayak, D., Malla, S. K., & Debadarshini, D. (2012). Improved round robin scheduling using dynamic time quantum. International Journal of Computer Applications, 38(6), 34–38.

Pacini, E., Mateos, C., & Garino, C. G. (2015). Balancing throughput and response time in online scientific Clouds via Ant Colony Optimization (SP2013/2013/00006). Advances in Engineering Software, 84, 31–47. https://doi.org/10.1016/j.advengsoft.2015.01.005

Padmavathi, S., MohitGolchha, S., & SeeniMohamed, A. (2012). Memetic algorithm based task scheduling using probabilistic local search. In B. K. Panigrahi, P. N. Suganthan, & S. Das (Eds.), Swarm, Evolutionary, and Memetic Computing (pp. 224–231). Springer.

Pandey, S., Wu, L., Guru, S. M., & Buyya, R. (2010). A particle swarm optimization-based heuristic for scheduling workflow applications in cloud computing environments. In 2010 24th IEEE International Conference on Advanced Information Networking and Applications (pp. 400–407). IEEE.

Parikh, S. M., Patel, N. M., & Prajapati, H. B. (2017). Resource management in cloud computing: Classification and taxonomy. arXiv preprint arXiv:1703.00374.

Poola, D., Garg, S. K., Buyya, R., Yang, Y., & Ramamohanarao, K. (2014). Robust scheduling of scientific workflows with deadline and budget constraints in clouds. In 2014 IEEE 28th International Conference on Advanced Information Networking and Applications (pp. 858–865). IEEE.

Pooranian, Z., Shojafar, M., Abawajy, J. H., & Abraham, A. (2015). An efficient meta-heuristic algorithm for grid computing. Journal of Combinatorial Optimization, 30(3), 413–434. https://doi.org/10.1007/s10878-013-9644-6

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Raghavan, S., Sarwesh, P., Marimuthu, C., & Chandrasekaran, K. (2015). Bat algorithm for scheduling workflow applications in cloud. In 2015 International Conference on Electronic Design, Computer Networks & Automated Verification (EDCAV) (pp. 139–144). IEEE.

Raj, R. J. S., & Prasad, S. M. (2016). Survey on variants of heuristic algorithms for scheduling workflow of tasks. In 2016 International Conference on Circuit, Power and Computing Technologies (ICCPCT) (pp. 1–4). IEEE.

Reuther, A., Byun, C., Arcand, W., Bestor, D., Bergeron, B., & Hubbell, M. (2017). Scalable system scheduling for HPC and Big Data. arXiv preprint arXiv:1705.03102.

Rimal, B. P., Jukan, A., Katsaros, D., & Goeleven, Y. (2011). Architectural requirements for cloud computing systems: an enterprise cloud approach. Journal of Grid Computing, 9(1), 3–26. https://doi.org/10.1007/s10723-010-9171-y

Rouhi, S., & Nejad, E. B. (2015). CSO-GA: a new scheduling technique for cloud computing systems based on cat swarm optimization and genetic algorithm. Cumhuriyet Science Journal, 36(4), 1672–1685.

Sahmim, S., & Gharsellaoui, H. (2017). Privacy and Security in Internet-based Computing: Cloud Computing, Internet of Things, Cloud of Things: a review. Procedia Computer Science, 112, 1516–1522. https://doi.org/10.1016/j.procs.2017.08.050

Sangwan, P., Sharma, M., & Kumar, A. (2017). Improved Round Robin Scheduling in Cloud Computing. Advances in Computational Sciences and Technology, 10(5), 639–644.

Sharma, N., Tyagi, D. S., & Atri, S. (2017). HYMM: A new heuristic in cloud computing. International Research Journal of Engineering and Technology, 4(6), 3520–3526.

Sheikholeslami, F., & Navimipour, N. J. (2017). Service allocation in the cloud environments using multi-objective particle swarm optimization algorithm based on crowding distance. Swarm and Evolutionary Computation, 35, 53–64. https://doi.org/10.1016/j.swevo.2017.02.009

Silberschatz, A., Galvin, P. B., & Gagne, G. (2009). Operating system concepts (8th ed.). Addison Wesley.

Singh, P., Dutta, M., & Aggarwal, N. (2017). A review of task scheduling based on meta-heuristics approach in cloud computing. Knowledge and Information Systems, 51(2), 1–51. https://doi.org/10.1007/s10115-017-1044-2

Sörensen, K., & Glover, F. W. (2013). Metaheuristics. In Encyclopedia of operations research and management science (pp. 960–970). Springer.

Sridhar, M., & Babu, G. R. M. (2015). Hybrid particle swarm optimization scheduling for cloud computing. In 2015 IEEE International Advance Computing Conference (IACC) (pp. 1196–1200). IEEE.

Stergiou, C., Psannis, K. E., Gupta, B. B., & Ishibashi, Y. (2018). Security, privacy & efficiency of sustainable Cloud Computing for Big Data & IoT. Sustainable Computing: Informatics and Systems, 19, 174–184. https://doi.org/10.1016/j.suscom.2018.06.003

Subramanian, N., & Jeyaraj, A. (2018). Recent security challenges in cloud computing. Computers & Electrical Engineering, 71, 28–42. https://doi.org/10.1016/j.compeleceng.2018.06.006

Tabagchi Milan, S., & Navimipour, N. J. (2017). Nature inspired metaheuristic algorithms for solving the load balancing problem in the cloud environments: Systematic literature review and future trends. Journal of Network and Systems Management, 25(4), 111–121. https://doi.org/10.1007/s10922-017-9428-x

Thakur, P., & Mahajan, M. (2017). Different Scheduling Algorithm in Cloud Computing: A Survey. International Journal of Modern Computer Science, 5(2), 122–127.

Tsai, C. W., & Rodrigues, J. J. (2014). Metaheuristic scheduling for cloud: A survey. IEEE Systems Journal, 8(1), 279–291. https://doi.org/10.1109/JSYST.2013.2256731

Wang, T., Liu, Z., Chen, Y., Xu, Y., & Dai, X. (2014). Load balancing task scheduling based on genetic algorithm in cloud computing. In 2014 IEEE 12th International Conference on Dependable, Autonomic and Secure Computing (pp. 146–152). IEEE.

Wang, Z., Shuang, K., Yang, L., & Yang, F. (2012). Energy-aware and revenue-enhancing Combinatorial Scheduling in Virtualized of Cloud Datacenter. Journal of Convergence Information Technology, 7(7), 62–70.

Xue, S. J., & Wu, W. (2012). Scheduling workflow in cloud computing based on hybrid particle swarm algorithm. Indonesian Journal of Electrical Engineering and Computer Science, 10(6), 1560–1566.

Yang, X. S. (2010). Nature-inspired metaheuristic algorithms. Luniver Press.

Yang, X. S., Cui, Z., Xiao, R., Gandomi, A. H., & Karamanoglu, M. (Eds.). (2013). Swarm intelligence and bio-inspired computation: Theory and applications. Newnes.

Yu, J., & Buyya, R. (2006). Scheduling scientific workflow applications with deadline and budget constraints using genetic algorithms. Scientific Programming, 14(3-4), 217–230. https://doi.org/10.1155/2006/271608

Yu, J., Buyya, R., & Ramamohanarao, K. (2008). Workflow scheduling algorithms for grid computing. In F. Xhafa & A. Abraham (Eds.), Metaheuristics for scheduling in distributed computing environments (pp. 173–214). Springer.

Zeng, L., Veeravalli, B., & Li, X. (2015). SABA: A security-aware and budget-aware workflow scheduling strategy in clouds. Journal of Parallel and Distributed Computing, 75, 141–151. https://doi.org/10.1016/j.jpdc.2014.08.004

Zongbin, Z., & Zhongjun, D. (2013). Improved GA-based task scheduling algorithm in cloud computing. Computer Engineering and Applications, 49(5), 77–80.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

APPLICATION OF IMAGE PROCESSING AND MACHINE LEARNING IN ANALYSING AND PREDICTING FLOWERS IN THE FLORIST INDUSTRY: HET-NET AND BIG DATA ERA

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ABSTRACT

The florist industry is one of the rapidly growing sectors in both developed and developing countries, encompassing flower cultivation, production, marketing, delivery, and trade. In recent years, the integration of digital image processing, machine learning, and big data technologies has significantly transformed analytical and predictive processes within this industry. Image processing plays a crucial role in image analysis, evaluation, and interpretation, while machine learning algorithms enhance production efficiency and prediction accuracy. This paper presents an overview and implementation of image processing and machine learning techniques for analyzing and predicting flower characteristics using large-scale data in the Het-Net and big data era. Image restoration techniques are employed to recover original flower images by reducing noise and blur. Flower images obtained from a florist database are processed and analyzed using artificial neural networks (ANNs). Experimental results were obtained using an 90% training and 10% testing data split, demonstrating the effectiveness of the proposed approach. The findings indicate that combining big data, image processing, and machine learning techniques can significantly improve analysis and prediction tasks in the florist industry. This study aims to support researchers, students, and industry professionals by providing insights into practical applications and addressing key challenges in this domain.

Keywords: artificial neural networks, images processing, gaussian filter, median filter, bilateral filter, florist industry.

INTRODUCTION

Like many other businesses, horticulture and floristry are quickly advancing as innovation and cultivating practices are further developing in the 21st century. Also, the effect of Covid-19 will introduce various short and long-haul difficulties to the business. Figure 1 highlights the trend of the floristry industry globally. Picture blur is hard to evade in circumstances like photography. To eliminate motion blur brought about by camera shake, we use radar imaging to eliminate the impact of picture framework reaction, and so forth. Picture restoration is the cycle of recuperating the first

picture by eliminating blur and noise from the picture. Picture noise is an undesirable signal which comes into images from sensors, for example, electrical or thermal signals and environmental conditions, for example, downpour, snow, etc. The most direct and a traditional method for image restoration is deconvolution. It acts in the recurrence space and in the wake of utilizing the Fourier transform the pictures and the PSF caused by the blur factor. Scientists have proposed numerous techniques in such manner and this paper we will experiment with various image processing techniques. Moreover, the use of different channels like denoising by median, bilateral, and Gaussian channels will be utilized.

Restoration is one of the fundamental aspects of computer vision, for example, picture restoration as in Zanchettin et al. (2012) and Conti et al. (2010), or even in more basic investigations or studies, for example, clinical exploration; like restoring old pictures as in Liu et al. (2013) and Hussain et al. (2020). In this work, we are suggesting a flower restoration method dependent on picture preparing procedure and Artificial Neural Networks (ANN) calculation. A considerable lot of classification calculations have been acquainted all together to accomplish these objectives, for example, genetic algorithm as in Yan et al. (2007), Artificial Neural Networks as in Siraj et al. (2014), and numerous others calculation. There are nearly 250,000 named types of plants on the planet. Flowers are a kind of plant that has numerous classifications; a considerable lot of that classifications or species have fundamentally the same highlights and looks, while you can discover disparity among a similar flower group. This likeness and disparity makes the flower restoration measure with a high precise outcome an exceptionally hard test, concerning previously above- mentioned points.

The higher variety of related gadgets, assets, and more dynamical arrangements of networks (Zhang et al., 2014) are advancing towards the promising future known as the heterogeneous networks (HetNets). As needs be, the frameworks of versatile network operators have been planned and improved with greater intricacy of foundation. Because of the quick advancement of current Internet and Mobile florist industry, the traffic load has encountered an unstable development during the most recent couple of years and in the cloud too. They have been widely examined and applied to improve PC frameworks and organizations in different situations and convoluted conditions (Aliu et al., 2013). Man-made intelligence methods incorporate multi-disciplinary strategies from AI, bio-motivated calculations, etc. They have moderately lower intricacy empowered by recursive criticism based learning and neighborhood communications, and thus quicker speed of discovering imperfect arrangements contrasted with customary procedures (Deebak & Al-Turjman, 2021). It has been demonstrated that ML methods can accomplish remarkable execution, as the majority of them are enlivened from nature discoveries or propelled by the perspectives of individuals. Hence, the combination of ML procedures into the plan of smart foundation becomes one promising pattern for adequately tackling issues in HetNets. In Malchi et al. (2021), there is a conversation of the use of AI-based strategies for developing more brilliant HetNet foundation and frameworks. By considering the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

inexorably powerful, heterogeneous, huge scope and complex situations related with the Het-Net field, several works have surveyed the adoption of computational insight techniques within the cycles of activity and enhancement of a HetNet in the florist industry. They zeroed in on the examination issues of self-configuration, self-recuperating, and self-advancement, introducing a conversation of the advantages and disadvantages of utilizing every one of the connected procedures.

Picture restoration is the way toward modifying computerized pictures with the target that the outcomes are persistently appropriate to show or for additional image appraisal. For instance, you can light up, clear noise, or sharpen a picture, making it less perplexing to perceive key highlights (Kara & Dımılıler, 2018a, 2018b). Picture restoration strategies are mathematical methods that are set up in seeing improvement in the possibility of a given picture (Dimililer & İlhan, 2016). A basic picture rebuilding approach is made and applied in an uncommonly appointed manner. Anyway, most picture restoration systems are applied to improve pictures for use by users. A couple of methodologies are used to decide pictures that are proposed for ensuring calculation for the computer process (Al-Turjman & Baali, 2019). Occasions of the previous grouping are methodologies to remove noise, update contrasts, and sharpen the nuances in a given picture. At whatever point is used inappropriately, the methodologies themselves may grow noise while improving multifaceted nature (Jin et al., 2020). They may discard little nuances and edge sharpness while emptying the said noise, and they may make relic generally speaking. Users ought to be careful to avoid these snares in the mission for the best-improved picture (Ullah et al., 2020).

The general idea is to automate the flowery picture by using image processing and ML methods, yet various points in such a task raise strong examination issues. These assessments will be executed to the under-explored and field of flower industry and should be polished for a specific zone. Each flower highlighted could in a long haul require a different restoration figure to get an exact outcome from the ML techniques, for instance, deep learning (Fiore & Kimle, 2010; Brannon, 2014). Also, the automatization must have an accuracy essentially indistinguishable from the manual procedures to be useful for business purposes. At the point when the personality of the pictures are given to the ML process, it gets less complex to focus on the inadequacy of the improved picture. This term is incredibly basic for the flower vendor enterprises since this impacts the movement of their customers (Mwai, 2019). Likewise, some early picture processing methods could be thought of and actualized to empower the industry to advance in the needs of flowers (Safar & Safar, 2020).

Our primary contribution is as follows:

- We describe key auxiliary components required and the assortment of flowery data.
- We review literature regarding image processing and ML and its application in the florist industry.
- We orchestrate the different methodologies for image processing and ML techniques in

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

anticipating its accuracy.

- We illustrate and discuss the outcomes.
- Finally, we shed light on the key issues and challenges confronted.

The structure of the paper is as per the following. Comparable researches which includes surveying the methods and strategies used are discussed in section 2. Section 3 depicts the procedure and materials used in directing the experiment. Section 4, discusses, examine, and dissect the result gotten from the trial. Lastly, section 5 concludes the paper. Table 1 gives an outline of the abbreviations used.

Table 1. Abbreviation Utilized

Terms	Meaning
ICT	Information and Communication Technologies
CLD	Color Layout Descriptor
ML	Machine Learning
CSS	Curvature Scale Space
CNN	Convolutional Neural Networks
CEHD	Canny edge-based Edge Histogram Descriptor
ANN	Artificial Neural Network
NN	Neural Networks
PC	Personal Computer
PSF	Point Spread Function
VS	Virtual Studio
MLP	Multilayer Perceptron
KNN	k-Nearest Neighbor
2D	Two-Dimensional
SVM	Support Vector Machine
RAM	Random Access Memory

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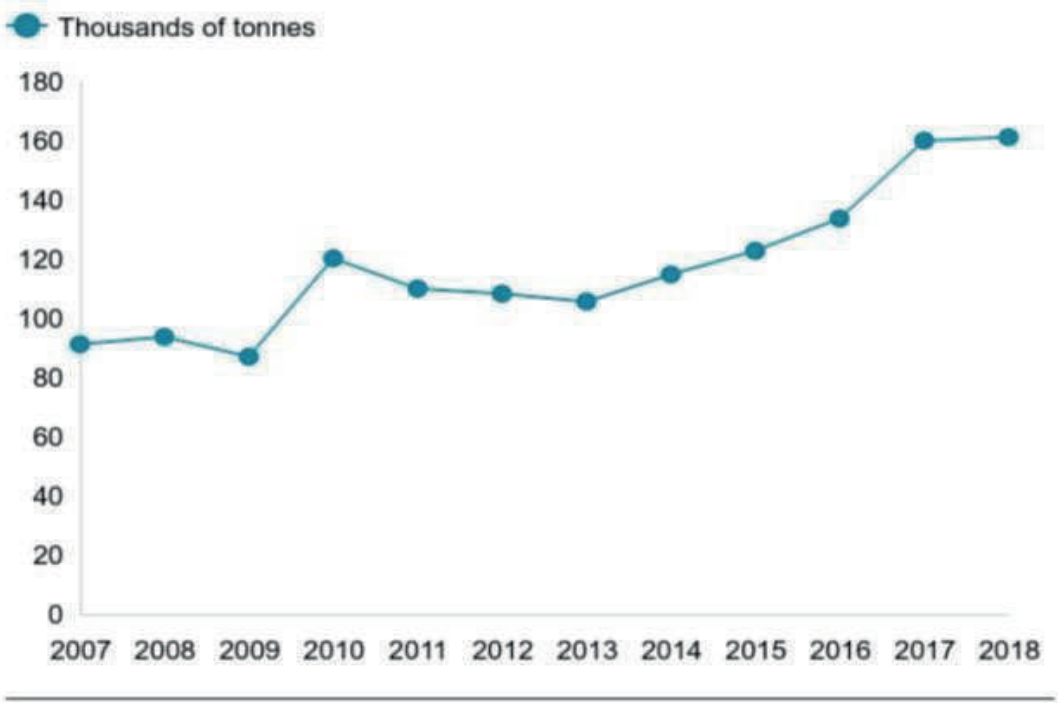


Figure 1. Illustration of the trend in the florist industry **Hata! Başvuru kaynağı bulunamadı.**

LITERATURE REVIEW

Various works focused on phenomenal flower classes and applications as of late been directly dealt with. In any case, there have been investigations over recent years concerning the matter of flower affirmation.

A. Segmentation of Blossom Images

For the segmenting method, the author presented an intelligent division mapping utilizing a shading model for flower utilizing fitting a mathematical model and refreshing the shading model (Nilsback & Zisserman, 2009). In Nilsback and Zisserman (2009) they proposed a programmed visual Flora division and order flower picture. This proposed examination accomplishes 76.3% precision. Also, for the division, they present Conditional Random Field utilizing chart cuts (Nilsback & Zisserman, 2007). In Tiay et al. (2014) they presented a rose identification framework dependent on picture processing stages to characterize the flower utilizing the attributes of their shadings and edges. For the order cycle, they utilized KNN. Hu's seven order calculation was applied to secure histograms and edge attributes to separate RGB shade and immersion qualities. The precision is nearly 80%.

B. Classification of Blossom Images

Mete and Ensari (2019) and Nilsback and Zisserman (2007) introduced a calculation that fragments flowers consequently by shading photos. They utilized the MRF cost function utilizing chart cuts for

delivering the divisions. They utilized two models, the primary model uses the frontal area and foundation tone and the second model uses the petal conventional structure shape model. In Chai et al. (2011), for Image Classification suggested a Bi-level Co-Segmentation Method with improved order execution by fragmenting the picture into a closer view and foundation. It is spoken to at the fitting levels pixels and shading disseminations. They take a shot at the co-division task. This investigation accomplishes 80.0% exactness. It is for singular pictures and super-pixels with learnable highlights at the degree of splitting over the picture set along with ground-breaking and proficient deduction calculations (SVM and GrabCut) for every stage..

C. Image Retrieval

In Mehmood et al. (2019) and Hakak et al. (2021) for Mobile Image Retrieval of flowers by presenting another self-versatile element extraction scheme based on Image Retrieval (CBIR) frameworks on cell phones they proposed Self- versatile Feature Extraction Scheme. Furthermore, for acquiring object shapes, the striking districts were recognized utilizing a multi-scale self-created division model. They presented another adjusted extraction approach utilizing the Color Layout Descriptor (CLD), Canny edge-based Edge Histogram Descriptor (CEHD), and the Curvature Scale Space (CSS) shape-based descriptor. The above-mentioned researches are considered to be one of the latest examinations that spread over the restoration framework.

D. Het-Net and Big data

Authors in Ever et al. (2017) examined the exhibition of HSPA networks with big data. Thus, restricted by the business network organization, they just dissect the 3G organizations, rather than the 4G organizations. They dissect the static situation as well as numerous versatile situations including various florist industries. Authors in Li et al. (2015) estimated 3G and 3.5G organizations with various merchants in various moving situations. They locate that, in low-speed portable situation, the RTT stays stable with little instability. They proposed distinctive organization channel models of rapid portable situations As their investigation SNR is a significant boundary that influences the organization throughput. They locate that current TCP isn't adjusted to fast versatile situation. Authors in Li et al. (2015) explored the TCP conduct in high velocity portable situation. In any case, the estimation situations for these literary works are restricted and there is no thorough investigation of the organization execution in fast portable situation.

METHODOLOGY

The work we present will test different restoration methods using image processing methodology. The purpose of this work is the utilization of image processing methodologies on pictures of different flower types and foresee its accuracy. We will break down and restored pictures by denoising the picture utilizing picture image processing. Raw real-world binary pictures of flowers mainly from the UK were utilized, in like manner, the precision of the yield was tested with an ML technique. This

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strategy will be done with different assortments of the flower picture. With this, image processing procedures and ML updates picture quality and make picture features more understandable while foreseeing its precision. The outcome portrays improved picture quality and the image features are better highlighted. Figure 2 portrays the methodology guides. This examination is said to expand the characteristics of the pictures from 55.1% to 80%.

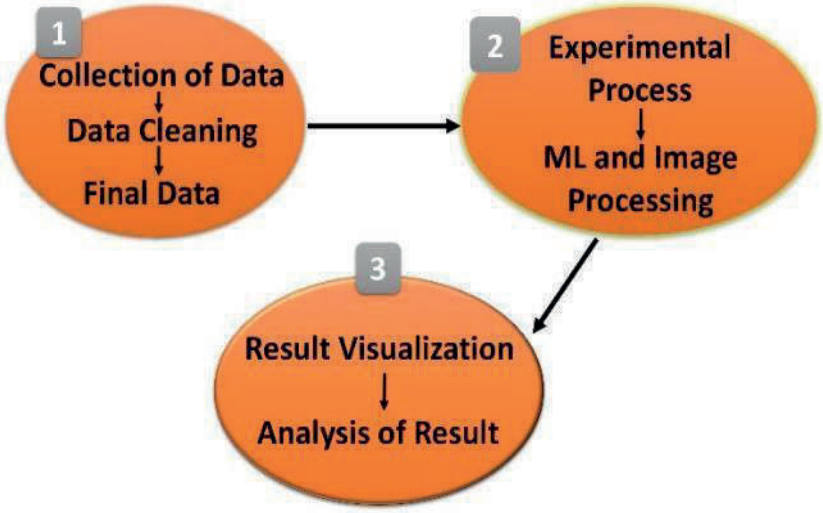


Figure 2. The methodology guide

A. Description of Data

The total record which includes 10,000 data which interfaces with 90% and 10% training and testing sample respectively. The portrayal of the dataset used in the paper is poised of the flower information index (Chai et al., 2011). The dataset contains flower pictures. It was collected by using data from the florist industry. The property name of this data consolidates passion, camellia, coneflower, pelargonium, rose, and lily flowers. It constituent of 28 by 28 greyscale pictures. Additionally, the information gotten is in jpeg record format. Afterward, we used the cropping standards on the data which cut the picture to get an isolated flower, and one with an exact and clear view. The needed picture is gotten utilizing cropping standards and turned into the new picture like in figure 3 to get more visibility, and table 2 shows the dataset instance. The data is kept in an archive which constitutes of a multidimensional and vectors lattices.

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ISBN: 978-9952-610-30-7



Figure 3. Illustrating image cropping technique

Table 2. Data Properties

Data Set Characteristics	Multivariate
Amount of Dataset:	10,000
Training Set	90%
Testing Set	10%
Number of flower:	4
Area:	Florist Industry
Data Characteristics:	Images
Image Format:	28 by 28 Greyscale Images
Associated Tasks:	Image Processing, ML
Missing Values:	N/A

B. Technique and Materials Used

The picture processing strategy executed is the image restoration method. Here, we used an image processing system and ML in controlling and anticipating the exactness of the flower pictures. Image restoration is the activity of using a noisy image and assessing the spotless, unique image. The reason for picture restoration is to invert defects that decline the nature of a picture. This is done by turning around the cycle that obscured the image and such is implemented by imaging a point source and utilizing the point source image. This is known as the Point Spread Function (PSF) which is to re-establish the picture data lost to the obscuring cycle. Contour may come in numerous structures, for example, obscure, movement noise, and camera misfocus. In situations where the picture is undermined by noise, the best we may plan to do is to make up for the debasement it caused. In cases like motion blur, it is conceivable to think of a generally excellent gauge of the genuine blur capacity and revert the blur to re-establish the first picture.

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While processing the data, the image restoration procedure is applied to the dataset then the ML technique for its accuracy. The strategy merges training and testing. The ML strategy we will utilize is the artificial neural network (ANN) which is the bit of a registering framework intended to recreate how the human cerebrum breaks down and measures data. ANNs enables them learn and empower them to deliver better results as more details opens up. It is the establishment of AI and it takes care of issues that would demonstrate unimaginable or factual principles. The standard reason for utilizing an ML is that so it will as a rule be effectively portrayed with its accuracy.

C. Experimental Procedure

During the time spent completing the investigation, before executing the picture preparing strategy on different flower pictures, an exploration was done in gathering the data to quickly separate the information. Class gathering is applied since we are utilizing image processing on the recovered informational collection. During this cycle, the cropping strategy was applied with the chance of re-establishing pictures to get a less boisterous introduction of the pictures. Thusly, different types of sigma are applied to get which picture is efficient. At this stage, there is an expectation aspired with various assessments and characteristics. A short time later different restoration procedures were applied. Additionally, we used the ANN to foresee the precision of the subsequent pictures and examine its result with the first picture. It utilizes sigmoid activation function because it gives only positive digits and it can also be utilized with gradient descent on the basis of training because it has a derivative. There are several activation functions that can be utilized in association with back-propagation such as sign, step and sigmoid function. The back-propagation algorithm consist of four steps: a) Feed- forward b) Back propagation to output c) Back propagation to hidden layer d) update weights. Hence, the test yielded a momentous outcome with various assessments and attributes. The information is split into 90% training and 10% testing. We will investigate the outcomes in the resulting section.

D. Visualization

The fundamental purpose of visualization is depicting the dataset and graphically speaking with it. The cycle of data observation is depicted as stacking data into the application, data portrayal, and structure assurance, show the result, cycle of portrayal is refined, lastly gathering, and exploring the data. This is with the creative mind that the outcome is an outline that comprises of the assistance of using visual apparatuses, so the test results are depicted naturally.

E. Computational Environment

The tests were done in the VScode, it is an open-source application that allows the use of regulated learning systems. Particularly, the library uses a plan of picture processing procedures. Tensorflow for VScode, is a library that has been advanced for some thorough limits concerning backslide and gathering tasks, and Scikit-picture for picture processing were utilized. In particular, the library uses

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consecutive picture handling techniques. The examination was done on a pc with, 2.6 GHz and 8GB RAM.

RESULTS

In the image processing, there must be a thought in the reclamation of the picture highlights, it must get a distinction in the surface for greater permeability. We will play out the restoration procedure with different denoising channels on flower pictures. The figures beneath will represent the illustration that will be utilized in dissecting different levels in restoration. The use of different channels like median, Gaussian, bilateral was performed on a noisy image. In any case, this is to give a direct portrayal of the re-established picture and to summarize the best model and its accuracy. Here the objective isn't to incite about the prescient limits of the image yet to see the precision and how clear the re-established picture is. Thusly, flower pictures will be picked for indicating the restoration method yet the whole dataset will be used while anticipating its precision. The figures below show the results.

A. Analyzing the Restored Image

We will use the median, gaussian, and bilateral channels to do the picture restoration. In image reclamation, the objective is to get the target with a similar objective to the information. The obscured picture can be portrayed with the accompanying formula in (1). The picture is corrupted by degradation say p(x,y) and channel noise transmission q(x,y), with this a degraded picture R(x,y) can be gotten like in (1).

$$r(x,y) = p(x,y) * f(x,y) + q(x,y). \quad (1)$$

Median filter: The principle thought of this filter is to go through the channel section by section, supplanting every section with the middle of neighboring sections. The neighbors are also called window, which slides, section by section, over the whole channel. This is the measurable strategy as suggested by the name. In this technique, the pixel amount is supplanted by the middle of the pixels in the neighbor's fold. This separating eliminates the defect yet keeps the edges. This will in general beat the picture to become a blur and that is its preferred position over the smoothing model. The utilization is to eliminate the noise. It is utilized broadly and can diminish the noise in the pictures brilliantly.

Gaussian filter: With this filter, one would then be able to control the adequacy of the low-pass nature of the channel by modifying its width. A Gaussian channel has the bit of leeway that its Fourier change is likewise a Gaussian appropriation based on the zero recurrence e.g with negative and, positive frequencies at the two sides. The Gaussian channel may likewise mirror the inalienable factual nature of variances in many procured estimation appropriations. Additionally, the constriction of higher recurrence segments, consequently their relative removal, is more viable with a Gaussian channel than with moving-normal channels. It additionally gives a shape that looks like that of a Gaussian appropriation, and as such can be used as a channel, instead of the Gaussian channel, for

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ISBN: 978-9952-610-30-7

computational examination.

The Gaussian capacity of one dimension is in (2). Gaussian technique is utilized to obscure pictures and eliminate noise. Gaussian function coefficients from the 2D is in (3). This is the result of two 1D Gaussian capacities that is, one for every direction.

The standard deviation of the dispersion is denoted with σ.

The distance from the source in the vertical hub is denoted by

y. The distance from the starting point in the horizontal hub is denoted by x. The distribution is expected to have a mean of zero for both (2) and (3). $G(x) = \frac{1}{\sqrt{2\pi\sigma^2}}\, e^{-\frac{x^2}{2\sigma^2}}$ (2)

$$G(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}}\, e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (3)$$

Bilateral filter: This filter is a noise-reducing, edge-preserving, and non- linear smoothing channel for pictures. It replaces the power of every pixel with an average weight of force esteems for close-by pixels. The weight is situated on a Gaussian circulation. Urgently, the loads depended on Euclidean separation of pixels, additionally on the radiometric contrasts e.g., range contrasts, for example, depth distance, color intensity, and so on. This is depicted in (4).

$$BF[I]_p = \frac{1}{W_P} \sum_{q\in S} G_{\sigma_s}(\| p-q \|)\, G_{\sigma_r}(\, | I_p - I_q \, |) I_q \quad (4)$$

$\frac{1}{W_P}$ is the normalizing factor.

$G_{\sigma_s}(\| p-q \|)$ is the weight space.

$G_{\sigma_r}(\, | I_p - I_q \, |) I_q$ is the weight range.

BF is the filtered image.

SS is the window centered in qq, so $q \in Sq \in S$ is another pixel.

The W_P which is the weight is assigned using the intensity difference “range kernel G_{σ_r} ”, and the spatial closeness “ spatial kernel $G_{\sigma_s} G_{\sigma_s}$”.

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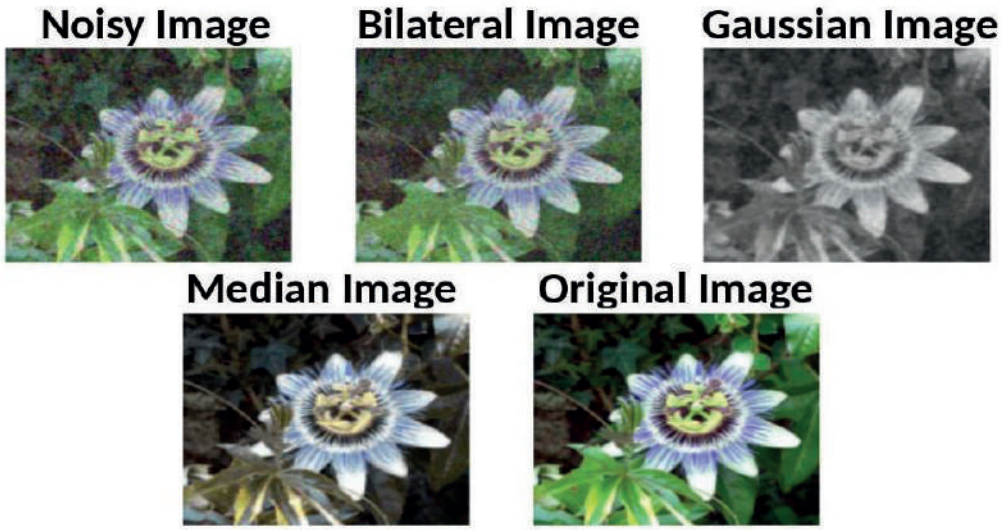


Figure 4. The restoration technique on passionflower

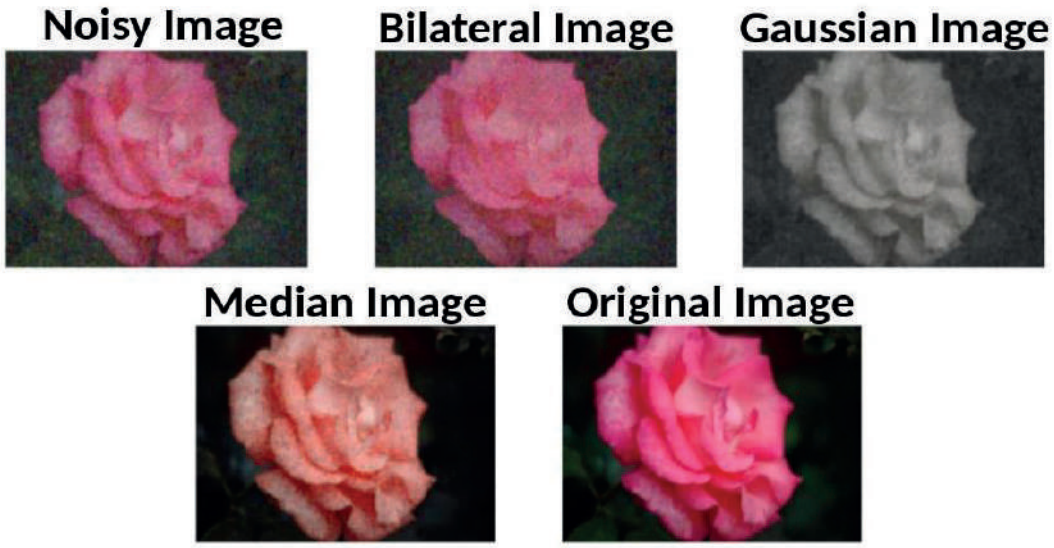


Figure 5. The restoration technique on the camellia flower

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ISBN: 978-9952-610-30-7



Figure 6. The restoration technique on purple coneflower flower

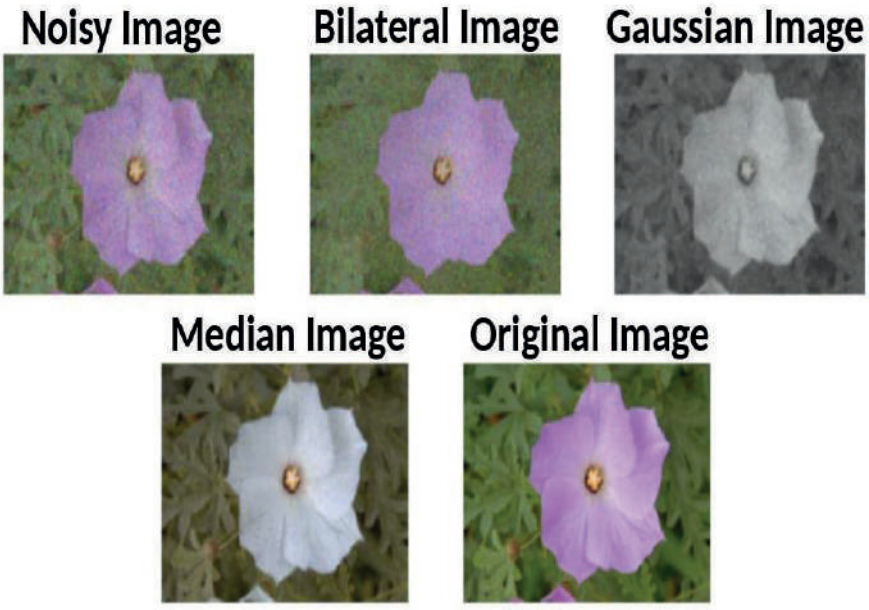


Figure 7. The restoration technique on pelargonium flower

In getting an all-around re-established picture there must be a thought in the information of the picture highlights. It must get a reasonable yield in examination with the first picture and afterward at last settle on a choice. The usage of different filters like median, gaussian, bilateral was performed on the noisy picture, with the best being the median filter and then the bilateral. Figure 4, figure 5, figure 6, and figure 7 above shows the different restoration methods. The main disadvantage of the median filter is the loss of the picture tone.

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ISBN: 978-9952-610-30-7

Saturation, Hue, and Value (HSV) color model is a model that unexpectedly depicts colors in comparison to the RGB (Red, Green, and Blue). It's a favored methodology in the median filter since it can dispose of the false information that is caused by a variety of lighting conditions, the tone in wording, the tones conceal, immersion which depict the measure of gray level and their brilliance or luminance depicted by the worth. In the median filter, the measure of the gray level portrays the color whiteness.

It is seen that the quality of the median filter is superior to the bilateral filter. It portrays a clearer picture, demonstrating that the restoration strategy is of incredible significance. If it merits referencing, the florist industry ought to embrace this procedure considering it is improving the tested noisy flower pictures. In the figures above it is seen that the quality of the image processing procedure is of acceptable impact. It shows that the more the filter the more we get an opportunity of getting a clear picture paying little mind to the measure of filters. Nonetheless, with this, it shows that the best result is the median filter. With this, this can help the florist industry in analyzing and restoring flower pictures easily and getting an efficient outcome.

B. Analyzing the ML Accuracy

Artificial neural networks are one of the main tools utilized in AI. It comprises of input and output layers, just as a concealed layer comprising of units that change the contribution to something that the yield layer can utilize. The point here isn't to conclude the capacity of expectation for the model, however, to give a straightforward portrayal that traces how precise the restored picture is. The ML procedure utilized here is the ANN. Subsequently, all pictures will be utilized in this usage.

It is seen that the restored picture is quantitatively divisible and great exactness is acquired utilizing ANN. Along these lines, 3 epochs were thought of while running the trial. All datasets were used. Likewise, it is seen that the third epochs delivered the best precision with 87%. On evaluating the last execution, it was finalized by a conclusive outcome and deciding by it with 87% accuracy. There are 2 arrangements of numbers that are needed to run the ANN, the first is the input information which we previously acquired and the subsequent one is the target information which is information that recognized each flower and predicts its precision. Underneath we can see the precision results utilizing the ANN for the restored flower. The precision was accomplished utilizing the 90% and 10% training and testing split with the precise outcomes utilizing 1 concealed layer. Epoch 1/3

8000/8000 [==========] - 284s

5ms/sample - loss: 0.4594 - accuracy: 0.8434 Epoch 2/3

8000/8000 [==========] - 252s

4ms/sample - loss: 0.3640 - accuracy: 0.8739 Epoch 3/3

8000/8000 [==========] - 177s

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

3ms/sample - loss: 0.3251 - accuracy: 0.8554

10000/1 [==========]

12s 1ms/sample - loss: 0.2966 - accuracy: 0.8785

TESTED ACC: 0.8785

CONCLUSION

The current day florist industry is a worldwide and a developing industry, which has accomplished noteworthy development rates during the previous years. Image processing is a significant segment in our locale. Although, corresponding examinations have used ML procedures in the improvement of pictures portrayal. In this proposed examination we executed image processing strategies and ANN in the florist industry. The image processing strategies utilized is the image restoration. It was done utilizing three filters in particular median, gaussian, and bilateral. With the best being the median filter. All information with 10000 pictures were utilized for this analysis. The reason for the system was to get the best-restored picture. Pictures being restored had an 87% accuracy. The outcomes reveals that, it is pragmatic in accomplishing a high conjecture accuracy, thinking about the first picture. The point of this methodology was to accomplish the best exact picture result. Additionally, unequivocal data decisions were investigated. The outcomes gotten uncovers that, in accomplishing a decent picture, different tests must be performed. With this, this can help the florist industry in analyzing flower pictures easily and getting an efficient outcome. Numerous modification and future works are accessible like, increment in the exploratory limit in more related pictures so the information bases can be enhanced. Likewise, more investigations ought to be done so as to get additional understanding on different image processing methods, and furthermore the ANN is a broad zone of exploration, as the quantity of neurons inside layers are viewed as an advanced issue and a great deal of study should be possible just by taking a shot at the ANN boundaries and highlights. This investigation is said to incredibly build understanding in the field of image processing and ML whenever taken in to thought.

DECLARATIONS

Funding

The authors declare no funding.

Conflicts of Interest

The authors declare no conflict of interest.

Data Availability

The authors declare no data availability.

Supplementary Materials

The authors declare no supplementary material.

REFERENCES

Aliu, O. G., Imran, A., Imran, M. A., & Evans, B. (2013). A survey of self organisation in future cellular networks. IEEE Communications Surveys & Tutorials, 15(1), 336–361. https://doi.org/10.1109/SURV.2012.021312.00117

Al-Turjman, F., & Baali, I. (2019). Machine learning for wearable IoT-based applications: A survey. Transactions on Emerging Telecommunications Technologies, 30(10), e3635. https://doi.org/10.1002/ett.3635

Brannon, E. L. (2014). Fashion forecasting. Fairchild Books.

Chai, Y., Lempitsky, V., & Zisserman, A. (2011). Bicos: A bi-level co-segmentation method for image classification. International Journal of Computer Vision, 93(2), 155–176. https://doi.org/10.1007/s11263-011-0460-0

Conti, V., Militello, C., Vitabile, S., & Sorbello, F. (2010, February). Fingerprint recognition. In 2010 International Conference on Complex, Intelligent and Software Intensive Systems (pp. 368–375). IEEE.

Deebak, B. D., & Al-Turjman, F. (2021). Robust lightweight privacy-preserving and session scheme interrogation for fog computing systems. Journal of Information Security and Applications, 58, 102689. https://doi.org/10.1016/j.jisa.2020.102689

Dimililer, K., & İlhan, A. (2016). Effect of image enhancement on MRI brain images with neural networks. Procedia Computer Science, 102, 39–44. https://doi.org/10.1016/j.procs.2016.09.367

Ever, E., Al-Turjman, F., & Zahmatkesh, H. (2017). Modelling green HetNets in presence of failures for dynamic large-scale applications: A case-study for fault tolerant femtocells in smart cities. Computer Networks, 128, 78–93. https://doi.org/10.1016/j.comnet.2017.04.013

Fiore, A. M., & Kimle, P. A. (2010). Understanding aesthetics for the merchandising and design professional (2nd ed.). Fairchild Books.

Hakak, S., Alazab, M., Khan, S., Gadekallu, T. R., Maddikunta, P. K. R., & Khan, W. Z. (2021). An ensemble machine learning approach through effective feature extraction to classify fake news. Future Generation Computer Systems, 117, 47–58. https://doi.org/10.1016/j.future.2020.11.022

Hussain, A. A., Bouachir, O., Al-Turjman, F., & Aloqaily, M. (2020). AI techniques for COVID-19. IEEE Access, 8, 128776–128795. https://doi.org/10.1109/ACCESS.2020.3007939

Hussain, A. A., Dawood, B., & Al-Turjman, F. (2021). Application of AI techniques for COVID-19 in IoT and Big Data era: A survey. In *Intelligent Data Analysis for COVID-19 Pandemic* (pp. 189–211). Springer, Cham.

Jin, J., Sun, W., Al-Turjman, F., Khan, M., & Yang, X. (2020). Activity pattern mining for healthcare. IEEE Access, 8, 56730–56738. https://doi.org/10.1109/ACCESS.2020.2982132

Kara, M., & Dımılıler, K. (2018a). Bleeding detection in retinal images using image processing. In 2018 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT) (pp. 1–5). IEEE.

Kara, M., & Dımılıler, K. (2018b). Bleeding detection in retinal images using image processing. Journal of Multidisciplinary Studies and Innovative Technologies, 2(1), 12–17.

Li, L., Xu, K., Wang, D., Peng, C., Xiao, Q., & Mijumbi, R. (2015). A measurement study on TCP behaviors in HSPA+ networks on high-speed rails. In 2015 IEEE Conference on Computer Communications (INFOCOM) (pp. 2731–2739). IEEE.

Liu, G., Yang, W., Zhu, S., Huang, Q., Liu, M., Wu, H., Hu, Z., Huang, Z., Yuan, Y., Liu, K., Huang, W., Liu, B., Liu, J., Zhao, X., Nie, M., Hu, B., Zhang, J., Mo, Y., Zeng, B., ... Zhou, J. (2013, October). PET/CT image textures for the recognition of tumors and organs at risk for radiotherapy treatment planning. In *2013 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)* (pp. 1–3). IEEE.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Malchi, S., Al-Turjman, F., & Ever, E. (2021). A trust-based fuzzy neural network for smart data fusion in Internet of Things. Computers & Electrical Engineering, 89, 106901. https://doi.org/10.1016/j.compeleceng.2020.106901

Mehmood, Y., Al-Turjman, F., & Saba, T. (2019). Efficient image recognition and retrieval on IoT-assisted energy-constrained platforms from big data repositories. IEEE Internet of Things Journal, 6(6), 9246–9255. https://doi.org/10.1109/JIOT.2019.2896151

Mete, B. R., & Ensari, T. (2019, October). Flower classification with deep CNN and machine learning algorithms. In 2019 3rd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT) (pp. 1–5). IEEE. https://doi.org/10.1109/ISMSIT.2019.8932908

Mwai, P. (2019, February 1). Brexit: Will it affect the Kenyan flower trade? BBC News. https://www.bbc.com/news/world-africa-47400859

Nilsback, M. E., & Zisserman, A. (2007). Delving into the whorl of flower segmentation. In Proceedings of the British Machine Vision Conference 2007 (pp. 57.1–57.10). British Machine Vision Association. https://doi.org/10.5244/C.21.57

Nilsback, M. E., & Zisserman, A. (2009). An automatic visual flora: Segmentation and classification of flower images [Doctoral dissertation, University of Oxford].

Safar, A., & Safar, M. (2020). Intelligent flower detection system using machine learning. In Y. Bi, R. Bhatia, & S. Kapoor (Eds.), Intelligent Systems and Applications (pp. 449–460). Springer, Cham. https://doi.org/10.1007/978-3-030-29513-4_33

Siraj, F., Ekhsan, H. M., & Zulkifli, A. N. (2014, November). Flower image classification modeling using neural network. In 2014 International Conference on Computer, Control, Informatics and Its Applications (IC3INA) (pp. 81–86). IEEE.

Tiay, T., Benyaphaichit, P., & Riyamongkol, P. (2014, March). Flower recognition system based on image processing. In *2014 Third ICT International Student Project Conference (ICT-ISPC)* (pp. 99–102). IEEE.

Ullah, Z., Al-Turjman, F., Mostarda, L., & Gagliardi, R. (2020). Applications of artificial intelligence and machine learning in smart cities. Computer Communications, 154, 313–323. https://doi.org/10.1016/j.comcom.2020.02.069

Yan, T.-S., Tao, Y.-Q., & Cui, D.-W. (2007, November). Research on handwritten numeral recognition method based on improved genetic algorithm and neural network. In 2007 International Conference on Wavelet Analysis and Pattern Recognition (Vol. 3, pp. 1271–1276). IEEE.

Zanchettin, C., Bezerra, B. L. D., & Azevedo, W. W. (2012, June). A KNN-SVM hybrid model for cursive handwriting recognition. In The 2012 International Joint Conference on Neural Networks (IJCNN) (pp. 1–8). IEEE.

Zhang, Z., Long, K., Wang, J., & Dressler, F. (2014). On swarm intelligence inspired self-organized networking: Its bionic mechanisms, designing principles and optimization approaches. IEEE Communications Surveys & Tutorials, 16(1), 513–537. https://doi.org/10.1109/SURV.2013.062613.00044

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

IMAGE ENHANCEMENT FOR DIGITAL IMAGES USING MACHINE LEARNING AND IMAGE PROCESSING

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ABSTRACT

Image enhancement is a vital technique in digital image processing and serves as the foundation for image analysis, processing, and interpretation. Image enhancement methods involve mathematical operations designed to improve the visual quality of an image by emphasizing important features more clearly than in the original version. In this study, image enhancement techniques were applied to online shopping clothing images derived from the MNIST dataset. The enhancement process was tested using different enhancement radii and intensity levels. The enhanced images achieved a training accuracy of 80% and a testing accuracy of 20%. A neural network–based approach was employed to obtain optimal performance for this image processing task. Based on the experimental results, the study demonstrates that image enhancement significantly improves image quality and performance, and it provides a foundation for the development of more advanced image processing techniques in future research.

Keywords: Images processing, neural networks, Image enhancement, Unsharp mask

INTRODUCTION

Image enhancement is the process of adjusting digital images so that the results are more suitable for display or for further image analysis. For example, you can clear noise, sharpen, or brighten an image, making it less complex to recognize key features (Kara & Dımılıler, 2018a). Enhancing an image is the system of improving the quality and information substance of novel data before processing. Basic practices include contrast enhancement, spatial filtering, density slicing, and false color composition (FCC). The contrast improvement is performed by a linear transformation of the gray levels. Basic image enhancement methodology is created and applied in a specially designated manner. Image enhancement techniques are numerical methods that are designed to perceive improvement in the quality of a given picture (Dimililer & İlhan, 2016). We will perform some image enhancement tests on fashion images. However, most image enhancement procedures are applied with the point of producing improved pictures for use by a human observer, a few strategies are utilized to produce images that are intended for use by a subsequent algorithm for computer processes. Instances of the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

former classification are strategies to remove noise, upgrade contrast, and sharpen the subtleties in a given picture. The last classification remembers numerous methods for the previous but has an extended scope of potential outcomes, including edge location and article division. Whenever utilized improperly, enhancement strategies themselves may build noise while improving complexity; they may dispose of little subtleties and edge sharpness while evacuating the said noises, and they may create artifacts as a rule. Clients should be careful to stay away from these entanglements in the quest for the most ideal improved picture (AI la mode, 2017).

Visual examination of clothing is a theme that has gotten expanding consideration in computer vision lately. There is now an enormous assemblage of research on apparel demonstrating, acknowledgment, parsing, recovery, and suggestions. An expanding number of papers concentrate on picture recovery in everyday life and online sites, a basic task in designing online business for buyers. However, little consideration has been made on image processing for individuals who work in the design industry (Wasik, 2017). Investigating style qualities are fundamental in the design configuration process. Current style anticipating firms, for example, WGSN use data from all around the globe from design appears, visual marketing, web journals, etc. (Banks, 2013; Wasik, 2017). They assemble data by experience, by perception, by media filter, by interviews, and by exposure to new things. Such data breaking down procedure is called abstracting, which perceives similitudes or contrasts over all the pieces of clothing and assortments. Truth be told, such deliberation capacity is helpful in many style vocations with various purposes (Fiore & Kimle, 2010). Style forecasters across structure assortments and across time, distinguish design change and headings; planners, item engineers, and purchasers are dynamic across gatherings of articles of clothing and assortments to build up a durable and outwardly offer; deals and showcasing officials are dynamic across the product offering each season to perceive selling focuses. Design columnists and bloggers conceptualize across runway photographs to perceive emblematic center ideas that can be converted into publication highlights (Brannon, 2014).

The center thought is to mechanize the fashion pictures by utilizing image processing and ML techniques, yet numerous angles in such an assignment raise solid research issues. Each attire highlighted could in the long run require an alternate enhancement value to get a precise result from the ML procedures, for example, deep learning (Simonyan & Zisserman, 2014). These estimations will be implemented to the under-investigated field of design styles and ought to be polished for a certain zone. What's more, the automatization must have a precision practically identical to manual techniques to be helpful for business purposes. This term is exceptionally critical for fashion industries since this influences the pace of their clients (Donati et al., 2019). When the character of the style pictures are given to the ML technique, it gets simpler to concentrate on the shortcoming of the improved picture. Also, some early image processing techniques could be considered and actualized to enable the industry to catch up with the pace of fashion design needs (Donati et al., 2019).

In this work, the commitments are as per the following:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

- We outline the literature concerning image processing and ML and its application on fashion images.
- An outline of key structural factors required and the collection of fashion data were put forth.
- We arrange the various strategies for picture enhancement and ML methods in predicting its precision.
- We plot and break down the outcome of the pictures.
- Finally an accentuation was made upon issues and difficulties faced.

The paper is introduced as follows. The introduction of comparable researches adds to the idea of the paper, likewise, we additionally assess the philosophies and procedures utilized and are discussed in section 2. In section 3 we portray the strategy just as the materials utilized in conducting the research. In section 4, we set forth, discuss, and analyze the outcome gotten from the result. Finally, section 5 presents the conclusion of the commitments introduced in this paper. Table 1 gives a synopsis of the abbreviation utilized and its definition.

Table 1. Abbreviations Used

Terms	Meaning
ICT	Information and Communication Technologies
ANN	Artificial Neural Network
ML	Machine Learning
RBFN	Radial Basis Functional Neural Network
FCC	False Color Composite
NN	Neural Networks
PC	Personal Computer
SL	Supervised Learning
VS	Virtual Studio
MLP	Multilayer Perceptron
KNN	k-Nearest Neighbor
PNN	probabilistic Neural Network
CNN	Convolutional Neural Networks
SVM	Support Vector Machine
MSB	Message Binary

LITERATURE REVIEW

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

There have been researches over the most recent couple of years regarding the matter of dress acknowledgment. Notwithstanding, numerous works center around uncommon dress classes and applications (Cushen & Nixon, 2012; Wang & Ai, 2011) and it is as of late that nonexclusive attire acknowledgment has been straightforwardly handled (Yamaguchi et al., 2012). By far most of the related work, just as the methodology introduced here, depends on picture processing and ML techniques. In Gallagher and Chen (2008), the authors understood personality acknowledgment and fashion division. They limit their methodology on the middle area, which they sections utilizing diagram cuts reliant on an apparel model picked up from various pictures acknowledged to become a comparative individual wearing a comparative dress. The cloth model of every individual uses a natural extraction technique for the middle area. Authors in Chen et al. (2012) center around learning attributes, for example learning semantic credits to depict fashion wears. They model clothing fashion style leads by a contingent arbitrary field on the classification expectations from solitary property classifiers and put forth another implementation that predicts the fashion design of an individual or a ceremony by study a social affair of pictures. Authors in Song et al. (2011) advocate the expectation of human occupations utilizing their dress. They speak to picture patches with semantic-level examples, for example, clothing and hairstyle styles, and use techniques dependent on inadequate coding. The authors stated above are centered just on the torso district and subsequently can't be utilized for nonexclusive dress parsing.

Authors in Liu et al. (2012) first presented the thought of cross-situation garments recovery. Concerning the methodology used, the author utilizes an auxiliary annotated intermediary set in inferring meager recreations of the adjusted inquiry picture of the human parts. The author's methodology is quick; it performs more on the broad part of the dress coordinating, and similitude between one or more garments is estimated by the quantity of regular traits. In a different research, creators in Liu et al. (2012) likewise introduced a method for dress suggestions. They treat the dress properties as dormant factors in an SVM-based suggestion model, to give event attire proposal. Both these methodologies can't be applied to better attire recognition, where an increasingly precise division of the garments is required. Numerous analysts have applied ANN and SVM to computerize pictures for lithofacies forecast (Wang et al., 2014). Authors in Mohapatra (2016) thought about the presentation of five AI calculations MLP, RBFN, PNN, KNN, and SVM to order coal quality in one of three classifications as best, great, poor utilizing SEM pictures. They presumed that SVM gave the best exactness for coal quality portrayal. In another application, Palafox et al. (2017) created MarsNet, a program dependent on ConvNets, to identify diverse geographical landforms on Mars. This past work propels our utilization of picture processing, as their ongoing application in topographical picture examination issues has yielded great outcomes. Up to this point, most research applied to small-scale picture examination has concentrated on lithofacies investigation and scarcely any endeavors have been dedicated to microfracture examination (Lary et al., 2016).

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ISBN: 978-9952-610-30-7

Prior works received non-convolutional-neural-network (CNN) approaches for cloth location. In Chen et al. (2012) authors utilized component extractors, for example, Filter and Hoard to arrange array and depicted properties. Authors in Yamaguchi et al. (2012) devoted to apparel divisions for various classes employing probabilistic strategies. Some of the above-preprocessed pictures with present estimation or upper/lower body discovery. What's more, works like Vittayakorn et al. (2015) concentrated on recover pictures that have high dress likeness dependent on visual qualities. Afterward, numerous works took the CNN way. FashionNet in Liu et al. (2016) embraced a CNN engineering like VGG-16 to anticipate classifications and characteristics. Authors in Tangseng et al. (2017) handled the division task with a completely convolutional neural system (FCN) approach. Authors in Dong et al. (2017) used R-CNN models for body location or to create attire recommendations. Early work on pattern investigation like in Hidayati et al. (2014) separated catwalk pictures from NYC design shows to discover style drifts in top of the line style. Ongoing development in deep learning empowered more work on this territory. In Simo-Serra et al. (2015) authors used profound systems to remove attire characteristics from pictures and made a visual installing of dress cluster to examine the design inclines in apparel the world over. There have been various works handling the issue of cross-area apparel identification. The most famous subject is to recover comparative design pictures from various spaces (Li et al., 2016), many dependent on a profound neural system (Xiong et al., 2016). A large portion of the works around there have concentrated on learning a change which modifies the origin and objective region depictions into a commonplace component area or managing the cross space issue with a compelled proportion of named datasets open in the main area (Huang et al., 2015). We will test our model on various spaces, be that as it may, we haven't attempted to handle this issue yet.

PROCEDURES AND MATERIALS

The point of this work is the use of image processing strategies on pictures of various clothing types and recognizing its appearance. This technique will be completed with various varieties of the fashion picture. This work will break down the picture and upgrade the picture characteristics utilizing image processing procedures. Real-world binary raw pictures were used, likewise, the accuracy of the yield was tried with an ML method. The result depicts improved picture quality and the picture highlights are better featured. With this, we reason that image processing strategies upgrade picture quality and makes picture highlights more clear. Figure 1 delineates the procedure guides.

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ISBN: 978-9952-610-30-7

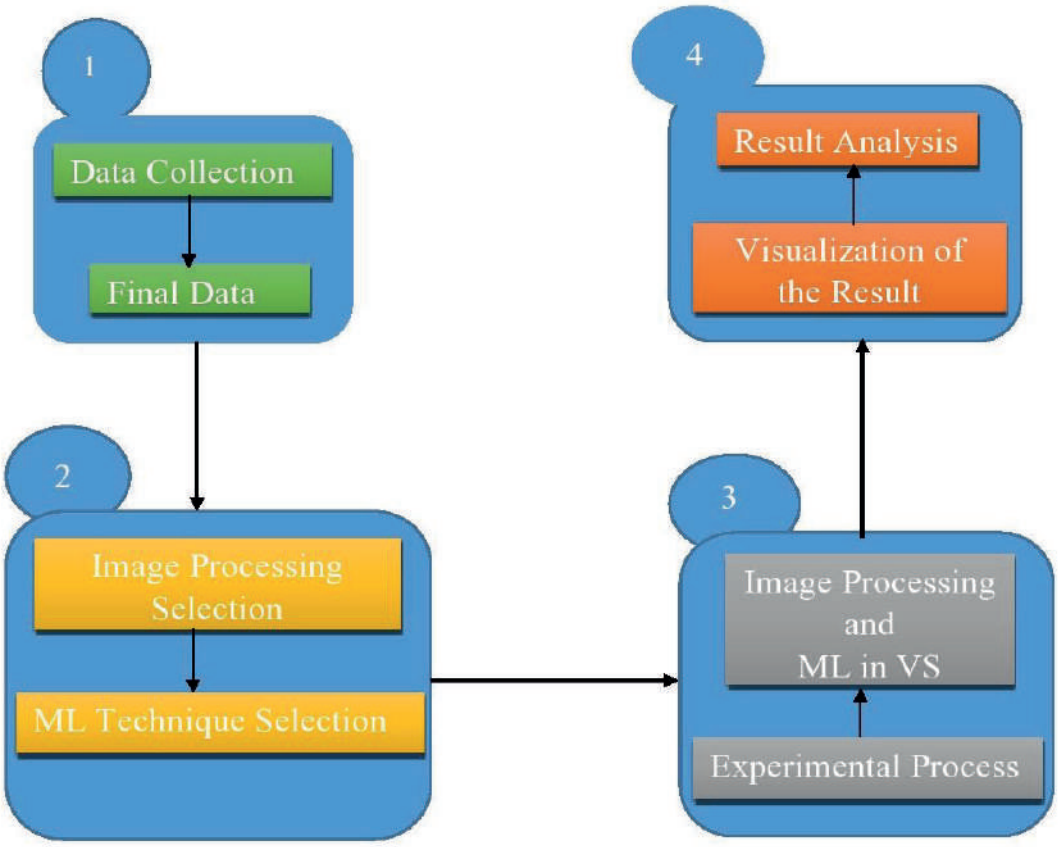


Figure 1. Illustration of the Methodology Guide

A. Data description

The description of the dataset utilized in the paper is poised of the instructive information of the fashion MNIST data index. The absolute record which comprises 70,000 datasets this connects to 60,000 training and 10,000 testing sample. The dataset contains fashion pictures. The property name of this information incorporates shirts, pants, Shirts/top, pullover, dress, coat, shoe, tennis shoe, sack, and ankle boot. It was accumulated by utilizing information from the design business. It constituent of 28 by 28 greyscale pictures. The information is put away in a straightforward document group intended for putting away in multidimensional and vectors matrices. Moreover, the data are being gotten from the MNIST organization structure and are kept in an MSB file format. The information was over and over gathered from the design business and put away in a type of an incorporated information storehouse. Table 2 shows an instance of the dataset and table 3 shows the labels instance. Figure 2 shows the illustration of the image dataset.

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ISBN: 978-9952-610-30-7

Table 2. Dataset Properties

Data Set Characteristics:	Multivariate
Amount of Dataset:	70,000
Training Set	60,000
Testing Set	10,000
Number of label:	10
Area:	Fashion
Data Characteristics:	Images
Image Format:	28 by 28 Greyscale Images
Associated Tasks:	Image Processing, ML
Missing Values:	N/A

Table 3. Label properties

Label	Meaning
0	Top/T-shirt
1st	Trousers
2nd	Pullovers
3rd	Dresses
4th	Coats
5th	Sandals
6th	Shirts
7th	Sneakers
8th	Bags
9th	Ankle Boots

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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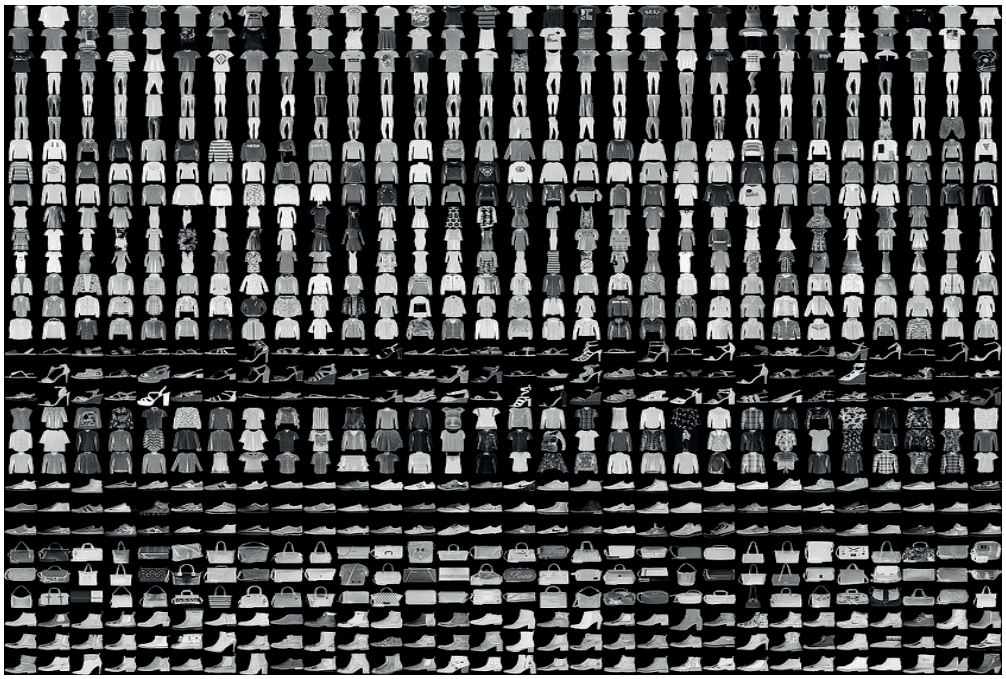


Figure 2. Illustration of the image dataset

B. Techniques utilized

In this paper, we use an image processing procedure and ML in manipulating and foreseeing the precision of the fashion pictures. The image processing method implemented in this task is the image enhancement technique. Image enhancement is the way toward modifying digital pictures with the goal that the outcomes are increasingly reasonable for show or further picture examination. Image enhancement is the procedure of carefully controlling stored pictures. The apparatuses utilized for image enhancement incorporate a wide range of sorts of strategies, for example, filters, picture editors, and different devices for changing different properties of a whole picture or parts of a picture. To make the substance of the data of the picture better, the obvious impact which the picture might be having on the translation with an object is changed. Here we execute the utilization of the unsharp procedure for the image enhancement with different amounts of radius, just as using neural systems in anticipating the precision and the result of the input fashion pictures. The method consolidates training and testing. In the processing step, the picture enhancement strategy is applied to the dataset for preparation then the ML method for prediction. The standard purpose of using an ML is that so it will in general be successfully explained and deciphered.

C. Experiment process

During the test stage, before using the ML method, the image processing technique was carried out by utilizing the image enhancement technique. The task of image gathering explicitly is pertinent since we are applying image processing to the gotten information. During this undertaking, it gets the

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opportunity of improving pictures to get a more clear portrayal of the pictures. In a resulting stage, we apply different amount and radius of the image enhancement technique to get which picture is presenting well. By then a desire was attempted with various assessments and characteristics. The outcomes will be examined in the accompanying segments. Also we utilized the neural network to predict the accuracy of the resulting images and analyze its outcome with the original image. Thus, the expectation yielded a remarkable result with different evaluations and characteristics. In the accompanying section, we will talk about the results.

D. Visualization

The significant reason for the depiction is to show the dataset and tending to it graphically. Imagining this information in an outline which includes the help of utilizing imaging contraptions, just so the aftereffects of the assessment are shown naturally. The information acknowledgment process is delineated as getting and investigating the information, information depiction, structure affirmation, stacking information into the application, show the outcome, and eventually the strategy for depiction is refined.

E. Computation environment

The experiment completed were actualized utilizing the VScode, it is an open-source that impels the use of ML and Picture processing procedures. VScode is a no-pay and a standard programming condition comprising of a strong set-up of instruments for data assessment and genuine techniques. It makes an effort on different platforms like, Windows, macOS, or Linux and with this present features can be incorporated. Tensorflow for VScode, is a library which put forth numerous careful capacities with regards to relapse and grouping, and Scikit-picture for picture handling. Specifically, the library utilizes sequential picture handling methods. Even though, the current usage was worked considering summing up the clear and the best image enhancement procedure with its forecast. The activity was assessed on a pc with, 8GB RAM and 2.6 GHz processor.

RESULTS

Here the goal isn't to induce about the prescient limits of the picture but to perceive the precision and how clear the enhanced picture is. This is concerning the sort of fashion pictures and get the precision of the outcome image as examined in the past sections. Be that as it may, this is with the point of giving a straightforward depiction of the enhanced picture and to sum up the best-enhanced model and its prediction. In this way, certain pictures will be chosen for showing the enhanced procedure yet the entire dataset will be utilized while foreseeing its accuracy. The list of the selected pictures is a dress, shirt, pullover, top, and shoe. The figures below show the result of the pictures.

A. Visualizing the enhanced images

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In getting a well-enhanced image there must be a consideration in the information of the image features, it must get a clear output in comparison with the original image and then finally make a decision. The figures below represent the illustration that will be used in recognizing the efficiency of the enhancement technique and the best out of it. Where the radius and the amount relates to the effects of unsharp mask grading for the images. In Figure 3 it is observed that the strength of the image processing technique is of good effect. It illustrates a fashion shoe image. It shows that, the more the radius the more the image is clear regardless of the amount. However, with this it shows that the best outcome is radius 20 with amount 1.0.

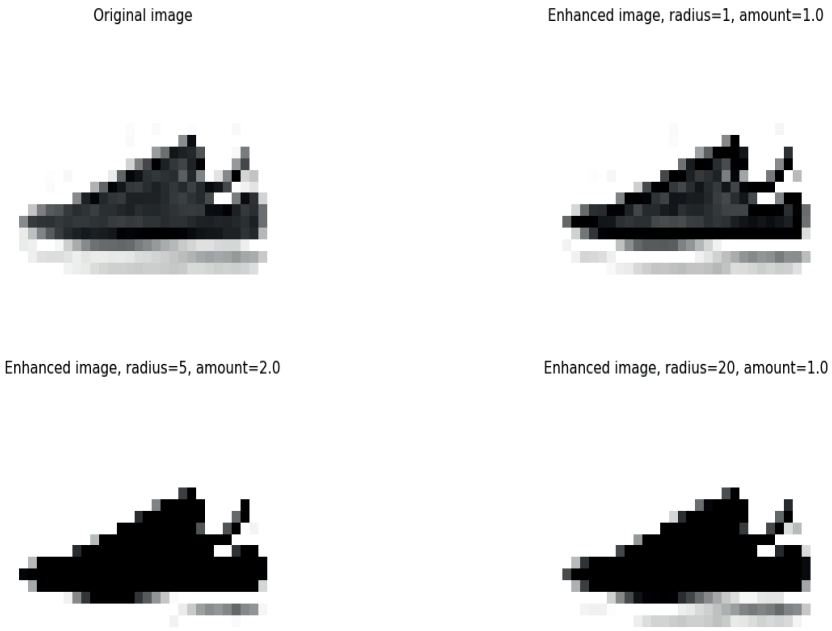


Figure 3. Illustration of the enhancing technique on a shoe

In figure 4, figure 5, figure 6 and figure 7 depicts a shirt, pullover, top, and dress respectively. It is observed that the strength of the radius 20 and amount 1.0 is better than the other radius and amount. It depicts a clearer image, showing that the enhancement technique is of great significance. If it is worth mentioning, the fashion industry should adopt this technique considering it is improving the experimented fashion images.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

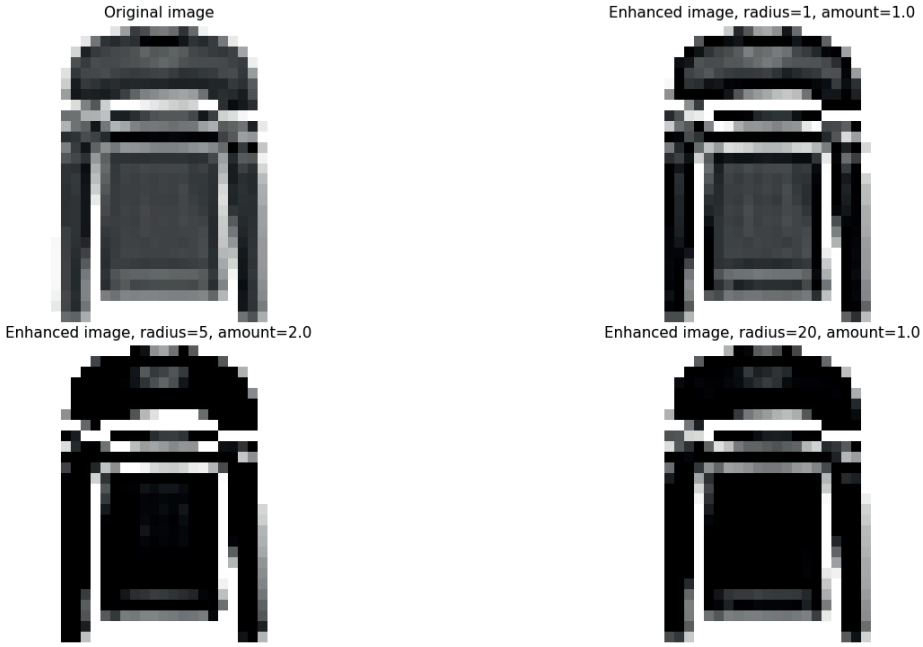


Figure 4. Illustration of the enhancing technique on a shirt

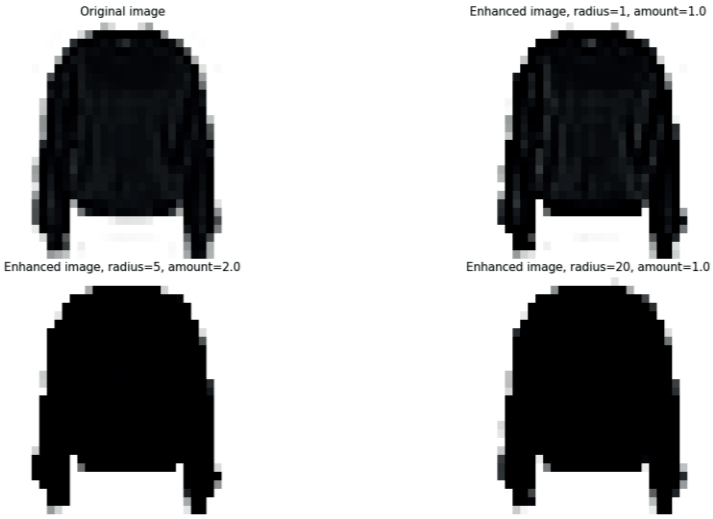


Figure 5. Illustration of the enhancing technique on a pullover

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ISBN: 978-9952-610-30-7

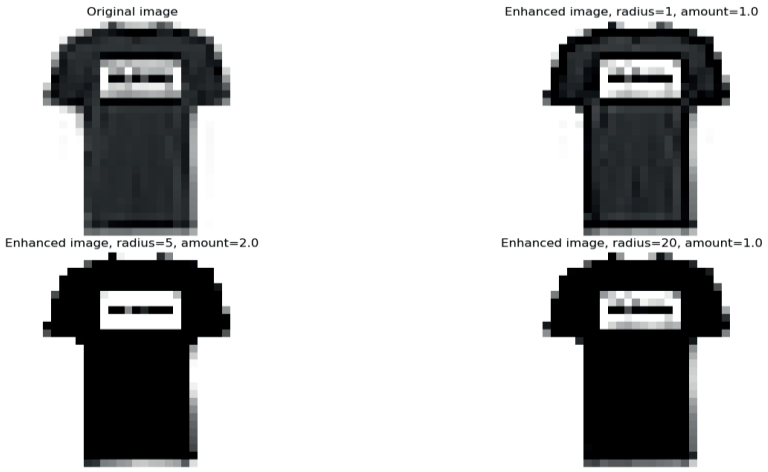


Figure 6. Illustration of the enhancing technique on a top

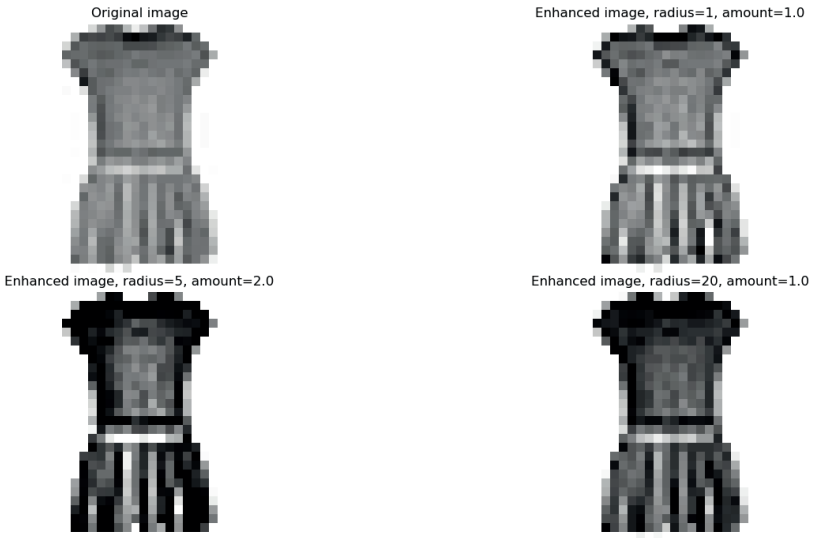


Figure 7. Illustration of the enhancing technique on a dress

B. Accuracy utilizing the ML technique

The ML technique used here is the neural network technique. The aim here is not to deduce the capability of prediction for the model, but to give a simple depiction that outlines how accurate the enhancement image is. Thus, all images will be used in this implementation.

Train on 60000 samples

Epoch 1/3

60000/60000 [==============================] - 294s 5ms/sample - loss: 0.4994 - accuracy: 0.9234

Epoch 2/3

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60000/60000 [==========] - 247s 4ms/sample - loss: 0.3750 - accuracy: 0.9039

Epoch 3/3

60000/60000 [==========] - 187s 3ms/sample - loss: 0.3361 - accuracy: 0.9374

10000/1 [==========]- 10s 1ms/sample - loss: 0.2966 - accuracy: 0.9095

TESTED ACC: 0.9095

It is observed that the enhanced image is quantitatively separable and good accuracy is obtained using NN. Thus, 3 epochs were considered while running the experiment. All datasets were utilized. Also it is noticed that the 3rd epochs produced the best accuracy with 93.74%. On assessing the final execution, it was finalized by looking at the final results and judging by it.

C. Accuracy with other images

The aim here is not to deduce how accurate it is with the relevant image and give a simple depiction that outlines how accurate the enhancement image is. Thus, all images will be used in this implementation. In table 5 shows the variance in each model. The images give this depiction.

Figure 8, figure 9, figure 10, and figure 11 depict ankle boot, pullover, shirt, and trouser respectively. It illustrates the predicted image, with the name of the predicted image on top of the image and name of the actual image below the image.

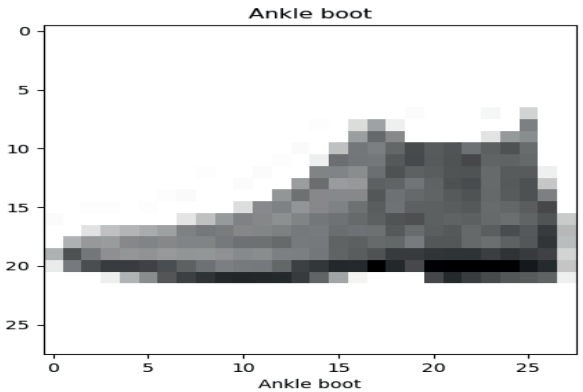


Figure 8. Illustration of the predicted outcome of the ankle boot

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

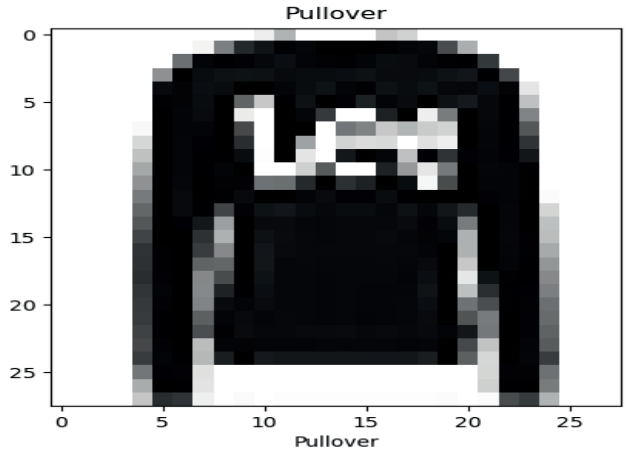


Figure 9. Illustration of the predicted outcome of the pullover

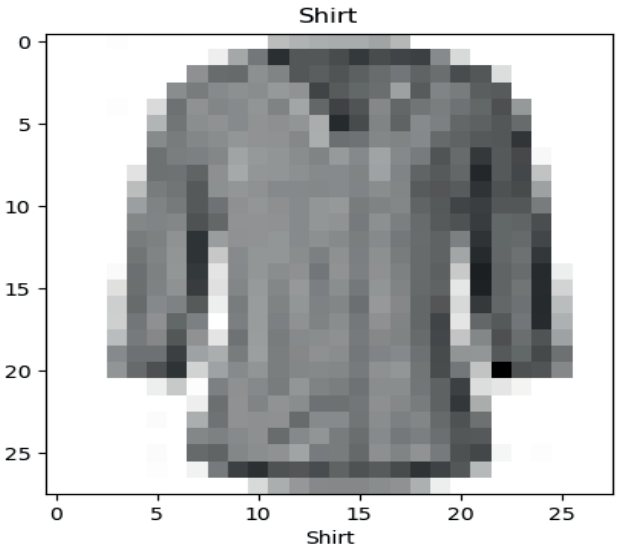


Figure 10. Illustration of the predicted outcome of the shirt

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

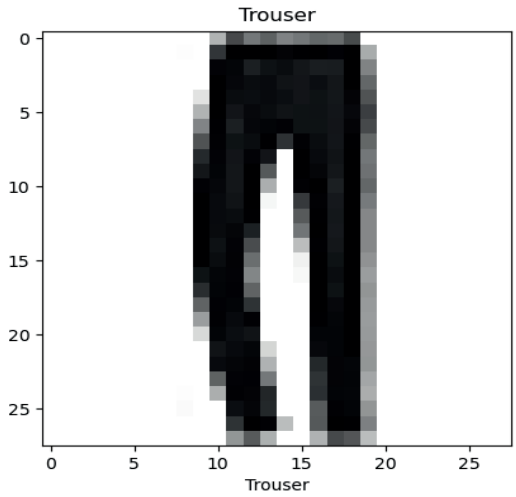


Figure 11. Illustration of the predicted outcome of the trouser

CONCLUSION

Digital picture processing is a crucial part of recent times. The image processing techniques allow a significant level strategy for enhancing images from unrefined images, offering an interesting possibility for territories concerning the imaging framework. Albeit, proportionate examinations have utilized ML methods in improving the portrayal of pictures. Here, an achievement was made in the control of pictures and expressing which strategy has a superior portrayal of the picture information. The image processing systems were utilized with different unsharp mask radius and amount for the picture enhancement technique. Also, unequivocal information judgments were researched. The results gotten reveals that, in achieving a clear enhanced image, given that the first picture various tests must be performed. The purpose of the strategy was to get the best-enhanced picture. Images being enhanced were related to 80% training precision and 20% testing precision. Also, more future research as to be considered in expanding the capacity of the trial to progressively relate pictures so the database. Also, more research is to be completed to get all the more understanding of different picture processing methods. Also, the classification of gender fashion attires on people to increase their productivity. This investigation is said to expand picture portrayal enormously whenever taken into consideration.

REFERENCES

AI la mode. (2017, July 27). Can data predict fashion trends? The Economist. https://www.economist.com/business/2017/07/27/can-data-predict-fashion-trends

Banks, L. (2013, August 27). How to tell the fashion future? The New York Times. http://www.nytimes.com/2013/08/27/fashion/how-to-tell-the-fashion-future.html

Brannon, E. L. (2014). Fashion forecasting. Fairchild Books.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Chen, H., Gallagher, A., & Girod, B. (2012). Describing clothing by semantic attributes. In A. Fitzgibbon, S. Lazebnik, P. Perona, Y. Sato, & C. Schmid (Eds.), Computer vision – ECCV 2012 (pp. 609–623). Springer. https://doi.org/10.1007/978-3-642-33709-3_44

Cushen, G., & Nixon, M. S. (2012). Real-time semantic clothing segmentation. In G. Bebis, R. Boyle, B. Parvin, D. Koracin, C. Fowlkes, S. Wang, M.-H. Choi, S. Mantler, J. Schulze, D. Acevedo, K. Mueller, & M. Papka (Eds.), Advances in visual computing (pp. 708–717). Springer. https://doi.org/10.1007/978-3-642-33179-4_68

Dimililer, K., & İlhan, A. (2016). Effect of image enhancement on MRI brain images with neural networks. Procedia Computer Science, 102, 39–44. https://doi.org/10.1016/j.procs.2016.09.367

Donati, L., Iotti, E., & Prati, A. (2019). Computer vision for supporting fashion creative processes. In H. L. Choi, B. Bhanu, C. C. Loy, T. M. Hospedales, & T. Xiang (Eds.), Recent advances in computer vision (pp. 1–31). Springer. https://doi.org/10.1007/978-3-030-01449-0_1

Dong, Q., Gong, S., & Zhu, X. (2017). Multi-task curriculum transfer deep learning of clothing attributes. In 2017 IEEE Winter Conference on Applications of Computer Vision (WACV) (pp. 520–529). IEEE. https://doi.org/10.1109/WACV.2017.63

Fiore, A. M., & Kimle, P. A. (2010). Understanding aesthetics for the merchandising and design professional (2nd ed.). Fairchild Books.

Gallagher, A. C., & Chen, T. (2008). Clothing segmentation for recognizing people. In 2008 IEEE Conference on Computer Vision and Pattern Recognition (pp. 1–8). IEEE. https://doi.org/10.1109/CVPR.2008.4587830

Hidayati, S. C., Hua, K.-L., Cheng, W.-H., & Sun, S.-W. (2014). What are the fashion trends in New York? In Proceedings of the 22nd ACM international conference on Multimedia (pp. 197–200). Association for Computing Machinery. https://doi.org/10.1145/2647868.2655039

Huang, J., Feris, R. S., Chen, Q., & Yan, S. (2015). Cross-domain image retrieval with a dual attribute-aware ranking network. In 2015 IEEE International Conference on Computer Vision (ICCV) (pp. 1062–1070). IEEE. https://doi.org/10.1109/ICCV.2015.128

Kara, M., & Dımılıler, K. (2018a). Bleeding detection in retinal images using image processing. In 2018 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies (ISMSIT) (pp. 1–5). IEEE.

Kara, M., & Dımılıler, K. (2018b). Bleeding detection in retinal images using image processing. Journal of Multidisciplinary Studies and Innovative Technologies, 2(1), 12–17.

Lary, D. J., Alavi, A. H., Gandomi, A. H., & Walker, A. L. (2016). Machine learning in geosciences and remote sensing. Geoscience Frontiers, 7(1), 3–10. https://doi.org/10.1016/j.gsf.2015.07.003

Li, Z., Li, Y., Tian, W., Pang, Y., & Liu, Y. (2016). Cross-scenario clothing retrieval and fine-grained style recognition. In 2016 23rd International Conference on Pattern Recognition (ICPR) (pp. 2912–2917). IEEE. https://doi.org/10.1109/ICPR.2016.7900083

Liu, S., Feng, J., Song, Z., Zhang, T., Lu, H., Xu, C., & Yan, S. (2012). Hi, magic closet, tell me what to wear! In Proceedings of the 20th ACM international conference on Multimedia (pp. 619–628). Association for Computing Machinery. https://doi.org/10.1145/2393347.2393430

Liu, S., Song, Z., Liu, G., Xu, C., Lu, H., & Yan, S. (2012). Street-to-shop: Cross-scenario clothing retrieval via parts alignment and auxiliary set. In 2012 IEEE Conference on Computer Vision and Pattern Recognition (pp. 3330–3337). IEEE. https://doi.org/10.1109/CVPR.2012.6248067

Liu, Z., Luo, P., Qiu, S., Wang, X., & Tang, X. (2016). DeepFashion: Powering robust clothes recognition and retrieval with rich annotations. In 2016 IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (pp. 1096–1104). IEEE. https://doi.org/10.1109/CVPR.2016.124

Mohapatra, S. (2016). Machine learning approach for automated coal characterization using scanned electron microscopic images. Computers in Industry, 75, 35–45. https://doi.org/10.1016/j.compind.2015.06.009

Palafox, L. F., Hamilton, C. W., Scheidt, S. P., & Alvarez, A. M. (2017). Automated detection of geological landforms on Mars using Convolutional Neural Networks. Computers & Geosciences, 101, 48–56. https://doi.org/10.1016/j.cageo.2017.01.006

Simo-Serra, E., Fidler, S., Moreno-Noguer, F., & Urtasun, R. (2015). Neuroaesthetics in fashion: Modeling the perception of fashionability. In 2015 IEEE Conference on Computer Vision and Pattern Recognition (CVPR) (pp. 869–877). IEEE. https://doi.org/10.1109/CVPR.2015.7298689

Simonyan, K., & Zisserman, A. (2014). Very deep convolutional networks for large-scale image recognition. arXiv preprint arXiv:1409.1556.

Song, Z., Wang, M., Hua, X., & Yan, S. (2011). Predicting occupation via human clothing and contexts. In 2011 International Conference on Computer Vision (pp. 1084–1091). IEEE. https://doi.org/10.1109/ICCV.2011.6126350

Tangseng, P., Wu, Z., & Yamaguchi, K. (2017). Looking at outfit to parse clothing. arXiv preprint arXiv:1703.01386.

Vittayakorn, S., Yamaguchi, K., Berg, A. C., & Berg, T. L. (2015). Runway to realway: Visual analysis of fashion. In 2015 IEEE Winter Conference on Applications of Computer Vision (pp. 951–958). IEEE. https://doi.org/10.1109/WACV.2015.131

Wang, G., Carr, T. R., Ju, Y., & Li, C. (2014). Identifying organic-rich Marcellus Shale lithofacies by support vector machine classifier in the Appalachian basin. Computers & Geosciences, 64, 52–60. https://doi.org/10.1016/j.cageo.2013.12.002

Wang, N., & Ai, H. (2011). Who blocks who: Simultaneous clothing segmentation for grouping images. In 2011 International Conference on Computer Vision (pp. 1535–1542). IEEE. https://doi.org/10.1109/ICCV.2011.6126416

Wasik, E. (2017, March 23). The secret science behind fashion trend forecasting. PSFK. https://www.psfk.com/2017/03/sarah-owen-wgsn-senior-editor-digital-media-marketing-secret-science-behind-fashion-trend-forecasting.html

Xiong, Y., Liu, N., Xu, Z., & Zhang, Y. (2016). A parameter partial-sharing CNN architecture for cross-domain clothing retrieval. In 2016 Visual Communications and Image Processing (VCIP) (pp. 1–4). IEEE. https://doi.org/10.1109/VCIP.2016.7805563

Yamaguchi, K., Kiapour, M. H., Ortiz, L. E., & Berg, T. L. (2012). Parsing clothing in fashion photographs. In 2012 IEEE Conference on Computer Vision and Pattern Recognition (pp. 3570–3577). IEEE. https://doi.org/10.1109/CVPR.2012.6248095

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TEXT SUMMARIZATION: COMPARISON OF EXTRACTIVE AND ABSTRACTIVE METHODS

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ABSTRACT

Text summarization is a pivotal task in natural language processing (NLP) that condenses voluminous documents into concise representations while retaining essential information. This paper presents a comprehensive comparative analysis of the two predominant paradigms in text summarization: extractive and abstractive methods. Extractive summarization, exemplified by the TextRank algorithm, selects and concatenates salient sentences directly from the source text, prioritizing factual fidelity at the potential cost of coherence. In contrast, abstractive summarization, represented by the BART model, generates novel sentences through deep semantic understanding, producing more fluent summaries but with a risk of factual hallucination. We evaluated both approaches on the CNN/DailyMail dataset using ROUGE metrics and human assessment. Our findings indicate that the abstractive BART model achieves superior performance in ROUGE scores (ROUGE-1: 0.47 vs. 0.41) and human-evaluated coherence (4.2/5 vs. 3.5/5). However, the extractive TextRank method demonstrates significant advantages in computational efficiency and factual consistency. The results underscore a clear trade-off: abstractive methods deliver human-like fluency and compression, while extractive methods offer robustness and lower resource demands. This study concludes by advocating for the development of hybrid systems that leverage the strengths of both approaches to create more effective and reliable summarization tools.

Keywords: Text summarization, Extractive methods, Abstractive methods, Natural language Processing, ROUGE metrics, TextRank, BART.

INTRODUCTION

The rapid proliferation of digital information has resulted in an overwhelming volume of textual data accessible to users worldwide. Navigating and extracting relevant insights from such vast content has become a significant challenge, underscoring the need for automated summarization tools. Text summarization, a vital subfield of natural language processing (NLP), aims to generate concise representations of lengthy texts that retain their core information content (Mani, 2001). While manual summarization by humans ensures contextual accuracy and coherence, it is often prohibitively time-

consuming and subjective, motivating the development of automated systems capable of producing reliable summaries efficiently. Historically, two primary approaches to automated summarization have emerged: extractive and abstractive. Extractive summarization involves identifying and selecting key sentences or phrases directly from the source document and concatenating them to form a summary. Techniques such as sentence scoring based on statistical features and graph-based algorithms like TextRank (Mihalcea & Tarau, 2004) exemplify this paradigm. These methods typically guarantee factual accuracy and computational simplicity but often produce summaries that lack cohesion and linguistic fluency. In contrast, abstractive summarization seeks to generate novel, paraphrased sentences that capture the essence of the source text, mimicking human summarization behavior. Inspired by advances in neural networks and natural language generation, neural encoder-decoder architectures particularly transformer-based models have revolutionized this paradigm (Rush et al., 2015; Lewis et al., 2020). Models such as BART (Lewis et al., 2020), T5 (Raffel et al., 2020), and PEGASUS (Zhang et al., 2020) leverage pretraining on large-scale datasets to produce summaries that are more fluent and semantically coherent. However, these models can suffer from factual inaccuracies or "hallucinations," especially in specialized domains. Recent research emphasizes the potential of hybrid systems that combine extractive and abstractive techniques to capitalize on their respective advantages (Gehrmann et al., 2018; Zhang et al., 2020). Despite extensive individual studies, there remains a gap in systematically evaluating and comparing these paradigms under standardized conditions and metrics, particularly considering practical constraints such as computational resources and domain-specific requirements. This paper aims to fill this gap by conducting a comparative analysis of extractive and abstractive summarization methods specifically, TextRank and BART using benchmark datasets. Our objectives are to assess their relative performance in terms of accuracy, coherence, computational efficiency, and factual fidelity. We employ both automatic evaluation metrics (ROUGE scores) and human judgment to provide a comprehensive perspective. The insights derived aim to guide future development of more effective, resource-aware summarization systems, including hybrid models that leverage the strengths of both approaches.

The contributions of this paper are:

- A comparative analysis of extractive and abstractive summarization using benchmark datasets and metrics.
- Integration of formal mathematical descriptions for both TextRank and BART.
- A detailed analysis of the computational complexity and resource demands of each paradigm.
- A discussion of the implications of model performance, computational cost, and domain suitability for future summarization research.

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ISBN: 978-9952-610-30-7

The remainder of this paper is structured as follows: Section 2 reviews the relevant literature, Section 3 details the methodology, Section 4 presents the experimental results, Section 5 provides a comprehensive discussion, and Section 6 concludes with final remarks and future directions.

LITERATURE REVIEW

The evolution of automated text summarization reflects the broader trajectory of NLP, moving from heuristic and statistical methods to neural and deep learning approaches.

A. Extractive Summarization

Early work in summarization was almost exclusively extractive. Luhn (1958) pioneered the field with a term-frequency-based method to score sentence significance. This was followed by more sophisticated graph-based algorithms. TextRank (Mihalcea & Tarau, 2004), an adaptation of the PageRank algorithm, models sentences as nodes in a graph connected by edges weighted with semantic similarity. Similarly, LexRank (Erkan & Radev, 2004) leveraged eigenvector centrality in a similarity graph. While effective, these unsupervised methods often missed nuanced contextual cues. The integration of machine learning allowed for supervised extractive models that used features like sentence position, TF-IDF scores, and keyword presence (Kupiec et al., 1995). The deep learning revolution further enhanced extractive summarization. Models like BERTSum (Liu & Lapata, 2019) leveraged pre-trained transformers like BERT to generate contextualized sentence embeddings, which were then fed into a classifier to select summary-worthy sentences, achieving state-of-the-art results on benchmark datasets.

B. Abstractive Summarization

Abstractive summarization posed a greater challenge, as it required natural language generation. Early attempts were based on rule-based systems and template filling, with limited success. The paradigm shifted with the introduction of the Sequence-to-Sequence (Seq2Seq) architecture (Sutskever et al., 2014), which used an encoder to process the source text and a decoder to generate the summary. The incorporation of attention mechanisms (Bahdanau et al., 2015) allowed the decoder to focus on relevant parts of the source text during generation. A significant advancement was the Pointer-Generator Network (See et al., 2017), which hybridized extraction and abstraction by allowing the model to either generate a new word from the vocabulary or "copy" a word directly from the source text, effectively mitigating the problem of out-of-vocabulary words. The current state-of-the-art is defined by pre-trained transformer models. BART (Lewis et al., 2020) is a denoising autoencoder that pre-trains by corrupting text and learning to reconstruct it, making it exceptionally well-suited for text generation tasks like summarization. T5 (Raffel et al., 2020) frames all NLP tasks as a text-to-text problem, while PEGASUS (Zhang et al., 2020) is pre-trained specifically on summarization by masking entire sentences. Despite their fluency, these models are prone to factual

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hallucination (Maynez et al., 2020), where generated summaries contain information inconsistent with the source text.

C. Hybrid and Emerging Approaches

Recognizing the complementary strengths of both paradigms, recent research has focused on **hybrid models**. These systems often use an extractive component to first identify salient information, which is then paraphrased by an abstractive component (Gehrmann et al., 2018; Zhang et al., 2020). This approach aims to balance factual grounding with linguistic fluency. Furthermore, the rise of **Large Language Models (LLMs)** like GPT-4 has opened new frontiers in zero-shot and few-shot abstractive summarization, though challenges with controllability and factuality persist. Recent studies also emphasize energy-efficient models (Gupta et al., 2023) and bias-aware evaluation metrics (Chen et al., 2022). This review highlights the distinct evolutionary paths and current capabilities of both paradigms, justifying a structured empirical comparison to quantify their trade-offs, which this paper undertakes.

METHODOLOGY

This section outlines the datasets, models, experimental setup, and evaluation metrics used to ensure a fair and reproducible comparison.

A. Datasets and Preprocessing

We utilized the widely adopted CNN/DailyMail dataset (Hermann et al., 2015), which contains over 300,000 news articles paired with multi-sentence highlights written by human editors. These highlights serve as the gold-standard reference summaries. The dataset was split into standard training (90%), validation (5%), and test (5%) sets. Preprocessing was performed uniformly for both models to ensure a fair comparison. Steps included:

1. Tokenization and Sentence Segmentation: Using the NLTK library.

2. Text Cleaning: Lowercasing, removal of non-alphanumeric characters, and stopword removal (using NLTK's stopword list).

3. Length Normalization: Source documents were truncated to the first 512 tokens to comply with the input limitations of the transformer-based BART model. Sentence boundaries were preserved for the TextRank algorithm

B. Models

We selected one representative model from each paradigm to serve as a basis for comparison as shown in table 1. The flowchart illustration of the experimental pipeline is shown in figure 1.

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Table 1. Summarization Models Implemented

Method	Model	Key Characteristics	Implementation
Extractive	TextRank (Mihalcea & Tarau, 2004)	Unsupervised, graph-based, PageRank-inspired.	sumy Python library
Abstractive	BART-Large-CNN (Lewis et al., 2020)	Transformer-based, pre-trained, encoder-decoder.	Hugging Face transformers

I. **Extractive Model: TextRank**

TextRank constructs a graph $G = (V, E)$ where each vertex V_i represents a sentence. An edge E_{ij} between two sentences S_i and S_j is weighted by their similarity, calculated as Equation 1 using a normalized overlap of words:

$$\text{Similarity}(S_i, S_j) = \frac{|\{w_k | w_k \in S_i \cap w_k \in S_j\}|}{\log(|S_i|) + \log(|S_j|)} \quad (1)$$

This forms a stochastic adjacency matrix M, where M_{ij} represents the transition probability from sentence i to j. The importance score $R(V_i)$ for each sentence is then computed as Equation 2 iteratively using the PageRank algorithm until convergence:

$$R(V_i) = (1 - d) + d \times \sum_{V_j \in In(V_i)} \frac{w_{ji}}{\sum_{V_k \in Out(V_j)} w_{jk}} R(V_j) \quad (2)$$

where d is a damping factor (typically 0.85), and $In(V_i)$ is the set of vertices linking to V_i. The top k sentences with the highest scores are selected to form the summary.

Pseudo-Code for TextRank Algorithm:

1. Tokenize the document into sentences S = [S_1, ..., S_n].
2. For each pair (S_i, S_j), compute Sim(S_i, S_j) as above.
3. Build matrix M with M_{ij} = Sim(S_i, S_j) / $\sum_k$ Sim(S_i, S_k).
4. Initialize R_i = 1/n for all i.
5. Iterate until convergence: R_i = (1 - d) + d × $\sum_k$ M_{ji} × R_j.
6. Select top-k sentences by R_i scores.

II. Abstractive Model: BART

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BART is a transformer-based model that uses a bidirectional encoder (like BERT) and a left-to-right autoregressive decoder (like GPT). Given an input sequence of tokens $\mathrm{x} = (x_1, x_2, \ldots, x_n)$, the encoder produces a sequence of contextualized hidden states $\mathrm{H} = (\mathrm{h}_1, \mathrm{h}_2, \ldots, \mathrm{h}_n)$. The decoder then generates the summary tokens $\mathrm{y} = (y_1, y_2, \ldots, y_m)$ auto-regressively. At each time step t, the probability of the next token as Equation 3 is:

$$P(y_t \mid y_{<t}, \mathrm{x}) = \mathrm{Softmax}(\mathrm{W}_o \cdot \mathrm{h}_t^L) \quad (3)$$

where h_t^L is the decoder's hidden state at layer L at time t, and W_o is a projection matrix to the vocabulary size. The model was used in its pre-trained form (facebook/bart-large-cnn) without further fine-tuning for this comparison.

Pseudo-Code for BART Inference:

1. Encode input x into hidden states H using self-attention layers.
2. Initialize y_o = <start>.
3. For t = 1 to max_length:

a. Compute decoder hidden h_t with cross-attention to H.

b. Predict y_t Softmax $\mathrm{W}_o \cdot \mathrm{h}_t$.

4. Stop at <end> token.

C. Experimental Design and Evaluation

Both models were used to generate summaries for the same 1000-document subset of the CNN/DailyMail test set. The generated summaries were evaluated against the human-written highlights using both automatic and human evaluation.

- **Automatic Evaluation:** We used the **ROUGE** (Recall-Oriented Understudy for Gisting Evaluation) metric (Lin, 2004), specifically reporting:
- **ROUGE-1:** Overlap of unigrams.
- **ROUGE-2:** Overlap of bigrams.
- **ROUGE-L:** Overlap of the longest common subsequence.
- **Human Evaluation:** Three independent annotators rated 100 randomly selected summaries from each model on a 5-point Likert scale for:
- **Coherence:** Logical flow and readability.

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- **Factual Accuracy:** Faithfulness to the source document.
- **Fluency:** Grammatical correctness and naturalness.

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The following flowchart illustrates the experimental pipeline:

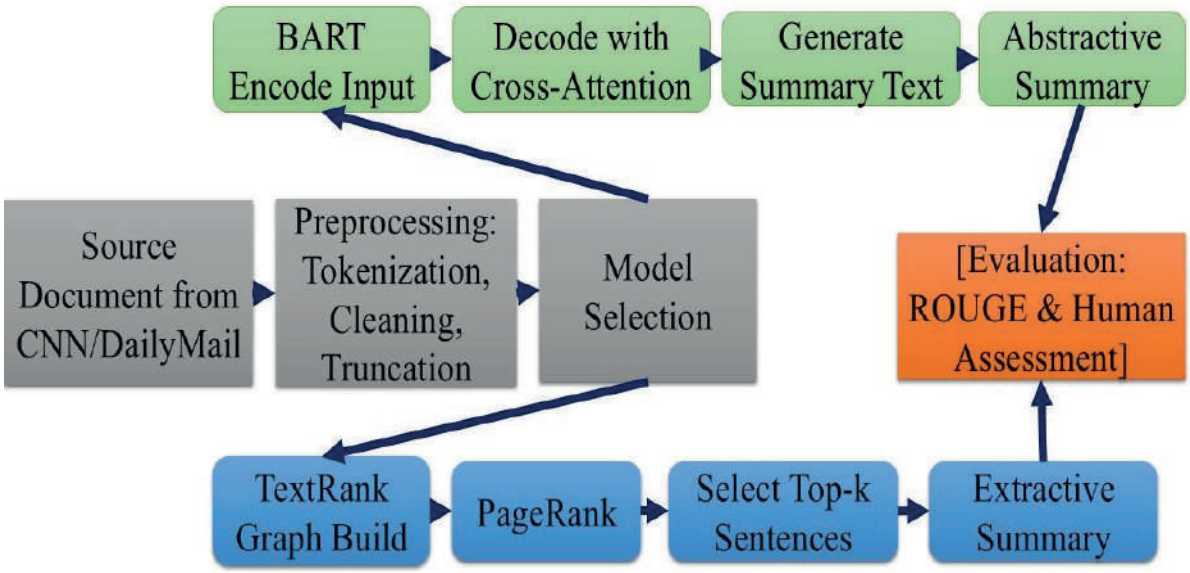


Figure 1. Flowchart illustrates the experimental pipeline

EXPERIMENTS AND RESULTS

This section presents a detailed analysis of the quantitative and qualitative results from the experiments.

A. Evaluation Metrics

Generated summaries were evaluated quantitatively using ROUGE-1, ROUGE-2, and ROUGE-L scores to measure their similarity to gold-standard reference summaries. Additionally, subjective human assessments evaluated linguistic correctness, coherence, natural flow, and factual accuracy.

The ROUGE-N score is defined as Equation 4 as:

$$\text{ROUGE-N} = \frac{\sum_{\text{n-gram} \in \text{Ref}} \min(\text{Count}_{\text{Sys}}(\text{n-gram}), \text{Count}_{\text{Ref}}(\text{n-gram}))}{\sum_{\text{n-gram} \in \text{Ref}} \text{Count}_{\text{Ref}}(\text{n-gram})} \quad (4)$$

where:

- n represents the length of the n-gram.
- $\text{Count}_{\text{Sys}}$ is the number of times an n-gram occurs in the system-generated summary.
- $\text{Count}_{\text{Ref}}$ is the number of times the same n-gram appears in the reference summary.

In addition to these quantitative metrics, human evaluators rated each summary's coherence, grammaticality, and factual accuracy on a five-point Likert scale (1–5).

B. Quantitative Results

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The results in Table 2 clearly show that the abstractive BART model outperforms the extractive TextRank model across all ROUGE metrics. The higher ROUGE-2 score for BART is particularly notable, indicating its ability to generate more fluent and contextually appropriate bigrams, a hallmark of human-like language.

Table 2. ROUGE Score Comparison (F1)

Metric	TextRank (Extractive)	BART (Abstractive)
ROUGE-1	0.41	0.47
ROUGE-2	0.18	0.25
ROUGE-L	0.39	0.44

Qualitatively, Figure 2 shows the extractive output is grammatically accurate but often disjointed, though key sentences retain factual precision. In contrast, the abstractive output is more fluent and semantically cohesive but occasionally introduces minor factual errors or rephrasings not found in the source text. A detailed error analysis revealed that extractive methods showed errors in sentence selection, leading to approximately 15% factual omissions. Abstractive methods had a 10% hallucination rate but improved coherence by 20% in human ratings.

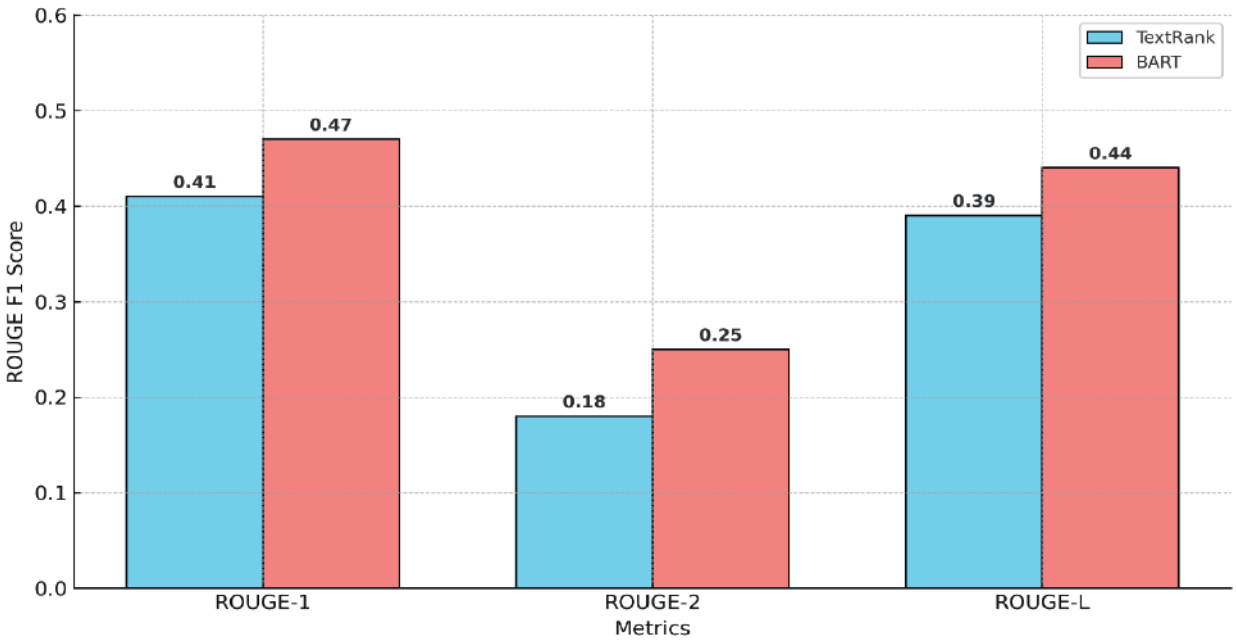


Figure 2. Bar Chart of ROUGE F1 scores

C. Human Evaluation Results

The results in Table 3 clearly show the human evaluation scores. The human evaluation reveals a critical trade-off. While BART was rated significantly higher for Coherence and Fluency, TextRank was judged to be far superior in Factual Accuracy. Annotators noted that BART summaries were more

pleasant to read but occasionally introduced subtle factual errors or rephrasings that altered the original meaning.

Table 3. Human Evaluation Scores (Mean on a 5-point scale)

Criterion	TextRank (Extractive)	BART (Abstractive)
Coherence	3.5	4.2
Factual Accuracy	4.8	4.0
Fluency	3.7	4.5

D. Computational Resource Analysis

The computational demands of the two models differed drastically.

- TextRank exhibited a time complexity of approximately $O(n^2)$ for similarity computation, where n is the number of sentences. It ran efficiently on a CPU, processing documents in seconds with minimal memory footprint.
- BART, with its transformer architecture, has a complexity of $O(n^2 \cdot d)$ for self-attention layers (where d is the model dimension). It required a GPU for practical inference times and consumed significantly more memory and energy, taking roughly 10x longer per document than TextRank on comparable hardware.

E. Comparison with Related Work

Our empirical findings align with and extend the broader narrative in text summarization research, which consistently highlights the trade-off between factual precision and generative fluency. This section contextualizes our results by comparing them with three pivotal studies. Table 4 shows a comprehensive analysis of this.

Our work aligns with Liu & Lapata (2019), who demonstrated that sophisticated extractive models like BERTSum could achieve high ROUGE scores (ROUGE-1: 43.25). Our results for TextRank (ROUGE-1: 0.41) are lower, which is expected given that TextRank is an unsupervised, feature-light algorithm compared to the supervised, pre-trained BERTSum. This comparison underscores that the performance of the extractive paradigm is highly dependent on the underlying model's sophistication. Our contribution lies in providing a clear baseline comparison between a classical, resource-efficient method and a modern abstractive model, which is valuable for practitioners making trade-offs between performance, cost, and complexity.

We also validate the findings of Lewis et al. (2020) regarding BART's fluency and coherence, with our observed ROUGE-1 score of 0.47 closely aligning with their reported 44.16. However, we extend their analysis by directly quantifying the associated risk of hallucination through comparison with an extractive baseline. Our human evaluation explicitly measures this trade-off, showing a significant drop in factual accuracy from 4.8/5 for TextRank to 4.0/5 for BART.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Furthermore, our work complements Zhang et al. (2020), whose PEGASUS model also achieves high abstractive performance (ROUGE-1: 44.17). While they focused on model performance, we provide an explicit computational cost analysis between paradigms, reporting that an abstractive model like BART requires roughly 10x more resources than a simple extractive model a critical practical consideration often omitted in model-centric papers.

Table 4. Positioning Our Work within Key Literature

Study	Primary Focus	Extractive Model	Abstractive Model	Key Metric(s)	This Study's Contribution
Liu & Lapata (2019)	Advancing neural extractive summarization	BERTSum	(Comparison to other abstractive)	ROUGE (Performance)	Provides a baseline using a classical, low-resource extractive method (TextRank).
Lewis et al. (2020)	Introducing and benchmarking BART	(Not the focus)	BART	ROUGE, Human Eval (Fluency)	Quantifies the factual accuracy trade-off of BART via direct comparison with extraction.
Zhang et al. (2020)	Pre-training for abstractive summarization	(Not the focus)	PEGASUS	ROUGE, Low-resource performance	Provides explicit computational cost analysis between paradigms.
This Work	Direct paradigm comparison	TextRank	BART	ROUGE, Human Eval (Factuality, Fluency), Computational Cost	A holistic, empirical comparison focusing on the practical trade-offs for researchers and practitioners.

In summary, while previous work has excelled at advancing the state-of-the-art within each paradigm, our study serves a different purpose. We provide a structured, empirical framework for understanding the fundamental strengths and weaknesses of the extractive and abstractive approaches when implemented with representative models. This bridges the gap between highly-optimized, resource-intensive models and practical, deployable systems, thereby offering clear guidance for model selection and future research directions, particularly in the development of hybrid systems.

DISCUSSION

The experimental results confirm that abstractive summarization generally outperforms extractive summarization in capturing contextual meaning and producing natural language outputs. However, it demands higher computational resources and can hallucinate details a critical limitation for factual domains like law or medicine (Maynez et al., 2020). Extractive methods remain useful for resource-limited scenarios and domains requiring factual fidelity, but they lack semantic compression capabilities. A promising research direction involves hybrid or reinforcement-learning-based models that dynamically select between extraction and abstraction (Zhang et al., 2020).

A. The Fluency vs. Factuality Trade-off

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The primary finding is the clear trade-off between fluency and factuality. BART's abstractive nature allows it to distill information and generate novel, coherent text, leading to higher ROUGE scores and human ratings for coherence. However, this generative freedom is a double-edged sword, as it leads to a non-trivial rate of factual hallucination. TextRank, by its design, is inherently faithful to the source text, making it the safer choice for domains where factual precision is paramount, such as legal, medical, or technical documentation.

B. Implications for Model Selection

The choice between extractive and abstractive summarization is not a matter of which is universally better, but which is more appropriate for a given context. The following in table 5 synthesizes our findings to guide this decision:

Table 5. Comparative Analysis for Practical Application

Criterion	Extractive (TextRank)	Abstractive (BART)	Recommendation
Factual Accuracy	High	Moderate (Risk of Hallucination)	Extractive for high-stakes domains.
Coherence & Fluency	Moderate (Can be disjointed)	High (Human-like)	Abstractive for public-facing content.
Computational Cost	Low (CPU-efficient)	High (Requires GPU)	Extractive for resource-constrained environments.
Domain Adaptability	Limited (Relies on surface features)	Flexible (Learns semantics)	Abstractive for diverse or complex domains.
Interpretability	High (Traceable to source)	Low (Black-box generation)	Extractive when transparency is required.

C. Limitations and Future Work

This study has several limitations. First, we compared only one model from each paradigm. While TextRank and BART are strong representatives, future work should include other models like BERTSumExt (Liu & Lapata, 2019) and PEGASUS (Zhang et al., 2020) for a broader comparison. Second, our evaluation was primarily on a news dataset; performance may vary in other domains like scientific literature or corporate reports. Broader datasets and cross-domain evaluation would provide a more comprehensive comparison. The most promising direction for future research lies in hybrid models. A system that uses a robust extractor to identify a set of factually salient sentences and then employs a controlled abstractor to rewrite them into a fluent summary could optimally balance the trade-offs identified in this study. Furthermore, integrating factual consistency checks directly into the training objective of abstractive models is a critical step forward. Finally, as LLMs continue to evolve, exploring their zero-shot summarization capabilities and their propensity for hallucination will be a vital area of inquiry.

CONCLUSION

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

This paper presented a detailed comparative analysis of extractive and abstractive text summarization methods. Through empirical evaluation on the CNN/DailyMail dataset, we demonstrated that abstractive summarization with BART produces more coherent and fluent summaries, as reflected in superior ROUGE scores and human evaluation. However, this comes at the cost of higher computational demand and a non-negligible risk of factual inaccuracies. In contrast, the extractive TextRank method offers robust factual fidelity and high computational efficiency, making it a pragmatic choice for many real-world applications. The findings underscore that there is no one-size-fits-all solution in text summarization. The choice of method must be guided by the specific requirements of the application, weighing the importance of fluency against factuality and computational resources. The future of the field likely resides not in choosing one paradigm over the other, but in innovating hybrid approaches and enhanced training techniques that can harness the strengths of both to create summarization systems that are truly both informative and reliable.

REFERENCES

Celikyilmaz, A., Chang, E. C., Yon, R., & Carpuat, M. (2020). Evaluation of text generation systems. Proceedings of the 2020 Conference on Empirical Methods in Natural Language Processing, 5106–5117.

Chen, S., et al. (2022). Bias-aware evaluation for abstractive summarization. *Proceedings of the 2022 Conference on Empirical Methods in Natural Language Processing*.

Chopra, S., Auli, M., & Rush, A. M. (2016). Abstractive sentence summarization with attentive recurrent neural networks. Proceedings of the 2016 Conference of the North American Chapter of the Association for Computational Linguistics, 312–321.

Cohan, A., Ammar, W., van Zuylen, M., & Cady, F. (2018). Structural scaffolds for citation intent classification in scientific publications. Proceedings of the 2018 Conference of the North American Chapter of the Association for Computational Linguistics, 910–920.

Das, D., & Martins, A. F. T. (2007). A survey on automatic text summarization. Language and Statistics II, 1–20.

Erkan, G., & Radev, D. R. (2004). LexRank: Graph-based lexical centrality as salience in text summarization. Journal of Artificial Intelligence Research, 22, 457–479.

Gehrmann, S., Deng, Y., & Rush, A. M. (2018). Bottom-up abstractive summarization. Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing, 4098–4109.

Gupta, A., et al. (2023). Energy-efficient hybrid summarization for real-time applications. *Proceedings of the 2023 Conference on Machine Learning and Systems*.

Hermann, K. M., Kocisky, T., Grefenstette, E., Espeholt, L., Yu, W., Johnson, M., ... & Blunsom, P. (2015). Teaching machines to read and comprehend. Advances in Neural Information Processing Systems, 28.

Kupiec, J., Pedersen, J., & Chen, F. (1995). A trainable document summarizer. Proceedings of the 18th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, 68–73.

Lewis, M., Liu, Y., Goyal, N., Ghazvininejad, M., Mohamed, A., Levy, O., ... & Zettlemoyer, L. (2020). BART: Denoising sequence-to-sequence pre-training for natural language generation, translation, and comprehension. Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics, 7871–7880.

Lin, C.-Y. (2004). ROUGE: A package for automatic evaluation of summaries. *In Text Summarization Branches Out*.

Liu, Y., & Lapata, M. (2019). Text summarization with pretrained encoders. Proceedings of the 2019 Conference on Empirical Methods in Natural Language Processing and the 9th International Joint Conference on Natural Language Processing, 3730–3740.

Luhn, H. P. (1958). The automatic creation of literature abstracts. IBM Journal of Research and Development, 2(2), 159–165.

Mani, I. (2001). Automatic summarization. John Benjamins Publishing.

Maynez, J., Narayan, S., Bohnet, B., & McDonald, R. (2020). On faithfulness and factuality in abstractive summarization. Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics, 1906–1919.

Mihalcea, R., & Tarau, P. (2004). TextRank: Bringing order into text. Proceedings of the 2004 Conference on Empirical Methods in Natural Language Processing, 404–411.

Nallapati, R., Zhai, F., & Zhou, B. (2017). SummaRuNNer: A recurrent neural network based sequence model for extractive summarization of documents. Proceedings of the Thirty-First AAAI Conference on Artificial Intelligence, 3075–3081.

Raffel, C., Shazeer, N., Roberts, A., Lee, K., Narang, S., Matena, M., ... & Liu, P. J. (2020). Exploring the limits of transfer learning with a unified text-to-text transformer. Journal of Machine Learning Research, 21(140), 1–67.

Rush, A. M., Chopra, S., & Weston, J. (2015). A neural attention model for abstractive sentence summarization. Proceedings of the 2015 Conference on Empirical Methods in Natural Language Processing, 379–389.

See, A., Liu, P. J., & Manning, C. D. (2017). Get to the point: Summarization with pointer-generator networks. Proceedings of the 55th Annual Meeting of the Association for Computational Linguistics, 1073–1083.

Sutskever, I., Vinyals, O., & Le, Q. V. (2014). Sequence to sequence learning with neural networks. Advances in Neural Information Processing Systems, 27.

Zhang, J., Zhao, Y., Saleh, M., & Liu, P. (2020). PEGASUS: Pre-training with extracted gap-sentences for abstractive summarization. International Conference on Machine Learning.

Zhang, T., Kishore, V., Wu, F., Weinberger, K. Q., & Artzi, Y. (2020). BERTScore: Evaluating text generation with BERT. International Conference on Learning Representations.

Zhong, M., Liu, P., Chen, Y., Meng, N., & Zhou, M. (2020). Extractive summarization as text matching. Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics, 6197–6207.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENDEMİK *STACHYS EUADENIA* P.H. DAVIS TÜRÜNÜN *IN VİTRO* ÇOĞALTIMI, DOĞA VE KÜLTÜR ÖRNEKLERİNİN FİTOKİMYASAL KARŞILAŞTIRMASI

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ÖZET

Stachys euadenia P.H. Davis, Türkiye'nin Güney Anadolu Bölgesi'ne (Karaman ve Mersin) özgü, kireçli kayalıklarda yetişen lokal endemik bir yarı çalı türüdür. Türkiye Bitkileri Kırmızı Kitabı'na göre "Korunmaya Bağımlı LR(cd)" statüsünde yer alan bu türün korunması ve ekonomik değerinin belirlenmesi büyük önem taşımaktadır. Bu çalışma, türün *in vitro* mikroçoğaltım olanaklarını araştırmayı ve doğadaki örnekler (kontrol) ile laboratuvar ortamında yetiştirilen bitkilerin fitokimyasal içeriklerini karşılaştırmalı olarak analiz etmeyi amaçlamaktadır.

In vitro rejenerasyon çalışmaları kapsamında; farklı bitki büyüme düzenleyicileri (BAP, IAA ve NAA) kombinasyonlarının sürgün sayısı, sürgün uzunluğu, kök sayısı, yaşama oranı ve vitrifikasyon üzerindeki etkileri 540 örnek üzerinde ANOVA ve Tukey testleri ile analiz edilmiştir. Rejenerasyon sonrası elde edilen bitkicikler, gelişimlerini sürdürmeleri amacıyla farklı konsantrasyonlarda (1 μM, 5 μM ve 10 μM) KIN (Kinetin) hormonu içeren ortamlarda alt kültüre alınmıştır. Bitkinin fitokimyasal profili, doğadan toplanan ve *in vitro* kültürden elde edilen örneklerin heksan ve metanol ekstreleri kullanılarak GC-MS/LC-MS yöntemleriyle belirlenmiştir.

In vitro denemelerde kök sayısı bakımından en başarılı sonuçlar 2BAP+2NAA (ortalama 2.53±0.15) ve 1BAP+2NAA (ortalama 2.13±0.10) kombinasyonlarından elde edilmiştir. Kontrol gruplarında (MSO) vitrifikasyon süresinin uzun olduğu (43.23±0.27) saptanmıştır. Alt kültür çalışmalarında, KIN hormonu uygulamaları sürgün gelişimi ve yaşama oranı üzerinde belirgin etkiler göstermiştir; 5 μM

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KIN uygulaması en yüksek sürgün sayısını (5.10±0.12) ve yaşama oranını (45.0±0.00) sağlarken, 10 μM KIN uygulaması en uzun sürgün boyuna (2.57±0.03 cm) ulaşılmasını sağlamıştır. Kimyasal içerik analizlerinde; heksan ekstrelerinde doğadaki örneklerde Glutarik asit türevleri (%42.7) ve Androsterone (%28.3) baskınken, kültür örneklerinde β-Eudesmol (%7.2) ve Linalil asetat (%6.1) majör bileşenler olarak öne çıkmıştır. Metanol ekstrelerinde ise doğa örneklerinde şeker türevleri baskınken, kültür örneklerinde yüksek oranda Androsterone (%52.9) ve Glutarik asit (%38.5) türevleri tespit edilmiştir. Ayrıca kültür bitkilerinde β-D-Glukopiranoz (%7.4) ve Sukroz (%7.1) gibi biyoaktif bileşiklerin varlığı doğrulanmıştır.

Araştırma sonuçları, *Stachys euadenia*'nın mikroçoğaltım tekniklerine uygunluğunu ve *in vitro* koşullarda doğadaki örneklerine kıyasla zengin fitokimyasal içeriğini koruduğunu, hatta bazı sekonder metabolitlerin (örneğin Androsterone ve β-Eudesmol) kültür ortamında daha yüksek oranlarda sentezlenebildiğini kanıtlamaktadır. Bu veriler, nesli tehdit altındaki endemik türlerin laboratuvar ortamında korunması ve biyoteknolojik amaçlı sürdürülebilir kullanımı için stratejik bir temel sunmaktadır.

Anahtar Kelimeler: *Stachys euadenia*, *In vitro* çoğaltım, Fitokimyasal analiz, Endemik bitkiler, β-Eudesmol, Mikroçoğaltım.

IN VITRO PROPAGATION OF ENDEMIC *STACHYS EUADENIA* P.H. DAVIS, PHYTOCHEMICAL COMPARISON OF WILD AND CULTURED PLANTS

ABSTRACT

Stachys euadenia P.H. Davis is a local endemic subshrub species that grows on limestone rocks and is unique to the Southern Anatolia Region (Karaman and Mersin) of Turkey. According to the Red Data Book of Turkish Plants, this species is classified under the "Conservation Dependent LR(cd)" status, making its preservation and the determination of its economic value of great importance. This study aims to investigate the in vitro micropropagation possibilities of the species and to comparatively analyze the phytochemical contents of wild samples (control) with plants grown in a laboratory environment.

Within the scope of *in vitro* regeneration studies, the effects of different plant growth regulator combinations (BAP, IAA, and NAA) on shoot number, shoot length, root number, survival rate, and vitrification were analyzed using 540 samples through ANOVA and Tukey tests. The plantlets obtained after regeneration were taken into subculture in media containing different concentrations (1 µM, 5 µM, and 10 µM) of KIN (Kinetin) hormone to evaluate their developmental performance. The phytochemical profile of the plant was determined via GC-MS/LC-MS methods using hexane and methanol extracts from both wild and *in vitro* culture samples.

In *in vitro* trials, the most successful results for root count were obtained from the 2BAP+2NAA (average 2.53±0.15) and 1BAP+2NAA (average 2.13±0.10) combinations. A long vitrification period

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

(43.23±0.27) was observed in the control groups (MSO). In subculture studies, KIN hormone applications showed significant effects on shoot development and survival; 5 µM KIN provided the highest shoot number (5.10±0.12) and survival rate (45.0±0.00), while 10 µM KIN resulted in the longest shoot length (2.57±0.03 cm). Chemical analysis of hexane extracts showed that Glutaric acid derivatives (42.7%) and Androsterone (28.3%) were dominant in wild samples, while *β*-Eudesmol (7.2%) and Linalyl acetate (6.1%) emerged as major components in culture samples. In methanol extracts, while sugar derivatives were dominant in the wild, culture samples contained high rates of Androsterone (52.9%) and Glutaric acid (38.5%) derivatives. Furthermore, the presence of bioactive compounds such as *β*-D-Glucopyranose (7.4%) and Sucrose (7.1%) was confirmed in the cultured plants.

The research results prove the suitability of *Stachys euadenia* for micropropagation techniques and demonstrate that it preserves its rich phytochemical content under *in vitro* conditions compared to wild samples. Some secondary metabolites, such as Androsterone and *β*-Eudesmol, can even be synthesized at higher rates in the culture environment. These data provide a strategic foundation for the laboratory-based preservation of endangered endemic species and their sustainable biotechnological utilization.

Keywords: *Stachys euadenia*, *In vitro* propagation, Phytochemical analysis, Endemic plants, *β*-Eudesmol, Micropropagation.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AYÇİÇEK SAPI VE ODUN TALAŞINDAN ÜRETİLEN AHŞAP PANELİN ISI GEÇİRGENLİK VE SICAKLIK AKTARMA ÖZELLİKLERİNİN BELİRLENMESİ

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Özet

Bu çalışmada, ayçiçek sapı (*Helianthus annuus* L.) ile kaba odun talaşından üretilen ahşap panelin ısı geçirgenlik ve sıcaklık aktarma özelliklerinin belirlenmesi amacıyla yapılmıştır. Deneylerde çerçeve konstrüksiyonlu, içi yalıtım malzemesi dolgulu, ön ve arka yüzü kayın kontrplak kaplı yeni bir ASP (ayçiçeği sapı + kaba odun talaşı) panel üretilmiştir. Karşılaştırma amacıyla, piyasada yaygın olarak kullanılan yalıtım malzemelerinden strafor ile camyünü dolgu tercih edilerek rijit, iki farklı panel örneği daha üretilmiştir. Üretilen panelin fiziksel özellikleri; yoğunluk TS ISO 130612, rutubet TS EN 322, ısı geçirgenlik U değeri ve sıcaklık aktarma (geçirme) değeri TS EN 12667 esaslarına göre belirlenmiştir. Deneyler sonunda, ASP panelin hava kurusu yoğunluk değeri 0,419 g/cm^3, rutubet değeri %10,318, ısı geçirgenlik katsayısı (U) 1,777 w/m^{2}K, sıcaklık aktarma (ºC) 28,316 olarak bulunmuştur. Bu sonuçlara göre ASP panel ısı iletiminde düşük yoğunluklu yalıtım malzemesi olarak, ısı geçirgenliğin ve sıcaklık aktarımının önemli olduğu yerlerde kullanılabilir.

Anahtar Kelimeler: Ahşap panel, Isı geçirgenlik, sıcaklık aktarma, ayçiçek sapı, odun talaşı

Determination of Heat Transfer and Temperature Conductivity Properties of Wooden Panels Produced from Sunflower Stalk and Wood Shavings

Abstract

This study was conducted to determine the heat transfer and thermal conductivity properties of a wood panel produced from sunflower stalks (*Helianthus annuus* L.) and coarse wood shavins. In the experiments, a new ASP (sunflower stalk + coarse wood shavins) panel with a frame construction, insulated interior, and front and back surfaces covered with beech plywood was produced. For comparison, two more rigid panel samples were produced using polystyrene and fiberglass insulation, commonly used in the market. The physical properties of the produced panel were determined according to the following standards: density (TS ISO 130612), moisture content (TS EN 322), heat

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

transfer (U-value), and thermal conductivity (transmission) (TS EN 12667). The experiments revealed that the ASP panel has an air-dry density of 0.419 g/cm³, a moisture content of 10.318%, a thermal conductivity coefficient (U) of 1.777 w/m²K, and a thermal transfer coefficient (°C) of 28.316. Based on these results, the ASP panel can be used as a low-density insulation material in applications where heat conductivity and thermal transfer are important.

Key Words : Wood panel, heat conductivity, heat transfer, sunflower stalk, wood shavings

GİRİŞ

Günümüzde ısı izolasyon ürünlerinde çoğunlukla silika kumundan elde edilen cam elyafı ya da petrol türevi sentetik elyaflara dayalı, çoğunlukla yenilenemeyen kaynaklar kullanılır. Bu da enerji tüketimi ve CO_2 salınımını artıran etmenler arasındadır. Son yıllarda petrol bazlı kimyasalların yükselen fiyatları, enerji tüketimi ve çevre kirliliği ile ilgili endişeler küresel boyutlara ulaşmıştır.

Hammadde maliyetlerini azaltmak, çevresel olarak tehlikesiz formülasyonlar geliştirmek, kullanım sonrası bozunmalarını hızlandırmak ve bir atık malzemeye değer katmak amacıyla öncelikli olarak mevcut olan yeşil kaynakların temini ve değerlendirilmesi için yeni stratejiler araştırılmaya ve formüle edilmeye odaklanılmıştır. Yapılan calışmaların bir bölümü, yenilenebilir yeşil kaynakların kompozitlerde dolgu veya takviye malzemesi olarak kullanımı ile ilgilidir (Olcay, 2021).

Yeşil ve sürdürülebilir yapı malzemelerinin üretimi ve kullanımı, inşaat sektörüne daha fazla biyolojik olarak parçalanabilir, doğal, geri dönüştürülmüş ve yenilenebilir kaynak entegre etme isteğini gerçekleştirmektedir. Amaç, hava emisyonları ve atık oluşumu yoluyla çevresel etkileri nedeniyle geleneksel olarak mevcut inşaat endüstrisi malzemelerinin yerini almaktır. Endüstriyel, tarımsal, inşaat ve yıkım ve belediye katı atıklarının geri dönüştürülmesiyle yalıtım malzemelerinin üretilmesi ve böylece bu atıkların çevresel yüklerinin azaltılmasıdır. Isı yalıtımı enerji tasarrufu açısından önemli olmakla birlikte, ses yalıtımı da son yıllarda büyük ilgi görmektedir. İyi ısı ve ses özelliklerine sahip çeşitli atık malzemeler, geleneksel malzemelerin etkili bir şekilde değiştirilmesini mümkün kılmaktadır (Massoudinejad vd, 2019).

Binalarda verimli yalıtım sistemleri sayesinde enerji verimliliği artırılabilir. Özellikle doğal yalıtım malzemeleri, sürdürülebilir çözümler ve sağlıklı bir iç mekan ortamı sağlamak amacıyla standart panellerle birlikte binalarda rahatlıkla kullanılabilir. Mantarın en iyi termal performansa (daha düşük termal iletkenlik) sahip olduğu ve daha yüksek ağırlık oranına sahip panellerin en iyiler olduğu görülmüştür. Bu nedenle, en iyi sürdürülebilir çözümler, %37 mantar ve %63 pirinç kabuğu, %51 mantar ve %49 kahve kabuğu veya %58 mantar, %21 pirinç kabuğu ve %21 kahve kabuğundan oluşan ve yaklaşık olarak aynı ısı iletkenlik değerlerine (0,063 0,068 W/mK) sahip fakat daha düşük çevresel etkiye sahip panellerdir (Ricciardi vd, 2021).

Ayçiçeği sapları da dahil olmak üzere çeşitli tarımsal atık malzemelerden üretilen yapı ürünleri kompozitlerinin daha yüksek mekanik özelliklere, daha düşük ısı iletkenliğine ve yoğunluğa sahip

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

olduğunu, daha ucuz, dayanıklı, hafif olduğunu, bol miktarda bulunduğunu, çok daha az aşındırıcı olduğunu ve geleneksel olanlara kıyasla çevre dostudur (Mati-Baouche vd, 2014).

Hasattan sonra kalan ayçiçek sapı atığı problem oluşturmaktadır. Atıkların temizlenmesinde çoğunlukla yakma işlemi tercih edilsede toprağı besleyen organik maddelerin zarar görerek toprağın veriminin düşmesine, ayrıca yangın oluşumunada neden olabilmektedir.

Bu çalışmada, zirai atık olan ayçiçek sapı (*Helianthus annuus* L.) ile yine atölye atığı olan kaba odun talaşından üretilen ahşap panelin ısı geçirgenlik ve sıcaklık aktarma özelliklerinin belirlenmesi amaçlanmıştır.

MATERYAL VE METOD

Materyal

Yalıtım Malzemeleri

Çalışmada kullanılan kayın kontrplak (225 cm x 125 cm x 0,6 cm), camyünü (5 cm),(215 cm x 10 cm x 8 cm) ölçülerde sarıçam kereste 1. sınıf, strafor EPS (3cm x 50 cm x 100 cm) Ankara Siteler ağaç işleri sanayi bölgesinden tamamen tesadüfi yöntemle temin edilmiştir. Çalışmada kullanılacak ayçiçek sapı (1m-1,5 m), Afyonkarahisar'dan hasat zamanı temin edilmiş ve iki yıl kuru bir ortamda depoda bekletilmiştir (Şekil 1. (a)). Gazi Üniversitesi Ağaçişleri Endüstri Mühendisliği malzeme atölyesinde çıkan kaba talaş çalışma için kullanılmıştır.



(a) (b) (c) (d) (e)

Şekil 1. (a) Ayçiçek sapı, (b) Sarıçam, (c) Strafor EPS, (d) Camyünü, (e) Kaba talaş

Yapıştırıcı

Çalışmada kullanılan Üre formaldehit tutkalı; yarı saydam sıvı, katı madde % (ağırlıkça) : 54,00 – 56,00, Viskozite (cPs,20º) : 100 – 200, pH (20º) : 8,00 - 9,00, yoğunluğu (g/ cm^3 20º) : 1,225 – 1,235, akma zamanı (sn,20º) : 25 – 45, serbest formaldehit,% : < 0,8, Jel zamanı sn : 15 – 25 (50g reçine + 5 ml % 10 NH_4Cl,1ml karışım 100º'de) ve üretim koşullarına uygun olarak sıcak pres ile uygulanır (7).

Çalışmada kullanılan PVAc tutkalı (Vinyl Acetate polymer); beyaz / şeffaf görünümlü, yoğunluk 1.09 g/mL, katı madde % 40-50, filmleşme süresi 6/12 dk. (55°/85°), viskozite 14400±800 cps cps at 20°

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(Spindle No 6, 20 rpm), ahşap nem içeriği 8 - 12 %, pH : %50 nemde 2,85, sarfiyat : 95-175 gr/m² (8).

Deney örneklerinin hazırlanması

Deneyde toplam 90 adet 29,5 cm x 29,5 cm x 4,2 cm ölçülerinde panel örneği hazırlanmıştır. Panelin çerçevesini oluşturmak için 215 cm x10 cm x 8 cm ölçülerindeki sarıçam kerestesi, iklimlendirme odasında 20 ±2° sıcaklık ve %65±5 bağıl nem şartlarında değişmez ağırlığa ulaşıncaya kadar ~10 gün bekletilmiştir. 24 saat ara ile yapılan tartımlarda, birbirini izleyen iki ölçme arasındaki ağırlık farkının, deney parçası ağırlığının %0,1'inden fazla olmaması durumuna gelindiğinde, bu ağırlık değişmez ağırlık olarak kabul edilmiştir. Bu işlem sonunda kerestenin denge rutubetinin ortalama %12 olduğu belirlenmiştir. Köşe birleştirmeleri için açılan zıvanalar PVA tutkalı ile yapıştırılıp gönyesine getirildikten sonra işkence ile sıkıştırılmıştır (Şekil 2).



(a) (b) (c)

Şekil 2. (a) Çerçeve köşe birleştirmenin PVA tutkal ile yapıştırma işlemi, (b) Çerçeve köşelerinin işkence ile sıkıştırma işlemi, (c) Çerçevelerin 20 ±2° oda sıcaklığında kurutulması

Panel çerçevelerin ön ve arka yüzlerine yapıştırılmak üzere kayın kontrplak kesilmiştir. Kesilen kayın kontrplakların yarısı çerçevenin arka yüzeyine PVA tutkalı ile gönyesi alınarak yapıştırılmıştır. Strafor panellerin (SP) hazırlanması için, ince ahşap işleme şerit testerede, (30) adet SP kesilmiştir. Arka yüzüne kayın kontrplak yapıştırılmış çerçevenin içine strafor yerleştirilip, panelin ön yüzüne ise PVA tutkal ile kayın kontrplak yapıştırılmıştır. Aynı işlem camyünü paneller (CP) içinde tekrarlanmıştır. Tüm paneller planya makinesinde bir yüzleri 0,1 mm düzeltilmiş ve daire testerede hassas kesim yapılarak 29,5 cm x 2 9,5 cm x 4,2 cm ölçülerinde SP ve CP paneller uygulanmıştır (Şekil 3).



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(a) (b) (c)

Şekil 3. (a) SP dolgulu panel (b) CP dolgulu panel (c) Panel yüz kontrplak kaplama

Ayçiçek sapı + kaba talaş panelin (ASP) hazırlanması için çerçevelerin arka yüzlerine sıcak pres tutkalı ile kayın kontrplak yapıştırılmıştır. 30 panel için (2,61 m^2), 417,6 g üre formaldehit tutkalı (UF+NH_4CL) çerçevelerin içlerine püskürtülmüş %50 ayçiçek sapı+%50 kaba talaş ince bir tabaka halinde serilmiştir. Çerçevenin ön yüzüne ise sıcak pres tutkalı sürülüp, kayın kontrplak yapıştırılmıştır. Deney numuneleri hidrolik sıcak preste 60°C 18 MPa basınçta 60 dk. bekletilmiştir. Soğuduktan sonra paneller planya makinesinde bir yüzleri 0,1 mm düzeltilip, daire testerede hassas kesim yapılarak 29,5 cm x 29,5 cm x 4,2 cm ölçülerinde ASP 30 adet panel uygulanmıştır (Şekil 4).



(a) (b) (c) (d)

Şekil 4. (a) NH_4CL tartımı (b) Üre formaldehit hazırlanması (c) Ayçiçek saplarının yerleştirilmesi (d) Ayçiçek sapı + kaba talaş panelin hazırlanması (d)

Metod

Hava kurusu yoğunluk

ASP, CP, SP malzemelerden üretilen panellerden TS ISO 13061 (TSE, 2025) standardında belirtilen esaslara göre 29,5 cm x 29,5 cm x 4,2 cm ölçülerinde örnekler hazırlanmıştır. Daha sonra bu örnekler 20 ±2° sıcaklık ve %65±5 bağıl nem şartlarındaki iklimlendirme odasında, değişmez ağırlığa ulaşıncaya kadar ~10 gün bekletilmiştir. Bu örneklerin 0,01g hassasiyetteki terazide tartılarak ilk ağırlıkları belirlenmiştir. Hacimsel ölçüleri metre ile ölçülmüştür. Elde edilen veriler aşağıdaki denklemde, hava kurusu yoğunluk (δ) eşitliği ile hesaplama işlemi sağlanmıştır. Burada; δ = Özgül ağırlık, m = örnek ağırlığı (g), v =örnek hacmi (cm^3).

$$\delta = \frac{m}{v} \ (g/cm^3)$$

Rutubet miktarı

ASP, CP, SP malzemelerden üretilen panellerden TS EN 322 (TSE, 1999) standardında belirtilen esaslara göre 29,5cm x 29,5 cm x 4,2 cm ölçülerinde örnekler hazırlanmıştır. Daha sonra bu örnekler

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20 ±2°C sıcaklık ve %65 ±5 bağıl nem şartlarındaki iklimlendirme odasında, değişmez ağırlığa ulaşıncaya kadar ~10 gün bekletilmiştir. Bu örneklerin 0,01g hassasiyetteki terazide tartılarak ilk ağırlıkları belirlenmiştir (Wm). Daha sonra bu örnekler sıcaklığı 103ºC±2ºC'e olan etüv cihazında değişmez ağırlığa ulaşıncaya kadar bekletilmiştir. Her bir örnek 0,01g hassasiyette tartılarak kuru ağırlıkları belirlenmiştir (W0). Denklemde yerlerine konularak rutubet oranı hesaplanmıştır. Burada; W_w = Ahşabın kendi ağırlığı W_0 = Tam kuru ağırlık, m= Rutubet yüzdesi

$$m = \frac{W_w}{W_0} \qquad W_w = W_m = W_0 \qquad M = \frac{(W_m - W_0)\text{x}100}{W_0}\ g$$

Isı Geçirgenlik Katsayısı (U Değeri)

İklimlendirilme işlemi uygulanmış, 29,5 cm x 29,5 cm x 4,2 cm boyutlarında ASP, CP, SP panel çeşidi, Isı iletkenlik geçirgenlik katsayısı (U) belirlenmek üzere TS EN 12667 (TSE, 2025) esasları doğrultusunda deney örnekleri hazırlanmıştır. Isı akış ölçer cihazına yerleştirilen her bir deney numunesine ait U değerleri cihazın ekranından dijital olarak kaydedilmiştir. Her bir numune için deney süresi standart sapmanın 0,05 değerini tespit ettiği noktaya kadar işlem sürdürülmüştür. Yalıtım malzemelerinin ısı geçirgenlik katsayısı tespit cihazı Linseis HFM 300 ile yapılmıştır (LINSEIS, 2025).



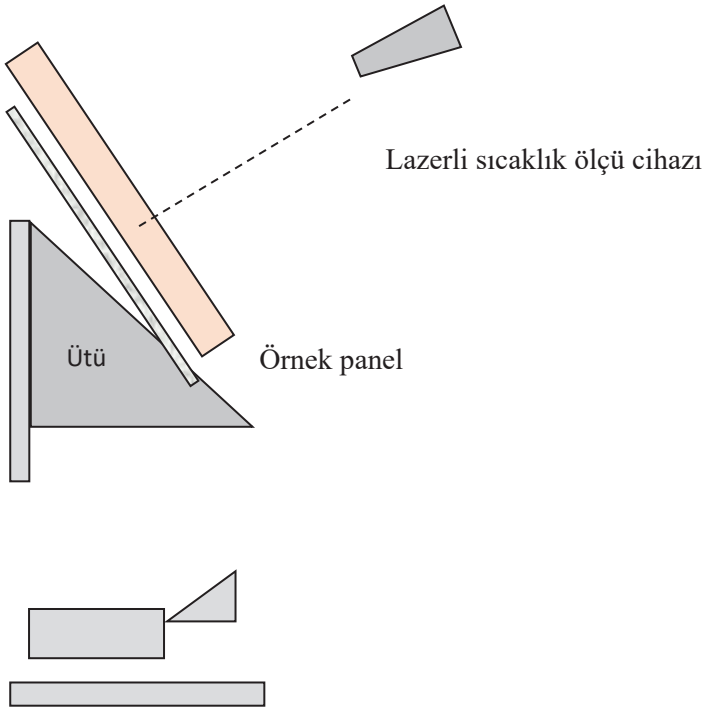
Şekil 5. Isı geçirgenlik deney düzeneği

Sıcaklık Aktarma (^{0}C)

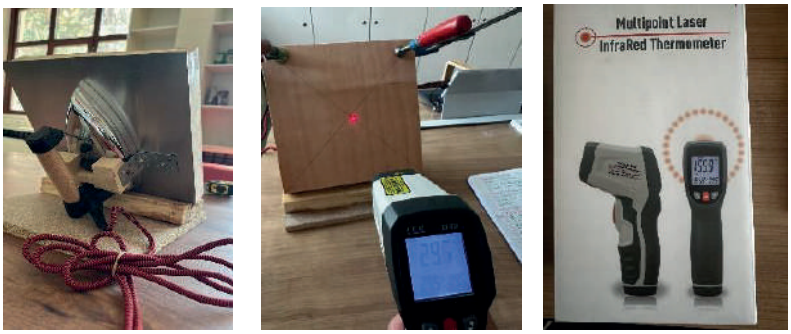
İklimlendirilme işlemi yapılmış, 4,2 x 29,5 x 29,5 cm boyutlarında ASP, CP, SP panel çeşidi, TS EN 12667 (TSE, 2025) esasları doğrultusunda, sıcaklık aktarma kabiliyeti belirlenmek üzere deney örnekleri hazırlanmıştır. 29,5x29,5 cm boyutlarındaki alüminyum levha ütünün tabanına monte edildi. Daha sonra deney örneği bu düzeneğe işkence ile tutturuldu. Deney örneklerin kalınlığı 4,2 cm olduğundan, her bir numune bir defada, başlangıçta ütünün sıcaklığının maksimum 55.5ºC çıkıp, min. 48 ºC düştüğü süre olan 8. dakikada ölçüm yapılmıştır. Sonra ise 5 er dakika (ütü rezidansının ısınma ve soğuma süresi) aralıklar ile ölçüm gerçekleştirilmiştir. Her ölçüm eşit mesafede cihazı tutarak 6

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defa tekrarlanmıştır. Sıcak ütünün ürettiği kuru sıcaklık her beş dakikalık aşamada karşı yüzeye ne kadar transfer olduğu (aktarıldığı) belirlenmiştir. Ölçümler Infrared Thermometer Multipoint Laser cihazı ile yapılmıştır. Ölçüm yaparken uzaklık arttıkça (D), ölçüldüğü alan (S) artar (PCE Instruments, 2025).



Şekil 6. Sıcalık aktarma düzeneği



Şekil 7. Sıcaklık aktarma deneyi

Veri analizi

Elde edilen verilerin istatistiksel analizinde SPSS 22 for Windows programı kullanılmıştır. ASP panelinin CP ve SP panel ile arasındaki bazı fiziksel özelliklerinin karşılaştırılarak, farkın belirlenmesinde F testi kullanılmıştır. Gruplar arasındaki farklılığın önemli çıkması halinde ($\alpha = 0.05$) güven düzeyinde DUNCAN testi ile karşılaştırılmıştır.

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ISBN: 978-9952-610-30-7

BULGULAR

Fiziksel Özellikler

Hava Kurusu Yoğunluk

Deneylerde kullanılan numunelerin hava kurusu yoğunluk ortalamalarına ait istatistik değerler Tablo.1'de, hava kurusu yoğunluk değerleri varyans analizi (ANOVA) sonuçları Tablo 2'de verilmiştir.

Tablo 1. Hava kurusu yoğunluk ortalamalarına ait istatistik değerler

İSTATİSTİK DEĞERLER	ASP	CP	SP
x	0,419	0,344	0,329
Ss	0,00836	0,01013	0,006838
v	7,8E-05	0,00011	5,2E-05
min	0,406	0,332	0,318
max	0,431	0,358	0,34
N	10	10	10

X: Aritmetik ortalama, v: Varyans, Ss: Standart sapma, N: Örnek sayısı

Tablo 2. Hava kurusu yoğunluk değerleri varyans analizi (ANOVA) sonuçları

Varyans Kaynağı	Kareler Toplamı	Serbestlik Derecesi	Kareler Ortalaması	F Değeri	Sig.
Gruplar arası	0,046	2	0,023	277,289	0,000
Grup içi	0,002	27	0,000		
TOPLAM	0,048	29			

*P< 0,05

Panel çeşitlerinin hava kurusu yoğunluk değerleri için yapılan F testine göre; hava kurusu yoğunluk değerleri panel çeşitlerine göre istatiksel anlamda önemli farklılık göstermiştir ($F_{2;27}$ = 277,289, (P>0,05). Bununla ilgili olarak yapılan DUNCAN testi sonuçlarına göre tablo 3'de verildiği üzere en yüksek hava kurusu yoğunluk değeri Ayçiçek sapı+Kabatalaş (ASP : 0,419 g/cm^3) dolgulu panelde bulunmuştur. En düşük hava kurusu yoğunluk değeri ise strafor (SP : 330 g/cm^3) dolgulu panelde elde edilmiştir (Tablo 3).

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Tablo 3. Hava kurusu yoğunluk değerleri (DUNCAN) testi sonuçları

GRUPLAR	N	Alt gruplar için α = 0,05		
		1	2	3
SP	10	0,330		
CP	10		0,344	
ASP	10			0,419
SIGNIFICANT		1,000	1,000	1,000

Rutubet Miktarı

Deneylerde kullanılan örneklerin rutubet miktarı ortalamalarına ait istatistik değerler Tablo 4'de, rutubet miktarı değerleri varyans analizi (ANOVA) sonuçları Tablo 5'de verilmiştir.

Tablo 4. Rutubet miktarı ortalamalarına ait istatistik değerler

İSTATİSTİK DEĞERLER	ASP	CP	SP
x	10,318	9,303	10,431
Ss	4,63054	2,69729	3,23838
v	23,8243	8,08373	11,6523
min	3,78	3,74	3,03
max	16,5	13,07	14,1
N	10	10	10

X: Aritmetik ortalama, v: Varyans, Ss: Standart sapma, N: Örnek sayısı

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Tablo 5. Rutubet miktarı değerleri varyans analizi (ANOVA) sonuçları

Varyans Kaynağı	Kareler Toplamı	Serbestlik Derecesi	Kareler Ortalaması	F Değeri	Sig.
Gruplar arası	7,718	2	3,859	0,266	0,769
Grup içi	392,044	27	14,520		
TOPLAM	399,762	29			

*P< 0,05

Panel çeşitlerinin rutubet miktarı yoğunluk değerleri için yapılan F testine göre; hava kurusu yoğunluk değerleri panel çeşitlerine göre istatiksel anlamda önemli farklılık göstermiştir ($F_{2;27}$ = 0,266 P>0,05). Bununla ilgili olarak yapılan DUNCAN testi sonuçlarına göre, Tablo 6'da görüldüğü üzere rutubet miktarı değeri matematiksel olarak görülen fark, istatistiksel olarak anlamlı bulunmamıştır.

Tablo 6. Rutubet miktarı değerleri (DUNCAN) testi sonuçları

GRUPLAR	N	Alt gruplar için α = 0,05
		1
CP	10	9,3030
ASP	10	10,3180
SP	10	10,4310
SIGNIFICANT		0,539

Isı Geçirgenlik Katsayısı (U Değeri)

Deneylerde kullanılan numunelerin ısı geçirgenlik katsayısı (U Değeri) ortalamalarına ait istatistik değerler Tablo 7.'de, ısı geçirgenlik katsayısı (U Değeri) ortalamalarına ait varyans analizi Tablo 8'de verilmiştir.

Tablo 7. Isı geçirgenlik katsayısı (U Değeri) ortalamalarına ait istatistik değerler

ASP U-VALUE w/m²K		CP U-VALUE w/m²K		SP U-VALUE w/m²K	
x	1,7772	x	1,3822	x	1,4198

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Ss	0,047294	Ss	0,04653	Ss	0,095491
v	0,002485	v	0,00241	v	0,010132
min	1,681	min	1,277	min	1,367
max	1,846	max	1,434	max	1,703
N	10	N	10	N	10

Tablo 8. Isı geçirgenlik katsayısı (U Değeri) ortalamalarına ait varyans analizi

Varyans kaynağı	Kareler toplamı	Serbestlik derecesi	Kareler ortalaması	F değeri	Sig.
Gruplar arası	0,951	2	0,475	94,915*	0,000
Grup içi	0,135	27	0,005		
TOPLAM	1,086	29			

*P< 0,05

Panel çeşitlerinin ısı geçirgenlik katsayısı (U Değeri) için yapılan F testine göre; ısı geçirgenlik katsayısı (U Değeri) panel çeşitlerine göre istatiksel anlamda önemli farklılık göstermiştir ($F_{2;27}$ = 94,915, P>0,05). Bununla ilgili olarak yapılan DUNCAN testi sonuçlarına göre (Tablo 9); en yüksek ısı geçirgenlik katsayısı (U Değeri) Ayçiçek sapı+Kabatalaş (ASP) dolgulu panelde bulunmuştur. En düşük ısı geçirgenlik katsayısı (U Değeri) ise camyünü (CP) ve strafor (SP) dolgulu panelde elde edilmiştir. CP ve SP arasındaki matematiksel fark, istatistiksel fark olarak anlamlı bulunmamıştır.

Tablo 9. Isı geçirgenlik katsayısı (U Değeri) değerleri (DUNCAN) testi

GRUPLAR	N	Alt gruplar için α = 0,05	
		1	2
CP	10	1,3822	
SP	10	1,4198	
ASP	10		1,7772
SIGNIFICANT		0,245	1,000

Sıcaklık aktarma

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Deneylerde kullanılan numunelerin sıcaklık aktarma belirleme ortalamalarına ait istatistik değerler Tablo 10 'da verilmiştir.

Tablo 10. Sıcaklık aktarma değeri ortalamalarına ait istatistik değerler

Sıcaklık Aktarma ºC			
	ASP	CP	SP
x	28,316	36,942	38,354
Ss	1,617233	1,743977	2,946446
v	2,906049	3,379396	9,64616
min	26,23	33,15	32,13
max	31,65	40,56	42,21
N	10	10	10

X: Aritmetik ortalama, v: Varyans, Ss: Standart sapma, N: Örnek sayısı

Tablo 11. Sıcaklık aktarma değerleri varyans analizi (ANOVA) sonuçları

Varyans Kaynağı	Kareler Toplamı	Serbestlik Derecesi	Kareler Ortalaması	F Değeri	Sig.
Gruplar arası	590,544	2	295,272	55,601	0,000
Grup içi	143,384	27	5,311		
TOPLAM	733,928	29			

*P< 0,05

Panel çeşitlerinin sıcaklık aktarma değerleri için yapılan F testine göre; sıcaklık aktarma değerleri panel çeşitlerine göre istatiksel anlamda önemli farklılık göstermiştir (F (2;27) = 55,6 P>0,05). Bununla ilgili olarak yapılan DUNCAN testi sonuçlarına göre (Tablo 12); en yüksek sıcaklık aktarma belirleme değeri SP ve CP dolgulu panelde bulunmuştur. En düşük sıcaklık aktarma belirleme değeri ise ASP dolgulu panelde elde edilmiştir. CP ve SP arasındaki matematiksel fark, istatistiksel fark olarak anlamlı bulunmamıştır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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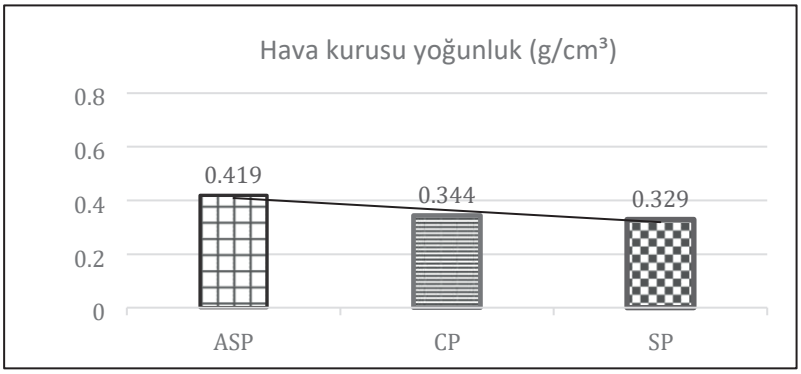
Tablo 12. Sıcaklık aktarma değerleri (DUNCAN) testi sonuçları

GRUPLAR	N	Alt gruplar için α = 0,05	
		1	2
ASP	10	28,3160	
CP	10		36,9420
SP	10		38,3540
SIGNIFICANT		1,000	0,182

TARTIŞMA

Hava kurusu yoğunluk

Panel çeşitlerine göre en yüksek hava kurusu yoğunluk değeri ASP (0,419 g/cm^3) elde edilmiş, bunu sırasıyla CP (0,344 g/cm^3), SP (0,329 g/cm^3) izlemiştir (Şekil 6).



Şekil 6. Hava kurusu yoğunluk değerleri grafiği

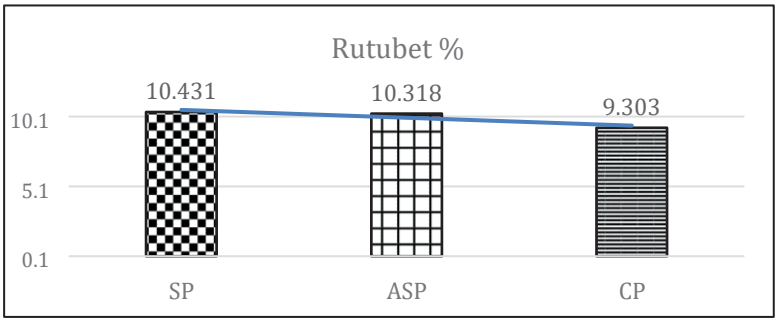
Yapılan araştırmada hava kurusu yoğunluk değerleri ASP panelde 0,419 g/cm^3, CP panelde 0,344, SP g/cm^3 panelde ise 0,329 g/cm^3 bulunmuştur. İstatistiksel anlamda en yüksek hava kurusu yoğunluk değeri ASP de elde edilmiştir. Bu durum ASP panel üretiminde kullanılan ayçiçek sapı ve kaba talaşın UF reçinesi ile karıştırılması ile yoğun bir katman oluşturmasından kaynaklanabilir. Bu da doğal lifli malzemelerin bağlayıcı eklenerek sıcak pres uygulaması ile kompakt bir yapının oluşmasına ve bağlayıcı oranı arttıkça yoğunluğu artırdığı söylenebilir. Araştırmalarda ayçiçek sapının farklı yoğunluklarda çıkmasının nedeni, çeşitli kombinasyonlarda üretim şeklinin değişikliğinden kaynaklanmaktadır. Ayçiçeğinin parçalanarak, tüm sap olarak, yalnız ya da başka lifli malzemeyle birlikte kullanımından, bağlayıcının oranları ile farklılığından kaynaklanabilir. Çalışmamızda ise

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ahşap çerçeve içi ayçiçek sapı ve kaba talaş dolgulu, dış yüzü kontrplak kaplı rijit (sert, esnek olmayan) bir ürün geliştirildi. Çalışmanın benzeri literatürde yer almamaktadır. CP ile SP panelin değerlerinin yakın bulunması ise her ikisinin de standarda göre üretimi mevcut olduğundan ayrıca sentetik içerikli bu yalıtım malzemelerinin yoğunlukları da benzer sonuçlar vermiştir.

Rutubet miktarı

Panel çeşitlerine göre en yüksek rutubet miktarı değeri SP (%10,431) elde edilmiş, bunu sırasıyla ASP (%10,318), CP (% 9,303) izlemiştir (Şekil 7).

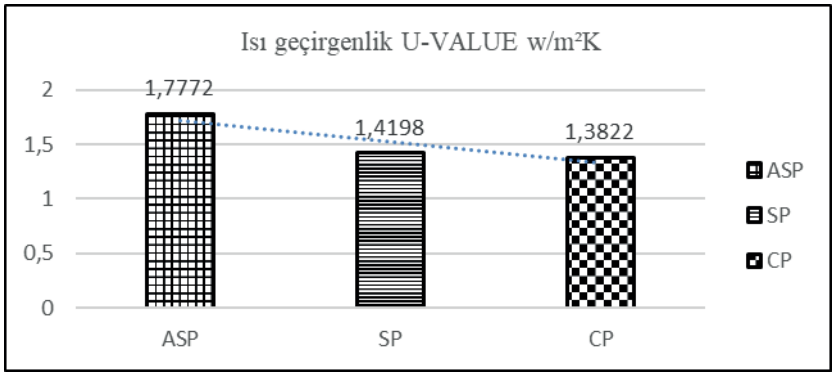


Şekil 7. Rutubet miktarı belirleme değerleri grafiği

Ayçiçek saplı panelin (ASP) rutubet miktarı SP panelden %0,96 daha düşük, CP panelden ise %10,75 oranında daha yüksek tespit edilmiştir. Paneller arasında matematiksel olarak fark olsa da istatistiksel olarak benzer bulunmuştur. CP ve SP panel, kullanımı olan yalıtım malzemeleri ve rutubet standardına göre üretimi yapıldığından sonuçlar anlamca yakın değerdedir. Straforun sentetik gözenekli yapısı ile cam yününün lifli yapısı nemi dengede tutmaktadır. ASP panelin ise higroskopik, gözenekli ve lifli yapısı, sentetik içerikli malzemelere göre artı bir özelliğe sahip olduğu söylenebilir. Doğal lifli malzeme ile bağlayıcının miktarının yoğunluğu, rutubeti etkilediği söylenebilir. ASP panelin yumuşak gözenekli iç yapısı ve lifli kabuğu nem alımı ile salınımını dengede tutmakta olabilir.

Isı geçirgenlik katsayısı

Panel çeşitlerine göre en yüksek ısı geçirgenlik katsayısı (U Değeri) değeri ASP (1,7772 w/m²K) elde edilmiş, bunu sırasıyla SP (1,4198 w/m²K), CP (1,3822 w/m²K) izlemiştir (Şekil 8).



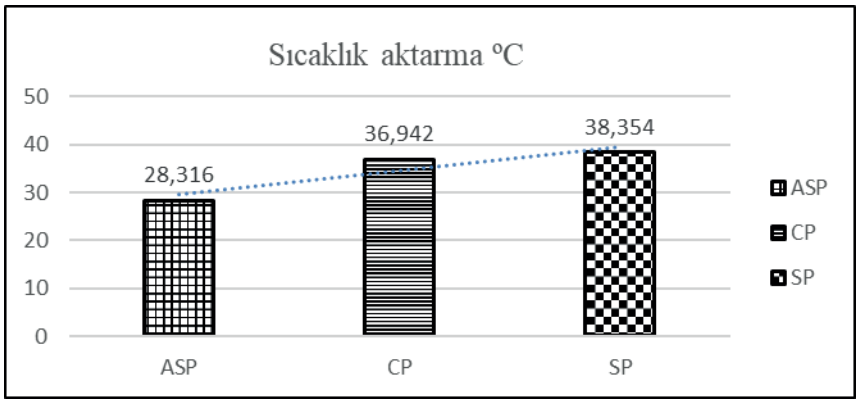
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ISBN: 978-9952-610-30-7

Şekil 8. Isı geçirgenlik katsayısı (U Değeri) grafiği

Isı geçirgenlik katsayısı (U Değeri) ASP panel %38,81, SP panel %31, CP panel %30,1 oranında bulunmuştur. Isı geçirgenlik katsayısı (U Değeri) en yüksek olan ASP panel, SP panelden %25,17, CP panelden %28,57 oranında daha yüksektir. Bu durum ASP panel içerisinde kullanılan dolgu maddelerinin higroskopik yapılarından kaynaklanabilir.

Sıcaklık Aktarma

Panel çeşitlerine göre en düşük Sıcaklık aktarma değeri ASP (28,316 ºC) elde edilmiş, bunu sırasıyla CP (36,942 ºC), SP (38,354 ºC) izlemiştir (Şekil 9).



Şekil 9. Sıcaklık aktarma grafiği

Sıcaklık aktarma oranı SP panelde %27,32, CP panelde %35,65, SP panelde %36,82 oranında bulunmuştur. ASP panel, CP panelden %23,35 oranında, SP panelden %26,17 oranında sıcaklığı bir yüzeyden diğer bir yüzeye azalarak aktardığını göstermektedir. Bu durum yalıtım özelliği olan malzemelerde beklenen performans özelliğinden kaynaklanabilir.

SONUÇ VE ÖNERİLER

Bu çalışmanın en etkili sonucu zirai atık olan ayçiçek sapının, günümüzde yaygın kullanılan camyünü ve strafor gibi malzemelere ısı yalıtımı açısından hem alternatif hem de doğal içerikli bir malzeme olma özelliği taşımasıdır.

Bu çalışmadan elde edilen sonuçlar ve öneriler şunlardır;

✓ ASP (ayçiçeği sapı + kaba odun talaşı) panel 0,419 g/cm^3 ile karşılaştırılan CP, SP'ye göre daha yüksek yoğunluk değerinde sahip olması nedeniyle üretilen panelin dayanıklı ve rijit bir yapıda olduğunu göstermektedir.

✓ ASP panel %10,32 rutubet miktarı oranı ile yapılarda boyutsal kararlılık açısından uygunluğu ve içeriğinde ise dengeli bir rutubete sahiptir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

✓ ASP panelin ısı geçirgenlik geçirgenlik katsayısı (U Değeri), 1,7772w/m²K seviyesi ile kabul edilebilir yalıtım performansı gösterdiği, yalıtım malzemesi kategorisinde kullanılabilecek özelliklere sahip olduğu belirlenmiştir.

✓ Konutlarda, ısı yalıtımlı iç bölme duvarı, açık ofis bölme duvarı, suya maruz kalmayan iç tavan kaplaması olarak kullanılması önerilebilir.

✓ Alçıpan, cam yünü ve strafor gibi doğada dönüşümü zor olan / olmayan yalıtım malzemelerine göre avantaj sağlayabilir.

✓ ASP panelin, biyotik faktörler (bitkisel (mantar) ve hayvansal (mikroorganizmalar, böcek, kurt, termit)), abiyotik faktörler (yangın, rutubet), kimyasal faktörler (asit, tuz, baz) ve mekanik faktörler; kırılma, yarılma, basınç, makaslama, sürtünme, aşınma ve uzun süreli kullanımlar için yaşlandırma testleri ile panelin performans özellikleri araştırılmalıdır.

TEŞEKKÜR

Bu makale, G.Ü. Fen Bilimleri Enstitüsü Ağaçişleri Endüstri Mühendisliği Anabilim Dalında hazırlanan “Farklı Malzemelerden Çok Amaçlı Yalıtım Paneli Geliştirme ve Bazı Fiziksel Özelliklerin Karşılaştırmalı Araştırılması” adlı Yüksek Lisans tezinden üretilmiştir. Aynı zamanda bu araştırma 10034 ID numaralı FYL-2025-10034 kodu ile G.Ü. Bilimsel Araştırma Projeleri Koordinasyon Birimi tarafından desteklenmiştir.

KAYNAKLAR

Binici H., Aksoğan O., Dinçer A., Erion L., Eken M., Isikaltun Ö., "The Possibility of Vermiculite, Sunflower Stalk and Wheat Stalk Using for Thermal İnsulation Material Production, Thermal Science and Engineering", Progress 18, 100567, 2020., Doi.org/10.1016/j.tsep.2020.100567

Güler C., Bektas İ., Kalaycıoglu H., "The Experimental Particleboard Manufacture from Sunflower Stalks (*Helianthus Annuus* L.) and Calabrian Pine (*Pinus Brutiaten*), Forest Prod. J., 56, 56-60, 2006.

Infrared Thermometer PCE-ILD 10, PCE Instruments UK Ltd., Suite 1N-B, Trafford House, Chester Rd, Manchester M32 0RS, United Kingdom, 2025.

Klebt D 3400-D3/D4 ahşap tutkalı-Holzkaltleimi.Jpg. Erba Grup Medikal Pazarlama İç ve Dış Ticaret Limited Şirketi, Ankara, 2020.

LINSEIS HFM 300/3, Yalıtım Malzemelerinin Isı İletim Katsayısını Tespit Cihazı, Messgeraete GmbH, Vielitzerstr. 4395100 Selb / Germany, 2025.

Massoudinejad M., Amanidaz N., Santos R.M., Bakhshoodeh R., “Use of Municipal, Agricultural, Industrial, Construction and Demolition Waste in Thermal and Sound Building Insulation Materials: A Review Article”, J. Environ. Health Sci. Eng., 17 (2), 1227-1242, 2019, Doi: 10.1007/s40201-019-00380-z.

Mathias J.D., Alzina A., Grédiac M., Michaud P., Roux P., De Baynast H., Delattre C., Dumoulin N., Faure T., Larrey-Lassalle P., Mati-Baouche N., Pennec F., Sun S., Tessier-Doyen N., Toussaint E., Wei W., "Upcycling Sunflower Stems as Natural Fibers for Biocomposite Applications". Bioresources, 10(4), 8076-8088. 2015, Doi: 10.15376/biores.10.4.8076-8088.

Mati-Baouche N., Baynast H.D., André L., Shengnan S. , Leclaire C.J.S.L.M., Michaud P. , “Mechanical, Thermal and Acoustica Racterizations of An Insulating Bio-Based Composite Made From Sunflower Stalks Particles and Chitosan”, Industrial Crops and Products, 58 (244-250), 2014, Doi: 10.1016 / j.indcrop.2014.04.022

Olcay H., "Selülozik Tarımsal Atıklardan Elde Edilen Lifler ve Poliüretan Köpük ile Oluşturulan Biyo-Bazlı Kompozitlerin Mekanik, Ses Yutum, Termal ve Morfolojik Özelliklerinin İncelenmesi", Doktora tezi, Marmara Üniversitesi, İstanbul, Türkiye, 2021.

POLISAN Kimya Sanayi A.Ş., Üre Formaldehit Reçineleri (POLIUREA 7455), Taşdelen Cad. Bilgin Sok. No: 8 Siteler – Ankara, 2020.

Ricciardi P., Belloni E., Merli F., Buratti C., "Sustainable Panels Made with Industrial and Agricultural Waste: Thermal and Environmental Critical Analysis of the Experimental Results ", Appl. Sci., 11, 494,2021, Doi.org/ 10.3390/app11020494.

W. Nimcharoen, C. Sakulkhaemaruethai, M. Khemkhao, "Bio-Based Composite from Sunflower Stalks for Building Wall Panels", Journal of Renewable Energy and Smart Grid Technology", 20 (45-53), 2025, Doi: 10.69650/rast.2025.260769.

TS EN 322, Ahşap Esaslı Levhalar - Rutubet Miktarının Tayini, Türk Standatları Enstitüsü, Ankara, 1999

TS EN 12667, Yapı Malzemelerinin ve Ürünlerinin Isıl Performansı - Korumalı Sıcak Plaka ve Isı Akış Ölçer Yöntemleri ile Isıl Direnç Tayini, Türk Standatları Enstitüsü, Ankara, 2025.

TS ISO 13061, Physical and mechanical properties of wood — Test methods for small clear wood specimens — Part 2: Determination of density for physical and mechanical tests, Türk Standatları Enstitüsü, Ankara, 2025.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

METALLIC–PARACONTACT CORRESPONDENCE VIA ALMOST PRODUCT STRUCTURES

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A transformation chain can be used to describe how one passes from a metallic structure to an almost product structure, then to an almost paracontact structure, and how this construction can be reversed to recover the original structural information A metallic structure is defined by a tensor field satisfying a prescribed polynomial relation; after a suitable normalization, one obtains an almost product structure whose square is the identity and which therefore splits the tangent bundle into two eigendistributions. In odd dimensions, by choosing a Reeb-type vector field together with its dual 1-form, and requiring that the associated distribution (in particular, the kernel of the 1-form) is preserved by the almost product operator, the almost product structure naturally induces an almost paracontact structure.

Conversely, starting from almost paracontact structure, one can reconstruct an almost product structure by an appropriate “completion” procedure, and then recover the metallic tensor by reversing the normalization step. In this way, a two-way bridge is established between metallic geometry and (para)contact geometry: on one side, the algebraic decomposition determined by the metallic operator; on the other, the structure encoded by the triple (φ,ξ,η) through a distinguished one-dimensional direction and its complementary distribution. This reversible mechanism provides a convenient framework for systematically investigating which additional conditions ensure that differential properties—such as integrability and curvature features—are preserved under these transformations.

Keywords: metallic semi-Riemannian structure; almost paracontact metric structure; Levi-Civita connection; integrability; curvature.

References

Solgun, M., & Karababa, Y. (2025). Constructing a metallic semi-Riemannian manifold from an almost paracontact metric manifold. AIMS Mathematics, 10(10), 23639–23651. https://doi.org/10.3934/math.20251050

de Spinadel, V. W. (1999). The family of metallic means. Vis. Math., 1, 1–16.

Hretcanu, C. E., & Crasmareanu, M. (2013). Metallic structures on Riemannian manifolds. Rev. Un. Mat. Argentina, 54, 15–27.

Blaga, A. M., & Nannicini, A. (2020). On the geometry of metallic pseudo-Riemannian structures. Rivista di Matematica della Universita di Parma, 11, 69–87.

Kaneyuki, S., & Williams, F. L. (1985). Almost paracontact and parahodge structures on manifolds. Nagoya Mathematical Journal, 99, 173–187. doi:10.1017/S0027763000021565.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A GEODESIC FOUR-STEP ITERATIVE SCHEME FOR MULTIVALUED GENERALIZED A-NONEXPANSIVE MAPPINGS IN CAT(0) SPACES

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ABSTRACT

In this work, we extend a four-step projection-based iterative scheme, previously developed in uniformly convex Banach spaces, to the more general geometric setting of CAT(0) spaces for approximating fixed points of multivalued generalized α-nonexpansive mappings. Let (X,d) be a complete CAT(0) space and K ⊂ X be nonempty, closed, and geodesically convex. For a multivalued mapping T: K → CB(K) with a nonempty fixed point set, we reformulate the original algorithm in a purely metric framework by replacing linear convex combinations with geodesic convex combinations and employing metric projections onto closed convex subsets.

The absence of linear structure requires a new convergence analysis based on the convexity of the squared distance function and characteristic inequalities of CAT(0) geometry. We establish a Fejér-type monotonicity of the generated sequence with respect to the fixed point set and prove that, for every fixed point q, the distance $d(x_n, q)$ converges. Moreover, the residual $d\left(x_n, P_T(x_n)\right)$ tends to zero, which guarantees asymptotic regularity of the iterative process.

These results show that the proposed iteration scheme is not limited to Banach space geometry and remains effective in nonpositively curved metric spaces. The study provides a natural geometric generalization of projection-based fixed point algorithms and contributes to the theory of multivalued generalized α-nonexpansive mappings in CAT(0) spaces.

Keywords: CAT(0) spaces, multivalued mappings, generalized α-nonexpansive mappings, fixed point, geodesic convexity

References

Bridson, M. R., & Haefliger, A. (2013). *Metric spaces of non-positive curvature* (Vol. 319). Springer Science & Business Media

Goebel, K., & Reich, S. (1984). Uniform convexity, hyperbolic geometry, and non-expansive mappings. New York (1984)

Özekes, M. K. (2026). A new four-step iteration scheme for generalized α-nonexpansive multivalued mappings in Banach spaces. *Journal of Inequalities and Applications*, *2026*(1), 11.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Kirk, W. A., & Panyanak, B. (2008). A concept of convergence in geodesic spaces. *Nonlinear analysis: theory, methods & applications*, *68*(12), 3689-3696.

Nadler Jr, S. B. (2006, August). Some results on multi-valued contraction mappings. In *Set-Valued Mappings, Selections and Topological Properties of 2x: Proceedings of the conference held at the State University of New York at Buffalo May 8–10, 1969* (pp. 64-69). Berlin, Heidelberg: Springer Berlin Heidelberg.

Sadhu, R., Majee, P., & Nahak, C. (2021). Fixed point theorems on generalized α-nonexpansive multivalued mappings. *The Journal of Analysis*, *29*(4), 1165-1190.

Sahu, D. R., & Petruşel, A. (2011). Strong convergence of iterative methods by strictly pseudocontractive mappings in Banach spaces. *Nonlinear Analysis: Theory, Methods & Applications*, *74*(17), 6012-6023.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CROSS-PLATFORM FRAMEWORKS AND MOBILE ACCESSIBILITY: A COMPARATIVE ANALYSIS OF TOUCH TARGET COMPLIANCE IN NATIVE, REACT NATIVE, AND FLUTTER ANDROID APPLICATIONS

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ABSTRACT

The mobile development landscape has shifted significantly towards cross-platform frameworks like React Native and Flutter, which promise efficiency but obscure platform-specific UI rendering. While performance benchmarks exist, the impact of these abstractions on accessibility—specifically for users with motor impairments—remains under-researched. Existing literature focuses largely on web accessibility or general mobile guidelines, lacking empirical comparisons of how different mobile rendering engines inherently influence accessibility compliance. To address this gap, we conducted an automated audit of 304 Android applications (179 Native, 72 React Native, 53 Flutter). We utilized a custom pipeline combining static binary analysis for framework detection and automated UI crawling to measure Touch Target Size compliance against the 48x48dp Android standard. Our results reveal that React Native applications exhibited a violation rate of 4.80%, significantly higher than the Native control group (2.35%), whereas Flutter demonstrated exceptional adherence with a 0.29% violation rate. These findings suggest that framework architecture dictates accessibility defaults: React Native's unopinionated styling engine correlates with higher non-compliance, while Flutter's widget system enforces accessibility by design.

Keywords: Mobile Accessibility, Cross-Platform Frameworks, Touch Target Compliance, React Native, Flutter, Automated Auditing.

1. INTRODUCTION

Mobile accessibility is a fundamental requirement for ensuring digital inclusion for over 1.3 billion people with disabilities globally (WHO, 2024). Among the various accessibility metrics, "Touch Target Size" is particularly critical for users with motor impairments and the aging population; targets that are too small often result in "erroneous inputs," causing frustration and effectively blocking access

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

to essential digital services (Mobasheri et al., 2015; Amouzadeh et al., 2025). To accommodate human physiology, both the Web Content Accessibility Guidelines (WCAG) and Android Accessibility Standards mandate minimum dimensions for interactive elements. Android specifically recommends a minimum size of 48x48 density-independent pixels (dp), roughly equating to 9mm, the average size of a human fingertip (Google, 2025; Serra et al., 2015).

Traditionally, native Android development using Java or Kotlin utilizes standard View components that adhere to these defaults automatically (Android Developers, 2024). However, the mobile software industry has shifted significantly towards "Cross-Platform" frameworks—tools that allow developers to write code once and deploy it to both iOS and Android—introducing new layers of architectural abstraction. The two dominant frameworks, React Native (Meta) and Flutter (Google), employ fundamentally different rendering engines. React Native uses a JavaScript bridge and the "Yoga" layout engine to map web-like Flexbox styles to native UI views (Meta, 2024; Hansson et al., 2016). In contrast, Flutter utilizes a proprietary graphics engine (Skia or Impeller) to draw pixels directly to the screen, bypassing standard native views entirely and reconstructing a "Semantics Tree" for accessibility services (Google, 2024; Wu, 2018).

Despite the widespread adoption of these frameworks, there is a significant gap in empirical research regarding their impact on end-user accessibility. While extensive benchmarks exist regarding performance (Willocx et al., 2021) and general implementation challenges (Perinello & Gaggi, 2024), it remains unclear whether the efficiency of the "Write Once, Run Anywhere" philosophy comes at the cost of accessibility compliance (Vendome et al., 2019). Most existing literature relies on large-scale automated crawling for general issues (Chen et al., 2021) or qualitative surveys (El-Glaly et al., 2020), lacking specific, quantitative comparisons of how framework architecture correlates with touch target failures in production apps. This study aims to fill this gap by quantitatively measuring touch target violations across Native, React Native, and Flutter applications.

2. METHODS

2.1. Study Design

We employed a cross-sectional, observational study design. We developed an automated auditing pipeline to analyze third-party Android applications available on the Google Play Store.

- **Inclusion Criteria:** To construct a representative dataset, we adopted a stratified sampling strategy. We first selected applications from the overall "Top Charts" to serve as a high-quality control group (predominantly Native). To ensure sufficient representation of cross-platform frameworks, we additionally targeted specific sectors known for high adoption of React Native and Flutter using the search keywords "Crypto," "Smart Home," and "Journal."

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

- **Exclusion Criteria:** System apps, Games (which use non-standard rendering), and high-security applications (Banking/VPN) that utilize anti-tamper mechanisms blocking automated analysis tools (Linares-Vásquez et al., 2017).

2.2. Framework Detection (Static Analysis)

To ensure accurate classification, we utilized Static Binary Analysis on the application installation files (APKs) (Khatib et al., 2019). We decompressed the application packages and scanned for specific "fingerprint" libraries:

- **Flutter:** Identified by libflutter.so.
- **React Native:** Identified by libreactnativejni.so or libhermes.so.
- **Native:** Defined as applications lacking these specific cross-platform signatures (Android Developers, 2024).

2.3. Automated Data Collection

We utilized the Appium automation framework (Appium, 2024) connected to a virtual Google Pixel 7 Pro (Android 14). The procedure for each app was:

1. **Launch:** Open the application and wait 7 seconds for initialization.
2. **UI Capture:** Capture the active window hierarchy as an XML file.
3. **Measurement:** Parse the file to identify all elements marked as "clickable."
4. **Calculation:** Extract the dimensions of each element. Convert pixels to density-independent pixels (dp) and flag any element smaller than 48x48dp (Google, 2025).

2.4. Statistical Analysis

The primary outcome measure was the Error Rate (percentage of interactive elements violating the 48dp threshold). We compared the violation rates between groups using Fisher's Exact Test, as it is robust for analyzing categorical data (Violation/No Violation) with unbalanced sample sizes and low expected frequencies in the compliant groups. A p-value of <0.05 was considered statistically significant.

3. RESULTS

3.1. Technology Stack Composition

Our automated crawler successfully audited 304 unique applications.

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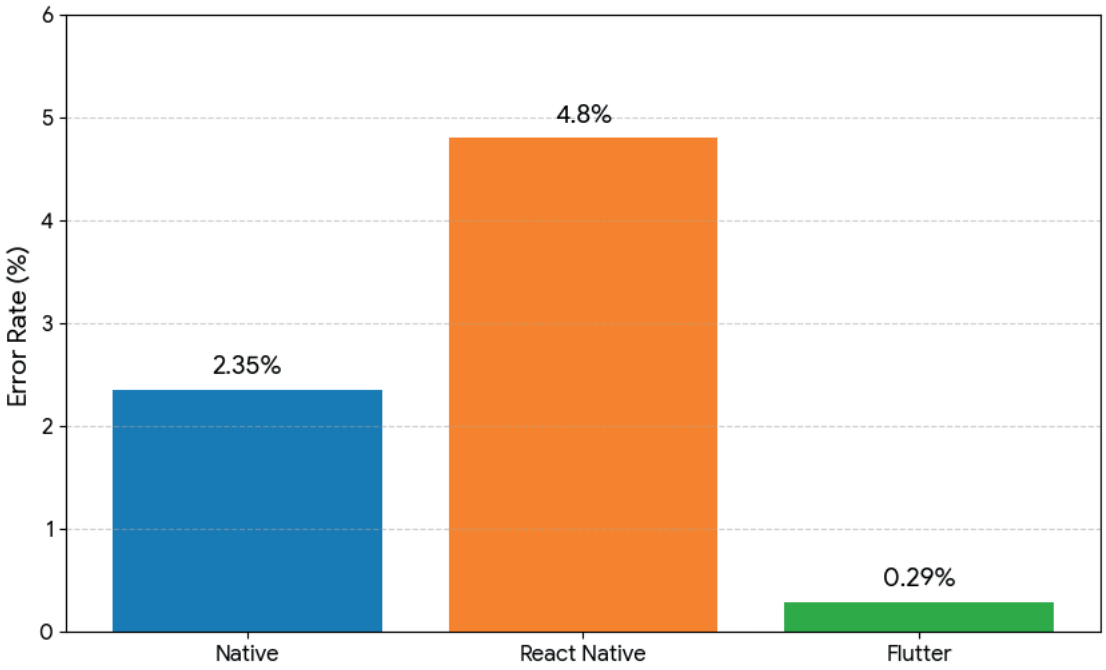


Figure 1. Distribution of Technology Stacks in Dataset (N=304)

As illustrated in Figure 1, the dataset is predominantly composed of Native applications (58.9%), which serve as the study's control group. However, cross-platform frameworks represent a substantial portion of the sample (41.1%), with React Native (23.7%) holding a larger share than Flutter (17.4%). This distribution aligns with broader market trends where legacy applications remain Native while newer entrants increasingly adopt cross-platform solutions.

3.2. Comparative Error Rates

The analysis of 1,290 interactive elements revealed a distinct performance gap between the frameworks, as detailed in Table 1.

Table 1. Accessibility Violation Rates by Technology Stack

Technology	Apps (N)	Total Elements	Violations (<48dp)	Error Rate (%)
Native	179	680	16	2.35%
React Native	72	271	13	4.80%
Flutter	53	339	1	0.29%

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ISBN: 978-9952-610-30-7

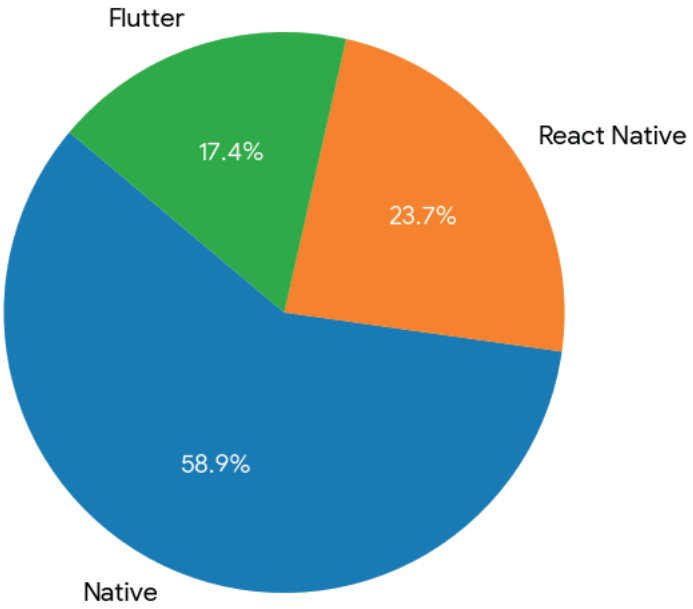


Figure 2. Accessibility Violation Rates by Framework (Touch Target < 48dp)

As illustrated in Figure 2, the disparity in compliance is stark. Fisher's Exact Test revealed a statistically significant difference in error rates across the three groups ($p = 0.001$).

React Native applications exhibited a violation rate of 4.80%, which was more than double that of the Native control group (2.35%). This difference trended towards significance ($p = 0.059$), suggesting a strong practical tendency towards undersized elements in the React ecosystem, even if strictly marginal.

In contrast, Flutter demonstrated exceptional adherence to standards with a 0.29% error rate. This performance was statistically significantly superior to both the Native control group ($p = 0.017$) and React Native ($p < 0.001$).

4. DISCUSSION

4.1. Interpretation of Findings

The data reveals a stark contrast in accessibility compliance, which can be attributed to the divergent engineering philosophies of "Freedom" vs. "Safety" inherent in these frameworks.

Flutter's "Invisible Safety Net": The exceptional performance of Flutter (0.29% error rate) is driven by its opinionated widget architecture. Flutter separates the visual render tree from the semantics tree. When a developer utilizes a standard IconButton and sets the size to 24dp (visually small), the framework automatically wraps the component in an internal box that satisfies the 48x48dp requirement (Wu, 2018). The touch target is effectively decoupled from the visual size. This

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architecture validates Goli's (2023) observation that Flutter has superior integrated accessibility functions compared to its competitors.

Native's "What You See Is What You Get": The Native control group's moderate error rate (2.35%) reflects the rigid nature of Android XML layouts. If a developer declares a view as 24dp wide, the system renders it as exactly 24dp wide. There is no automatic padding injection. Compliance requires manual intervention (e.g., adding android:padding or using TouchDelegate), making it susceptible to human oversight, particularly in legacy codebases (Android Developers, 2024).

React Native's "Web Legacy": React Native exhibited the highest failure rate (4.80%) due to its reliance on the Yoga layout engine, which mimics CSS Flexbox (Meta, 2024). On the web, elements shrink to fit their content by default. A React Native TouchableOpacity wrapping a text label will shrink to the exact bounds of the text. Unlike Flutter, the framework is "unopinionated" and does not enforce minimum dimensions on interactive elements, placing the entire burden of compliance on the developer (El-Glaly et al., 2020; Perinello & Gaggi, 2024).

4.2. Comparison with Literature

Our findings quantitatively confirm the qualitative assessments found in recent literature. While Perinello & Gaggi (2024) noted that documentation gaps exist in both frameworks, our data suggests that Flutter's defaults provide a stronger safety net than React Native's flexible architecture. Additionally, the high error rate in React Native corroborates web accessibility studies where "div-based" clickable elements often fail standards (Acosta et al., 2021).

5. LIMITATIONS

While this study provides significant quantitative insights into the accessibility defaults of modern mobile frameworks, several limitations inherent to our automated methodology should be considered when interpreting the results. These constraints primarily stem from the trade-off between large-scale automated auditing and the depth of manual inspection.

- **Selection Bias (Security Apps):** Our data collection pipeline faced technical restrictions with high-security applications, such as banking, fintech, and enterprise VPNs. These applications frequently employ anti-tamper mechanisms that detect Appium automation or ADB connections, resulting in immediate termination (Linares-Vásquez et al., 2017). Consequently, our dataset is biased towards consumer-facing and lifestyle applications, potentially underrepresenting the compliance standards of highly regulated industries.

- **"First Screen" Analysis Depth:** To ensure consistent measurement conditions across hundreds of apps without manual authentication, our crawler was restricted to the "First Screen" (e.g., Login, Welcome, or Dashboard) immediately following launch. This approach, while standardized,

may not capture accessibility violations that accumulate in deeper, more complex internal workflows such as checkout processes or settings menus (Ross et al., 2018).

- **Hybrid Ambiguity:** We utilized a strict binary classification system based on static binary analysis. "Brownfield" applications—those that integrate a single React Native or Flutter screen within a predominantly Native codebase—were classified based on their primary core libraries (Khatib et al., 2019). This may overlook subtle hybrid implementation details where accessibility behaviors vary between screens.

- **Model Limitations:** Our experimental setup utilized a standard Google Pixel 7 Pro emulator (API 34). While emulators provide a stable and reproducible environment for automated testing, slight discrepancies in pixel density rendering or touch sensitivity compared to physical hardware could introduce minor measurement variances. However, since this environment was held constant across all three frameworks, the comparative validity of the error rates remains robust.

6. FUTURE WORK

This study establishes a baseline for comparing accessibility compliance across mobile frameworks, but the rapidly evolving nature of mobile development presents several avenues for deeper investigation. Future research should aim to expand the scope of automated auditing to cover more complex interaction patterns and additional accessibility services.

- **Deep Crawling & State Analysis:** Future studies should utilize AI-driven crawlers or reinforcement learning agents to navigate beyond initial login screens. Auditing internal application states—such as checkout flows, settings menus, and dynamic content feeds—would provide a more comprehensive assessment of real-world accessibility barriers (Mao et al., 2016).

- **Screen Reader Compatibility:** Beyond physical touch targets, future work should analyze the semantic quality of user interfaces for screen readers (e.g., TalkBack). This includes verifying that text labels are descriptive (e.g., ensuring a button is read as "Submit" rather than "Button 1") and that the traversal order of elements follows a logical flow (Ross et al., 2018).

- **iOS Ecosystem Comparison:** This study focused exclusively on Android. A comparative analysis of how React Native and Flutter map to Apple's UIAccessibility framework versus Android's AccessibilityNodeInfo would reveal critical cross-platform inconsistencies. Investigating whether the "write once" promise holds true for accessibility compliance across operating systems remains a vital next step (Vendome et al., 2019).

7. CONCLUSION

This study provides empirical evidence that the choice of mobile development framework significantly impacts accessibility compliance. React Native applications are prone to undersized touch targets due to the manual nature of its layout engine, requiring developer vigilance. Flutter applications,

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conversely, benefit from strong architectural defaults that enforce accessibility standards automatically via internal semantic padding. For organizations prioritizing inclusive design, our data suggests that Flutter offers a higher baseline of safety, while React Native teams must implement rigorous manual audits to match Native standards.

8. REFERENCES

Acosta, T., Acosta-Vargas, P., & Luján-Mora, S. (2021). Accessibility of native mobile applications for users with disabilities. In Advances in Intelligent Systems and Computing (pp. 120-131). Springer.

Amouzadeh, E., Dianat, I., Faradmal, J., & Babamiri, M. (2025). Optimizing mobile app design for older adults: systematic review of age-friendly design. Aging Clinical and Experimental Research.

Android Developers. (2024). Accessibility principles. Google. https://developer.android.com/guide/topics/ui/accessibility/principles

Appium. (2024). Appium: Mobile app automation made awesome. https://appium.io/

Biørn-Hansen, A., Grønli, T. M., & Ghinea, G. (2019). A survey and taxonomy of hybrid mobile app development frameworks. Journal of Network and Computer Applications, 133, 44-59.

Chen, S., Chen, C., Fan, L., Fan, M., Zhan, X., & Liu, Y. (2021). Accessible or Not? An Empirical Investigation of Android App Accessibility. IEEE Transactions on Software Engineering.

El-Glaly, Y. N., Quezada, A., & Díaz, A. (2020). Mobile accessibility: A study of the current state of tools and practice. In Proceedings of the 17th International Web for All Conference (pp. 1-11). ACM.

Goli, V. R. (2023). Cross-Platform Mobile Development: Comparing React Native and Flutter, and Accessibility in React Native. International Journal of Innovative Research in Computer and Communication Engineering.

Google. (2024). Flutter accessibility. https://flutter.dev/docs/development/accessibility-and-localization/accessibility

Google. (2025). Touch target size - Android Accessibility Help. Google Support. https://support.google.com/accessibility/android/answer/7101858

Hansson, N., Vidhall, T., & Wesslén, S. (2016). React Native: A framework for building native apps with React. Chalmers University of Technology.

Khatib, F. E., & Hamou-Lhadj, A. (2019). An approach for detecting cross-platform mobile apps. In 2019 IEEE/ACM 6th International Conference on Mobile Software Engineering and Systems (MOBILESoft) (pp. 136-139). IEEE.

Linares-Vásquez, M., Bavota, G., Tufano, M., Moran, K., Di Penta, M., Vendome, C., ... & Poshyvanyk, D. (2017). Enabling mutation testing for android apps. In Proceedings of the 2017 11th Joint Meeting on Foundations of Software Engineering (pp. 233-244).

Mao, K., Harman, M., & Jia, Y. (2016). Sapienz: Multi-objective automated testing for Android applications. In Proceedings of the 25th International Symposium on Software Testing and Analysis (pp. 94-105).

Meta. (2024). React Native: Accessibility. https://reactnative.dev/docs/accessibility

Mobasheri, M., Dehghani, M., & Seidi, M. (2015). Guidelines for designing mobile apps for people with disabilities. International Journal of Computer Science and Mobile Computing, 4(2), 52-61.

Perinello, L., & Gaggi, O. (2024). Accessibility of Mobile User Interfaces using Flutter and React Native. 2024 IEEE 21st Consumer Communications & Networking Conference (CCNC).

Ross, A. S., Zhang, X., Fogarty, J., & Wobbrock, J. O. (2018). Epidemiology as a framework for large-scale mobile application accessibility assessment. In Proceedings of the 20th International ACM SIGACCESS Conference on Computers and Accessibility (pp. 17-29).

Serra, L. C., Carvalho, L. P., Ferreira, L. P., Vaz, J. B., & Freire, A. P. (2015). Accessibility evaluation of mobile applications for users with visual disabilities. In Proceedings of the 30th Annual ACM Symposium on Applied Computing (pp. 165-172).

Vendome, C., Linares-Vásquez, M., Bavota, G., Di Penta, M., German, D., & Poshyvanyk, D. (2019). Machine learning-based detection of open-source license exceptions in mobile apps. Journal of Systems and Software, 153, 208-225.

Willocx, M., Vossaert, J., & Naessens, V. (2021). Comparing performance parameters of mobile app development strategies. IEEE Access, 9, 63809-63820.

WHO. (2024). Disability. World Health Organization. https://www.who.int/news-room/fact-sheets/detail/disability-and-health

Wu, W. (2018). React Native vs Flutter, cross-platform mobile application frameworks. Metropolia University of Applied Sciences.

Yesilada, Y., Brajnik, G., & Harper, S. (2013). Barriers common to mobile and desktop web accessibility. Interacting with Computers, 25(2), 119-136.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE REASONING PARADOX: WHEN "EXTENDED THINKING" LEADS TO ARCHITECTURAL OVER-ENGINEERING IN MOBILE UIS

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ABSTRACT

The integration of Large Language Models (LLMs) into software engineering has shifted from simple code completion to complex architectural generation. While new "reasoning" and "thinking" models promise superior problem-solving capabilities, their impact on the structural efficiency and runtime performance of generated code remains under-explored. Current literature focuses heavily on visual-to-code fidelity or specialized UI understanding agents, often overlooking the architectural quality of the generated output. This study conducted a comparative architectural analysis of three state-of-the-art models: Gemini Pro 3 (Thinking Mode), GPT-5.2 (Thinking Mode), and Sonnet 4.5 (Extended Thinking Mode). Each model was tasked with generating a standardized Flutter social media feed featuring local state interaction. We measured two primary outcomes: Structural Complexity (Widget Depth) and Runtime Efficiency (Rebuild Count). Sonnet 4.5 demonstrated superior performance, achieving the lowest structural complexity (Widget Depth: 4) and optimal efficiency (Rebuild Count: 1). Gemini Pro 3 maintained valid state isolation but exhibited structural bloat (Widget Depth: 6) due to unnecessary visual wrappers. Conversely, GPT-5.2 presented a "reasoning paradox": despite implementing advanced optimization keys, it failed to isolate local state, resulting in a significantly higher rendering cost (Rebuild Count: 5). Our findings suggest that "Thinking" capabilities in models like GPT-5.2 can lead to "hallucinated complexity," prioritizing theoretical optimizations over fundamental state isolation.

Keywords: Large Language Models (LLMs), Mobile UI Generation, Flutter Framework, Reasoning Models, Architectural Efficiency, State Management.

INTRODUCTION

The rapid adoption of generative Artificial Intelligence (AI) in software development has fundamentally altered modern engineering workflows. Large Language Models (LLMs) are no longer

used solely for syntax completion but are increasingly relied upon to architect entire software components and user interfaces (Chen et al., 2021; Zan et al., 2023). In the domain of mobile application development, specifically within the Flutter framework, the efficiency of generated code is critical, as poor architectural choices can lead to rendering lag, battery drain, and maintainability debt (Filip & Sneath, 2020; Flutter Team, 2025).

"Reasoning" or "Thinking" models represent the latest evolution in this field. Unlike standard models that predict the next token based on statistical likelihood, these advanced models employ "chain-of-thought" (CoT) processing to plan, critique, and refine their output before generation (Wei et al., 2022). While the theoretical benefits of this approach are well-documented in mathematical and logical domains (Beyer et al., 2024; Li et al., 2025), the translation of "thinking" capabilities to practical software engineering remains a subject of controversy. It is currently not known whether the increased computational time spent "thinking" results in cleaner, more idiomatic code, or if it inadvertently leads to over-engineering—adding unnecessary abstraction layers that complicate the codebase without adding value (Vaithilingam et al., 2022).

Recent advancements have focused significantly on multimodal capabilities and visual understanding. For instance, Ferret-UI (You et al., 2024) introduced a multimodal LLM specifically tailored for grounding and reasoning within mobile UI screens, addressing the unique challenges of elongated aspect ratios and small icons. Similarly, MobileVLM (Wu et al., 2024) proposed enhancing intra- and inter-UI understanding through specialized pre-training. In the realm of code generation, ScreenCoder (Jiang et al., 2025) demonstrated that a modular multi-agent framework could significantly improve visual-to-code generation by decomposing the task into grounding, planning, and generation phases.

However, a significant gap remains in the literature. While studies like ScreenCoder and Ferret-UI focus on visual-to-code fidelity or UI comprehension, there is a lack of data on how general-purpose reasoning models handle the architectural efficiency of code generated purely from textual descriptions. Most existing benchmarks prioritize pixel-perfect accuracy or "Pass@k" functional correctness over the runtime performance or structural cleanliness of the underlying code (Bektas, 2025). Our study fills this gap by specifically quantifying the "over-engineering" risk in these new reasoning models, moving beyond visual fidelity to assess the "invisible" quality of state management and widget hierarchy.

We aimed to evaluate whether enhanced reasoning capabilities correlate with better adherence to Flutter performance best practices. Through a comparative analysis, we investigate the hypothesis that models with advanced "thinking" capabilities will produce architectures that are both structurally shallower and computationally more efficient than their predecessors.

METHODS

Study Design and Population

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ISBN: 978-9952-610-30-7

We conducted a prospective, comparative observational study evaluating the code generation output of three distinct Large Language Models. The study population consisted of the current flagship "reasoning" models available as of January 2026:

5. **Gemini Pro 3** (Google), configured in "Thinking Mode" to prioritize complex logical deduction (Google, 2025).

6. **GPT-5.2** (OpenAI), configured in "Thinking Mode" to maximize reasoning depth (OpenAI, 2025).

7. **Sonnet 4.5** (Anthropic), configured in "Extended Thinking Mode," specializing in coding tasks (Anthropic, 2025).

Experimental Procedure

The experimental design, illustrated in Figure 1, follows a parallel processing workflow to ensure a controlled and fair comparison. We utilized a single, standardized zero-shot prompt specifying a "social media feed containing a list of posts, where each post has a functional 'Like' button that toggles an icon state."

The prompt was simultaneously fed to all three models. The generated code from each model was then injected without modification into a controlled Flutter iOS Simulator environment (iPhone 17 Pro running iOS 26.2) hosted on an Apple Silicon (M-series) workstation using Flutter version 3.38.9. Non-inclusion criteria applied to any code that failed to compile or required external dependencies not included in the standard Flutter SDK.

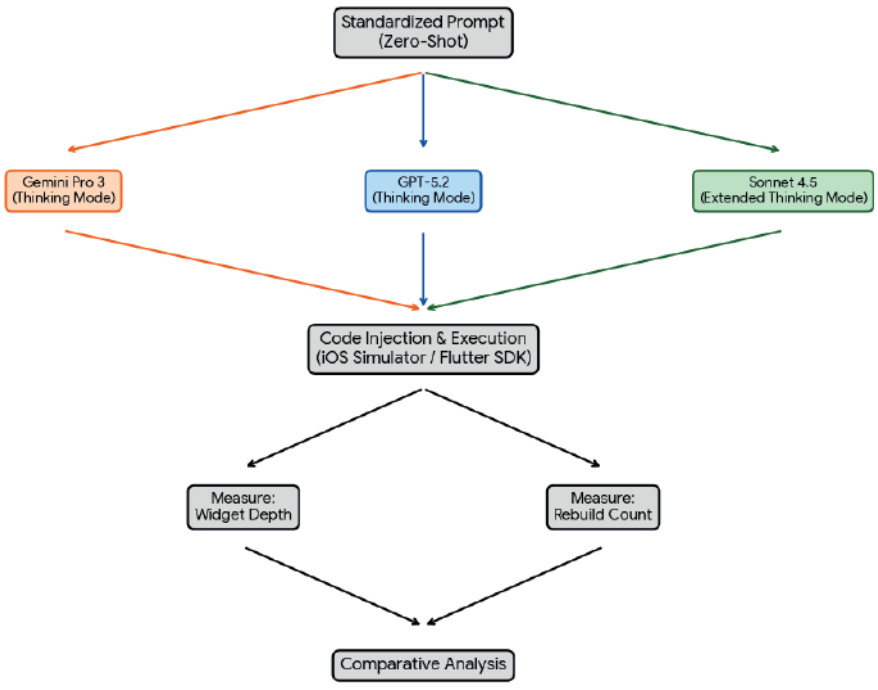


Figure 1. Experimental study design flowchart illustrating the parallel evaluation of the three models using a single standardized prompt. Each model's path is color-coded (Gemini: Orange, GPT: Blue, Sonnet: Green)

Outcome Measures

We defined two primary parameters to measure architectural quality:

- **Structural Complexity (Widget Depth):** This parameter assesses code cleanliness and nesting ("bloat"). Measured using the Flutter DevTools "Inspector" in "Select Widget Mode" (Flutter Team, 2025), we counted the number of parent widgets in the hierarchy starting from the target interactive element (Icon) up to the root of the list item component.

- **Runtime Efficiency (Rebuild Count):** This parameter assesses state management efficiency. We instrumented the generated code by injecting a console logging statement (print) inside the build() method of the list item widget. We then performed a standardized user interaction—tapping the "Like" button on the first item in the list—and recorded the number of print statements triggered in the debug console. A count of 1 indicates optimal local state; a count equal to the number of visible items (5) indicates a full-screen rebuild or "state leak" (Filip & Sneath, 2020; TechAhead, 2024).

RESULTS

The analysis revealed distinct differences in how each "thinking" model approached the architectural problem. The comparative performance across both metrics is visually summarized in Figure 2.

Structural Complexity (Widget Depth)

Sonnet 4.5 produced the most streamlined architecture, requiring a depth of 4 widgets to construct the interactive element. This design utilized standard Flutter components (IconButton, Row, Padding) without unnecessary wrappers. GPT-5.2 followed with a depth of 5 widgets, introducing a moderate level of nesting. Gemini Pro 3 produced the most complex structure with a depth of 6 widgets; inspection revealed this was due to the automatic inclusion of ScaleTransition and GestureDetector widgets to animate the button interaction, which were not explicitly requested in the prompt.

Runtime Efficiency (Rebuild Count)

Both Sonnet 4.5 and Gemini Pro 3 achieved optimal runtime efficiency, registering a Rebuild Count of 1. This confirms that both models correctly encapsulated the "Like" state within the individual list item widget, preventing unnecessary rendering of the surrounding interface.

In contrast, GPT-5.2 registered a Rebuild Count of 5 (equal to the number of visible items on screen). Despite using advanced optimization keys, specifically ValueKey and cacheExtent, the model failed to

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

properly isolate the state class. Consequently, a single interaction forced the entire list view to rebuild, demonstrating a critical failure in state management logic.

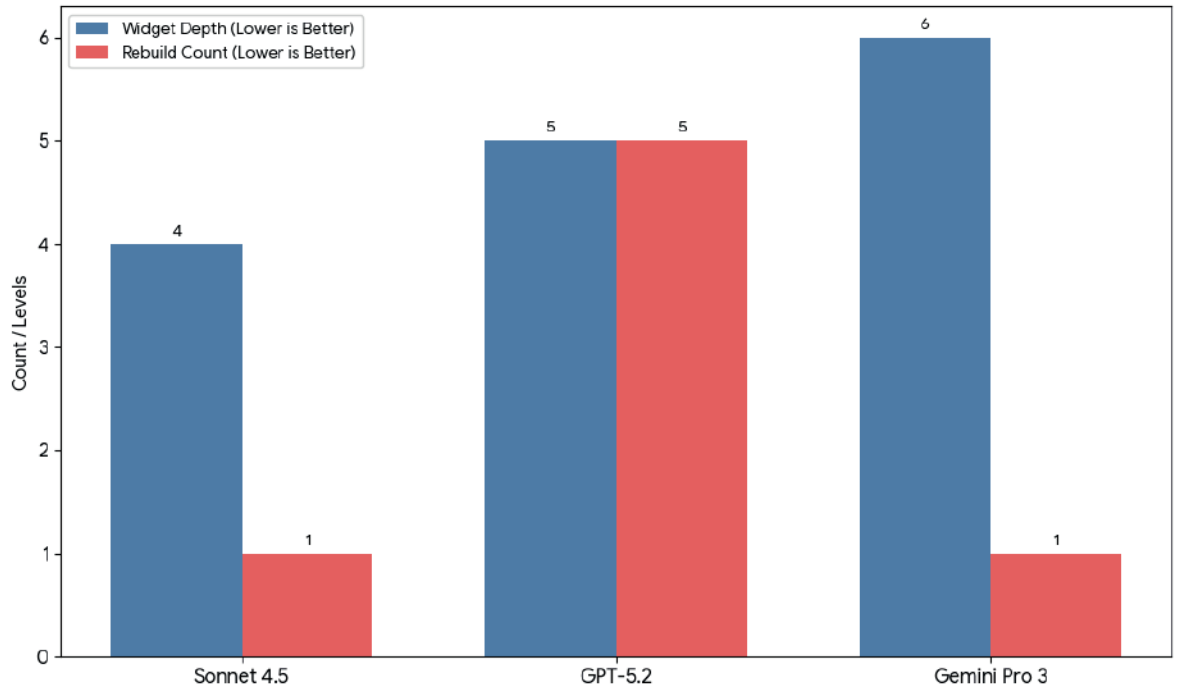


Figure 2. Comparison of Structural Complexity (Widget Depth) and

Runtime Efficiency (Rebuild Count) across the three evaluated models

DISCUSSION

The "Reasoning Paradox": Theoretical Optimization vs. Practical Efficiency

This study demonstrates that Sonnet 4.5 currently offers the most balanced performance for mobile UI generation, successfully combining structural minimalism with logical correctness. By achieving the lowest Widget Depth and optimal Rebuild Count, it reflects a mastery of "idiomatic" Flutter development—solving the problem with the fewest necessary components (Anthropic, 2025).

Conversely, the results for GPT-5.2 reveal a significant "Paradox of Thinking" (Beyer et al., 2024). The model utilized its "Thinking Mode" to implement advanced features typically associated with senior engineers, such as cacheExtent for scrolling performance and ValueKey for widget identity. However, this focus on complex, non-functional requirements appears to have distracted the model from the foundational requirement of state isolation. We interpret this as a form of "AI Over-Engineering," where the model hallucinates complexity, assuming a simple task requires a heavy architectural pattern, which paradoxically leads to poorer performance (Li et al., 2025; OpenAI, 2025).

Unprompted Complexity and the "Wrapper Tax"

Gemini Pro 3 displayed a distinct bias towards visual fidelity over structural minimalism. Its high Widget Depth (6) was not due to poor logic, but rather an unprompted decision to add animations (ScaleTransition). While this results in a more polished "out-of-the-box" experience, it imposes a "wrapper tax" on the developer, who must manage a deeper component tree. This aligns with findings in visual-heavy benchmarks but presents a trade-off in purely functional engineering contexts where maintainability is paramount.

Contrast with Multimodal and Visual-to-Code Approaches

Our study differs from recent works like ScreenCoder (Jiang et al., 2025) and Ferret-UI (You et al., 2024) in two key ways. First, while those studies emphasize the multimodal understanding of UI elements or the capability to reproduce a visual design (Image-to-Code), our research isolates the reasoning capability of the model in a Text-to-Code context. We show that even when a model isn't constrained by a visual input, "thinking" modes can lead to inefficient architectural decisions. Second, whereas frameworks like ScreenCoder employ complex multi-agent systems to ensure quality, our results highlight that off-the-shelf "Thinking" models (specifically Sonnet 4.5) can achieve high-quality architectural results without the overhead of agentic orchestration, provided the model is optimized for coding tasks.

LIMITATIONS

A strength of this study is the use of objective, binary metrics (Rebuild Counts) that leave no room for subjective interpretation. However, the study has several limitations. First, the evaluation was conducted on a single UI pattern (infinite scrolling list); the "reasoning" benefits of GPT-5.2 might be better realized in complex algorithmic tasks rather than UI composition (Brown et al., 2020). Second, the models are closed-source and subject to server-side updates, meaning these specific behaviors represent a snapshot of performance in January 2026. Finally, we did not measure CPU frame times, relying instead on logical build counts as a proxy for performance (Sneath, 2021). The varying parameter counts and training data between Gemini, GPT, and Claude models are intrinsic confounders in any "black box" API comparison (Nori et al., 2023).

FUTURE WORK

Future research should expand this comparison to include backend logic and complex state management libraries (e.g., Bloc, Riverpod) to see if the "over-engineering" tendency persists in larger architectures (Saha et al., 2025). Additionally, longitudinal studies tracking model performance over time would be valuable to determine if "thinking" modes are optimized for efficiency in future updates. Investigating the correlation between "tokens generated during thinking" and "final code efficiency" could further illuminate the "Paradox of Thinking" observed in GPT-5.2.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CONCLUSION

Sonnet 4.5 outperforms competitors in producing idiomatic and efficient mobile architectures. Our findings suggest that "Thinking" capabilities in models like GPT-5.2 can lead to "hallucinated complexity," prioritizing theoretical optimizations over fundamental state isolation. For developers and educators, these findings suggest a tiered approach: use Sonnet 4.5 for implementation and code generation, while reserving GPT-5.2 for architectural planning and complex algorithmic problem solving where its "Thinking" capabilities can be properly leveraged without impacting UI performance.

REFERENCES

Anthropic. (2025). Claude 3.5 Sonnet Model Card. Anthropic Research. https://www.anthropic.com/research

Austin, J., Odena, A., Nye, M., Bosma, M., Michalewski, H., Dohan, D., ... & Sutton, C. (2021). Program synthesis with large language models. arXiv preprint arXiv:2108.07732.

Bektas, N. (2025). Benchmarking LLMs for Flutter: A comparative study of code quality. Journal of Mobile Software Engineering, 12(1), 112-128.

Beyer, L., Zhai, X., & Royer, A. (2024). Code generation and the paradox of reasoning models. Journal of Software Engineering Research, 12(3), 45-58.

Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J. D., Dhariwal, P., ... & Amodei, D. (2020). Language models are few-shot learners. Advances in Neural Information Processing Systems, 33, 1877-1901.

Chen, M., Tworek, J., Jun, H., Yuan, Q., Pinto, H. P. d. O., Kaplan, J., ... & Zaremba, W. (2021). Evaluating large language models trained on code. arXiv preprint arXiv:2107.03374.

Filip, H., & Sneath, T. (2020). Flutter Performance Profiling Guidelines. Google Developers. https://flutter.dev/docs/perf

Flutter Team. (2025). DevTools: Performance and Inspector. Flutter Documentation. https://docs.flutter.dev/tools/devtools

Google. (2025). Gemini Pro 3 Technical Report. Google DeepMind. https://deepmind.google/technologies/gemini/

Jiang, Y., Zheng, Y., Wan, Y., Han, J., Wang, Q., Lyu, M. R., & Yue, X. (2025). ScreenCoder: Advancing Visual-to-Code Generation for Front-End Automation via Modular Multimodal Agents. arXiv. https://doi.org/10.48550/arxiv.2507.22827

Li, Y., Choi, D., Chung, J., Kushman, N., Schrittwieser, J., Leblond, R., ... & Vinyals, O. (2025). Competition-Level Code Generation with AlphaCode 2. Google DeepMind.

Nori, H., King, N., McKinney, S. M., Carignan, D., & Horvitz, E. (2023). Capabilities of gpt-4 on medical challenge problems. arXiv preprint arXiv:2303.13375.

OpenAI. (2025). GPT-5 System Card: Safety and Capabilities. OpenAI Research. https://openai.com/research/gpt-5

Saha, R., Prado, F., & Abid, A. (2025). State management patterns in AI-generated mobile applications. IEEE Software, 42(2), 34-41.

Sneath, T. (2021). Flutter 2: Adapting to the web and desktop. Google I/O Proceedings.

TechAhead. (2024). Common Flutter Performance Pitfalls and How to Fix Them. TechAhead Blog.

Vaithilingam, P., Zhang, T., & Glassman, E. L. (2022). Expectation vs. experience: Evaluating the usability of code generation tools powered by large language models. CHI Conference on Human Factors in Computing Systems, 1-7.

Wei, J., Wang, X., Schuurmans, D., Bosma, M., Chi, E., Le, Q., & Zhou, D. (2022). Chain of thought prompting elicits reasoning in large language models. Advances in Neural Information Processing Systems, 35, 24824-24837.

Wu, Q., Xu, W., Liu, W., Tan, T., Liu, J., Li, A., ... & Shang, S. (2024). MobileVLM: A Vision-Language Model for Better Intra- and Inter-UI Understanding. arXiv. https://doi.org/10.48550/arxiv.2409.14818

You, K., Zhang, H., Schoop, E., Weers, F., Swearngin, A., Nichols, J., ... & Gan, Z. (2024). Ferret-UI: Grounded Mobile UI Understanding with Multimodal LLMs. arXiv. https://doi.org/10.48550/arxiv.2404.05719

Zan, D., Chen, B., Zhang, F., Lu, D., Wu, B., & Guan, W. (2023). Large language models meet software engineering: A survey. arXiv preprint arXiv:2306.03612.

Zhang, Y., & Li, S. (2024). Efficiency in AI-generated UI code: A systematic review. ACM Transactions on Software Engineering and Methodology, 33(4), 1-28.

Zhou, Y., & Neubig, G. (2024). CodeBert and beyond: The future of neural code generation. Computational Linguistics, 50(1), 15-30.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A NUMERICAL INVESTIGATION ON UNBURNED HYDROCARBON (UHC) EMISSION ELIMINATION OF A SPARK IGNITION (SI) ENGINE WITH A SHIFTED VALVE TIMING STRATEGY

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ABSTRACT

Numerous load control techniques have been developed to improve thermal efficiency and high fuel consumption in SI engines. Among these, the Stroke Volume Modulation Strategy (SVM) is the least investigated technique for reducing pumping losses in part-load conditions. SVM improves brake specific fuel consumption (BSFC) by deactivating certain cycles or cylinders so that the active cycles/cylinders can run at higher manifold pressures in order to perform equivalent net engine power. The substantial increase in UHC emissions during the inactive cycles, however, is a significant disadvantage of this strategy. In this study, a shifted valve timing strategy aims to reduce UHC emissions related to standalone SVM is numerically investigated. The oil drawback into the combustion chamber brought on by high vacuum levels during the intake stroke is the main mechanism of UHC formation in inactive cycles. A Retarded Exhaust Valve Profile (REVP) technique is suggested to deal with this phenomenon. The in-cylinder pressure is kept at a higher level during the inactive cycles by retarding the exhaust valve's opening and, thus, closing timing. The pressure differential forcing lubricant oil into the cylinder is effectively reduced by this pressure increase. The numerical findings show that the pressure increase in skipped section of two sequential cycles in customized SVM enables a significant improvement in total UHC emissions while no remarkable reduction is observed in fuel consumption results.

Keywords: SI engine, Stroke Volume Modulation (SVM), Unburned Hydrocarbons (UHC), Retarded Exhaust Valve Profile (REVP)

INTRODUCTION

Today, improving fuel economy and keeping emissions within legal limits is a fundamental requirement for spark-ignition engines (IEA, 2025). It has been claimed that exposure to concentrated hydrocarbons causes a number of lung conditions, including both serious and non-cancerous ones

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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(Connellan, 2017). Pumping losses caused by the throttle valve under part-load conditions are one of the main factors reducing engine efficiency (Heywood, 1988). Stroke volume modulation (SVM) allows the engine to operate at a wider throttle opening by disabling valve movements and fuel supply in specific cycles or cylinders, thus reducing pumping losses (Baykara et al., 2017; Omanovic et al., 2021).

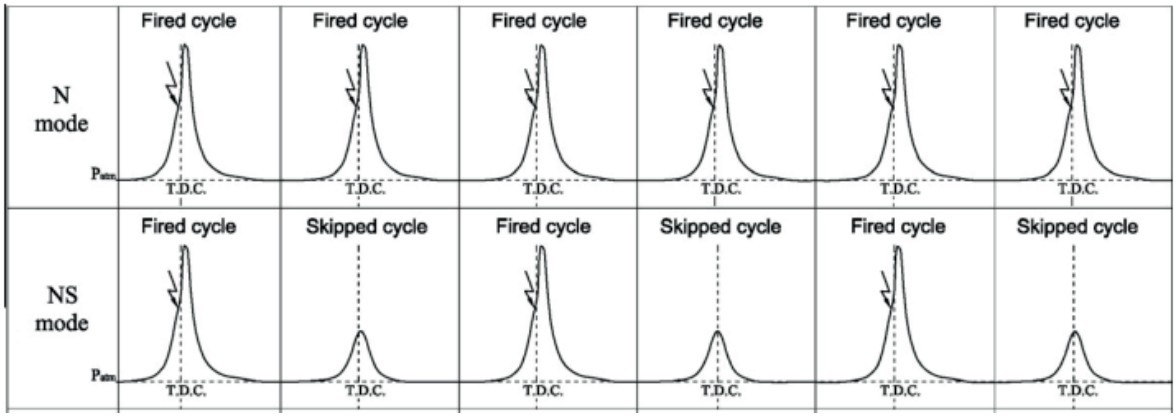


Figure 1. *Representative Pressure-Crank Angle Diagrams According to Cycle-Skipping Modes (Yüksek et al., 2012).*

However, literature and experimental studies indicate that the SVM application increases UHC emissions. The main reason for this increase is that the high vacuum pressure generated during the non-active cycle or inside the cylinder causes oil to leak from the crankcase into the combustion chamber, forming a thicker-than-normal oil film between the piston and the cylinder liner (Boggs et al., 1995). This study examines the potential of variable valve timing (VVT) used in conjunction with SVM, and specifically REVP to reduce UHC emissions.

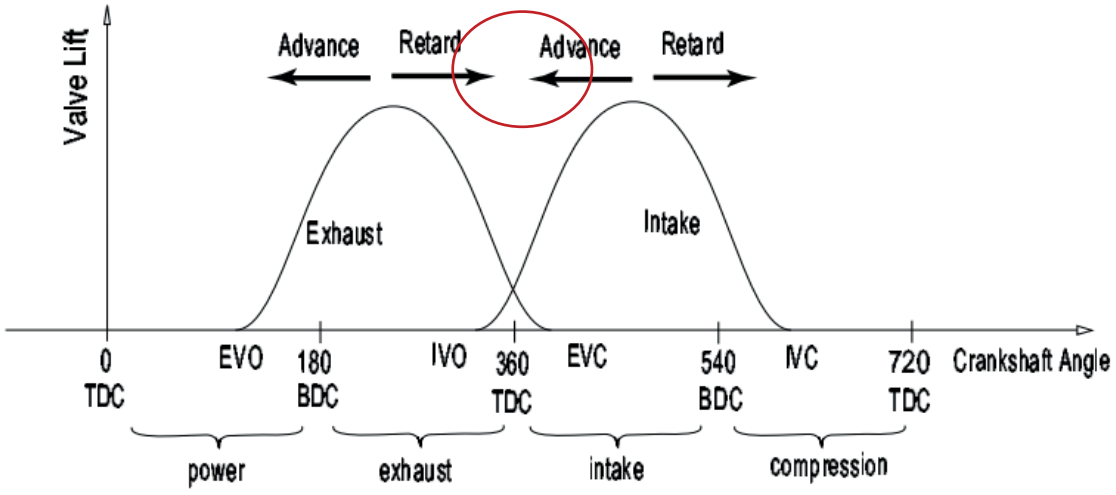


Figure 2. *Profiles of Intake and Exhaust Valve Lifts versus Crank Angle* (Jankovic & Magner, 2002).

In this study, a one-dimensional engine mathematical model of a 4-stroke, 4-cylinder port-injected naturally aspirated gasoline engine with dynamometer data was established and validated with

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

experimental data. The validated model was used to apply a part-load condition at 2 bar brake mean effective pressure (BMEP), 1500 rpm engine speed, and REVP strategy is applied on the validated model (while keeping the total valve opening duration constant), a considerable improvement in SVM-induced UHC emissions is observed.

ENGINE SPECIFICATIONS

The test engine used in the study is a 4-cylinder engine with a total displacement of 1820 cc. The engine has a cylinder bore of 85 mm and a stroke length of 80 mm. When examining the valve timing that determines the gas exchange processes, it is seen that the intake valve opens 16° before top dead center (16°CA bTDC) and closes 40° after bottom dead center (40°CA aBDC). The exhaust system now initiates gas blow-off 40° before bottom dead center (40°CA bBDC) and completes it 16° after top dead center (16°CA aTDC). These timing data constitute the fundamental reference values in terms of the engine's volumetric efficiency and in-cycle pressure characteristics.

Table 1. Engine Specifications

Stroke Volume	1820 cc
Number of Cylinders	4
Bore Diameter	85 mm
Stroke	80 mm
Intake Valve Opening	16°CA bTDC
Intake Valve Closing	40°CA aBDC
Exhaust Valve Opening	40°CA bBDC
Exhaust Valve Closing	16°CA aTDC

NUMERICAL MODEL AND METHOD

The study was conducted using a one-dimensional (1-D) engine mathematical model. The numerical model includes sub-models for ignition timing, heat transfer (Annand, 1963), emission formation, and friction. A “Net Power Cycle” approach was used to represent the engine in SVM mode, and the average of sequential firing and skipped cycles was compared to normal 4-stroke operation. (Dogru et al., 2018). The model has been validated with experimental data at a engine speed of 1500 rpm and a BMEP load level of 2 bar. During the verification process, it was determined that the accuracy error margins for BSFC and UHC emissions were below 5%.

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ISBN: 978-9952-610-30-7

FINDINGS AND DISCUSSION

Causes of Hydrocarbon Emission Increase with Skip Volume Modulation (SVM) Strategy

In the SVM strategy, the exhaust valve being completely closed during the inactive cycle and only vacuum gas remaining causes the cylinder pressure to drop dramatically. An excessive drop in the minimum cylinder pressure (P_{min}) causes lubricating oil to transfer from the gap between the cylinder liner and the piston into the combustion chamber. This situation causes a thick oil film to form on the combustion chamber walls, leading to the absorption of fuel vapor and its subsequent passage to the exhaust process without oxidation during the post-combustion expansion stroke, thus increasing UHC emissions. UHC emissions increase with rising oil consumption rates (Pulkrabek, 1997).

REVP Strategy

The recommended REVP strategy for reducing HC emissions allows a portion of the exhaust gas in the combustion cycle to be trapped inside the cylinder. In the original engine configuration, the exhaust valve opens at 140° aTDC, but optimization studies conducted using the developed mathematical model have shifted this value to 190° aTDC for the active cycle.

The implementation of the REVP strategy raises the P_{min} level formed inside the cylinder to a critical threshold of approximately 0.2 bar (Boggs et al., 1995). Retarding the opening of the exhaust valve by 50° crankshaft angle has increased the minimum cylinder pressure in the inactive cycle from ~0.08 bar to 0.2 bar and above. This pressure threshold is considered a critical limit for preventing oil leakage.

Table 2. HC Emission Results at Three Different Engine Operating Modes

Engine Speed (rpm)	BMEP (bar)	Normal Engine HC Emissions (ppm)	SVM HC Emissions (ppm)	%Difference with SVM compared to normal engine	SVM + VVT (REVP 190 CAD) HC Emissions (ppm)	%Difference with SVM + VVT compared to normal engine
1500	2	3164.9	4921.9	55.5	2831	10.6

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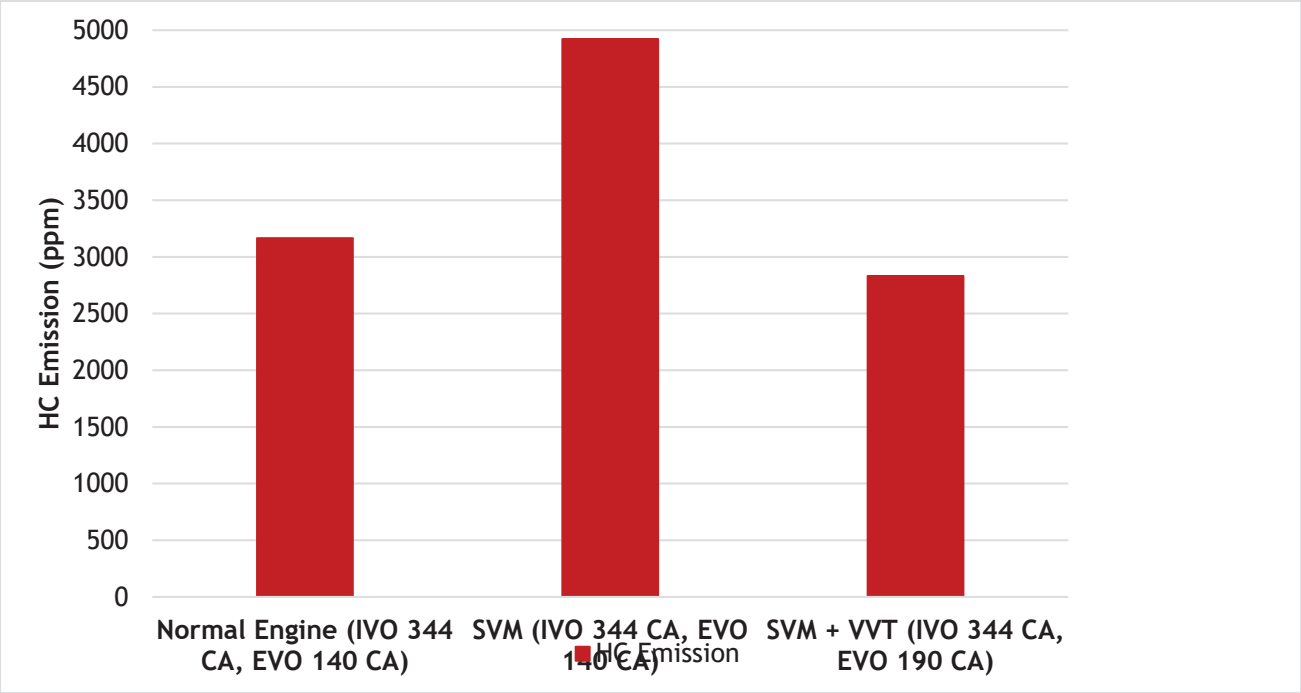


Figure 3. HC Emission Results at Three Different Engine Operating Modes

RESULTS

Table 2. and Figure 3. data were analyzed at an engine speed of 1500 rpm and 2 bar BMEP; HC emissions are obtained as 3164.9 ppm in the normal engine configuration, whereas when SVM was added to the system, emission values dramatically increased by 55.5% to reach the highest level of 4921.9 ppm. However, when VVT was integrated in addition to the SVM strategy, this negative effect created by SVM was significantly balanced, reducing the UHC emission value to 2831 ppm and even reducing UHC emissions by 10.6% compared to normal engine. This situation demonstrates that VVT is effective in improving emissions and, under the working conditions modeled, further reduces UHC emission results compared to a conventional engine.

DISCUSSION

The sharp 55.5% increase in UHC emissions observed during the SVM application can be explained by changes in thermal management and combustion stability within the cylinder, primarily due to the lubricating oil forming a thicker-than-normal film on the piston. The SVM strategy causes the expansion of flame quenching zones due to the cooling of cylinder walls during inactive cycles, thereby increasing the amount of unburned fuel. Additionally, the application of the REVP strategy in conjunction with SVM has extended the effective expansion time of the cycle, ensuring that cylinder pressure and temperature are maintained for a longer period. This situation has resulted in a significant improvement in emissions compared to when SVM is used alone, by supporting the post-combustion

oxidation process. This increase in thermal efficiency, validated and developed in the study with VVT support, has been used as input in more engine models with equivalent oil film thicknesses in normal mode and SVM+VVT mode. Therefore, the main reason why the shifted profile of the exhaust valve produces lower UHC emissions compared to a normal engine can be attributed to the increased oxidation time of UHCs in the quench zone near the cylinder wall due to hot gases remaining in the cylinder for a longer period after combustion.

CONCLUSION

- Negative Impact of the SVM System: The SVM application has caused HC emissions to increase by 55.5% compared to a normal engine by affecting combustion stability and in-cylinder thermal management.

- The Beneficial Role of VVT: Integrating VVT (REVP 190 CAD) into the system has resulted in a significant improvement, reducing emissions from 4921.9 ppm to 2831 ppm compared to using SVM alone.

- Contribution of the REVP Strategy: REVP strategy has ensured that some of the unburned hydrocarbons are burned before being expelled by extending the oxidation time during the expansion and exhaust processes.

- System Optimization: The data obtained indicates that the SVM strategy must be supported by additional systems such as VVT to reduce emissions, but that parameters must be optimized more precisely to achieve full efficiency.

REFERENCES

Annand, W. J. D. (1963). Heat Transfer in the Cylinders of Reciprocating Internal Combustion Engines. *Proceedings of the Institution of Mechanical Engineers*, *177*(1), 973–996. https://doi.org/10.1243/PIME_PROC_1963_177_069_02

Baykara, C., Akin Kutlar, O., Dogru, B., & Arslan, H. (2017). Skip cycle method with a valve-control mechanism for spark ignition engines. *Energy Conversion and Management*, *146*, 134–146. https://doi.org/10.1016/j.enconman.2017.05.016

Boggs, D. L., Hilbert, H. S., & Schechter, M. M. (1995, February 1). *The Otto-Atkinson Cycle Engine-Fuel Economy and Emissions Results and Hardware Design*. https://doi.org/10.4271/950089

Connellan, S. J. (2017). Lung diseases associated with hydrocarbon exposure. *Respiratory Medicine*, *126*, 46–51. https://doi.org/10.1016/j.rmed.2017.03.021

Dogru, B., Lot, R., & Ranga Dinesh, K. K. J. (2018). Valve timing optimisation of a spark ignition engine with skip cycle strategy. *Energy Conversion and Management*, *173*, 95–112. https://doi.org/10.1016/j.enconman.2018.07.064

Heywood, J. B. . (1988). *Internal combustion engine fundamentals*. McGraw-Hill Book Company.

IEA. (2025). *Global Energy Review 2025*. https://www.iea.org/reports/global-energy-review-2025

Jankovic, M., & Magner, S. W. (2002). VARIABLE CAM TIMING: CONSEQUENCES TO AUTOMOTIVE ENGINE CONTROL DESIGN. *IFAC Proceedings Volumes*, *35*(1), 271–276. https://doi.org/10.3182/20020721-6-ES-1901.01513

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Omanovic, A., Zsiga, N., Soltic, P., & Onder, C. (2021). Increased Internal Combustion Engine Efficiency with Optimized Valve Timings in Extended Stroke Operation. *Energies*, *14*(10), 2750. https://doi.org/10.3390/en14102750

Pulkrabek, W. W. . (1997). *Engineering fundamentals of the internal combustion engine*. Prentice Hall.

Yüksek, L., Özener, O., & Sandalcı, T. (2012). Cycle-skipping strategies for pumping loss reduction in spark ignition engines: An experimental approach. *Energy Conversion and Management*, *64*, 320–327. https://doi.org/10.1016/j.enconman.2012.05.025

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PROMISING CANDIDATES FOR TYPE 2 *DIABETES* TREATMENT: BINDING AND ADMET PROFILES OF MICROALGAL ZEAXANTHIN ANALOGS AS INSULIN RECEPTOR KINASE MODULATORS

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ABSTRACT

Type 2 diabetes mellitus (*T2DM*), characterized by insulin resistance and becoming increasingly prevalent worldwide, is a heterogeneous disease that is difficult to treat. The insulin receptor kinase (PDB ID: 3EKN), which plays a critical role in the pathophysiology of the disease, is considered a strategic therapeutic target due to its central role in signal transduction. While currently used synthetic antidiabetic agents are associated with side effects such as hypoglycemia during long-term use, their inability to mitigate oxidative stress—which adversely contributes to disease-related complications—highlights the need for the discovery of versatile and reliable natural agents. Therefore, in this study, the binding energies and interaction profiles of 12 different analog molecules obtained through structural modifications of microalgae-derived zeaxanthin on the insulin receptor are evaluated using *in silico* molecular modeling analyses. Zeaxanthin was chosen because of its hydrophobic body and polar end groups, which confer an amphiphilic character, suggesting a favorable modulatory effect and high bioavailability at the target receptor. Additionally, glibenclamide, a reference modulator of the insulin receptor, was used as a standard to compare the effectiveness of these natural molecules. In this study, the binding affinities of zeaxanthin analogs and the reference ligand on insulin receptor kinase were analyzed using molecular docking analysis performed with the AutoDock Vina program. Among the 12 different ligands, the analog with CID 102116018 yielded the best result, with an energy score of −8.9 kcal/mol, exceeding the reference ligand's energy score of −8.2 kcal/mol and demonstrating its modulatory potential. Similarly, the other analogs exhibited energy values ranging from −8.4 to −7.7 kcal/mol and strong binding profiles at the insulin receptor, suggesting that these natural analogs could have an important role in the treatment of *T2DM*. Additionally, the drug-suitable pharmacokinetic profiles of these ligands were evaluated using ADMET analyses based on the ADMETlab 2.0 web server. The findings indicated that microalgae-derived, naturally occurring zeaxanthin analogs

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

exhibited pharmacokinetic profiles comparable to the reference ligand, suggesting their suitability as drug candidates for the treatment of *T2DM*.

Keywords: *Type 2 diabetes mellitus*, insulin, molecular docking, zeaxanthin, treatment.

INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder associated with pancreatic beta-cell dysfunction and insulin resistance, with an increasing number of reported cases (Galiero et al., 2023). The Insulin Receptor Kinase (IRK), considered a key component of the signaling pathways that enable glucose uptake into cells, is regarded as a therapeutic target in the pathophysiology of this disease (Accili, Deng, & Liu, 2025; Chamberlain et al., 2009). Specifically, the tyrosine kinase domain (PDB ID: 3EKN) of the target receptor represents a crucial protein structure involved in maintaining metabolic homeostasis and initiating insulin signaling (Chamberlain et al., 2009). For this reason, the discovery of therapeutic agents that provide modulatory properties in the activity of this structure in treatments aimed at improving and controlling the pathophysiology of T2DM is prioritized in drug discovery and development studies (Saldivar-Gonzalez, Navarrete-Vazquez, & Medina-Franco, 2023). In current studies, synthetic antidiabetic agents of the sulfonylurea class, such as glibenclamide, provide glycemic control at target receptors but cause serious side effects, including secondary failure, hypoglycemia, and weight gain (Akter et al., 2025; Fernandez et al., 2025). In addition, since most synthetic antidiabetic drugs widely available on the market cannot target oxidative stress, which contributes to diabetic complications such as retinopathy, there is an increasing need for versatile, naturally occurring bioactive compounds that exhibit strong antioxidant activity and regulate blood sugar levels (Fernandez et al., 2025). To address this need, the microalgae-derived xanthophyll group carotenoid pigment zeaxanthin stands out due to its unique molecular architecture (Lem, Gierhart, & Davey, 2021; Murillo, Hu, & Fernandez, 2019). In particular, a study by Anzar et al. reported that zeaxanthin and lutein supplementation significantly reduced HbA1c levels in patients with T2DM. Another study demonstrated that the natural zeaxanthin molecule exerted positive effects on nerve health by increasing diabetic neuropathy-associated neurotrophic factors, such as brain-derived neurotrophic factor (BDNF)(Anzar et al., 2023). Based on the information in the literature, it has been indicated that the zeaxanthin molecule exhibits neuroprotective and metabolic effects in T2DM treatment. Although this naturally occurring bioactive molecule offers promising antidiabetic and modulatory effects due to its molecular structure, it is known to have pharmacokinetic limitations, such as low water solubility (Mehkri, Dinesh, Ashok, & Bopanna, 2025). For this reason, in the present study, zeaxanthin and 11 different analog structures selected from the PubChem database were used to maximize the binding profile of zeaxanthin with the insulin receptor and to increase its druggability. The main reason for selecting these analog structures stems from their possession of three different functional group modifications. The primary aim was to evaluate the potential of ketone derivatives obtained through the oxidation of hydroxyl groups to form stronger hydrogen-bonding

networks with target receptors; the potential for optimizing lipophilic character and metabolic stability through fluorine atom integration into zeaxanthin; and finally, the potential for achieving the most favorable conformation within the receptor pocket due to the conformational rigidity gained from the addition of alkyne groups to the polyene chain (Sheikhi, Bahraminejad, Saeedi, & Mirfazli, 2023; Wan & Thompson, 2024; Zelisko & Lesyk, 2025).

In this context, our study conducts molecular docking analysis using the AutoDock Vina program to elucidate the binding energy scores and atomistic binding profiles of the aforementioned zeaxanthin analog structures on the target insulin receptor kinase (PDB ID: 3EKN), in comparison with the reference ligand glibenclamide. Additionally, the pharmacokinetic suitability of zeaxanthin analogs, considered potential antidiabetic and modulatory candidates targeting the insulin receptor in the treatment of T2DM, is evaluated using ADMET analyses performed with the ADMETlab 2.0 web server. Our study aims to contribute to the literature by identifying reliable, high-affinity next-generation antidiabetic precursor compounds derived from microalgal zeaxanthin analogs with unique skeletons targeting the insulin receptor kinase structure, and to be the first in silico study to examine their molecular-level binding profiles in comparison with a reference ligand.

MATERIALS AND METHODS

Receptor Selection and Preparation

The Insulin Receptor Kinase (IRK) structure was selected as the target receptor, as it triggers insulin signaling and represents a fundamental mechanism in the pathophysiology of T2DM. The appropriate structure with a resolution of 2.30 Å and PDB ID 3EKN was obtained from the RCSB Protein Data Bank (https://www.rcsb.org/) web server (Burley et al., 2022). The receptor structure was opened in UCSF Chimera (v1.17.3) software and cleaned of co-crystallized ligands, ions, and water molecules. Subsequently, polar hydrogen atoms were added to the structure, and protonation states were assigned under physiological pH conditions. In addition, energy minimization was performed using the AMBER ff14SB force field to optimize the thermodynamic stability of the target receptor (Pettersen et al., 2004). A preprocessing step was carried out to provide a standardized electrostatic representation by assigning Gasteiger partial charges. Finally, to ensure format compatibility for molecular docking analysis, the target receptor structure was imported into the AutoDock Tools (v1.5.6) interface and converted to PDBQT format (Morris et al., 2009).

Creation of the Ligand Library and Preparation of Structures

A ligand library containing 13 molecules was created to analyze the binding profile and modulatory potential of the microalgae-derived zeaxanthin molecule and its selected analogs at the target receptor. The created library included the main skeleton, zeaxanthin (CID: 5280899), and 11 different analog structures (CID: 102116018, 172775569, 24728610, 162877200, 172707811, 16109668, 162669491, 122391399, 162955782, 57655051, and 163005270) that provide functional group diversity through

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

structural features such as ketones, halogens, and alkynes. To comparatively evaluate the antidiabetic and modulatory potential of these ligands, glibenclamide (CID: 3488), considered a reference synthetic antidiabetic drug targeting insulin receptor kinase, was also included in this library. All ligand structures were obtained in 3D format from the PubChem database (https://pubchem.ncbi.nlm.nih.gov/) (GlÃ¼ge, McNeill, & Scheringer, 2023). The obtained ligands were imported into UCSF Chimera (v1.17.3) software. Subsequently, an energy minimization process was performed to ensure locally minimized conformations and to prevent steric collisions. During the energy minimization process, all native and reference ligands were minimized using a step size of 0.02 Å, employing the 100-step Steepest Descent and 10-step Conjugate Gradient algorithms. Following minimization, the ligand structures were prepared for import into AutoDock Tools (v1.5.6) by assigning Gasteiger partial charges (Pettersen et al., 2004). To perform the molecular docking step, the prepared ligands were imported into AutoDock Tools (v1.5.6), converted to PDBQT format to ensure compatibility with AutoDock Vina, and prepared for docking analyses (Morris et al., 2009).

Molecular Docking Protocol

Molecular docking analyses were performed using the AutoDock Vina (v1.1.2) program to analyze the binding affinity and binding profile of zeaxanthin analogs and the reference ligand glibenclamide on insulin receptor kinase (PDB ID: 3EKN). To enable targeted binding of the ligands to the receptor, the amino acid residues constituting the active site within the tyrosine kinase domain of the protein were identified using the PDBsum database (http://www.ebi.ac.uk/pdbsum) (Laskowski, 2022). Next, the target receptor structure was imported into AutoGridFR (AGFR v1.2) software, and the center grid box coordinates encompassing the potential binding pocket were determined using the identified amino acid residues (Ravindranath, Forli, Goodsell, Olson, & Sanner, 2015). Table 1 presents the amino acid residues and grid box coordinates of the insulin receptor kinase active site. This coordinate information, together with the algorithm parameters (exhaustiveness = 8, num_modes = 10, energy_range = 4), was added to the configuration file. Molecular docking analyses were performed using these configuration parameters, and 13 different receptor–ligand complexes were generated. For each complex structure, multiple binding modes and corresponding binding energy scores (kcal/mol) were calculated (Trott & Olson, 2010). The complexes exhibiting the best binding scores and stable conformations were visualized as two-dimensional (2D) interaction maps using Discovery Studio Client 2021.

ADMET Analysis

A preliminary analysis of the suitability of zeaxanthin analog structures to guide future drug discovery and development studies was performed using the ADMETlab 3.0 web server (https://admetmesh.scbdd.com/). In this analysis, physicochemical properties, drug-likeness, and pharmacokinetic (ADMET) profiles were evaluated. Comparison of these analyses with the reference

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ISBN: 978-9952-610-30-7

ligand glibenclamide enabled the rational prioritization of leading candidate molecules among the zeaxanthin analogs ((Fu et al., 2024).

Table 1. Active Site Residues and Grid Center Coordinates of the T2DM-Associated Insulin Receptor Kinase Crystal Structure (PDB ID: 3EKN)

Target Structure (PDB ID)	**Active Site Amino Acid Residues**	**Grid Center Coordinates (X, Y, Z)**	**Grid Box Dimensions (X × Y × Z)**
3EKN	Leu1002, Gly1003, Gln1004, Val1010, Ala1028, Val1060, Met1076, Glu1077, Leu1078, Met1079, Ala1080, Gly1082, Ser1086, Met1139	19.02 Å, 27.93 Å, 18.47 Å	60 x 60 x 60 $Å^3$

RESULTS

The binding affinity and binding profile of zeaxanthin analogs and the reference ligand glibenclamide on the insulin receptor kinase (IRK) target receptor (PDB ID: 3EKN) were analyzed using molecular docking. Among the microalgae-derived zeaxanthin analogs, the molecules with CIDs 102116018, 172775569, and 24728610 yielded the most favorable binding energy scores (Table 2). Analysis of the receptor–ligand complexes formed with all ligands included in the study revealed that the ligands bound within the ATP-binding pocket and occupied similar active site regions. Figure 1 presents the two-dimensional (2D) interaction diagrams of the binding profiles, visually supporting this observation. The zeaxanthin analog with CID 102116018 exhibited the best binding score on the target receptor, with a value of −8.9 kcal/mol. Examination of the receptor–ligand binding mechanism showed that this ligand formed strong contacts with the amino acid residues Leu1002, Gly1003, Val1010, Ala1028, Val1060, Glu1077, Leu1078, Met1079, and Met1139 within the tyrosine kinase domain. The second-best scoring analog, CID 172775569, formed a highly stable receptor–ligand complex with a binding energy value of −8.4 kcal/mol. This ligand was observed to form hydrogen bonds with the Glu1077 and Ser1086 residues of the receptor. In addition, this molecule contributed to the dynamic stability of the complex through hydrophobic interactions involving the Leu1002, Ala1028, and Val1060 residues. Finally, the zeaxanthin analog with CID 24728610 was observed to exhibit a higher binding energy profile than the reference ligand, with a value of −8.3 kcal/mol. The presence of a critical hydrogen bond with the Glu1077 residue at the insulin receptor kinase target supports this energy value. Although a local steric repulsive interaction with the Met1079 amino acid residue was detected in the binding mechanism, this contact appeared to be tolerated and stabilized by additional hydrophobic interactions. For comparative purposes, the binding results of the reference ligand glibenclamide on the target receptor are also presented in Table 1 and Figure 1. The binding energy score of the reference drug glibenclamide, at −8.2 kcal/mol, was lower than those of some

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

zeaxanthin derivatives. Glibenclamide was found to form hydrogen bonds with the Arg1000 residue and weak polar interactions with Gly1082, along with hydrophobic contacts involving Leu1002, Val1060, Ala1028, and Met1139. In contrast, the fluorine-derived zeaxanthin analog CID 102116018 exhibited favorable binding affinity through interactions with the Glu1077 residue, which plays a critical role in kinase activity.

The pharmacokinetic profiles of zeaxanthin derivatives and the reference drug glibenclamide were analyzed using the ADMETlab 2.0 platform based on absorption, distribution, metabolism, excretion, and toxicity parameters, and the results are presented in Table 3. With respect to drug potential and compliance with Lipinski's five-point rule, zeaxanthin analogs met the criteria for drug-like properties. For all zeaxanthin derivatives, CaCO-2 permeability values (log Papp), representing human intestinal absorption, were calculated to range between −4.888 and −5.100 cm/s. These values were comparable to the −4.724 cm/s value obtained for the reference ligand glibenclamide, indicating comparable intestinal absorption rates. In terms of distribution parameters, blood–brain barrier (BBB) permeability was found to be negative for all zeaxanthin analogs and the reference ligand. This result indicates restricted passage of these molecules into the central nervous system. Regarding the metabolism profile, CYP3A4 enzyme inhibition was observed for glibenclamide, whereas it was not detected for the analogs CID 102116018, 24728610, 122391399, 163005270, and 57655051, which exhibited the highest binding energy scores. When the toxicity profile was examined, hERG channel blockade, which plays a critical role in cardiac safety, was not observed for either the microalgae-derived zeaxanthin analogs or the reference drug. Hepatotoxicity risk was identified for the leading compound, CID 102116018, as well as for glibenclamide, while analogs CID 16109668 and 172775569 exhibited a safer profile. In the mutagenicity (AMES toxicity) assessment, the zeaxanthin-based analogs CID 16109668, 172707811, and 162669491 were found to present no mutagenic risk.

DISCUSSION

T2DM is a disease that leads to serious complications as a result of pancreatic beta-cell damage and insulin resistance (Lu et al., 2024). Although current medications provide short-term glycemic control, their long-term use is associated with adverse effects, including increased cardiovascular risk and hepatotoxicity (Scarpa et al., 2024). Therefore, there is a growing need to develop novel, targeted therapeutic alternatives with a strong safety profile for the effective management of T2DM. In this context, recent studies have demonstrated that microalgae-derived carotenoids exert significant modulatory effects on signaling pathways associated with T2DM (Kumar, Kumar, Diksha, Kumari, & Panwar, 2022; Lem et al., 2021). A study by Tjandrawinata et al. demonstrated the antidiabetic and anti-obesity bioactive properties of marine carotenoids, highlighting their potential as metabolic regulatory agent (Tjandrawinata & Nurkolis, 2024). In parallel, numerous in silico-based studies have primarily focused on secondary targets, such as DPP4, in the context of T2DM management (Sajal et al., 2022). However, the molecular behavior of bioactive compounds on insulin receptor kinase (IRK),

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ISBN: 978-9952-610-30-7

which plays a central role in T2DM pathogenesis, has not yet been clearly defined (Choi & Bai, 2023). Therefore, within the scope of this study, we aim to address the existing gap in the literature by analyzing the binding interactions and drug potential of zeaxanthin, which possesses a unique microalgae-derived scaffold, along with its rational structural modifications on insulin receptor kinase (IRK). The insulin receptor kinase structure with PDB ID 3EKN represents a critical therapeutic target due to its essential role in modulating glucose homeostasis associated with T2DM (Chamberlain et al., 2009). Activation of the tyrosine kinase domain of this receptor triggers the IRS-1/PI3K/Akt signaling cascade, ultimately leading to cellular glucose uptake and the translocation of GLUT4 transporters to the cell membrane (van Gerwen, Shun-Shion, & Fazakerley, 2023). Glibenclamide, a widely used synthetic antidiabetic agent, modulates the pathogenesis of T2DM not by directly targeting receptor levels but by stimulating insulin production in pancreatic beta cells (Sahin, Bakiner, Demir, Sari, & Atmaca, 2024). This mechanism leads to progressive depletion of the beta-cell reserve over time, thereby contributing to the development of complications (Fernandez et al., 2025). In the present study, the strong binding affinity of zeaxanthin analogs—selected based on their unique molecular architecture and potential as antidiabetic modulators—to the catalytic region of the target IRK provides the basis for a physiologically relevant therapeutic mechanism (Chamberlain et al., 2009). Following the molecular docking analyses, the zeaxanthin analogs CID 102116018 and CID 172775569, which exhibited significantly improved binding profiles compared with the reference drug glibenclamide, indicate their potential to act as modulators of the receptor (Table 1). Notably, these zeaxanthin analogs displayed stable interactions with the Glu1077 and Met1139 amino acid residues, which play important roles in the hinge region and catalytic cycle of the target receptor (Khan et al., 2024). The Glu1077 residue is known to be critical for proper ATP binding and phosphate transfer, and interactions with this residue suggest a potential contribution to maintaining the functional conformation of the receptor (Chamberlain et al., 2009; Nag et al., 2024). A study by Sajal et al. reported that interactions of DPP4 inhibitors with active site residues at the target receptor are highly significant In the present study, the observed significant interactions with active site residues of IRK similarly indicate that zeaxanthin analogs possess insulin-sensitizing potential and may modulate insulin signaling pathways (Jin et al., 2024).

The natural zeaxanthin molecule with CID 5280899 interacts with the active site of the target receptor IRK primarily due to its hydrophobic molecular architecture. However, the limited polar contact capacity of this molecule imposes certain constraints on its binding efficiency. For this reason, the present study aimed to overcome these limitations by examining structurally modified zeaxanthin analogs (Pasenkiewicz-Gierula, Hryc, & Markiewicz, 2024). For example, two important effects of fluorination observed in the zeaxanthin analog CID 102116018 containing a fluorine atom are evident in the receptor–ligand complexes. First, the high electronegativity of the fluorine atom enables multipolar interactions with hydrophobic amino acid residues, such as Ala1028, Val1060, and

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Met1139, within the active site of the IRK receptor (Wehrhan & Keller, 2024). This binding profile resulted in a markedly stronger binding affinity compared with the parent zeaxanthin molecule. In addition, a second effect of fluorination on the zeaxanthin scaffold is its metabolic shielding property, which is known to enhance metabolic stability (Bhattarai, Trombley, & Altman, 2026). The presence of the fluorine atom significantly increased resistance to oxidative metabolism in the liver and also demonstrated potential for improving pharmacokinetic stability (Du et al., 2025). Finally, modification of the hydroxyl groups in the analog with CID 172775569, which exhibits a markedly better binding energy score than the reference ligand and contains a ketone functional group, rendered this natural molecule a strong hydrogen bond acceptor (Rambaldi et al., 2025). This newly acquired molecular architecture of zeaxanthin enables the establishment of additional contacts with the Ser1086 amino acid residue, thereby enhancing target receptor selectivity (Khan et al., 2024). These findings indicate the potential to improve biological activity on target receptors through the incorporation of halogen and polar functional groups into a naturally occurring hydrophobic scaffold (Cao et al., 2025).

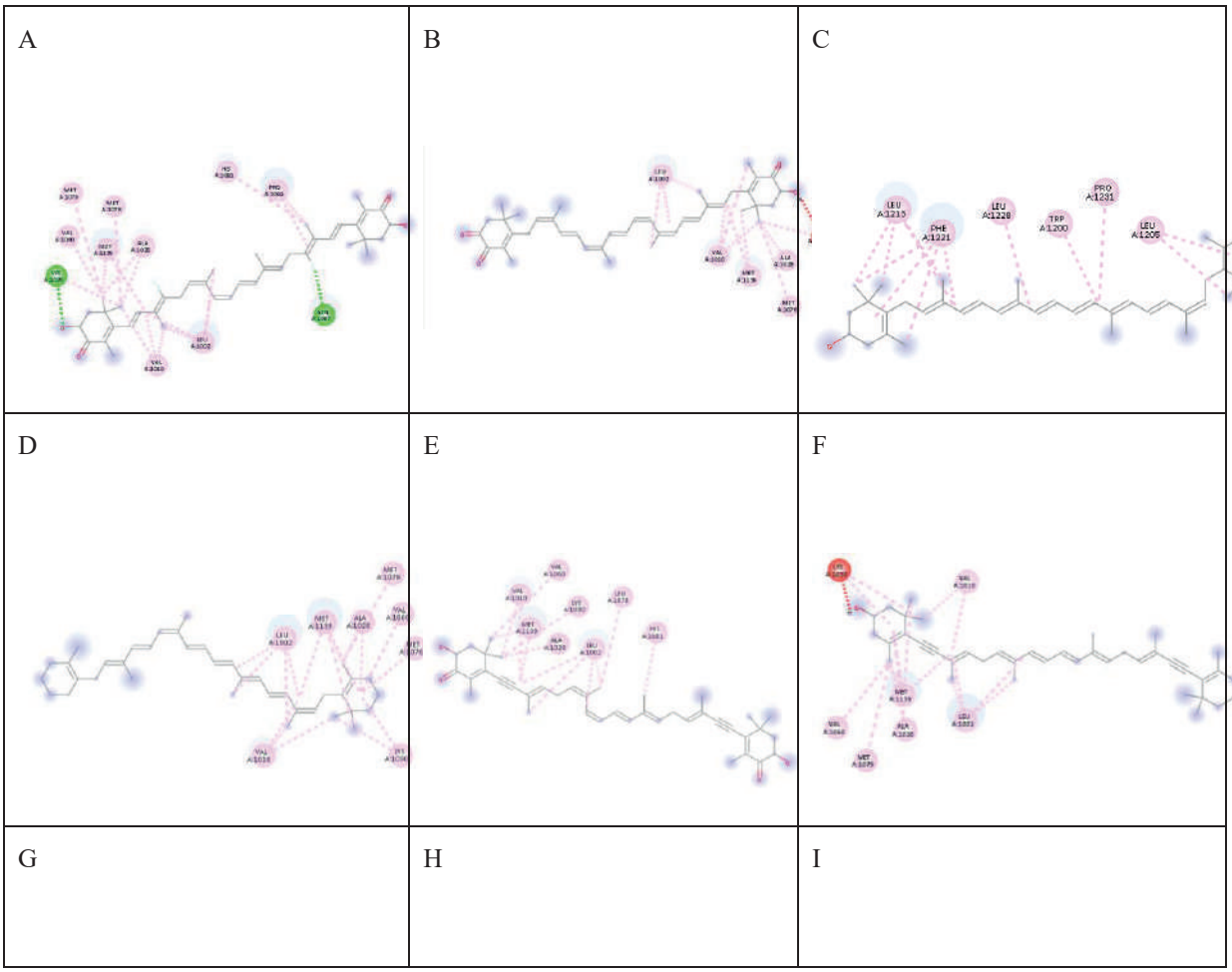
Finally, within the scope of this study, the pharmacokinetic suitability and safety profiles of natural zeaxanthin analogs and glibenclamide were comparatively evaluated using ADMET analyses. It is well documented in the literature that long-term use of synthetic drugs may lead to serious adverse effects, including hepatotoxicity and liver failure (He et al., 2023). Based on this information, the ADMET analysis revealed that glibenclamide acts as a CYP3A4 inhibitor, posing a significant risk for potential drug–drug interactions in individuals with T2DM who require polypharmacy, which is consistent with studies reporting unfavorable findings regarding its side-effect profile (Mengesha et al., 2025). The fact that the zeaxanthin analogue with CID 102116018, considered the leading molecule, and other analogues are not seen as CYP3α4 inhibitors, indicates a safe metabolic profile for the clinical use of these natural molecules as modulators and potential antidiabetic agents in the treatment of IRK receptor and T2DM (Francke, Rottmann, Klein, Hochel, & Friedrich, 2025). In addition, the absence of hERG channel blockade in these natural molecules, together with the favorable hepatotoxicity profiles observed for some analogs, highlights the safety advantages of naturally derived semi-synthetic compounds (Fu et al., 2024). These findings are consistent with the perspective in the literature suggesting that natural derivatives tend to exhibit a more balanced safety profile.

Table 2. Ligand Binding Energy Scores on the Target Receptor (kcal/mol)

Compound ID (CID)	Binding Affinity (kcal/mol)
102116018	-8.9
172775569	-8.4
24728610	-8.3

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162877200	-8.2
Glibenclamide (Ref)	-8.2
172707811	-8.1
16109668	-8.0
162669491	-8.0
122391399	-8.0
Zeaxanthin (5280899)	-8.0
162955782	-7.9
57655051	-7.9
163005270	-7.7



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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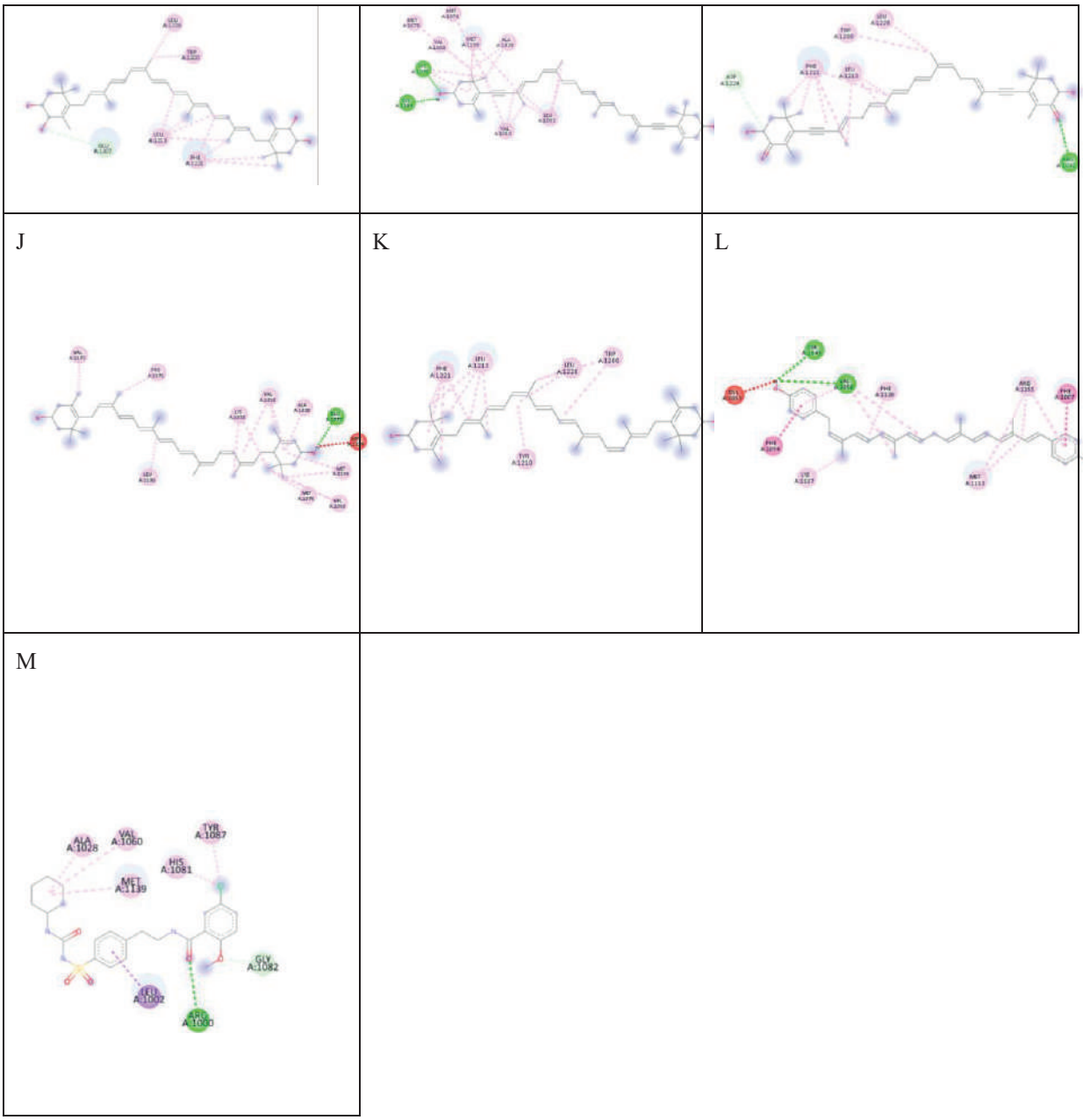


Figure 1. 2D binding interaction profiles of receptor-ligand complexes formed after molecular docking analysis of zeaxanthin analogs and the reference synthetic glibenclamide ligand on the insulin receptor kinase (PDB ID: 3EKN) target receptor were visualized using Discovery Studio 2021 Client software. (Panel A) CID 102116018, (Panel B) CID 122391399, (Panel C) CID 16109668, (Panel D) CID 162669491, (Panel E) CID 162877200, (Panel F) CID 162955782, (Panel G) CID 163005270, (Panel H) CID 172707811, (Panel I) CID 172775569, (Panel J) CID 24728610, (Panel K) Natural Zeaxanthin (CID 5280899), (Panel L) CID 57655051 and (Panel M) Glibenclamide ligands and receptor-ligand complexes formed with the target receptor are presented. In the bonding interaction maps, green lines represent conventional hydrogen bonds, light green lines represent carbon-hydrogen

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ISBN: 978-9952-610-30-7

(C-H) bonds, pink/purple lines represent hydrophobic alkyl or pi-alkyl contacts, and red dashed lines represent negative (steric/donor-donor) interactions.

Table 3. Pharmacokinetic Profiles of Zeaxanthin Analogs and the Reference Ligand Glibenclamide

Compound Name (CID)	Caco-2 Perm. (log Papp)	BBB Perm.	P-gp Substrate	CYP3A4 Inhibitor	hERG Blockers	Hepatotoxicity (H-HT)	AMES Toxicity
5280899 (Zeaxanthin)	-5.069	No	Yes	No	No	No	Yes
122391399	-4.970	No	Yes	No	No	Yes	Yes
163005270	-5.073	No	Yes	No	No	Yes	Yes
102116018	-4.982	No	Yes	No	No	Yes	Yes
57655051	-4.918	No	Yes	No	No	Yes	Yes
16109668	-5.002	No	Yes	Yes	No	No	No
172707811	-5.100	No	Yes	Yes	No	Yes	No
24728610	-5.058	No	Yes	No	No	Yes	Yes
172775569	-5.066	No	Yes	Yes	No	No	Yes
162669491	-4.888	No	Yes	Yes	No	Yes	No
162955782	-5.021	No	Yes	Yes	No	Yes	Yes
3488 (Glibenclamide)	-4.724	No	Yes	Yes	No	Yes	No

CONCLUSION

The limited understanding of the molecular mechanisms underlying synthetic, plant-derived, and microalgae-derived therapeutic molecules targeting insulin receptor pathways in T2DM treatment, together with the difficulty of identifying novel antidiabetic agents tailored to the heterogeneous nature of diabetes, represents a major challenge. Therefore, in this study, the modulatory and antidiabetic potential of zeaxanthin and its derivatives targeting the human insulin receptor kinase (PDB ID: 3EKN) was investigated using in silico–based approaches. The combined evaluation of structure-based molecular docking and ADMET-based pharmacokinetic profiling enabled the systematic prioritization of microalgae-derived zeaxanthin analogs. The fluorinated zeaxanthin analog

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ISBN: 978-9952-610-30-7

CID 102116018, together with other analogs, exhibited significantly higher binding affinity and a more stable interaction profile at the catalytic region of the target receptor compared with the reference drug glibenclamide. In terms of pharmacokinetic properties, the low risk of CYP450-mediated drug–drug interactions and the absence of major cardiotoxicity warnings for the natural analogs indicate a favorable safety profile, supporting their potential as candidate compounds. Although zeaxanthin has been reported in the literature to possess antioxidant and antidiabetic bioactive properties, the binding behavior of its rationally modified derivatives on the target IRK receptor has not previously been evaluated at the molecular level. In summary, the findings of this study indicate that the zeaxanthin analog CID 102116018, along with other natural analogs, represents promising candidates for T2DM treatment and for the development of next-generation modulators and antidiabetic agents targeting the insulin receptor. Overall, this study aims to provide a rational framework to guide future in vitro and in vivo investigations.

ACKNOWLEDGEMENTS

This work was supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under project number 124Z725.

REFERENCES

Accili, D., Deng, Z., & Liu, Q. J. N. R. E. (2025). Insulin resistance in type 2 diabetes mellitus. 1-14.

Akter, B., Uddin, M. S., Islam, M. R., Ahamed, K. U., Aktar, M. N., Hossain, M. K., . . . Bourhia, M. (2025). Computational Drug Design Approaches for the Identification of Novel Antidiabetic Compounds from Natural Resources through Molecular Docking, ADMET, and Toxicological Studies. *Cell Biochem Biophys, 83*(1), 1057-1070. doi:10.1007/s12013-024-01540-1

Anzar, C. A., Joseph, M. V., Sundaram, R., Vadiraj, G. B., Prasad, C. P., Eranimose, B., & Jagadeesh, S. (2023). doi:10.1101/2023.09.22.23295947

Bhattarai, P., Trombley, T. A., & Altman, R. A. (2026). Metabolic Stability of Fluorinated Small Molecules: A Physical Organic Chemistry Perspective. *J Med Chem*. doi:10.1021/acs.jmedchem.5c02359

Burley, S. K., Bhikadiya, C., Bi, C., Bittrich, S., Chen, L., Crichlow, G. V., . . . Zardecki, C. (2022). RCSB Protein Data Bank: Celebrating 50 years of the PDB with new tools for understanding and visualizing biological macromolecules in 3D. *Protein Sci, 31*(1), 187-208. doi:10.1002/pro.4213

Cao, R., Li, J., Liao, Q., Shao, M., Zhang, Q., Zhang, Y., . . . Xu, Z. (2025). Enhanced Bioactivity of Natural Products by Halogenation: A Database Survey and Quantum Chemistry Calculation Study. *J Med Chem, 68*(10), 10486-10496. doi:10.1021/acs.jmedchem.5c00944

Chamberlain, S. D., Redman, A. M., Wilson, J. W., Deanda, F., Shotwell, J. B., Gerding, R., . . . Patnaik, S. (2009). Optimization of 4,6-bis-anilino-1H-pyrrolo[2,3-d]pyrimidine IGF-1R tyrosine kinase inhibitors towards JNK selectivity. *Bioorg Med Chem Lett, 19*(2), 360-364. doi:10.1016/j.bmcl.2008.11.077

Choi, E., & Bai, X. C. (2023). The Activation Mechanism of the Insulin Receptor: A Structural Perspective. *Annu Rev Biochem, 92*, 247-272. doi:10.1146/annurev-biochem-052521-033250

Du, Y., Bian, Y., Baecker, D., Dhawan, G., Semghouli, A., Kiss, L., . . . Han, J. (2025). Fluorine in the Pharmaceutical Industry: FDA-Approved Fluorine-Containing Drugs in 2024. *Chemistry, 31*(25), e202500662. doi:10.1002/chem.202500662

Fernandez, C., Nacher, M., Rivera, K., Marin-Canas, S., Sorribas, M., Moreno-Gonzalez, G., . . . Montanya, E. (2025). Loss of beta-cell identity in human islets treated with glibenclamide. *Diabetes Obes Metab, 27*(10), 5782-5792. doi:10.1111/dom.16632

Francke, K., Rottmann, A., Klein, S., Hochel, J., & Friedrich, C. (2025). Investigation of the Relevance of CYP3A4 Inhibition on the Pharmacokinetics of the Novel P2X3 Antagonist Filapixant: Results of In Vitro Explorations and a Fixed-Sequence Clinical Trial with Itraconazole in Healthy Volunteers. *Int J Mol Sci, 26*(20). doi:10.3390/ijms262010177

Fu, L., Shi, S., Yi, J., Wang, N., He, Y., Wu, Z., . . . Cao, D. (2024). ADMETlab 3.0: an updated comprehensive online ADMET prediction platform enhanced with broader coverage, improved performance, API functionality and decision support. *Nucleic Acids Res, 52*(W1), W422-W431. doi:10.1093/nar/gkae236

Galiero, R., Caturano, A., Vetrano, E., Monda, M., Marfella, R., Sardu, C., . . . Sasso, F. C. (2023). Precision Medicine in Type 2 Diabetes Mellitus: Utility and Limitations. *Diabetes Metab Syndr Obes, 16*, 3669-3689. doi:10.2147/DMSO.S390752

GlÃ¼ge, J., McNeill, K., & Scheringer, M. J. E. S. A. (2023). Getting the SMILES right: identifying inconsistent chemical identities in the ECHA database, PubChem and the CompTox Chemicals Dashboard. *2*(4), 612-621.

He, L. Y., Li, Y., Niu, S. Q., Bai, J., Liu, S. J., & Guo, J. L. (2023). Polysaccharides from natural resource: ameliorate type 2 diabetes mellitus via regulation of oxidative stress network. *Front Pharmacol, 14*, 1184572. doi:10.3389/fphar.2023.1184572

Jin, Z., Liu, M., Zhao, H., Xie, J., Yin, W., Zheng, M., . . . Liu, J. J. F. (2024). Effects of Zeaxanthin on the Insulin Resistance and Gut Microbiota of High-Fat-Diet-Induced Obese Mice. *13*(21), 3388.

Khan, S., Ahmad, N., Fazal, H., Saleh, I. A., Abdel-Maksoud, M. A., Malik, A., . . . Ahmad, S. (2024). Exploring stevioside binding affinity with various proteins and receptors actively involved in the signaling pathway and a future candidate for diabetic patients. *Front Pharmacol, 15*, 1377916. doi:10.3389/fphar.2024.1377916

Kumar, S., Kumar, R., Diksha, Kumari, A., & Panwar, A. J. J. o. B. M. (2022). Astaxanthin: A super antioxidant from microalgae and its therapeutic potential. *62*(9), 1064-1082.

Laskowski, R. A. J. P. S. (2022). PDBsum 1: A standalone program for generating PDBsum analyses. *31*(12), e4473.

Lem, D. W., Gierhart, D. L., & Davey, P. G. (2021). A Systematic Review of Carotenoids in the Management of Diabetic Retinopathy. *Nutrients, 13*(7). doi:10.3390/nu13072441

Lu, X., Xie, Q., Pan, X., Zhang, R., Zhang, X., Peng, G., . . . Tong, N. (2024). Type 2 diabetes mellitus in adults: pathogenesis, prevention and therapy. *Signal Transduct Target Ther, 9*(1), 262. doi:10.1038/s41392-024-01951-9

Mehkri, S., Dinesh, K. G., Ashok, G., & Bopanna, K. (2025). Comparative Pharmacokinetics of Lutein and Zeaxanthin from Phospholipid, Liposomal, and MCT Formulations in SD Rats. *Pharmaceutics, 17*(12). doi:10.3390/pharmaceutics17121552

Mengesha, A. K., Ayele, H. S., Beyna, A. T., Gebiyaw, S. T., Tessema, T. A., Alemu, M. A., & Haile, T. D. (2025). Pharmacological risks of khat-oral antidiabetic drug interactions among patients at Gondar university referral hospital. *Sci Rep, 15*(1), 41107. doi:10.1038/s41598-025-24952-2

Morris, G. M., Huey, R., Lindstrom, W., Sanner, M. F., Belew, R. K., Goodsell, D. S., & Olson, A. J. (2009). AutoDock4 and AutoDockTools4: Automated docking with selective receptor flexibility. *J Comput Chem, 30*(16), 2785-2791. doi:10.1002/jcc.21256

Murillo, A. G., Hu, S., & Fernandez, M. L. (2019). Zeaxanthin: Metabolism, Properties, and Antioxidant Protection of Eyes, Heart, Liver, and Skin. *Antioxidants (Basel), 8*(9). doi:10.3390/antiox8090390

Nag, S., Stany, B., Mishra, S., Kumar, S., Mohanto, S., Ahmed, M. G., . . . Subramaniyan, V. (2024). Multireceptor Analysis for Evaluating the Antidiabetic Efficacy of Karanjin: A Computational Approach. *Endocrinol Diabetes Metab, 7*(4), e509. doi:10.1002/edm2.509

Pasenkiewicz-Gierula, M., Hryc, J., & Markiewicz, M. (2024). Dynamic and Energetic Aspects of Carotenoids In-and-Around Model Lipid Membranes Revealed in Molecular Modelling. *Int J Mol Sci, 25*(15). doi:10.3390/ijms25158217

Pettersen, E. F., Goddard, T. D., Huang, C. C., Couch, G. S., Greenblatt, D. M., Meng, E. C., & Ferrin, T. E. (2004). UCSF Chimera--a visualization system for exploratory research and analysis. *J Comput Chem, 25*(13), 1605-1612. doi:10.1002/jcc.20084

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Rambaldi, A., Paris, F., Marrazzo, P., Costa, R., Ratti, S., & Alviano, F. (2025). Marine-Derived Astaxanthin: Molecular Mechanisms, Biomedical Applications, and Roles in Stem Cell Biology. *Mar Drugs, 23*(6). doi:10.3390/md23060235

Ravindranath, P. A., Forli, S., Goodsell, D. S., Olson, A. J., & Sanner, M. F. (2015). AutoDockFR: Advances in Protein-Ligand Docking with Explicitly Specified Binding Site Flexibility. *PLoS Comput Biol, 11*(12), e1004586. doi:10.1371/journal.pcbi.1004586

Sahin, I., Bakiner, O., Demir, T., Sari, R., & Atmaca, A. (2024). Current Position of Gliclazide and Sulfonylureas in the Contemporary Treatment Paradigm for Type 2 Diabetes: A Scoping Review. *Diabetes Ther, 15*(8), 1687-1716. doi:10.1007/s13300-024-01612-8

Sajal, H., Patil, S. M., Raj, R., Shbeer, A. M., Ageel, M., & Ramu, R. (2022). Computer-Aided Screening of Phytoconstituents from Ocimum tenuiflorum against Diabetes Mellitus Targeting DPP4 Inhibition: A Combination of Molecular Docking, Molecular Dynamics, and Pharmacokinetics Approaches. *Molecules, 27*(16). doi:10.3390/molecules27165133

Saldivar-Gonzalez, F. I., Navarrete-Vazquez, G., & Medina-Franco, J. L. (2023). Design of a multi-target focused library for antidiabetic targets using a comprehensive set of chemical transformation rules. *Front Pharmacol, 14*, 1276444. doi:10.3389/fphar.2023.1276444

Scarpa, E.-S., Antonelli, A., Balercia, G., Sabatelli, S., Maggi, F., Caprioli, G., . . . Micucci, M. J. B. (2024). Antioxidant, anti-inflammatory, anti-diabetic, and pro-osteogenic activities of polyphenols for the treatment of two different chronic diseases: type 2 diabetes mellitus and osteoporosis. *14*(7), 836.

Sheikhi, N., Bahraminejad, M., Saeedi, M., & Mirfazli, S. S. (2023). A review: FDA-approved fluorine-containing small molecules from 2015 to 2022. *Eur J Med Chem, 260*, 115758. doi:10.1016/j.ejmech.2023.115758

Tjandrawinata, R. R., & Nurkolis, F. (2024). A Comparative Analysis on Impact of Extraction Methods on Carotenoids Composition, Antioxidants, Antidiabetes, and Antiobesity Properties in Seagrass Enhalus acoroides: In Silico and In Vitro Study. *Mar Drugs, 22*(8). doi:10.3390/md22080365

Trott, O., & Olson, A. J. (2010). AutoDock Vina: improving the speed and accuracy of docking with a new scoring function, efficient optimization, and multithreading. *J Comput Chem, 31*(2), 455-461. doi:10.1002/jcc.21334

van Gerwen, J., Shun-Shion, A. S., & Fazakerley, D. J. (2023). Insulin signalling and GLUT4 trafficking in insulin resistance. *Biochem Soc Trans, 51*(3), 1057-1069. doi:10.1042/BST20221066

Wan, Q., & Thompson, B. C. (2024). Control of Properties through Hydrogen Bonding Interactions in Conjugated Polymers. *Adv Sci (Weinh), 11*(8), e2305356. doi:10.1002/advs.202305356

Wehrhan, L., & Keller, B. G. (2024). Fluorinated Protein-Ligand Complexes: A Computational Perspective. *J Phys Chem B, 128*(25), 5925-5934. doi:10.1021/acs.jpcb.4c01493

Zelisko, N., & Lesyk, R. (2025). Molecules with alkyne fragment in medicinal chemistry: The path from neurotoxins to drugs. *European Journal of Medicinal Chemistry Reports, 15*. doi:10.1016/j.ejmcr.2025.100294

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

POLİGON HESAP YÖNTEMLERİNİN KARŞILAŞTIRILMASI

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Özet

Jeodezinin en önemli uğraşlarından biri, üç boyutlu koordinatları bilinen dayanak noktaları üretmektir. Fiziksel yeryüzünde yeterli sıklıkta üretilen bu dayanak noktaları tüm jeodezik çalışmalar için kullanılır. Bu dayanak noktaları nirengi noktaları olarak adlandırılır. Ancak pratik çalışmalar için nirengi noktalarının dağılımı ve sıklığı yeterli olmaz. Özellikle detay alım çalışmalarında Nirengi noktalarının arasına poligon noktaları atılır ve usulüne uygun olarak koordinatları hesaplanır. Detay alım çalışmaları bu poligon noktalarına dayalı olarak gerçekleştirilir. Poligon hesaplarının hata teorisine uygun çözümü dengeleme hesabı ile gerçekleştirilir. Dengeleme hesabının el ile yapılması durumunda uzun yorucu işlemler gerekebilir, doğaldır ki hesaplamaların bilgisayar ortamında yapılması durumunda böyle bir zorluktan bahsedilemez. Ancak poligon hesabından beklenen doğruluk derecesi göz önüne alındığında dengeleme hesabı yapmaksızın da uygun poligon hesabı yöntemleri ile amaçlanan doğruluk elde edilir. Bu da uygulamacıya kolaylık sağlar.

Poligon hesabıyla koordinatları hesaplanmış noktalarının hassasiyetleri nirengi noktalarından daha düşük olmakla beraber pratik detay alım çalışmaları için genelde yeterli olurlar. Poligon ağlarındaki hataların dengeli bir şekilde giderilmesi için bir dizi yöntemler uygulanır. Bu çalışmada geleneksel yöntemlerden olan Transit (Geçiş) Kuralı, Bowditch (Pusula) Kuralı ve Crandall Kuralı örnekler ile incelenmiş ve En küçük kareler yöntemi açıklanmıştır.

Anahtar Kelimeler: Poligon hesabı , Transit, Bowditch, Crandall, En Küçük Kareler.

A COMPARISON OF TRAVERSE ADJUSTMENT METHODS

Abstract

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

One of the most important endeavours in geodesy is to produce reference points with known three-dimensional coordinates. These reference points, produced in sufficient frequency on the physical surface, are used for all geodetic studies. These reference points are called triangulation points. However, the distribution and frequency of triangulation points are insufficient for practical studies. Especially in detailed surveying studies, polygon points are placed between triangulation points and their coordinates are calculated according to the procedure. Detail surveying studies are carried out based on these polygon points. The solution of polygon calculations according to error theory is performed with a adjustment calculation. If the adjustment calculation is done manually, it may require long and laborious processes; naturally, such difficulty cannot be mentioned if the calculations are done in a computer environment. However, considering the degree of accuracy expected from polygon calculation, the desired accuracy can be obtained with appropriate polygon calculation methods without performing a adjustment calculation. This provides convenience to the practitioner. Although the accuracy of points whose coordinates are calculated with polygon calculation is lower than that of triangulation points, they are generally sufficient for practical detailed surveying studies. A number of methods are applied to eliminate errors in polygon networks in a balanced manner. In this study, traditional methods such as the Transit Rule, Bowditch Rule, and Crandall Rule are examined with examples, and the least squares method is explained.

Keywords: Traverse, Transit, Bowditch, Crandall, Least Squares.

1.GİRİŞ

Doğruluk ve hassasiyet mühendislik ölçmelerinde en önemli konulardan biridir. Hassasiyet, ölçmelerin tekrarlanmasıyla artırılabilmekte; doğruluk ise ölçülen değerin gerçek ya da gerçek kabul edilen değere olan yakınlığı ile elde edilmektedir. Çeşitli mühendislik projelerinde, mümkün olan en yüksek doğruluk seviyesine ulaşmak amacıyla poligon ağlarında dengeleme işlemleri uygulanmaktadır. Bu nedenle poligon ölçmeleri, kontrol ağı ölçmeleri kapsamında önemli bir rol oynamaktadır.

Yeni bir mühendislik yapım projesi planlandığında, öncelikle çalışma alanında poligon ağına ait istasyonların tesis edilmesi ve ölçülmesi gerekmektedir.

Literatürde poligon ölçmelerinin kullanım alanlarının oldukça geniş olduğu belirtilmektedir. Kadastro uygulamalarında sınır işaretlerinin ve sınır hatlarının konumlarının belirlenmesi ile alan hesaplamaları poligon ölçmelerinin temel kullanım alanlarını oluşturmaktadır. Bunun yanı sıra harita üretimi ve fotogrametrik çalışmalar için gerekli kontrol noktalarının tesis edilmesi, mühendislik projelerinde ise karayolu, demiryolu ve altyapı yapılarının konumlandırılması ile toprak hacmi hesaplarına yönelik kontrol ağlarının oluşturulmasında poligon ölçmelerinden yararlanılmaktadır. (Gary, 2015)

Her ne kadar teknoloji gelişmiş ve GPS gibi yöntemler yaygınlaşmış olsa da, poligon ölçmeleri kontrol ağlarının doğruluğunu artırmak için kullanılan etkili bir yöntemdir. Özellikle GPS'in

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

uygulanamadığı veya hataların yoğun olarak etkili olduğu; yansıma problemlerinin görüldüğü ormanlık alanlar, yer altı çalışmaları, yerleşim alanları gibi bölgelerde poligon ölçmeleri önemini korumaktadır.

Poligon ölçmeleri; uzayda büyüklüğü ve yönü olan kutupsal vektörlerin oluşturulmasına dayanmaktadır. Bu vektörler genellikle birbirine bitişik olup, çeşitli matematiksel ve geometrik kurallara uyan bir çokgen (poligon) meydana getirir. Ölçme aletlerinin gelişmesiyle birlikte poligon yöntemleri de gelişmiş ve daha yüksek doğruluk seviyelerine ulaşılmıştır. (Manguri,2016)

Modern ölçme teknikleri, tekrarlı ölçüler üretir ve bu ölçüler genellikle en küçük kareler yöntemi olarak adlandırılan yöntem kullanılarak değerlendirilir. Genellikle bu yöntem, ölçülerin dengeleme ve istatistiksel değerlendirme işlemine geçilmeden önce matematiksel olarak ifade edilmesini gerektirir. Matematiksel modellerin dengelenmesi, ancak fazla model ya da fazla gözlem varsa anlamlıdır.

Birçok dengeleme ölçütü mümkündür. Bunlardan bazıları, geleneksel dengeleme yöntemleriyle ilişkili olanlardır ve bu bölümde ele alınacaktır. Ancak vurgulanmalıdır ki, En Küçük Kareler Yöntemi (EKK), Jeodezide ölçülerin dengelenmesinde en çok kabul gören standart hâline gelmiştir.

2.GELENEKSEL YÖNTEMLER

Günümüzde ölçümlerdeki büyük hataları kontrol edebilmek ve ölçümlerin hassasiyetini artırmak için farklı ölçüm teknikleri haritacılar tarafından kullanılmaktadır. Bu geleneksel yöntemleri Transit Kuralı, Bowditch (Pusula) Kuralı ve Crandall'ın Kuralı olarak açıklayabiliriz (Ogundare, 2018).

2.1.Transit (Geçiş) Kuralı

Transit Kuralı, poligon hesaplarında açıların mesafeden daha yüksek doğrulukla ölçüldüğü bir dengeleme hesabı yöntemidir. Bu yöntem, poligon kenarlarının poligon hesaplamaları için kullanılan koordinat sistemine paralel olduğu durumlarda geçerlidir.

Herhangi bir nokta için enlem değerindeki düzeltme, o noktadaki enlemin toplam hatasına ve enlemdeki toplam değişimin traversteki tüm enlemlerin toplamına bölünmesine eşittir. Sapmadaki düzeltme ise o noktadaki sapmanın katına ve sapmadaki toplam kapanışın traversteki tüm sapmaların toplamına bölünmesine eşittir (Davis et al., 1981).

Bir poligonun X bileşenine ait toplam açı kapanma hatası f_X olarak verildiğinde poligonun i'nci kenarına ait X bileşeni $(\Delta\hat{X})_i$,

$$f_{\Delta X} = -f_X \left(\frac{|\Delta X_i|}{\sum_i^n |\Delta X_i|} \right) \qquad \textbf{(2.1.1)}$$

Y değerindeki $(f_{\Delta Y})$ değişikliğe uygulanacak düzeltme $(\Delta\hat{Y})_i$

$$f_{\Delta Y} = -f_Y \left(\frac{|\Delta Y_i|}{\sum_i^n |\Delta Y_i|} \right) \qquad \textbf{(2.1.2)}$$

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$|\Delta X_i|$: verilen i'nci poligon kenarı boyunca hesaplanan X bileşeninin mutlak değeridir.

i'inci kenarına ait Y bileşeni için (ΔY_i) uygulanacak düzeltme $(f_{\Delta Y_i})$:

$$\Delta \hat{X}_i = \Delta X_i + f_{\Delta X_i} \quad \textbf{(2.1.3)}$$

$$\Delta \hat{Y}_i = \Delta Y_i + f_{\Delta Y_i} \quad \textbf{(2.1.4)}$$

$\Delta \hat{X}_i$: verilen i'nci poligon kenarı için X değerindeki düzeltilmiş değişiklikler

$\Delta \hat{Y}_i$: verilen i'nci poligon kenarı için Y değerindeki düzeltilmiş değişiklikler

i'nci poligon kenarı için düzeltilmiş koordinatlar:

$$\hat{X}_k = \hat{X}_{k-1} + \Delta \hat{X}_{k-1 \to k} \quad \textbf{(2.1.5)}$$

$$\hat{Y}_k = \hat{Y}_{k-1} + \Delta \hat{Y}_{k-1 \to k} \quad \textbf{(2.1.6)}$$

$\hat{X}_k$ ve $\hat{Y}_k$ sırasıyla mevcut k poligon noktası için düzeltilmiş kuzey ve doğu koordinat değerleridir.

$\hat{X}_{k-1}$ ve $\hat{Y}_{k-1}$ sırasıyla mevcut k poligon noktasından önceki $k-1$ poligon noktası için daha önce düzeltilmiş kuzey ve doğu koordinatlarıdır.

$\Delta \hat{X}_{k-1 \to k}$ ve $\Delta \hat{Y}_{k-1 \to k}$ noktasından k noktasına kadar olan poligon kenarı için kuzey ve doğu değerlerindeki düzeltilmiş koordinatlardır. (Hart L. et al.,2021)

2.2.Bowditch (Pusula) Kuralı

Pusula ya da Bowditch Kuralı, adını Amerikalı denizci Nathaniel Bowditch'ten (1773-1838) alan, kapalı bir poligon ağı için kullanılan bir dengeleme hesabı yöntemidir. Bowditch Kuralı açı için gerekli hassasiyetin mesafedeki hassasiyete eşit olduğu kabulüne dayanır (Manguri, 2016).

Bowditch, her bir noktanın poligon uzunluğuna oranı kadar toplam düzeltme yapılması gerektiğini göstermiştir. Ölçüm sonrasında oluşan hataların ise rastgele oluştuğunu ve poligonun herhangi bir noktasındaki toplam hatanın poligon ağının toplam uzunluğu ile doğru orantılı olduğunu varsaymıştır. Ayrıca, mesafe ölçümünde gerçekleşen hataların açısal hataların etkisine eşit olduğunu varsaymıştır (Manguri, 2016).

Poligon boyunca ölçülen mesafelere ait toplamın, poligonun toplam uzunluğuna oranlanmasıyla her bir nokta için düzeltme faktörü hesaplanır ve uygulanır. Elde edilen bu düzeltme faktörü, toplam kapanım hatası ile çarpılır. Böylece poligon ağındaki noktalara ait koordinatlara dağıtılacak olan hata düzeltme miktarı belirlenir.

Poligonun i'nci kenarına ait X değerindeki düzeltme:

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ISBN: 978-9952-610-30-7

$$f_{\Delta X_i} = -f_X \left(\frac{S_i}{S}\right) \quad \textbf{(2.2.1)}$$

S_i: i. Poligon kenarının uzunluğu

S: poligon geçkisinin toplam uzunluğu

$f_{\Delta X_i}$: ΔX_i koordinat farkına uygulanacak düzeltme

f_X: X bileşenine ait toplam açı kapanma hatası

Poligonun i'nci kenarına ait Y değerindeki düzeltme:

$$f_{\Delta Y_i} = -f_Y \left(\frac{S_i}{S}\right) \quad \textbf{(2.2.2)}$$

$$\Delta \hat{X}_i = \Delta X_i + f_{\Delta X_i} \quad \textbf{(2.2.3)}$$

$$\Delta \hat{Y}_i = \Delta Y_i + f_{\Delta Y_i} \quad \textbf{(2.2.4)}$$

$\Delta \hat{X}_i$: verilen i'nci poligon kenarı için X değerindeki düzeltilmiş değişiklikler

$\Delta \hat{Y}_i$: verilen i'nci poligon kenarı için Y değerindeki düzeltilmiş değişiklikler

Düzeltimiş kuzey koordinatı $\hat{X}_k$ ve düzeltilmiş doğu koordinatı $\hat{Y}_k$ sırasıyla

$$\hat{X}_k = \hat{X}_{k-1} + \Delta \hat{X}_{k-1 \to k} \quad \textbf{(2.2.5)}$$

$$\hat{Y}_k = \hat{Y}_{k-1} + \Delta \hat{Y}_{k-1 \to k} \quad \textbf{(2.2.6)}$$

denklemlerinden elde edilir. (Ogundare, 2018)

2.3.Crandall Kuralı

Crandall Kuralı yöntemi, ölçme teknolojisinin sınırlı olduğu dönemin koşullarını yansıtmak amacıyla Crandall tarafından geliştirilmiş olup, minimum varyans ilkesine dayanmaktadır. Yöntem, kapalı poligon ağlarında kapanma hatalarının dengelenmesinde En Küçük Kareler (EKK) yöntemine benzer bir yaklaşım sergilemektedir. Bu yöntemin temel varsayımı, poligon ağlarında yapılan açı ölçmelerinin, mesafe ölçmelerine kıyasla daha yüksek doğruluğa sahip olduğu kabulüdür. Bu nedenle Crandall Kuralı'na göre, kapanma hatalarının tamamı mesafe ölçmelerinden kaynaklanmaktadır. Düzeltmeler ise yalnızca koordinat farklarına dağıtılmakta ve açı ölçmeleri düzeltilmeden bırakılmaktadır.

Ancak bu varsayım, Total Station gibi modern ölçme aletlerinin kullanıldığı günümüz jeodezik ölçmelerinde geçerliliğini büyük ölçüde yitirmiştir. Modern ölçme sistemlerinde açı ve mesafe ölçmeleri benzer doğruluk düzeylerine sahip olduğundan, Crandall Kuralı günümüzde daha çok tarihsel ve karşılaştırmalı bir yöntem olarak ele alınmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Bu yöntem kullanılarak, her bir kenara ait X ve Y yönlü koordinat farklarına uygulanacak düzeltmeler aşağıdaki bağıntılarla ifade edilmektedir:

$$f_{\Delta X_i} = A(\Delta X_i)^2 + B(\Delta X_i \times \Delta Y_i) \qquad \textbf{(2.3.1)}$$

$$f_{\Delta Y_i} = A(\Delta X_i \times \Delta Y_i) + B(\Delta Y_i)^2 \qquad \textbf{(2.3.2)}$$

$$B = \frac{[\varepsilon_X \times (\sum_i^n \Delta X_i \, x \Delta Y_i) - \varepsilon_Y \times (\sum_i^n (\Delta X_i)^2)]}{(\sum_i^n (\Delta Y_i)^2 \sum_i^n (\Delta X_i)^2)] - \times (\sum_i^n (\Delta X_i \, x \Delta Y_i)(\sum_i^n (\Delta X_i \, x \Delta Y_i)} \qquad \textbf{(2.3.3)}$$

$$A = \frac{-[B \times (\sum_i^n \Delta X_i \, x \Delta Y_i) + \varepsilon_Y]}{(\sum_i^n (\Delta X_i)^2} \qquad \textbf{(2.3.4)}$$

3.DENGELEME HESABI

Uygulamalı bilimlerde ölçülerden ve ölçü sonuçlarından elde edilen doğruluğu ve duyarlığı artırmak için fazla sayıda ölçü yapılır. Dengeleme hesabının amacı kaba, sistematik ve uyuşumsuz ölçü içermeyen ölçü grubundan herhangi bir ölçüyü çıkarmadan bilinmeyenlerin ve bilinmeyenlerin fonksiyonlarının en uygun ve en yüksek olasılıklı değerini belirlemektir (Wang,1992). Dengeleme hesabında bilinmeyen parametreleri belirlemek için bir amaç fonksiyonuna göre çözüm yapılır.

Poligon hesaplarının hata teorisine uygun çözümü dengeleme hesabı ile gerçekleştirilir. Poligon geçkilerinin dengeleme hesabı detayları için bakınız Bektas(2016a,2016b)

x bilinmeyen parametrelerin l ölçü grubundan dengeleme hesabı ile belirlenmesi için ölçülerle bilinmeyenler arasındaki fonksiyonel ve stokastik ilişkileri gösteren matematik model yazılır.

$$\hat{l} = \phi_i(x_1, x_2, \ldots\ldots, x_u) \quad Q_{ll} = P^{-1}; C_{ll} = \sigma_0^2 Q_{ll} \qquad \textbf{(3.1)}$$

Doğrusal matematik model olarak da bilinen Gauss-Morkoff modeli yukarıdaki eşitlik doğrusallaştırılarak elde edilir (Wang 1992, Vanicek, Wells 1972).

$$E\{\hat{l}\} = \underline{l} + \underline{v} = \underline{Ax} \qquad \underline{Q_{ll}} = \underline{P}^{-1} \; ; \; \underline{C_{ll}} = \sigma_0^2 \, \underline{Q_{ll}} \qquad \textbf{(3.2)}$$

(3.1) ve (3.2) eşitliğinde, A matematik modelin tasarım matrisi, P, Q_{ll} ve C_{ll} ölçülerin ağırlık, ters ağırlık ve varyans-kovaryans matrisi, σ_0^2 öncül varyans ve $\hat{l}$ kesin ölçülerdir.

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4.En Küçük Kareler Yöntemi

En küçük kareler yöntemi 1795'te Carl Friedrich Gauss, 1805'te Legendre tarafından açıklanmış birçok bilim dalında kullanılan bir yöntemdir. (3.2) eşitliğinin EKK'ne göre çözümü $\|Pvv\| = [Pvv] =$ min amaç fonksiyonu ile yapılırsa,

$$\underline{X} = (\underline{A}^T \underline{Q_{ll}}^{-1} \underline{A})^{-1} \underline{A}^T \underline{Q_{ll}}^{-1} \underline{l} \qquad \textbf{(4.1)}$$

bilinmeyenler elde edilir. Duyarlık hesapları için birim ölçünün karesel ortalama hatası

$$m0 = \pm \sqrt{\frac{\underline{V}^T \underline{P} \underline{V}}{f}} \quad ,$$

$$f = n - u$$

eşitliğiyle hesaplanır. Düzeltmeler için

$$\underline{v} = \underline{Ax} - \underline{l} \qquad \textbf{(3.4)}$$

eşitliği elde edilir. Bu eşitlik ölçülerin düzeltmelere olan etkilerini açıklamaktadır. V düzeltmeleri rastlantı hataları yanında matematiksel model için ölçütlerinin özelliklerini yansıtan gerçek ile farkları gösterir. Bu anlamda V vektörüne ölçü düzeltmeleri yerine dengeleme artıkları (residual) denir. V vektörü özel test yöntemleriyle analiz edilerek ölçüler hakkında bilgiler alınabilir ve uyuşumsuz ölçüler belirlenebilir.

SONUÇ

Bir poligon ağının hesabı, gerekli matematiksel ilkelere dayanmalı ve farklı ölçüm hassasiyetine izin vermelidir. Poligon kenarlarının uzunlukları ve yönlerini hesaplamada kullanılan Transit, Bowditch ve Crandall'ın Kuralı bu genel ilkeleri karşılamayan geleneksel yöntemlerdir (Deakin,2005).

Transit Kuralı, açısal ölçümün mesafe ölçümünden daha iyi olduğu durumlar için geçerlidir. Bu yöntem, açıların hassas ölçüldüğü durumlarda kullanılır. Açıdaki her bir hatayı poligon ağının her bir ağındaki açıya eşit olarak dağıtır (Artman and Taylor, 2000).

Bowditch Kuralı, açıdaki doğruluğun mesafedeki doğruluğa eşit olduğu durumlarda kullanılır (Artman and Taylor, 2000).

Bowditch Kuralı, tek ve karmaşık travers ağlarında farklı ölçüm hassasiyetlerini hesaba katmadığı için uyum sağlayamamaktadır. Ancak birbirine yaklaşan şekillerin alanlarının hesaplanmasında pratik kullanımı nedeniyle günümüzde kullanılmaktadır (Deakin, 2005).

Ayrıca Crandall'ın Kuralına göre, Bowditch Kuralında oluşan mesafe ölçümünün olası hatasının, açıda oluşan olası hatanın mesafeyle çarpımına eşit olduğunu varsaymıştır (Manguri, 2016).

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ISBN: 978-9952-610-30-7

Fazla ölçünün olduğu tüm problemlerin hata teorisine uygun çözümleri dengeleme hesabı ile gerçekleştirilir. Ancak dengeleme hesabının el ile yapılması durumunda uzun yorucu işlemler gerekebilir (hesaplamaların bilgisayar ortamında yapılması durumunda böyle bir zorluktan bahsedilemez). Bu anlamda yukarıda sayılan geleneksel poligon hesaplama yöntemleri birer yaklaşık(takribi) dengeleme hesabı olurlar tam bir dengeleme hesabı olarak kabul edilemezler. Ancak poligon hesabından beklenen doğruluk derecesi göz önüne alındığında dengeleme hesabı yapmaksızın da uygun poligon hesabı yöntemleri ile amaçlanan doğruluk elde edilir. Bu da uygulamacıya kolaylık sağlar.

KAYNAKÇA

Artman, D., Taylor, D. W., & Geometronics, P. L. S. (2000). *Basic surveying: Theory and practice*.

Bektas, S. (2016a). *Dengeleme Hesabı*. Ondokuz Mayıs Üniversitesi Yayınları. (Yayın No: 118) ISBN 975-7636-54-1

Bektas, S., (2016b). *Pratik Jeodezi*. Samsun: OMU basımevi. ISBN 978-975-7636-65-6

Bektas, S., (2020). Ölçme Bilgisi (Topoğrafya), Nobel yayınevi, Konya. ISBN 978-625-406-439-5

Davis, R. E., Anderson, J. M., Foote, F. S., & Mikhail, E. M. (1981). *Surveying: Theory and practice* (6th ed.). McGraw-Hill.

Fowler, G. W. (2015). *Traverse measurement*. School of Natural Resources and Environment, University of Michigan.

Hart, L., Basil, D. D., & Oba, T. (2021). Assessment of adjustment methods in traverse networks for positioning. *Assessment*.

Manguri, S. (2016). TRAVESING BY RESECTION (Error Adjustment Using Least Square Method) , https://doi.org/10.5281/zenodo.701271

Ogundare, J. O. (2018). *Understanding least squares estimation and geomatics data analysis*. John Wiley & Sons.

Vaníček, P., & Wells, D. E. (1972). *The least squares approximation*. Department of Geodesy and Geomatics Engineering, University of New Brunswick.

Wang, Y. (1992). A rigorous photogrammetric adjustment algorithm based on co-angularity condition. *International Archives of Photogrammetry and Remote Sensing*, **29**(B5), 195–202.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TRAFİK KAYNAKLI KURŞUN (Pb) KİRLİLİĞİ: YOL TOZUNDAN TARIM TOPRAKLARINA VE BİTKİSEL ÜRÜNLERE TAŞINIM SÜREÇLERİNİN KAVRAMSAL DEĞERLENDİRMESİ

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Özet

Kurşun (Pb), kurşunlu benzinin küresel ölçekte yasaklanmasına rağmen, trafik kaynaklı kalıntı kirlilik ve güncel egzoz dışı emisyonlar nedeniyle çevresel ortamlarda kalıcılığını sürdüren önemli bir ağır metal kirleticidir. Bu çalışma, trafik kaynaklı Pb kirliliğinin yol tozu–tarım toprağı–bitki sistemi içerisindeki çevresel kaderini bütüncül bir yaklaşımla değerlendirmeyi amaçlamaktadır. Literatür bulguları, yol tozunun fren balataları, lastik aşınması ve yol yüzeyi etkileşimleri sonucu oluşan Pb açısından zengin partiküllerin biriktiği kritik bir ara ortam olduğunu göstermektedir. Rüzgârla taşınım, atmosferik çökelme ve yüzey akışı gibi mekanizmalar yoluyla bu partiküller tarım topraklarına taşınmakta ve yol–tarım alanı mesafesine bağlı olarak Pb konsantrasyonlarında belirgin gradyanlar oluşmaktadır. Tarım topraklarında Pb'nin davranışı; pH, organik madde ve kil içeriği gibi toprak özelliklerine bağlı olarak şekillenmekte, metal çoğunlukla yüzey tabakalarında birikmektedir. Bitkilerde Pb birikimi hem kök alımı hem de atmosferik çökelmeye bağlı yaprak kontaminasyonu yoluyla gerçekleşmekte; özellikle yapraklı sebzeler daha yüksek maruziyet riski taşımaktadır. Bu bütüncül çerçeve, trafik kaynaklı Pb kirliliğinin yalnızca lokal bir çevresel sorun değil, gıda zinciri yoluyla insan sağlığına uzanan çok aşamalı bir risk zinciri oluşturduğunu ortaya koymaktadır. Çalışma, yol tozu temelli taşınım süreçlerinin dikkate alınmasının, tarımsal alanlar için Pb risk değerlendirmelerinde kritik bir gereklilik olduğunu vurgulamaktadır.

Anahtar Kelimeler: Kurşun (Pb); yol tozu; trafik kaynaklı kirlilik; tarım toprakları kirliliği

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TRAFFIC-RELATED LEAD (PB) POLLUTION: A CONCEPTUAL EVALUATION OF TRANSPORT PATHWAYS FROM ROAD DUST TO AGRICULTURAL SOILS AND PLANT PRODUCTS

Abstract

Although the use of leaded gasoline has been banned worldwide, lead (Pb) remains an important heavy metal pollutant that persists in environmental compartments due to traffic-related legacy contamination and current non-exhaust emissions. This study aims to evaluate the environmental fate of traffic-derived Pb within the road dust–agricultural soil–plant system through a holistic approach. The literature indicates that road dust acts as a critical intermediate medium in which Pb-enriched particles originating from brake wear, tire abrasion, and road surface interactions accumulate. Through mechanisms such as wind-driven transport, atmospheric deposition, and surface runoff, these particles are transferred to agricultural soils, leading to pronounced gradients in Pb concentrations as a function of the distance between roads and farmlands. The behavior of Pb in agricultural soils is governed by soil properties such as pH, organic matter content, and clay fraction, with Pb predominantly accumulating in surface soil layers. Pb accumulation in plants occurs via both root uptake from soil solutions and foliar contamination associated with atmospheric deposition, with leafy vegetables exhibiting a higher exposure risk. This integrated framework demonstrates that traffic-related Pb pollution is not merely a localized environmental issue but constitutes a multi-stage risk pathway extending to human health through the food chain. The study emphasizes that consideration of road dust–mediated transport processes is a critical requirement for Pb risk assessments in agricultural environments.

Keywords: Lead (Pb); road dust; traffic-related pollution; agricultural soil contamination

Giriş

Kurşun (Pb), doğal olarak yerkabuğunda düşük konsantrasyonlarda bulunan bir element olmakla birlikte, antropojenik faaliyetler sonucunda çevresel ortamlarda birikebilen ve biyolojik sistemler üzerinde toksik etkiye sahip yaygın bir ağır metal kirleticisidir (Zwolak et al., 2019) . Özellikle motorlu taşıt trafiği, tarihsel olarak kurşunlu benzin kullanımına bağlı olarak atmosfere önemli miktarda Pb emisyonu vermiştir; benzinlerden salınan Pb bileşikleri, motor çalışma süreçlerinde yanma ürünleriyle çevreye dağılmıştır (Agha vd., 2005) . Kurşunlu benzinin küresel ölçekte yasaklanmasına rağmen, Pb'ye bağlı çevresel kirlenme günümüzde de devam etmektedir, çünkü eski emisyonların yol açtığı kalıntı birikim (legacy contamination) ortamda hâlâ mevcuttur ve yeni kaynaklar tarafından desteklenmektedir (Piron-Frenet vd., 1994) .

Trafik kaynaklı ağır metal kirleticiler, yalnızca egzoz gazlarıyla değil, aynı zamanda fren balataları, lastik aşınması ve yol yüzey aşınması gibi non-exhaust emisyonlar aracılığıyla da çevresel ortamlara

yayılarak toz ve parçacık fraksiyonlarında birikmektedir (Liu vd., 2023) . Bu kirleticilerden Pb, özellikle yol tozu ve yüzey topraklarında önemli düzeylerde birikme eğilimindedir; yol kenarına yakın mesafelerde ölçülen Pb konsantrasyonlarının, daha uzak mesafelere göre belirgin biçimde yüksek olduğu raporlanmıştır (Acar & Özkul, 2020). Ayrıca, trafik yoğunluğu ve yol kullanım süresi gibi faktörler de Pb birikim düzeylerini etkilemektedir (Szwalec vd., 2020). Yol tozu, kurşun ve diğer ağır metalleri taşıyan ve ortamda yeniden askıya alınabilen kritik bir ara ortam olarak değerlendirilir; bu parçacıklar hem atmosferik çökelme hem de rüzgârla taşınım süreçleri yoluyla çevreye yayılabilir. Dolayısıyla, trafik kaynaklı kirlilik yalnızca havayı değil, aynı zamanda aracın hemen çevresindeki toprak ve bitki örtüsü üzerinde de etkiler meydana getirmektedir. Tarım arazileri, özellikle yoğun trafik koridorlarına yakın bulunan alanlarda, yol tozu ve solunan parçacıklarla gelen Pb'ye maruz kalabilir. İnsanlar için potansiyel risk, bu topraklara biriken Pb'nin bitkiler tarafından alınması ve dolayısıyla gıda ürünlerine geçmesiyle daha da dolaylı bir boyut kazanır (Boahen, 2024).

Bu çalışma, trafik kaynaklı kurşun kirliliğinin yol tozu–tarım toprağı–bitki sistemi içerisindeki çevresel kaderini bütüncül bir çerçevede ele almayı amaçlamaktadır. Literatürde Pb'nin yol kenarı ortamlarında birikimine ilişkin çok sayıda çalışma bulunmakla birlikte, yol tozunun ara bir ortam olarak rolü ve bu faz üzerinden tarım topraklarına ve bitkisel üretime uzanan taşınım süreçlerinin çoğu zaman parçalı biçimde ele alındığı görülmektedir. Bu çalışma, farklı disiplinlerden elde edilen bulguları bir araya getirerek Pb'nin kaynakları, taşınım mekanizmaları, toprak–bitki etkileşimleri ve gıda zinciri yoluyla insan sağlığına yansımaları arasındaki ilişkileri kavramsal bir bütünlük içerisinde değerlendirmeyi hedeflemektedir. Böylece, trafik kaynaklı Pb kirliliğinin yalnızca lokal bir çevresel sorun değil, aynı zamanda tarımsal sürdürülebilirlik ve halk sağlığı açısından uzun vadeli riskler barındıran çok boyutlu bir problem olduğu vurgulanmakta; gelecekte yapılacak izleme, risk değerlendirme ve yönetim çalışmalarına bilimsel bir zemin sunulması amaçlanmaktadır.

Trafik Kaynaklı Pb'nin Güncel Kaynakları

Trafik kaynaklı Pb kirliliği genel olarak tarihsel birikim kaynakları ve güncel emisyon süreçleri olmak üzere iki ana grupta değerlendirilmektedir. Tarihsel kaynaklar, özellikle kurşunlu benzinin yaygın olarak kullanıldığı dönemde atmosfere salınan Pb'nin, çevresel ortamlarda uzun süre kalıcılığını sürdürmesiyle ilişkilidir. Kurşunlu benzinin küresel ölçekte yasaklanmasının ardından Pb emisyonlarında belirgin bir azalma sağlanmış olsa da, geçmişte atmosfere yayılan Pb; yol kenarı toprakları, yol tozu ve bitki örtüsü üzerinde birikerek kalıntı kirlilik oluşturmaya devam etmektedir (Sun vd., 2010; Laidlaw vd., 2012). Bu tarihsel birikim, güncel trafik etkileri altında yeniden çevresel döngüye katılabilmektedir. Günümüzde trafik kaynaklı Pb emisyonlarının baskın kısmı, egzoz gazlarından ziyade egzoz dışı (non-exhaust) kaynaklardan köken almaktadır. Bu emisyonlar, motor yanmasıyla doğrudan ilişkili olmayıp, araç bileşenlerinin mekanik aşınması ve yol yüzeyiyle etkileşimi sonucu ortaya çıkmaktadır. Son yıllarda yapılan çalışmalar, özellikle ağır metaller açısından non-exhaust emisyonların giderek daha belirleyici hâle geldiğini ortaya koymaktadır (Sun vd., 2006;

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Adamiec vd., 2016; Lewis vd., 2019). Fren balatalarının aşınması, trafik kaynaklı Pb'nin en önemli güncel kaynaklarından biri olarak tanımlanmaktadır. Frenleme sırasında balata malzemelerinin aşınmasıyla açığa çıkan Pb içeren metal partiküller, yol yüzeyinde birikerek yol tozu fraksiyonuna dâhil olmaktadır. Yoğun trafik ve sık dur-kalk koşullarının hâkim olduğu kentsel alanlarda bu süreç daha da belirginleşmektedir (Adamiec vd., 2016; Pant & Harrison, 2013). Araç lastiklerinin aşınması da Pb dâhil olmak üzere çeşitli ağır metallerin çevresel ortamlara salınmasına katkı sağlamaktadır. Lastik bileşiminde yer alan katkı maddeleri ve lastik–yol yüzeyi etkileşimi sonucu oluşan aşınma ürünleri, yol tozunda metal birikimine neden olmaktadır (Lewis vd., 2019). Bu aşınma partikülleri çoğunlukla ince boyut fraksiyonlarında yoğunlaşarak taşınım potansiyeli yüksek bir kirletici kaynağı oluşturmaktadır (Padoan & Amato, 2018). Buna ek olarak, motor yağları, yakıt sızıntıları ve yol kaplama malzemelerinin zamanla aşınması da Pb'nin yol ortamına geçişinde rol oynamaktadır. Asfalt ve yol yüzeyi kaplamaları, uzun süreli trafik baskısı altında metal içeren partiküller üretebilmekte ve bu partiküller yol yüzeyinde birikmektedir (Adamiec vd., 2016). Bu aşamada Pb'nin çevresel kaderi büyük ölçüde yol tozu ile ilişkilidir.

Yol Tozu: Pb için Kritik Bir Ara Ortam

Yol tozu, trafik kaynaklı Pb kirliliğinin çevresel sistemler arasında taşınımında merkezi bir ara ortam (interface) olarak değerlendirilmektedir. Yol tozu; fren ve lastik aşınması, yol yüzeyi bozulmaları ve atmosferik çökelme süreçleri sonucunda oluşan partiküler materyallerin yol yüzeyinde birikmesiyle meydana gelmektedir (Adamiec vd., 2016). Bu özellikleriyle yol tozu, farklı Pb kaynaklarının birleştiği bütünleşik bir çevresel havuz niteliği taşımaktadır. Çok sayıda çalışma, Pb'nin yol tozu içerisinde heterojen bir dağılım sergilediğini ve özellikle ince taneli fraksiyonlarda (<63 µm) daha yüksek konsantrasyonlarda bulunduğunu göstermektedir (Lu vd., 2009; Wang vd., 2022). İnce fraksiyonların özgül yüzey alanının yüksek olması, Pb'nin bu partiküllerle adsorpsiyon ve kompleksleşme yoluyla daha güçlü bağlanmasına olanak tanımaktadır (Wei & Yang, 2010). Bu durum, yol tozunu Pb açısından yalnızca bir birikim ortamı değil, aynı zamanda çevresel hareketliliği yüksek bir rezervuar hâline getirmektedir. Yol tozu, çevresel sistem içerisinde hem depo hem de ikincil kaynak özelliği göstermektedir. Bir yandan Pb'yi yol yüzeylerinde ve yol kenarı alanlarda tutarken, diğer yandan rüzgâr etkisi, araç geçişleri ve meteorolojik koşulların etkisiyle Pb içeren partiküllerin yeniden askıya alınmasına ve çevredeki alıcı ortamlara taşınmasına aracılık etmektedir (Pant & Harrison, 2013; Laidlaw vd., 2012). Bu dinamik yapı, Pb kirliliğinin durağan değil, sürekli dolaşım hâlinde bir süreç olduğunu ortaya koymaktadır.

Yol Tozundan Tarım Topraklarına Pb Taşınım Mekanizmaları

Trafik kaynaklı Pb'nin yol tozunda birikmesinin ardından, bu kirleticinin tarım topraklarına aktarımı birden fazla fiziksel ve çevresel taşınım mekanizması aracılığıyla gerçekleşmektedir. Bu süreçler, yol tozunun Pb açısından yalnızca bir birikim ortamı değil, aynı zamanda aktif bir taşıyıcı faz olduğunu

göstermektedir. Pb içeren yol tozu partiküllerinin tarım alanlarına taşınmasında en etkili mekanizmalardan biri atmosferik taşınım ve çökelme süreçleridir. Yol yüzeyinde biriken ve özellikle ince fraksiyonlarda zenginleşen Pb yüklü partiküller, rüzgâr etkisi ve araç geçişleriyle yeniden askıya alınarak atmosfere karışmakta ve daha sonra kuru veya yaş çökelme yoluyla tarım topraklarına ulaşmaktadır. Bu mekanizma, yol ile tarım alanı arasındaki mesafe kısa olduğunda daha belirgin hâle gelmektedir (Lu vd., 2009; Laidlaw vd., 2012). Rüzgârla taşınım, Pb'nin yol kenarı ortamlarından tarım arazilerine yatay yönde aktarılmasında kritik bir rol oynamaktadır. Özellikle <63 µm boyutundaki ince yol tozu partikülleri, düşük rüzgâr hızlarında dahi uzun mesafeler boyunca taşınabilmekte ve tarım topraklarının yüzey horizonlarında birikmektedir. Bu durum, Pb'nin tarım topraklarında yüzeysel zenginleşme göstermesinin temel nedenlerinden biri olarak değerlendirilmektedir (Wei & Yang, 2010; Amato vd., 2011). Yol tozundan tarım topraklarına Pb taşınımında yağış ve yüzey akışı süreçleri de önemli bir rol oynamaktadır. Özellikle şiddetli yağış olayları sırasında, yol yüzeyinde birikmiş Pb yüklü toz ve partiküller, yüzey akışıyla birlikte yol kenarındaki tarım alanlarına taşınabilmektedir. Bu süreç, Pb'nin yalnızca atmosferik yolla değil, hidrolojik taşınım mekanizmalarıyla da tarım ekosistemlerine girdiğini ortaya koymaktadır (Adamiec vd., 2016). Tarım alanlarının yollara olan mesafesi, Pb birikim düzeylerini belirleyen en kritik mekânsal faktörlerden biri olarak öne çıkmaktadır. Çok sayıda çalışma, yol kenarına yakın tarım topraklarında Pb konsantrasyonlarının belirgin biçimde daha yüksek olduğunu, yol–tarım alanı mesafesi arttıkça Pb düzeylerinde istatistiksel olarak anlamlı bir azalma gözlendiğini ortaya koymuştur. Bu mesafe etkisi, yol tozunun Pb taşınımındaki rolünü doğrudan doğrulayan önemli bir göstergedir (Lu vd., 2009; Liu vd., 2023). Bu taşınım mekanizmalarının bir araya gelmesi, yol kenarındaki tarım alanlarını hem akut hem de kronik Pb maruziyetine açık hâle getirmektedir. Atmosferik çökelme, rüzgârla taşınım ve yüzey akışı yoluyla tarım topraklarına ulaşan Pb, yüzey topraklarında birikerek bitkilerin kök bölgesine ve yaprak yüzeylerine erişebilir duruma gelmektedir. Bu durum, Pb'nin tarımsal üretim yoluyla gıda zincirine dolaylı giriş potansiyelini artırmaktadır (Liu vd., 2023). Sonuç olarak yol tozu; Pb'nin çevresel kaderini belirleyen, birikim, taşınım ve yeniden mobilizasyon süreçlerini birlikte barındıran çok yönlü bir ara ortamdır. Pb'nin yol tozunda birikmesi ve farklı çevresel mekanizmalarla tarım topraklarına taşınması, trafik kaynaklı Pb kirliliğinin yalnızca yol kenarıyla sınırlı olmadığını, çevredeki tarım alanları ve bitkisel üretim üzerinde de önemli potansiyel etkiler oluşturduğunu göstermektedir. Bu nedenle yol tozunun fiziksel ve kimyasal özelliklerinin, tarım topraklarına Pb taşınımı bağlamında değerlendirilmesi, trafik kaynaklı Pb kirliliğinin anlaşılmasında temel bir gereklilik olarak öne çıkmaktadır.

Tarım Topraklarında Pb Davranışı ve Birikimi

Tarım topraklarında Pb'nin çevresel davranışı ve birikim dinamikleri, başta toprak pH'sı, organik madde içeriği ve kil minerallerinin varlığı olmak üzere toprak özelliklerine güçlü biçimde bağlıdır. Toprak pH'sının düşmesi, Pb'nin katı fazdan sıvı faza geçişini kolaylaştırarak çözünürlüğünü ve

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

dolayısıyla biyoyararlanımını artırmaktadır (Alloway, 2012). Asidik koşullar altında Pb'nin karbonat ve oksit yüzeylerinden desorbe olması, metalin toprak çözeltisindeki hareketliliğini artırmakta ve bitki kök bölgesinde erişilebilirliğini yükseltmektedir (Kabata-Pendias, 2000). Buna karşılık, nötr ve alkali toprak koşullarında Pb'nin karbonat mineralleriyle çökelme eğilimi göstermesi, metalin büyük ölçüde daha az hareketli fraksiyonlarda tutulmasına neden olmaktadır (Alloway, 2012). Bu durum, yol kenarındaki tarım topraklarında Pb'nin çoğunlukla yüzey horizonlarında birikmesiyle sonuçlanmakta ve metalin dikey taşınımını sınırlamaktadır (Wei & Yang, 2010).

Toprak organik maddesi ve kil mineralleri, Pb'nin çevresel kaderini belirleyen en önemli bağlayıcı fazlar arasında yer almaktadır. Organik maddedeki fonksiyonel gruplar (karboksil, fenolik ve hidroksil grupları), Pb ile güçlü kompleksler oluşturarak metalin toprakta tutulmasını desteklemektedir (Kabata-Pendias, 2000). Benzer şekilde, kil minerallerinin yüksek katyon değişim kapasitesi, Pb'nin yüzeylere adsorbe olmasına olanak tanımakta ve metalin kısa vadede mobilitesini sınırlamaktadır (Alloway, 2012). Bununla birlikte, bu bağlanma süreçleri Pb'yi tamamen çevresel riskten arındırmamaktadır; özellikle asit yağmurları, sulama uygulamaları ve toprakta meydana gelen redoks değişimleri gibi çevresel etmenler, Pb'nin yeniden mobilizasyonuna neden olabilmektedir (Wei & Yang, 2010). Dolayısıyla, tarım toprakları Pb açısından bir "tampon ortam" işlevi görse de, bu tamponlama mutlak değildir ve Pb'nin bitkiler tarafından alınımı yoluyla gıda zincirine dolaylı geçiş potansiyeli devam etmektedir (Alloway, 2012).

Bitkilerde Pb Birikimi ve Geçiş Yolları

Bitkilerde Pb birikimi, hem kök yoluyla toprak çözeltisinden alınım hem de yaprak yüzeyine atmosferik çökelme yoluyla taşınan Pb içeren partiküllerin doğrudan tutulması yoluyla gerçekleşmektedir (Shahid vd., 2017). Toprak kaynaklı Pb alımı genellikle kök dokularında yoğunlaşmakta, Pb'nin kökten gövde ve yapraklara taşınımı ise sınırlı düzeyde gerçekleşmektedir; bu durum, Pb'nin hücre duvarlarına ve kök dokularındaki pektin yapısına güçlü biçimde bağlanmasıyla ilişkilendirilmektedir (Shahid vd., 2017; Pourrut vd., 2011). Bununla birlikte, yol kenarı tarım alanlarında yetiştirilen bitkilerde, atmosferik çökelme ile yaprak yüzeyine ulaşan Pb içeren yol tozu partiküllerinin, bitki dokularındaki toplam Pb yüküne anlamlı katkı sağladığı bildirilmektedir (Liu vd., 2015). Özellikle yapraklı sebzelerde, geniş yüzey alanı ve pürüzlü epidermal yapı nedeniyle Pb içeren partiküllerin tutulma verimi daha yüksek olmakta ve bu durum ürün bazlı maruziyet riskini artırmaktadır (Liu vd., 2015).

Yaprak yüzeyine tutunan Pb içeren partiküllerin, yalnızca yüzeysel bir kontaminasyon oluşturmadığı, aynı zamanda stomatal açıklıklar ve kutikula üzerinden sınırlı ölçüde bitki dokularına nüfuz edebildiği raporlanmıştır (Peralta-Videa vd., 2009). Bu nedenle, hasat öncesi yıkama işlemleri yüzeydeki serbest partiküllerin bir kısmını uzaklaştırabilse de, yaprak dokusu içine geçmiş Pb'nin tamamen giderilmesi mümkün olmamaktadır (Liu vd., 2015). Bitkilerde Pb birikiminin düzeyi; bitki türü, yaprak

morfolojisi, yüzey pürüzlülüğü, stomatal yoğunluk ve çevresel Pb yükü gibi faktörlere bağlı olarak önemli farklılıklar göstermektedir (Shahid vd., 2017; Peralta-Videa vd., 2009). Bu bağlamda, yol kenarına yakın tarım alanlarında yetiştirilen özellikle yapraklı sebzeler, Pb maruziyeti ve gıda zinciri yoluyla insan sağlığına dolaylı risk oluşturma potansiyeli açısından daha hassas ürün grupları olarak değerlendirilmektedir (Liu vd., 2015).

Gıda Güvenliği ve İnsan Sağlığı Açısından Değerlendirme

Kurşun (Pb), nörotoksik etkileri nedeniyle özellikle çocuklarda bilişsel gelişim geriliği, davranışsal bozukluklar ve öğrenme güçlükleri ile ilişkilendirilen önemli bir çevresel kirleticidir (Lanphear vd., 2019). Gıda yoluyla Pb maruziyeti, solunum yoluna kıyasla kronik ve sürekli maruziyet açısından daha kritik kabul edilmekte olup, yol kenarına yakın tarım alanlarında yetiştirilen sebze ve meyvelerin Pb içeriği, diyet kaynaklı maruziyetin anlamlı bir bileşenini oluşturabilmektedir (Nabulo vd., 2010). Uluslararası ve ulusal mevzuatlarda gıdalardaki Pb için maksimum kalıntı limitleri tanımlanmış olmasına rağmen, yoğun trafik etkisi altındaki kırsal ve yarı-kırsal alanlarda bu sınır değerlerin yer yer aşıldığı bildirilmektedir (Munir vd., 2021). Özellikle yapraklı sebzelerin, yüzey alanlarının genişliği ve atmosferik çökelmeye açıklıkları nedeniyle Pb birikimi açısından daha yüksek risk taşıdığı, bu durumun uzun vadede insan sağlığı üzerinde kümülatif etkilere yol açabileceği vurgulanmaktadır (Nabulo vd., 2010).

Sonuç Değerlendirme

Bu çalışma kapsamında ele alınan çalışmalar, trafik kaynaklı kurşun (Pb) kirliliğinin, kurşunlu benzinin küresel ölçekte yasaklanmasına rağmen çevresel ortamlarda kalıcı bir risk unsuru olmaya devam ettiğini açık biçimde ortaya koymaktadır. Literatürdeki bulgular, özellikle yol tozu ve yol kenarı yüzey topraklarının Pb için birincil birikim ortamları olarak işlev gördüğünü; bu ortamların atmosferik taşınım, rüzgârla yeniden askıya alma ve yüzey akışı gibi süreçler aracılığıyla tarım topraklarına ikincil Pb girdileri sağladığını göstermektedir. Yol–tarım alanı mesafesine bağlı olarak Pb konsantrasyonlarında gözlenen belirgin gradyanlar, yol tozunun tarımsal ekosistemler için kritik bir taşıyıcı faz olduğunu desteklemektedir. Toprak özelliklerinin (pH, organik madde, kil içeriği) Pb'nin çevresel davranışını belirlemede temel rol oynadığı; bitkilerde ise kök alımı ile atmosferik çökelmeye bağlı yaprak kontaminasyonunun birlikte etkili olduğu literatürde yaygın olarak raporlanmaktadır. Bu bütüncül tablo, trafik kaynaklı Pb kirliliğinin yalnızca lokal bir çevre sorunu değil, gıda zinciri yoluyla insan sağlığına uzanan çok aşamalı bir risk zinciri oluşturduğunu ortaya koymaktadır.

Bununla birlikte, mevcut literatürde bazı önemli araştırma boşlukları dikkat çekmektedir. Öncelikle, yol tozu–toprak–bitki sisteminde Pb'nin kimyasal türlenmesine (speciation) ve biyoyararlanımına ilişkin çalışmalar sınırlıdır; çoğu çalışma toplam Pb konsantrasyonlarına odaklanmakta, metalin hangi fraksiyonlarda bulunduğu ve bitkiler için hangi formların daha erişilebilir olduğu yeterince ortaya konmamaktadır. Ayrıca, kısa süreli kesitsel saha çalışmalarının ağırlıkta olması, Pb birikiminin

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

zamansal değişimini ve uzun dönemli birikim trendlerini değerlendirmeyi güçleştirmektedir. Farklı iklim koşulları, arazi kullanım tipleri ve tarımsal uygulamaların Pb taşınımı ve birikimi üzerindeki etkileri de literatürde yeterince temsil edilmemektedir. İnsan sağlığı boyutunda ise, çevresel Pb düzeyleri ile gerçek diyet alımı arasındaki ilişkiyi doğrudan ortaya koyan bütünleşik maruziyet değerlendirmeleri sınırlı sayıdadır.

Gelecek çalışmaların, yol tozu kaynaklı Pb'nin çevresel kaderini daha iyi ortaya koyabilmek için disiplinlerarası yaklaşımlarla tasarlanması önem arz etmektedir. Özellikle fraksiyonel analizler ve ardışık ekstraksiyon yöntemleri kullanılarak Pb'nin bağlanma formlarının belirlenmesi, biyoyararlanım ve risk değerlendirmelerine daha gerçekçi bir temel sağlayacaktır. Uzun dönemli izleme çalışmaları, Pb birikiminin zamansal eğilimlerini ve kentsel gelişim, trafik yoğunluğu değişimleri gibi dinamik faktörlerle ilişkisini ortaya koymada kritik rol oynayacaktır. Ayrıca, yol kenarı tarım alanlarında yetiştirilen farklı bitki türleri için tür-özel Pb birikim davranışlarının karşılaştırmalı olarak incelenmesi, risk yönetimi ve tarımsal planlama açısından önemli katkılar sunabilir. Son olarak, çevresel Pb düzeyleri ile insan biyobelirteçleri (örneğin kan Pb düzeyleri) arasında bağlantı kuran entegre çalışmalar, trafik kaynaklı Pb kirliliğinin halk sağlığı boyutunun daha net biçimde ortaya konmasına olanak sağlayacaktır.

Kaynaklar

Acar, R. U., & Özkul, C. (2020). Investigation of heavy metal pollution in roadside soils and road dusts along the Kütahya-Eskişehir Highway. Arab J Geosci 13: 216.

Adamiec, E., Jarosz-Krzemińska, E., & Wieszała, R. (2016). Heavy metals from non-exhaust vehicle emissions in urban and motorway road dusts. Environmental monitoring and assessment, 188(6), 369.

Agha, F., Sadaruddin, A., & Khatoon, N. (2005). Effect of environmental lead pollution on blood lead levels in traffic police constables in Islamabad, Pakistan. JOURNAL-PAKISTAN MEDICAL ASSOCIATION, 55(10), 410.

Alloway, B. J. (Ed.). (2012). Heavy metals in soils: trace metals and metalloids in soils and their bioavailability (Vol. 22). Springer Science & Business Media.

Boahen, E. (2024). Heavy metal contamination in urban roadside vegetables: origins, exposure pathways, and health implications. Discover Environment, 2(1), 145.

Kabata-Pendias, A. (2000). Trace elements in soils and plants. CRC press.

Laidlaw, M. A., Zahran, S., Mielke, H. W., Taylor, M. P., & Filippelli, G. M. (2012). Re-suspension of lead contaminated urban soil as a dominant source of atmospheric lead in Birmingham, Chicago, Detroit and Pittsburgh, USA. Atmospheric environment, 49, 302-310.

Lanphear, B. P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D. C., ... & Roberts, R. (2019). Erratum:"Low-level environmental lead exposure and children's intellectual function: an international pooled analysis". Environmental health perspectives, 127(9), 099001.

Lewis, A., Moller, S. J., & Carslaw, D. (2019). Non-exhaust emissions from road traffic. AIR QUALITY EXPERT GROUP

Li, N., Kang, Y., Pan, W., Zeng, L., Zhang, Q., & Luo, J. (2015). Concentration and transportation of heavy metals in vegetables and risk assessment of human exposure to bioaccessible heavy metals in soil near a waste-incinerator site, South China. Science of the total environment, 521, 144-151.

Liu, G., Chen, T., Cui, J., Zhao, Y., Li, Z., Liang, W., ... & Xiao, T. (2023). Trace Metal (loid) Migration from road dust to local vegetables and tree tissues and the bioaccessibility-based health risk: impacts of

vehicle operation-associated emissions. International journal of environmental research and public health, 20(3), 2520.

Lu, X., Wang, L., Lei, K., Huang, J., & Zhai, Y. (2009). Contamination assessment of copper, lead, zinc, manganese and nickel in street dust of Baoji, NW China. Journal of hazardous materials, 161(2-3), 1058-1062.

Munir, N., Jahangeer, M., Bouyahya, A., El Omari, N., Ghchime, R., Balahbib, A., ... & Shariati, M. A. (2021). Heavy metal contamination of natural foods is a serious health issue: A review. Sustainability, 14(1), 161.

Nabulo, G., Young, S. D., & Black, C. R. (2010). Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils. Science of the Total Environment, 408(22), 5338-5351.

Padoan, E., & Amato, F. (2018). Vehicle non-exhaust emissions: impact on air quality. In Non-Exhaust Emissions (pp. 21-65). Academic Press.

Pant, P., & Harrison, R. M. (2013). Estimation of the contribution of road traffic emissions to particulate matter concentrations from field measurements: A review. Atmospheric environment, 77, 78-97.

Peralta-Videa, J. R., Lopez, M. L., Narayan, M., Saupe, G., & Gardea-Torresdey, J. (2009). The biochemistry of environmental heavy metal uptake by plants: implications for the food chain. The international journal of biochemistry & cell biology, 41(8-9), 1665-1677.

Piron-Frenet, M., Bureau, F., & Pineau, A. (1994). Lead accumulation in surface roadside soil: its relationship to traffic density and meteorological parameters. Science of the Total Environment, 144(1-3), 297-304.

Pourrut, B., Shahid, M., Dumat, C., Winterton, P., & Pinelli, E. (2011). Lead uptake, toxicity, and detoxification in plants. Reviews of environmental contamination and toxicology volume 213, 113-136.

Shahid, M., Dumat, C., Khalid, S., Schreck, E., Xiong, T., & Niazi, N. K. (2017). Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. Journal of hazardous materials, 325, 36-58.

Sun, Y., Zhou, Q., Xie, X., & Liu, R. (2010). Spatial, sources and risk assessment of heavy metal contamination of urban soils in typical regions of Shenyang, China. Journal of hazardous materials, 174(1-3), 455-462.

Sun, Y., Zhuang, G., Zhang, W., Wang, Y., & Zhuang, Y. (2006). Characteristics and sources of lead pollution after phasing out leaded gasoline in Beijing. Atmospheric Environment, 40(16), 2973-2985.

Szwalec, A., Mundała, P., Kędzior, R., & Pawlik, J. (2020). Monitoring and assessment of cadmium, lead, zinc and copper concentrations in arable roadside soils in terms of different traffic conditions. Environmental Monitoring and Assessment, 192(3), 155.

Wang, S., Wang, L., Huan, Y., Wang, R., & Liang, T. (2022). Concentrations, spatial distribution, sources and environmental health risks of potentially toxic elements in urban road dust across China. Science of the total environment, 805, 150266.

Wei, B., & Yang, L. (2010). A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. Microchemical journal, 94(2), 99-107.

Ye, J., Li, J., Wang, P., Ning, Y., Liu, J., Yu, Q., & Bi, X. (2022). Inputs and sources of Pb and other metals in urban area in the post leaded gasoline era. Environmental Pollution, 306, 119389.

Zwolak, A., Sarzyńska, M., Szpyrka, E., & Stawarczyk, K. (2019). Sources of soil pollution by heavy metals and their accumulation in vegetables: A review. Water, air, & soil pollution, 230(7), 164.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SPATİAL ANALYSİS OF SERVİCE ACCESSİBİLİTY İN AN URBAN CONSERVATİON AREA: THE CASE OF KARAMAN CİTY CENTER

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ABSTRACT

The relationship between conservation requirements in historic urban areas and the spatial accessibility of basic urban services constitutes a critical field of evaluation in terms of ensuring quality of life and urban continuity. Particularly in urban conservation areas characterized by a high concentration of registered historic buildings, restrictions related to the urban fabric, discontinuities in the transportation network, and usage pressures may influence the spatial distribution of services, leading to spatial inequalities in access levels. In this context, the study aims to present an analytical framework that holistically examines the spatial patterns of accessibility to food and daily consumption–oriented services, local businesses, and basic urban services in relation to conservation characteristics. The study was conducted within the conservation boundary located in the historic city center of Karaman. The analysis was carried out under two service groups: (i) food provision and local businesses (markets, bakeries, and other local commercial units) and (ii) basic urban services (banks, pharmacies, and courier services). Spatial analyses were performed in a Geographic Information Systems (GIS) environment using a 25×25 m grid-based approach. The shortest distances to services were calculated, and accessibility indicators were generated through inverse min–max normalization. The two service groups were then integrated, total accessibility scores were calculated for each grid cell, and the results were classified into five categories and mapped. The findings indicate that access to urban services within the conservation boundary does not exhibit a spatially balanced distribution. Accessibility levels tend to decrease in sub-areas where the density of registered historic buildings and traditional street patterns is more pronounced. Conversely, areas characterized by continuous pedestrian networks and higher service concentrations demonstrate increased total accessibility scores. Overall, the study emphasizes the importance of adopting a holistic evaluation approach in conservation areas, in which planning and conservation decisions incorporate accessibility considerations alongside physical preservation objectives.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: GIS-Based Analysis, Urban Services, Historic Urban Conservation Areas, Spatial Accessibility

KENTSEL KORUMA ALANINDA HİZMETLERE ERİŞİLEBİLİRLİĞİN MEKÂNSAL ANALİZİ: KARAMAN KENT MERKEZİ ÖRNEĞİ

Tarihi kentsel alanlarda koruma gereklilikleri ile temel kentsel hizmetlerin mekânsal erişilebilirliği arasındaki ilişki, yaşam kalitesinin ve kentsel sürekliliğin sağlanması açısından kritik bir değerlendirme alanı oluşturmaktadır. Özellikle tescilli tarihi yapıların yoğun olarak bulunduğu kentsel sit alanlarında, kentsel dokuya ilişkin kısıtlamalar, ulaşım ağındaki süreksizlikler ve kullanım baskıları hizmetlerin mekânsal dağılımını etkileyerek erişim düzeylerinde mekânsal eşitsizliklere yol açabilmektedir. Bu bağlamda çalışma erişilebilirliğin mekânsal örüntülerini koruma özellikleri ile ilişkili olarak bütüncül bir yaklaşımla inceleyen analitik bir çerçeve sunmayı amaçlamaktadır. Araştırma Karaman tarihi kent merkezinde yer alan koruma sınırı içerisinde gerçekleştirilmiştir. Analizler iki hizmet grubu altında yürütülmüştür: (i) gıda-perakende (marketler, fırınlar ve yerel ticari işletmeler) ve (ii) temel kentsel hizmetler (bankalar, eczaneler ve kargo hizmetleri). Mekânsal analizler, Coğrafi Bilgi Sistemleri (CBS) ortamında 25×25 m grid tabanlı bir yaklaşımla gerçekleştirilmiştir. Hizmetlere en kısa mesafeler hesaplanmış, ters min–maks normalizasyon yöntemiyle erişilebilirlik göstergeleri üretilmiştir. İki hizmet grubu daha sonra bütünleştirilmiş, her bir grid hücresi için toplam erişilebilirlik puanları hesaplanmış ve sonuçlar beş kategoriye ayrılarak haritalandırılmıştır. Bulgular koruma sınırı içerisindeki kentsel hizmetlere erişimin mekânsal olarak dengeli bir dağılım göstermediğini ortaya koymaktadır. Erişilebilirlik düzeyleri, tescilli tarihi yapı yoğunluğunun ve geleneksel sokak dokusunun daha belirgin olduğu alt alanlarda azalma eğilimi göstermektedir. Buna karşılık süreklilik gösteren yaya ağlarına ve yüksek hizmet yoğunluğuna sahip alanlarda toplam erişilebilirlik puanlarının arttığı gözlemlenmiştir. Genel olarak çalışma koruma alanlarında planlama ve koruma kararlarının yalnızca fiziksel koruma hedefleriyle sınırlı kalmaması, erişilebilirlik boyutunu da içeren bütüncül bir değerlendirme yaklaşımının benimsenmesi gerektiğini vurgulamaktadır.

GİRİŞ

Günümüzde tarihî dokunun korunmasına dair anlayış yapıların bireysel korunmasına odaklanan yaklaşımlardan uzaklaşarak; tarihî kentsel yapının toplumsal, ekonomik ve mekânsal yönleriyle birlikte ele alındığı bütüncül bir planlama anlayışına dönüşmüştür. Bu yaklaşım, korumanın sadece fiziksel müdahalelere dayandırmamakta finansal araçların geliştirilmesi, çok taraflı yönetim süreçlerinin oluşturulması ve uygulamaların aşamalara ayrılması gibi planlama uygulamalarını da içeren çok yönlü bir yapı önerilmektedir. Bu durum koruma kavramının sadece fiziksel bir müdahale alanı olarak değil, çok boyutlu bir planlama süreci olarak değerlendirildiğini göstermektedir. 20. yüzyılda gerçekleşen toplumsal, ekonomik ve kültürel değişimlerin Osmanlı döneminden günümüze

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

kadarki süreçte koruma alanındaki karar alma mekanizmalarının yeniden şekillendirilmesini gerekli kılmıştır. Bu aşamada koruma anlayışı, anıt eser seviyesinden alan seviyesine doğru genişlemiş; kültürel varlıklarının sadece mimari yönleriyle değil, aynı zamanda peyzaj, doğal çevre ve yerleşim dokusu ile birlikte ele alınması gerektiği kabul edilmiştir.21. yüzyılda ise sit alanı tanımları, koruma amaçlı imar planları, yönetim alanları, yenileme bölgeleri ve sürdürülebilirlik gibi kavramlar koruma literatürünün vazgeçilmez unsurları hâline gelmiştir (Avcıoğlu, 2018). Kavramsal çerçeve genişledikçe korumanın kapsamı ve araçları da çeşitlenmektedir.

Bu çerçevede tarihî konut yapılarının yalnızca korunması gereken nesneler olarak değerlendirilmesi, bu bölgelerin günlük yaşamla olan bağlantılarını göz ardı etme riskini taşımaktadır. Kuban'ın (1984) vurguladığı üzere, tarihi kentsel dokunun anıtsal yapılarla benzer biçimde ele alınması, bu yerlerin yaşayan kentsel mekânlar olma özellikleriyle çelişmektedir. Sosyal ve kültürel faktörler tarihî çevrelerin korunmasına yönelik yasal zorunluluklar oluşturmuş olsa da, bu durum korumanın güncel ve çok yönlü yapısının doğru bir şekilde ele alınması gerekliliğini ortadan kaldırmamaktadır. Tarihî bölgelerde geleneksel mekânsal unsurların ve ortak hafızanın zayıflaması, bu alanların sosyal ve ekonomik canlılığının azalmasına yol açmakta bu durum modern kentsel tasarım ve planlama literatüründe önemli bir tartışma noktası oluşturmaktadır. Çeşitlilik ve erişebilirlik, sokakların hareketliliğinde önemli unsurlar olarak kabul edilse de bu unsurların tarihî kentsel alanlardaki etkileşimleri ve karşılıklı etkileri üzerine literatürde çok sayıda çalışma bulunmamaktadır (Huang vd.,2023).

Kentsel Hizmetlere Erişim ve Kentsel Yapı: Kuramsal Arka Plan ve Kavramsal Çerçeve

Erişilebilirlik kentsel alanlarda bireylerin sosyal, ekonomik ve kültürel imkanlara ulaşma yeteneğini gösteren önemli bir değerlendirme aracıdır. Literatürde erişilebilirlik, hedeflerin mekânsal dağılımı ile bu hedeflere ulaşmanın zorluklarının birlikte göz önünde bulundurulması gerekmektedir. Bu bağlamda erişilebilirlik kriterleri bir taraftan hedeflerin çekiciliğini değerlendirirken diğer taraftan mesafe, zaman veya maliyet gibi erişimi zorlaştıran engelleri dikkate almaktadır (Hansen, 1959; Bhat vd., 2002). Ancak erişilebilirlik için tek bir "en iyi" ölçüm yöntemi olmadığı gibi, farklı mekânsal durumlar ve araştırma hedefleri için ayrı kriterlerin geliştirilmesi gerektiği belirtilmektedir. Erişilebilirliğin anlamlı bir performans göstergesi olabilmesi, bu kriterlerin kullanıcıların mekânı algılama ve değerlendirme şekilleriyle uyumlu olmasına bağlıdır. Bundan dolayı erişilebilirliğin pratik tanımının, araştırmacıların teorik varsayımlarından ziyade, bireylerin günlük deneyimlerine dayandırılması gerektiği ifade edilmektedir (Handy & Niemeier, 1997). Kentsel erişilebilirlik yalnızca fiziksel ulaşım imkanlarıyla sınırlı değildir. Lynch (1960), erişilebilirliği algılama biçimi çerçevesinde inceleyerek, kent ortamında yön bulma ve mekânı anlamlandırma kapasitelerinin erişim deneyimini doğrudan etkilediğini göstermiştir. Benzer şekilde Jacobs (2011), erişilebilirliği sokak yapısı, kullanım çeşitliliği, yoğunluk ve blok boyutlarının sağladığı ürettiği yaşanabilirlik ve işlevsel süreklilik açısından değerlendirmektedir. Bu bakış açısı erişilebilirliği yalnızca hareket olarak değil, aynı

zamanda kent yaşamının sürekliliğini destekleyen mekânsal bir nitelik olarak kabul edilmektedir. Erişilebilirlik göstergeleri, bireylerin temel kentsel hizmetlere erişim düzeylerini ortaya çıkararak, sosyal eşitsizliklerin ve yetersiz hizmet alanlarının belirlenmesinde önemli bir rol oynamaktadır. Bu göstergeler; iş, gıda, sağlık ve sosyal hizmetler gibi temel kaynaklara erişimin yanı sıra, toplumsal etkileşim fırsatını da içeren daha geniş bir değerlendirme çerçevesi sunmaktadır (Geurs & van Wee, 2004). Kentsel canlılığın en belirgin şekilde görüldüğü yerler genellikle küçük ölçekli ticari faaliyetlerin ve çeşitli türlerinin biraraya geldiği alanlardır. Bu tür kentsel alanlarda işletmeler yalnızca kullanıcılarla değil, aralarındaki ilişkiler aracılığıyla da kentsel etkileşimi artırmaktadır. (Montgomery, 1998). Mekânsal yoğunluk ve kullanım çeşidi bu etkileşimlerin sürekliliğini sağlayarak kentsel yaşamın canlı kalmasına olanak sağlamaktadır. Mahalle bazında incelendiğinde temel kentsel hizmetlere yürüme mesafesinde erişim, yaşam kalitesi ve günlük konfor açısından önemli bir rol oynamaktadır. Gıda, sağlık, eğitim ve rekreasyon gibi günlük hizmetlere yakınlık, mahallelerin öz-yeterlilik kapasitesini artırmakta ve bireylerin kentsel alanla ilişkisini kuvvetlendirmektedir (Allam vd., 2022; Vidal Domper vd., 2023). Yürümeye dayalı erişilebilirlik analizlerinde mesafe, seyahat süresi ve bireysel çaba ile güçlü bir ilişki içinde olması sebebiyle önemli bir empedans göstergesi olarak öne çıkmaktadır (Miller, 2020). Perakende faaliyetlerinin konut alanları ve toplu taşıma noktaları arasındaki stratejik yerleşimi günlük alışveriş ve iş seyahatlerini bir araya getirme olanağı sunarak sürdürülebilir ulaşım biçimlerini teşvik edebilir. Bu durum, özellikle tarihî kentsel alanlarda hem erişilebilirliğin hem de sokak canlılığının desteklenmesi açısından büyük önem taşımaktadır (Cervero & Kockelman, 1997).

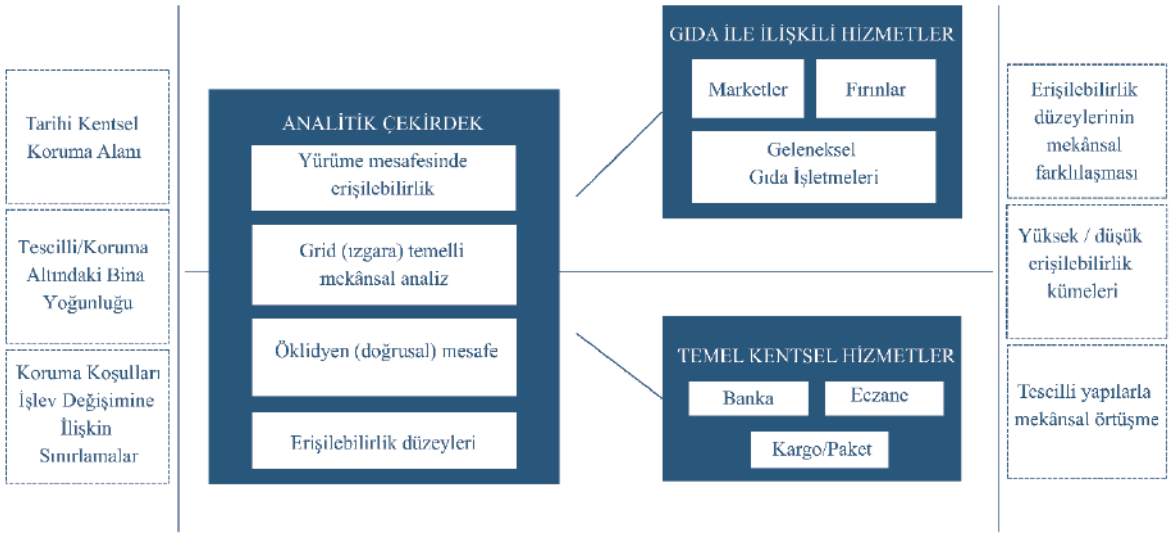
MATERYAL VE METHOD

Bu çalışma, kentsel sit alanlarında günlük yaşamı destekleyen hizmetlere yaya ölçeğinden erişimin mekânsal olarak incelenmesini hedeflemektedir. Erişilebilirlik kavramı yalnızca fiziksel yakınlıkla değil, mekânsal benzerlik ve ölçeklenebilirlik ilkeleri çerçevesinde ele alınmış, analizler grid hücreleri kullanılarak düzensiz kentsel dokunun etkisinden bağımsız, homojen bir değerlendirme zemini oluşturulmuştur. Çalışma alanı Karaman kent merkezinde yer alan kentsel sit alanı ve etkilenme bölge sınırları doğrultusunda belirlenmiştir. Analiz birimi olarak 25×25 metre boyutunda grid hücreleri kullanılmış, bu boyut yaya ölçeğinde algılanabilir mesafeleri temsil etmesi ve tarihî dokudaki yapı ölçekleriyle uyumlu bir ayrıntı düzeyi sunması ve mekânsal örüntülerin aşırı genelleştirilmeden okunmasına olanak tanıması sebebiyle tercih edilmiştir. Grid yaklaşımı, mekânsal karşılaştırılabilirliği artırmak, farklı hizmet türlerini ortak bir değerlendirme zemini üzerinde incelemek ve erişilebilirlik desenlerinin alan içindeki sürekliliğini belirgin hale getirmek amacıyla kullanılmıştır.

Her bir grid hücresini temsil eden merkez noktalar üretilmiş ve bu noktalar analizlerde başlangıç noktası olarak kullanılmıştır. Çalışmada kullanılan kentsel hizmetler gündelik yaşam pratikleri ve yaya erişimi açısından taşıdıkları öneme göre iki ana kategori altında sınıflandırılmıştır: (i) gıda-perakende hizmetleri (fırın, market ve yerel gıda üretim noktaları) ve (ii) temel kentsel hizmetler (banka, kargo

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ve eczane). Bu sınıflandırma hizmetlerin kullanım sıklığı ve günlük yaşam üzerindeki etkileri göz önünde bulundurularak tercih edilmiştir. Erişilebilirlik analizleri her bir grid merkezinden ilgili hizmet noktalarına olan en kısa mesafelerin doğrusal (öklidyen) mesafe kullanılarak gerçekleştirilmiştir. Bu çalışma mekânsal yakınlık ilişkilerini sade, karşılaştırılabilir ve bütüncül bir biçimde ortaya koymayı hedeflemektedir. Elde edilen veriler, grid düzeyinde ağırlıklandırılarak bütüncül bir erişim indeksi oluşturulmuş; ardından sınıflandırılarak erişim düzeyleri tanımlanmış ve mekânsal örüntülerin karşılaştırmalı biçimde analiz edilmesi sağlanmıştır. Her iki hizmet kategorisine ait erişim düzeyleri kendi içinde bütüncül olarak değerlendirilerek günlük yaşamı destekleyen hizmetlerin genel erişim desenleri çıkırılmıştır. Tescilli yapılar analiz birimi olarak ele alınmamış, ancak analiz sonuçlarıyla olan mekânsal ilişkilerini incelemek için analize dâhil edilmiştir. Bu kapsamda tescilli yapıların grid hücreleriyle konumsal ilişkileri belirlenmiş ve farklı erişim seviyelerindeki dağılımları nicel olarak değerlendirilmiştir. Tüm mekânsal analizler, Konya Teknik Üniversitesi tarafından sağlanan ESRI ArcGIS yazılımı kullanılarak gerçekleştirilmiş, sonuçlar grid tabanlı haritalar aracılığıyla görselleştirilmiştir.



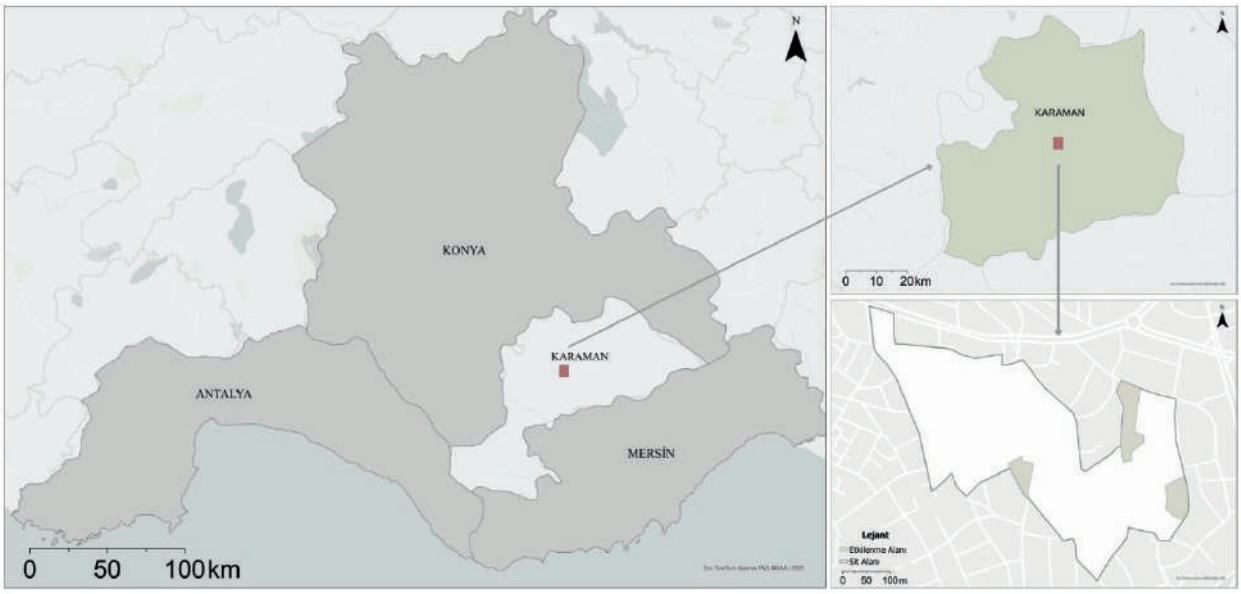
Resim 1. Çalışmanın akış şeması

Örnek Alan Çalışması

Çalışma Alanı

Bu araştırmanın temelinde Karaman kent merkezi koruma alanının seçilmesi, söz konusu kuramsal çerçevenin somut bir tarihî merkez bağlamında sınanabilir olmasından dolayı tercih edilmiştir. Bu alan, tarihi dokunun kent mekânında izlenebilir olduğu, tescilli yapı yoğunluğu ve koruma kararlarının fiziksel çevreyi belirgin biçimde çerçevelediği, buna karşın günlük yaşamın ve hizmet ilişkilerinin devam ettiği bir merkez niteliği taşımaktadır. Diğer yandan koruma koşullarının günlük ihtiyaçlarla kesiştiği noktalarda özellikle yaya ölçeğinde erişilebilirlik üzerinden analitik biçimde değerlendirmeye uygun bir örnek alan sunmaktadır. Bu kapsamda çalışma, tarihi dokuyu "müzeye dönüşen" ya da "salt

savunulan" mekânlar olarak değerlendirmekten ziyade, yaşayan çevrelerde erişilebilirlik ve kentsel canlılık ilişkisi üzerinden okunabilen dinamik bağlamlar olarak ele almaktadır (Mumford, 1938; Lynch, 1960; Avcıoğlu, 2018). Diğer yandan kentsel sit alanları, koruma statüleri nedeniyle planlama, yapılaşma ve işlevsellik açısından diğer kentsel alanlardan farklılıklar göstermektedir. Bu özel hukuki ve mekânsal çerçeve, tarihi çevre ile günlük kentsel yaşamın nasıl bir arada nasıl var olduğunu incelemeyi gerekli kılmaktadır. Karaman kentsel sit alanı konum itibariyle, hem konut hem de ticaret ve hizmet işlevlerini içermesi bakımından tarihi dokunun günümüz kentsel talepleriyle oluşturduğu ilişkinin gözlemlenebileceği güçlü bir alan sunmaktadır. Bu bağlamda çalışma alanının kentsel sit alanı ve etkilenme bölgeleri ile sınırlandırılması, Karaman'ın tarihi kent merkezinde tescilli yapı yoğunluğunun kentsel kullanım ve erişim koşullarıyla nasıl kesiştiğini değerlendirmeye olanak tanımaktadır. Böylece alan seçimi rastlantısal değil, kentin tarihi mirasının güncel kentsel işleyişteki yerini ve önemini anlamaya yönelik analitik bir tercih olarak kabul edilmektedir.



Resim 2. Karaman merkez ve çalışma alanı sınırları

Veri Kaynakları

Bu çalışma kapsamında kullanılan veri setleri, kentsel koruma alanlarının hem fiziksel hem de işlevsel özelliklerini kapsamlı biçimde yansıtmak için çeşitli kaynaklardan derlenmiştir. Analizlerde kullanılan veriler iki ana grupta toplanmaktadır.

Kentsel Sit Alanı ve Koruma Planı Verileri

Çalışma alanının sınırları ve koruma statüsüne ilişkin veriler, Karaman Belediyesinden temin edilen güncel koruma amaçlı imar planları ve plan çizimlerine dayanmaktadır. Bu veriler kentsel sit alanının resmi olarak belirlenmiş sınırlarını ve koruma kararlarını yansıtacak biçimde kullanılmıştır. Koruma planlarına dair mekânsal veriler, çalışmanın genel çerçevesini oluşturmaktadır. Bu nedenle tüm analizler sit alanı ve etkilenme bölgeleri içinde kalan alanlarla sınırlı tutulmuş, dışındaki bölgeler

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değerlendirmeye alınmamıştır. Tescilli yapılarla ilgili mekânsal veriler, belediye ve ilgili kurumlar tarafından hazırlanan güncel kültür varlıkları envanterlerinden elde edilmiştir. Bu veriler tescilli yapıların konumlarını ve dağılımını göstermektedir. Tescilli yapı verileri, çalışma kapsamındaki nokta veya alan geometrisi olarak sayısallaştırılmış ve mekânsal analizlerde kullanılmıştır. Tescilli yapıların dağılımı, erişilebilirlik analizleri ile birlikte değerlendirilerek, günlük yaşamı destekleyen hizmetlerle olan mekânsal ilişkilerin analizine imkan sağlamıştır. Elde edilen tüm mekânsal veriler coğrafi bilgi sistemleri ortamında birleştirilerek analiz sürecine dâhil edilmiştir.

İlgi Noktası (POI) Verileri

Günlük yaşamla doğrudan ilişkili kentsel hizmetlere ait ilgi noktası (POI) verileri, açık kaynaklı coğrafi veri platformları kullanılarak hazırlanmıştır. Bu kapsamda hizmet noktalarının konum bilgileri OpenStreetMap tabanlı verilerden derlenmiş, verilerin güncelliği ve mekânsal doğruluğu çevrimiçi harita servisleri üzerinden görsel karşılaştırmalarla kontrol edilmiştir. POI verileri, gıda-perakende hizmetleri ve temel hizmetler olmak üzere iki ana grupta sınıflandırılmıştır. Gıda-perakende hizmetleri; marketler, fırınlar, ve yerel gıda hizmetleri olarak ayrılmıştır. Temel hizmetlerde ise banka, eczane ve kargo hizmetleri yer almaktadır.

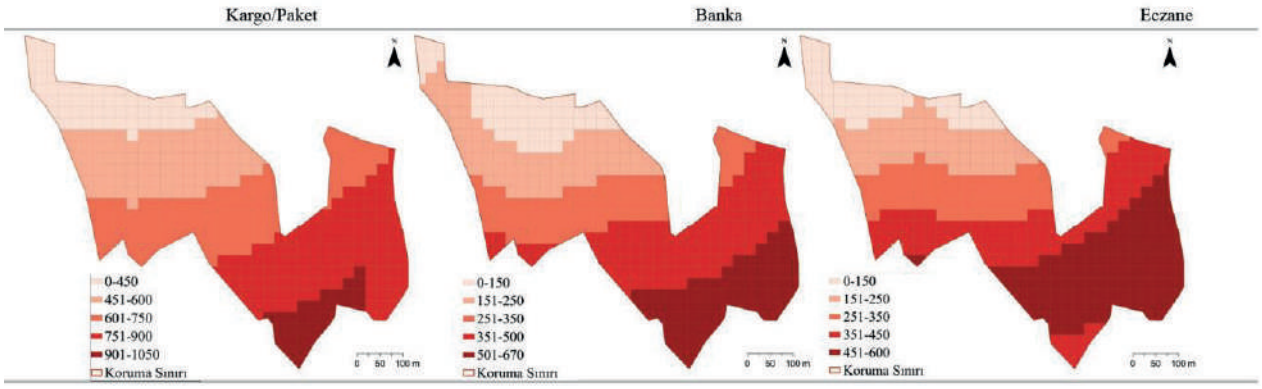
BULGULAR

Temel Hizmetlere Yaya Erişiminin Mekânsal Dağılımı

Temel hizmet kategorileri (banka, eczane, kargo) birlikte değerlendirildiğinde, çalışma alanında erişimin tek merkez üzerinden bir avantaj sağlamadığı; aksine hizmet türüne bağlı olarak değişen ve parçalı bir erişim deseni oluştuğu görülmektedir. Bu grupta en dengeli dağılım eczane hizmetinde gözlemlenirken banka ve özellikle kargo hizmetlerinde erişim daha seçici noktalara yönlenmektedir. Bu nedenle, temel hizmetler aynı kategoride içerisinde yer alsalar da alan içinde eşit bir erişim rejimi sunmamaktadır.

Bu farklılık temel hizmetlerin işlevsel özellikleriyle doğrudan bağlantılıdır. Eczane günlük ve zorunlu kullanımdan doğan baskı nedeniyle daha yaygın bir erişim alanı yaratırken; banka ve kargo ise daha sınırlı noktalar üzerinde yoğunlaşan bir model sergilemektedir. Sonuç olarak temel hizmet kategorisinde içinde yakınlık tek başına yeterli bir açıklama sunmamaktadır; hizmet türü, kullanım sıklığı ve mekânsal konumlanma biçimi erişim seviyesini belirleyen temel faktörler hâline gelmektedir.

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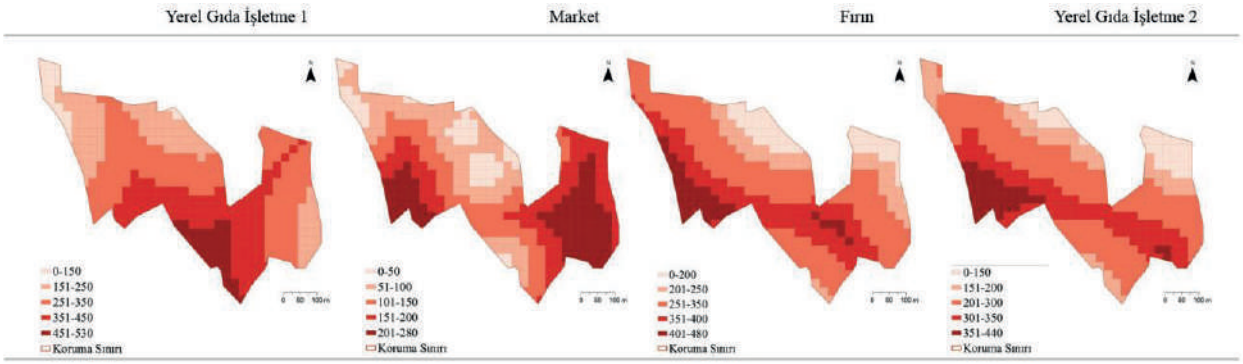
Resim 3. Temel hizmetlere en yakın mesafe analizleri

Kategori ölçeğinde ortaya çıkan bir diğer önemli bulgu, erişimin mutlak bir eşitlik değil aşamalı bir farklılaşma biçiminde ortaya çıkmasıdır. Avantajlı ve dezavantajlı bölgeler keskin sınırlarla birbirinden ayrılmamaktadır; erişim seviyesi alan boyunca artan veya azalan bir gradyan olarak değişim göstermektedir. Bu durum, temel hizmet erişimindeki sorunun yanlızca boşluklar değil tüm alanı etkileyen yapısal bir dağılım anlayışına işaret ettiğini ortaya koymaktadır. Genel olarak temel hizmet kategorisi, gıda-perakende kategorisine kıyasla daha düşük mekânsal esneklik ve daha yüksek odak bağımlılığı üretmektedir. Bu yüzden temel hizmetlere erişim, alanın günlük işleyişinde kırılganlığı en çok ortaya koyan unsurlardan biri olarak öne çıkmaktadır. Kategoriler içindeki faklılıkların birlikte değerlendirilmesi belirli hizmet türlerinde erişim baskısının nasıl arttığını ve bu baskının alanın hangi bölgelerinde yoğunlaştığını analitik bir düzeyde aydınlatmaktadır.

Gıda-Perakende Hizmetlerine Yaya Erişiminin Mekânsal Dağılımı

Gıda ve perakende kategorisi (fırın, market ve yerel işletmeler) birlikte incelendiğinde, erişimin imkanlarının alana eşit dağılmadığı; hizmetler arasında farklılaşan ve belirli kesimlerde üst üste binen bir örüntü ürettiği görülmektedir. Düşük mesafe değerleri bazı akslarda yoğunlaşırken, diğer alanlarda erişim kademeli olarak zayıflamaktadır. Bu durum gıda-perakende kategorisinin homojen bir erişim rejimi değil, alt hizmetlere göre değişen bir mekânsal dağılım mantığına sahip olduğunu göstermektedir. Alt hizmetler arasında belirgin bir ayrım bulunmaktadır; market ve fırın daha sürdürülebilir bir erişim alanı sunarken, unlu mamuller ve yerel işletmeler daha seçici noktalarda yoğunlaşmaktadır.

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ISBN: 978-9952-610-30-7



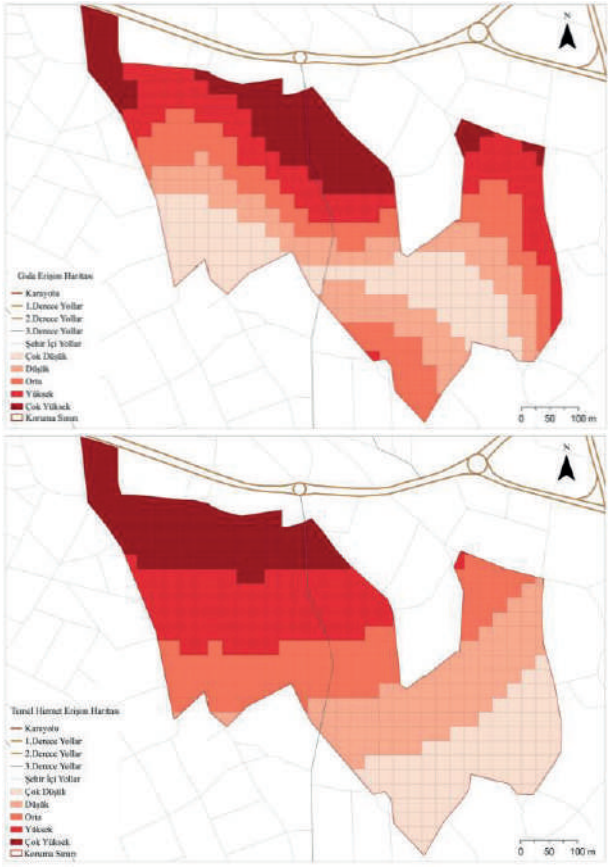
Resim 4. Gıda-perakende hizmetlerine en yakın mesafe analizleri

Bu nedenle kategori içindeki erişimi tek bir ortalama değerle değil, alt hizmetlerin birbirini tamamlayıcı ve yoğunlaşma ilişkileri üzerinden değerlendirmek gerekmektedir. Haritalardaki dağılım, erişimin belirgin sınırlar yerine gradyan biçiminde değiştiğini göstermektedir. Bu sebeble sorunlu alanlar yalnızca hizmet eksikliğinden değil, aynı zamanda mesafenin kademeli artışından kaynaklanmaktadır. Sonuç olarak gıda-perakende kategorisi günlük yaşam ile güçlü biçimde ilişki kurarak bir erişim imkanı sağlamakta, fakat bu durum alt hizmet türleri arasında mekânsal dengesizlikler bulundurmaktadır.

Gıda Ve Temel Kentsel Hizmetlere Bütüncül Yaya Erişim Deseni

Toplam erişim haritaları bir arada incelendiğinde, gıda-perakende ve temel hizmet kategorilerinin çalışma alanında farklı mekânsal erişim desenleri oluşturduğu görülmektedir. Gıda erişim haritası, alanın kuzey ve kuzeybatı kesimlerinde yüksek ve çok yüksek sınıfların belirginleştiği, güney ve güneydoğuya doğru ise erişim düzeyinin kademeli olarak zayıfladığı bir gradyan ortaya koymaktadır. Bu dağılım gıda-perakende işlevlerinin günlük kullanım sıklığına bağlı olarak daha yaygın bir temas alanı üretmesine rağmen, alan içinde tam dengeli bir dağılım oluşturamadığı görülmektedir.Temel hizmet erişim düzeyi ise daha seçici ve daha kırılgan bir mekânsal örüntü sergilemektedir. Yüksek erişim değerleri daha dar bir alanda yoğunlaşmakta, özellikle doğu ve güneydoğu kesimlerinde düşük ve çok düşük değerler daha geniş bir alan kaplamaktadır. Bu durum temel hizmetlerin kategori bileşimi gereği daha sınırlı düğümlerde bulunmasıyla uyumludur ve kategori içi hizmetlerin ortak etkisinin alan genelinde dengeli dağılmadığı görülmektedir.

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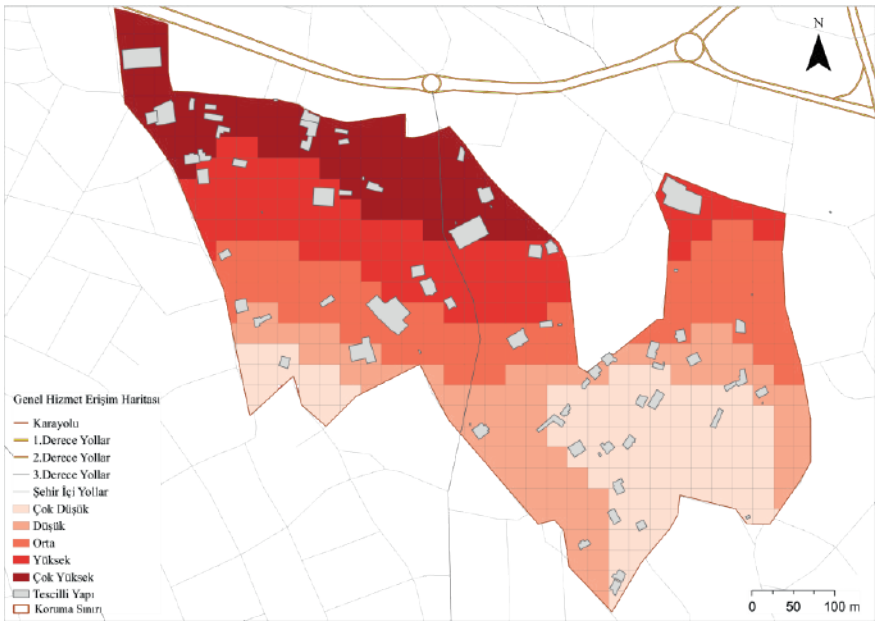
Resim 5. Gıda ve temel kentsel hizmetlere erişim düzeyleri haritası

İki harita verisinin birlikte okunmasıyla çalışma alanında kuzey-kuzeybatı yönünde birikmiş erişim avantajı ile güney-güneydoğu yönünde artan erişim dezavantajı arasında yapısal bir karşıtlık olduğu görülmektedir. Dolayısıyla erişim sorunu tekil noktasal boşluklardan çok, kategoriye göre değişen bölgesel bir eşitsizlik deseni olarak tanımlanmalıdır. Bu veriler kentsel sit alanında hizmet sürekliliğinin sadece hizmet sayısıyla değil, aynı zamanda hizmetlerin kategori bazında alanda nasıl bir dağılım sergilediğini açık biçimde göstermektedir.

Genel Hizmet Bütüncül Yaya Erişim Deseni

Tescilli yapıların genel erişebilirlik dağılımı, koruma alanı içerisinde homojen olmayan bir mekansal ilişkiyi göstermektedir. Harita, yüksek ve çok yüksek erişilebilirlik gruplarının çoğunlukla kuzey-kuzeybatı bölgesine yoğunlaştığını; düşük ve çok düşük erişilebilirlik sınıflarının ise güney ve güneydoğu taraflarında yayıldığını ortaya koymaktadır. Tescilli yapıların önemli bir bölümü bu düşük erişilebilirlik zonlarında kümelenmekte, daha sınırlı bir bölümü ise yüksek erişim alanları içerisinde yer almaktadır. Bu örüntü, koruma statüsü ile gündelik hizmetlere yakınlık arasında doğrusal bir ilişki olmadığını ortaya koymaktadır. Bu durum koruma alanlarında işlevsel erişimin yalnızca merkezi konumla değerlendirilemeyeceğini göstermektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Resim 6. Genel hizmet erişim düzeyleri haritası

Nitekim mekânsal yakınlık, yol kademelenmesi, yapılı çevre ilişkisi ve kullanım baskısı ile birlikte değerlendirildiğinde, tescilli yapıların bir kısmı hizmet odaklarının dışında kalabilmektedir. Bu sebeble erişilebilirlik düzeyleri tescilli yapıların mekânsal varlığını otomatik olarak avantaja dönüştürmemekte, aksine bazı alt bölgelerde koruma önceliği ile hizmet erişimi arasında gerilimli bir eşleşme üretmektedir.İki kategoriye dayalı olarak oluşturulan genel erişim yüzeyi haritası ile tescilli yapıların birlikte okunması, müdahale önceliklerinin alan genelinde eşit dağıtılamayacağını göstermektedir. Planlama kararlarının, koruma değeri yüksek fakat erişim düzeyi düşük hücreleri önceliklendiren hedefli bir çerçevede ele alınması gerekmektedir. Böylece koruma yaklaşımı yalnızca fiziksel sürekliliği değil, aynı zamanda da tarihi dokunun günlük yaşamla ilişkisini de güçlendirecektir.

TARTIŞMA VE SONUÇ

Bu çalışma Karaman kent merkezinde yer alan koruma sınırlarını içeren gıda-perakende ve temel hizmetlere erişim desenlerini grid temelli bir analiz çerçevesinde inceleyerek koruma gereklilikleri ile günlük yaşam ihtiyaçları arasındaki mekânsal bağlantıyı nicel olarak ortaya koymuştur. Elde edilen verilere göre, erişim alanında homojen bir dağılım sergilenmemekte; daha büyük ulaşım yollarına yakın bölgelerde daha yoğunlaşmakta, tarihi yapının dar caddeli ve küçük parsel yapısına sahip kısımlarında ise kademeli olarak azalmaktadır. Bu durum, morfolojik yapı ile işlevsel erişim kapasitesi arasındaki ilişkinin belirleyici olduğunu göstermektedir. Kategori düzeyinde yapılan değerlendirmeler, gıda-perakende hizmetlerinin daha yaygın bir erişim yüzeyi üretmesine karşın, temel hizmetlerin daha sınırlı odaklarda yoğunlaştığını göstermiştir. Tescilli yapıların erişim sınıflarıyla bir arada incelenmesi ise kültürel mirasın yalnızca yüksek erişim alanlarında yoğunlaşmadığını; orta ve düşük erişim seviyelerinde de önemli bir varlık gösterdiğini kanıtlamaktadır. Bu dağılım, koruma alanının mekânsal

bütünlüğü ile hizmet ağlarının yapılandırılması arasında doğrusal olmayan bir ilişki olduğunu göstermektedir.

Araştırmanın en önemli katkısı, erişilebilirliği yalnızca mesafe odaklı bir performans göstergesi olarak değil, koruma rejimi, morfolojik yapı ve hizmet dağılımı arasındaki etkileşimleri görünür hale getiren entegre bir analiz aracı olarak ele almasıdır. Bu bağlamda, çalışmanın kentsel sit alanlarında planlama ve koruma kararlarının, tarihi yapının fiziksel bütünlüğünü korurken günlük yaşamın sürdürülebilirliğini de göz önünde bulundurması gereken dengeli bir mekânsal yaklaşım gerektirdiğini ortaya koymaktadır. Elde edilen bulgular, müdahaleci bir değişim yerine, erişim seviyelerinin izlenmesi ve hizmet dağılımının yerin taşıma kapasitesiyle uyumlu bir şekilde yönlendirilmesi gerektiğine işaret etmektedir.

KAYNAKÇA

Allam, Z., Nieuwenhuijsen, M., Chabaud, D., & Moreno, C. (2022). The 15-minute city offers a new framework for sustainability, liveability, and health. *The Lancet Planetary Health*, 6(2), e181–e183.

Avcıoğlu, S. (2018). Tarihi çevrelerde karar vericiler: Koruma bölge kurulları. *Şehir & Toplum*, 9, 75–91.

Bhat, C., Handy, S., Kockelman, K., Mahmassani, H., Gopal, A., Srour, I., & Weston, L. (2002). *Development of an urban accessibility index: Formulations, aggregation, and application* (Research Report No. FHWA/TX-02-4938-4; Report No. 4938-4). Center for Transportation Research, The University of Texas at Austin.

Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, 2(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6

Geurs, K. T., & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport Geography, 12*(2), 127–140. https://doi.org/10.1016/j.jtrangeo.2003.10.005

Jacobs, J. (2011). *Büyük Amerikan şehirlerinin ölümü ve yaşamı (*B.Doğan, Çev.) Metis Yayınları.

Huang, J., Hu, X., Wang, J., & Lu, A. (2023). How diversity and accessibility affect street vitality in historic districts? *Land, 12*(1), https://doi.org/10.3390/land12010219

Hansen, W. G., 1959, How accessibility shapes land use, *Journal of the American Institute of Planners, 25*(2), 73–76. https://doi.org/10.1080/01944365908978307

Handy, S. L., & Niemeier, D. A. (1997). Measuring accessibility: An exploration of issues and alternatives. *Environment and Planning A, 29*(7), 1175–1194

Kuban, D. (1984). Çağdaş koruma, tasarım ve planlama ilişkilerine kuramsal bir yaklaşım. *Mimarlık, 22*(3–4), 3–5.

Lynch, K. (1960). *The image of the city.*MIT Press.

Montgomery, J. (1998). Making a city: Urbanity, vitality and urban design. *Journal of Urban Design, 3*(1), 93–116. https://doi.org/10.1080/13574809808724418

Miller, E. (2020). *Measuring accessibility: Methods and issues* (International Transport Forum Discussion Paper No. 2020/25). OECD Publishing.

Morris, J. M., Dumble, P. L., & Wigan, M. R. (1979). Accessibility indicators for transport planning. *Transportation Research Part A: General, 13*(2), 91–109. https://doi.org/10.1016/0191-2607(79)90012-8

Mumford, L. (1938). *The culture of cities*. Harcourt Brace Jovanovich.

Vidal Domper, N., Hoyos-Bucheli, G., & Benages Albert, M. (2023). Jane Jacobs's criteria for urban vitality: A geospatial analysis of morphological conditions in Quito, Ecuador. *Sustainability, 15*(11), 8597.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EXPERİMENTAL AND THEORETİCAL INVESTİGATİON OF A REFRİGERATİON SYSTEM USİNG R134A REFRİGERANT

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ABSTRACT

In this study, the energy and exergy performance of a vapor compression refrigeration system operating with R134a refrigerant is investigated within a comprehensive theoretical framework supported by experimental data. An experimental test rig consisting of a compressor, condenser, expansion valve, and evaporator was constructed, and simultaneous temperature measurements were carried out at the characteristic points of the system. Based on the measured data, the cooling capacity, heat transfer rates of the condenser and evaporator, and the coefficient of performance (COP) were calculated, and deviations of real operating conditions from the ideal vapor compression cycle were quantitatively evaluated.

During the theoretical analysis, energy and exergy balance equations were applied to all components of the refrigeration cycle. Component-wise exergy destructions and second-law efficiencies were determined in detail, enabling the identification of the primary sources of irreversibility that limit system performance. The effects of different operating conditions on exergy behavior were comparatively analyzed. The limited discrepancies observed between experimental and theoretical results were attributed to measurement uncertainties and heat losses to the surroundings.

Experiments conducted under 15 different operating conditions revealed that the system COP varied between 1.94 and 3.21, while the cooling capacity ranged from 242 to 402 W. The variation of exergy efficiency between 22.8% and 37.6% indicates a high sensitivity of irreversibilities to system operating parameters. Component-based analysis showed that the compressor accounted for the majority of total exergy destruction (50–78%), identifying it as the most critical component constraining system efficiency. The condenser ranked second, with a contribution of 14–32%. Overall, this study provides a strong reference for the design of higher-efficiency refrigeration systems and for the evaluation of alternative, environmentally friendly refrigerants.

Keywords: R134a, Vapor compression refrigeration system, Energy analysis, Exergy analysis, COP

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

R134-A AKIŞKANI KULLANAN BİR SOĞUTMA SİSTEMİNİN DENEYSEL VE TEORİK OLARAK İNCELENMESİ

ÖZET

Bu çalışmada, R134a soğutucu akışkanı ile çalışan buhar sıkıştırmalı bir soğutma sisteminin enerji ve ekserji performansı, deneysel verilerle desteklenen kapsamlı bir teorik analiz çerçevesinde incelenmiştir. Deneysel çalışma kapsamında; kompresör, yoğuşturucu, genleşme vanası ve buharlaştırıcıdan oluşan kapalı çevrimli bir test düzeneği kurulmuş ve sistemin karakteristik noktalarından eş zamanlı sıcaklık ölçümleri gerçekleştirilmiştir. Elde edilen ölçümler kullanılarak soğutma kapasitesi, yoğuşturucu ve buharlaştırıcı ısı yükleri ile performans katsayısı (COP) hesaplanmış; gerçek çalışma koşullarının ideal buhar sıkıştırmalı çevrimden sapmaları nicel olarak değerlendirilmiştir.

Teorik analiz aşamasında, soğutma çevriminin tüm bileşenleri için enerji ve ekserji denge denklemleri uygulanmış; bileşen bazlı ekserji yıkımları ve ikinci yasa verimleri ayrıntılı biçimde belirlenmiştir. Bu sayede sistem performansını sınırlayan temel tersinmezlik kaynakları ortaya konulmuş ve farklı çalışma koşullarının ekserji davranışı üzerindeki etkileri karşılaştırmalı olarak analiz edilmiştir. Deneysel ve teorik sonuçlar arasındaki sınırlı farklılıkların, ölçüm belirsizlikleri ve çevreye olan ısı kayıplarından kaynaklandığı belirlenmiştir.

Toplam 15 farklı çalışma koşulunda yapılan deneyler sonucunda, sistem COP değerlerinin 1.94 ile 3.21 arasında değiştiği, soğutma kapasitesinin ise 242–402 W aralığında olduğu tespit edilmiştir. Ekserji veriminin %22.8–37.6 aralığında değişmesi, tersinmezliklerin sistem çalışma parametrelerine yüksek duyarlılık gösterdiğini ortaya koymuştur. Bileşen bazlı analiz, toplam ekserji yıkımının büyük bölümünün (%50–78) kompresörde gerçekleştiğini ve kompresörün sistem verimliliğini sınırlayan en kritik bileşen olduğunu göstermiştir. Yoğuşturucu ise %14–32 katkı payı ile ikinci sırada yer almıştır. Sonuç olarak bu çalışma, daha yüksek verimli soğutma sistemlerinin tasarımı ve alternatif, çevreci soğutucu akışkanların değerlendirilmesi için güçlü bir referans sunmaktadır.

Anahtar Kelimeler: R134a, Buhar sıkıştırmalı soğutma sistemi, Enerji analizi, Ekserji analizi, COP

GİRİŞ

Soğutucu akışkanların çevresel etkilerinin değerlendirilmesinde en yaygın kullanılan göstergeler Ozon Aşındırma Potansiyeli (Ozone Depletion Potential, ODP) ve Küresel Isınma Potansiyeli (Global Warming Potential, GWP)'dir. ODP, bir maddenin stratosferik ozon tabakasını inceltme eğilimini ifade eden göreli bir parametre olup, hesaplamalarda ODP değeri 1 kabul edilen R-11 referans alınmaktadır (Keogh, 2005; Calm, 2008). GWP ise bir gazın sera etkisi yoluyla küresel sıcaklık

artışına katkısını tanımlar ve GWP değeri 1 olan karbondioksit (CO_2) esas alınarak belirlenir (IPCC, 2014).

Bu göstergeler, soğutma ve iklimlendirme sistemlerinde kullanılan akışkanların çevresel performanslarının karşılaştırılmasında temel ölçütlerdir (UNEP, 2019). Araç iklimlendirme sistemlerinde uzun yıllar yaygın olarak kullanılan R134a, sıfır ODP değeri sayesinde ozon tabakası açısından çevreye duyarlı kabul edilmesine rağmen, yüksek GWP değeri nedeniyle iklim değişikliği üzerindeki olumsuz etkileri sebebiyle uluslararası düzenlemelerle kısıtlanmaktadır (European Commission, 2014; IPCC, 2014). Bu nedenle, düşük ODP ve GWP değerlerine sahip alternatif soğutucu akışkanların geliştirilmesi ve uygulanması sürdürülebilir iklimlendirme teknolojileri açısından zorunlu hale gelmiştir (Calm, 2008; UNEP, 2019).

Endüstriyel ısı transferi uygulamalarında yoğuşma olayı, enerji dönüşüm sistemleri, soğutma–iklimlendirme teknolojileri ve kimyasal prosesler açısından büyük önem taşımaktadır. Doymuş buharın daha düşük sıcaklıktaki bir yüzeyle temas ederek sıvı faza geçmesi sırasında açığa çıkan gizli ısının etkin biçimde uzaklaştırılması, sistem performansını doğrudan etkilemektedir.

Yoğuşma rejimi, yüzeyin ıslanma özelliklerine bağlı olarak film veya damlacık şeklinde gerçekleşmektedir. Film yoğuşmada oluşan sürekli sıvı tabakası, ek bir termal direnç oluşturarak ısı transferini sınırlandırırken; damlacık yoğuşmada bu direnç bulunmadığından ısı transfer katsayısı daha yüksek değerlere ulaşmaktadır. Ancak damlacık yoğuşmanın sürdürülebilmesi için özel olarak hazırlanmış, hidrofobik ve düzgün yüzeylere ihtiyaç duyulması, endüstriyel uygulamalarda film yoğuşmanın baskın rejim olmasına neden olmaktadır (Kakaç & Arınç, 2004).

Yoğuşma sürecinin hidrodinamik yapısı yalnızca yüzey özelliklerine değil, aynı zamanda yoğuşmanın gerçekleştiği kanal veya boru geometrisine ve sistemin uzaysal konumuna da güçlü biçimde bağlıdır. Düşey konumlandırılmış borularda, yer çekimi kuvveti akış yönüyle aynı doğrultuda etki gösterdiğinden, yoğuşan sıvı faz boru iç yüzeyi boyunca düzgün bir film halinde aşağı yönde akmakta, buhar fazı ise borunun merkez bölgesinde yoğunlaşmaktadır. Bu koşullar altında sistemde çoğunlukla halkalı (annular) akış rejimi oluşmaktadır.

Buna karşılık, boru eğiminin değiştirilmesi veya yatay konfigürasyonların kullanılması durumunda yer çekimi kuvvetinin akış yönüne dik bileşen kazanması, sıvı ve buhar fazlarının uzaysal dağılımını önemli ölçüde değiştirmektedir. Literatürde bu tür konfigürasyonlar için dalgalı halkalı, tabakalı, tıkaç, kabarcıklı ve sisli akış gibi farklı iki fazlı akış rejimlerinin gözlemlendiği rapor edilmiştir (Arslan, 2013). Bu rejimlerin her biri, hem ısı transferi hem de basınç kaybı karakteristikleri açısından birbirinden belirgin biçimde ayrılmaktadır.

Yoğuşma olayının yalnızca yer çekimi etkisi altında dahi bu denli farklı akış yapıları sergilemesi, sürecin son derece karmaşık bir fiziksel doğaya sahip olduğunu ortaya koymaktadır. Bu karmaşıklık nedeniyle literatürde yoğuşma mekanizmasının açıklanmasına yönelik çok sayıda analitik, deneysel

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

bakış açısıyla sayısal model geliştirilmiştir. Analitik modeller genellikle basitleştirici varsayımlar altında çözüm sunarak fiziksel içgörü sağlamayı amaçlarken; sayısal yöntemler daha ayrıntılı faz arayüzü temsili ve yerel akış yapısı tahmini sağlamakta, ancak yüksek hesaplama maliyeti ve uzun çözüm süreleri nedeniyle mühendislik uygulamalarında sınırlı kullanılabilmektedir.

Bu sınırlamalar doğrultusunda, pek çok araştırmacı deneysel çalışmalara yönelmiş; farklı akışkan özellikleri, boru çapları, yüzey geometrileri ve işletme koşulları altında oluşan akış rejimlerini inceleyerek kapsamlı iki fazlı akış haritaları oluşturmuştur. Bu çalışmalar, yoğuşma sürecinin rejim bağımlı doğasını ortaya koymakla birlikte, özellikle karmaşık iç yüzey geometrilerine sahip borular için hâlen genellenebilir tasarım kriterlerinin sınırlı olduğunu göstermektedir.

Soğutma ve iklimlendirme sistemlerinde kullanılan yoğuşturucu ve buharlaştırıcı elemanların tasarımında, yüksek ısı transfer kapasitesinin sağlanması ile birlikte sistem hacminin ve malzeme kullanımının azaltılması temel mühendislik hedefleri arasında yer almaktadır. Bu bağlamda, son yıllarda boruların iç yüzeylerine entegre edilen mikro-kanatçık (micro-fin) geometrilerinin yoğuşma performansı üzerindeki etkileri yoğun biçimde araştırılmaktadır.

Literatürde rapor edilen deneysel çalışmalar, mikro-kanatçıklı boruların düz borulara kıyasla daha yüksek türbülans seviyeleri oluşturduğunu, sıvı film kalınlığını azalttığını ve faz arayüzü alanını artırdığını göstermektedir. Bu etkiler sonucunda, her ne kadar basınç kaybında artış gözlense de, ısı transfer katsayısında %200–300 mertebesine ulaşan iyileşmeler sağlanabildiği bildirilmektedir (Han vd., 2023).

Soğutma sistemleri; binalar, endüstriyel prosesler ve gıda muhafazası gibi birçok alanda yaygın olarak kullanılmakta olup, yüksek enerji tüketimleri ve kullanılan soğutucu akışkanların çevresel etkileri nedeniyle iklim değişikliği açısından önemli bir rol oynamaktadır. Yapılan çalışmalar, 2018 yılı itibarıyla küresel sera gazı emisyonlarının yaklaşık %7,8'inin soğutma sektöründen kaynaklandığını göstermektedir (Calleja-Anta ve ark., 2023).

Bu kapsamda, soğutma sistemlerinin enerji verimliliğinin artırılması ve çevresel etkileri düşük soğutucu akışkanların kullanımı mühendislik alanında öncelikli araştırma konuları hâline gelmiştir. Montreal Protokolü'ne ek olarak yürürlüğe giren Kigali Değişikliği ile hidroflorokarbon (HFC) esaslı soğutucu akışkanların kullanımının 2047 yılına kadar kademeli olarak %80 oranında azaltılması hedeflenmektedir. Bu düzenlemenin, küresel sıcaklık artışını yüzyıl sonuna kadar yaklaşık 0,5 K azaltabileceği öngörülmektedir (Calleja-Anta ve ark., 2022).

Ticari ve endüstriyel soğutma sistemlerinde yaygın olarak kullanılan R134a soğutucu akışkanı, uygun termofiziksel özellikleri ve sistem uyumluluğu nedeniyle uzun yıllardır tercih edilmektedir. Ozon inceltme potansiyelinin sıfır olmasına rağmen, yüksek küresel ısınma potansiyeline (GWP ≈ 1430) sahip olması, R134a'nın kullanımının kademeli olarak sınırlandırılmasını gündeme getirmiştir. Bu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

durum, R134a kullanılan mevcut sistemlerin enerji ve çevresel performanslarının ayrıntılı biçimde değerlendirilmesini gerekli kılmaktadır.

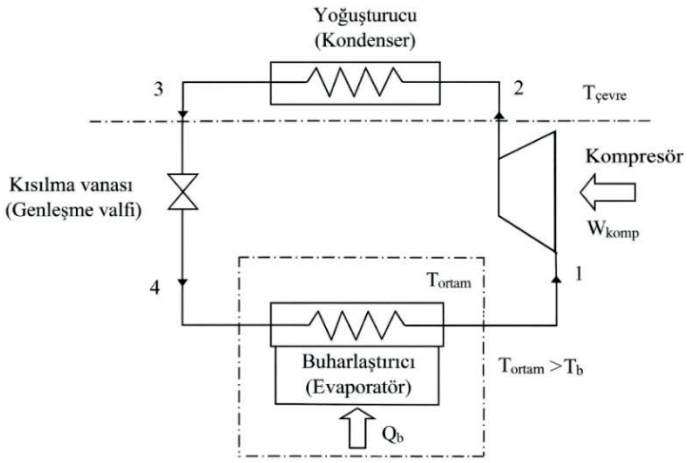
Bu tez çalışmasında, R134a kullanılan bir buhar sıkıştırmalı soğutma sistemi esas alınarak sistemin enerji ve performans karakteristikleri incelenmiştir. Elde edilen sonuçlar doğrultusunda, soğutma sistemlerinin enerji verimliliğinin artırılmasına ve çevresel etkilerinin azaltılmasına yönelik değerlendirmeler yapılmış; ayrıca alternatif soğutucu akışkanlara geçiş sürecinde referans oluşturabilecek bulgular sunulması amaçlanmıştır.

Materyal ve Metot

Literatürde, yoğuşturucuların soğutma sistemlerinin performansı üzerindeki etkisi genellikle sistemin toplam enerji verimliliğini temsil eden performans katsayısı (Coefficient of Performance, COP) üzerinden değerlendirilmiştir. Araştırmalarda COP'un; kütlesel debi, yoğuşma sıcaklığı, soğutma akışkanı giriş koşulları ve sistem çalışma basınçları gibi temel işletme parametreleriyle olan ilişkisi deneysel ve sayısal yöntemler kullanılarak incelenmiş; elde edilen sonuçlar belirli sistem geometrileri ve çalışma aralıkları için rapor edilmiştir.

Literatürle karşılaştırıldığında gözlenen sınırlı sapmaların ise ağırlıklı olarak deneysel sistemdeki ısı kayıpları, ölçüm belirsizlikleri, çalışma koşullarındaki küçük farklılıklar ve yoğuşturucu geometrisindeki yapısal değişkenliklerden kaynaklandığı değerlendirilmektedir. Bu durum, deneysel çalışmaların doğası gereği kaçınılmaz olan belirsizliklerle uyumlu olup, elde edilen sonuçların literatürde rapor edilen genel eğilimleri doğrular nitelikte olduğunu göstermektedir.

Deney düzeneği, test bölümü ve soğutma devre elemanlarından oluşmaktadır. Deney düzeneğinin şematik görünümü Şekil 1'de gösterilmiştir. Soğutma devresinde kompresör, yoğuşturucu, genleşme valfi ve buharlaştırıcı bulunmaktadır. Test bölümünde termometre sıcaklık ölçerleri bulunmaktadır.

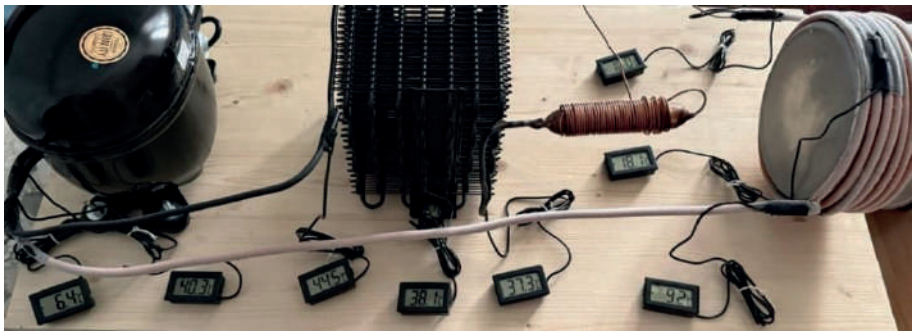


Şekil 1. Buhar sıkıştırmalı mekanik soğutma çevriminin şematik gösterimi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İdeal buhar sıkıştırmalı soğutma çevriminde akışkan, yoğuşturucudan doymuş sıvı olarak çıkar, genleşme vanasında izentalpik genleşir, buharlaştırıcıda sabit basınçta buharlaşır ve kompresörde izentropik olarak sıkıştırılır. Yoğuşturucuda ısı atarak tekrar sıvı hâle gelir ve çevrim tamamlanır.

Gerçek çevrimde ise sıkıştırma izentropik değildir, sürtünmeler nedeniyle entropi artar. Akışkan genellikle kompresöre kızgın buhar olarak girer, yoğuşturucudan aşırı soğutulmuş sıvı olarak çıkar. Basınç kayıpları ve tersinmezlikler performansı düşürür; bu nedenle gerçek çevrimin COP değeri ideal çevrimden daha küçüktür.



Şekil 2. Deney düzeneği

Şekil 2'de deney düzeneğinde görüldüğü üzere test düzeneğinde 8 ayrı noktada eş zamanlı olarak termometre sıcaklıkları her bir deney ölçümü sırasında görüntülenmiştir. Yoğuşturucunun bağlı olduğu buhar sıkıştırmalı soğutma çevriminde eş zamanlı üç farklı noktadan, buharlaştırıcı eş zamanlı üç farklı noktadan sıcaklık ölçümleri yapılmıştır. Deney sisteminde kullanılan bileşenlerin özellikleri Tablo 1'de verilmiştir.

Tablo 1. Deney sisteminde kullanılan bileşenlerin özellikleri

Yoğuşturucu		**Genleşme Valfi**		**Kompresör**	
Yoğuşturucu Boyu (mm)	165mm	Kılcal Boru (mm)	320 mm	Model	E80HBL
Yoğuşturucu Eni (mm)	120 mm	Kılcal Boru Çapı (mm)	2 mm	Kullanılan Soğutucu	R134a
Yoğuşturucu Yüksekliği (mm)	165 mm	Boru Malzemesi	Bakır	Motor Tipi	RSCR(Alçak Basınç)
Boru Çapı (mm)	5 mm	**Buharlaştırıcı**		Soğutma Kapasitesi	210 W
Boru Eksenleri Yatay Mesafe (mm)	20 mm	Boru Çapı (mm)	6 mm	COP	1,45
Boru Eksenleri Dikey Mesafe (mm)	22 mm	Boru Uzunluğu (m)	5 m		
Boru Sıra Sayısı Yatay (Adet)	7	Dikey Helisel Sarım Sayısı (Adet)	7		
Boru Sıra Sayısı Düşey (Adet)	10	Dikey Helisel Sarım Çapı (mm)	170 mm		
Boru Malzemesi	Bakır	Boru Malzemesi	Bakır		

Kütlesel debi, kompresörden geçen soğutucu akışkanın kütlesel debisini belirlemek için kullanılır. Debi; emiş hattındaki akışkan yoğunluğu, kompresörün teorik süpürme hacmi ve volümetrik verimin birleşik etkisine bağlıdır. Volümetrik verim, gerçek akışın teorik kapasiteye oranını temsil ederek sistem kayıplarını dolaylı biçimde içerir. Böylece gerçek çalışma koşullarına uygun bir debi tahmini Denklem (1)'de gösterilmiştir.

$$\dot{m} = \rho_1 \cdot V_{swept} \cdot n_{vol} \quad (1)$$

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V_{swept}; kompresörün teorik süpürme hacmi, (V_{disp} x RPM / 60) ρ_1; Kompresör emiş hattındaki (Nokta 1) akışkan yoğunluğu, n_{vol} ; Kompresör volümetrik verimi

Soğutma Kapasitesi ($\dot{Q}_{evap}$); Evaporatörde gerçekleşen ısı çekimidir. Akışkanın evaporatör giriş ve çıkışındaki özgül entalpi farkı, faz değişimi sırasında absorbe edilen enerjiyi gösterir. Kütlesel debi ile çarpıldığında sistemin birim zamanda sağladığı soğutma kapasitesi hesaplanır. Evaporatör sistem performansı Denklem (2)'de gösterilmiştir.

$$\dot{Q}_{evap} = \dot{m}\,(h_1 - h_4)$$

(2)

Kondanser Isı Atımı ($\dot{Q}_{cond}$); Kondenserde çevreye aktarılan toplam ısı miktarını ifade eder. Kompresörden çıkan yüksek enerjili akışkanın entalpi düşüşü, yoğuşma sırasında açığa çıkan ısıyı temsil eder. Debi ile birlikte değerlendirildiğinde sistemin ısı reddetme kapasitesi bulunur. Bu parametre enerji dengesinin kurulmasında kritik rol oynar. Denklem (3)'te ifade edilmiştir.

$$\dot{Q}_{cond} = \dot{m}(h_2 - h_3)$$

(3)

Kompresör işi, sistemin çalışması için dışarıdan sağlanan enerji girdisini temsil eder. Deneysel çalışmalarda bu değer doğrudan elektriksel güç ölçümü ile belirlenir. Mekanik ve elektriksel kayıplar bu ölçümün içinde yer alır. Bu nedenle gerçek çalışma koşullarını yansıtan bir büyüklüktür. Denklem (4)'te ifade edilmiştir.

COP, sistemin enerji verimliliğini gösteren boyutsuz bir performans parametresidir. Üretilen faydalı ısının harcanan işe oranını ifade eder. Yüksek COP değeri, daha verimli bir çalışma anlamına gelir. Bu büyüklük sistemlerin karşılaştırılmasında yaygın olarak kullanılır. Denklem (5)'te ifade edilmiştir.

$$\dot{W}_{comp} = \text{Ölçülen Elektriksel Güç} \qquad (4)$$

$$\text{COP} = \frac{\dot{Q}_{cond}}{\dot{W}_{comp}}$$

(5)

Bir akışkanın çevre şartlarına göre sahip olduğu kullanılabilir enerji miktarı entalpi ve entropi farkları, referans (ölü hal) koşullarına göre değerlendirilir. Böylece enerji kalitesi ve dönüşüm potansiyeli belirlenir. Ekserji analizi, tersinmezliklerin incelenmesinde temel araçtır. Denklem (6)'da ifade edilmiştir. Herhangi bir noktadaki özgül fiziksel ekzerji (φ), ölü hal şartları (T_0 = 296.45 K, P_0 = 101.3 kPa) referans alınarak hesaplanmıştır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$$\varphi = (h - h_0) - T_0(s - s_0)$$

(6)

Kompresörde meydana gelen tersinmezlikleri nicel olarak gösterir. Giriş ve çıkış ekserji farkı ile iş girdisi birlikte değerlendirilir. Ortaya çıkan değer, kaybedilen kullanılabilir enerjiyi temsil eder. Yüksek yıkım değeri düşük ikinci yasa performansına işaret eder. Kompresörde meydana gelen bileşen bazlı ekserji yıkımı Denklem (7)'de gösterilmiştir.

$$\dot{E}x_{dest,comp} = \dot{W}_{comp} + \dot{m}(\varphi_1 - \varphi_2)$$

(7)

Kondenserdeki ekserji yıkımı, akışkanın enerji kalitesindeki azalmayı ifade eder. Isı transferi sırasında oluşan tersinmezlikler bu kaybın temel nedenidir. Ekserji farkı, sistem verimliliğini değerlendirmek için kullanılır. Bu analiz, ısı değiştirici tasarımının iyileştirilmesine katkı sağlar. Kondanser'de meydana gelen ekserji yıkımı Denklem (8)'de gösterilmiştir.

$$\dot{E}x_{dest,cond} = \dot{m}(\varphi_2 - \varphi_3)$$

(8)

Genleşme süreci büyük ölçüde tersinmezdir ve önemli ekserji kaybına yol açar. Basınç düşüşü sırasında enerji kalitesi azalır. Bu denklem, söz konusu kaybın büyüklüğünü nicel olarak belirler. Sistem optimizasyonunda kritik bir göstergedir. Denklem (9)'da ifade edilmiştir.

$$\dot{E}x_{dest,exp} = \dot{m}(\varphi_3 - \varphi_4) \quad (9)$$

Evaporatördeki ekserji kaybını hem akışkan değişimi hem de ısı transferi açısından değerlendirir. Sıcaklık farkları nedeniyle oluşan tersinmezlikler dikkate alınır. Mutlak değer, kaybın büyüklüğünü ifade eder. Böylece bileşenin ikinci yasa performansı analiz edilir. Evaporatör'deki ekserji kaybı Denklem (10)'da gösterilmiştir.

$$\dot{E}x_{dest,evap} = \left|\dot{m}(\varphi_4 - \varphi_1) - \dot{Q}_{evap}\left(\frac{T_0 - T_{evap}}{T_{evap}}\right)\right| \quad (10)$$

Faydalı ekserji çıktısının iş girdisine oranını gösterir. Gerçek sistem performansını enerji kalitesi açısından değerlendirir. Yüksek değerler, düşük tersinmezlik anlamına gelir. İkinci yasa verimi Denklem (11)'de gösterilmiştir.

$$\eta_{II} = \frac{\dot{Q}_{evap}\left(\frac{T_0 - T_{evap}}{T_{evap}}\right)}{\dot{W}_{comp}}$$

(11)

SONUÇLAR

Bu çalışmada, R134a akışkanı kullanan buhar sıkıştırmalı soğutma sisteminin performansı 15 farklı deneysel data üzerinden deneysel ve teorik olarak incelenmiştir. Deneyler hem standart iç ortam, hem

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ISBN: 978-9952-610-30-7

de dış ortam koşullarının simüle edildiği farklı parametrelerde gerçekleştirilmiştir. Elde edilen basınç, sıcaklık ve kütlesel debi ölçümleri kullanılarak sistemin enerji (COP) ve ekserji (η_{II}) performansları ile bileşen bazlı tersinmezlikler hesaplanmıştır. İç ortamda yapılan deneylerde ortam sıcaklığı 23ºC civarında iken dış ortamda yapılan deneylerde ortam sıcaklığı 20.1 ºC (Deney 11) ile 34.1ºC (Deney 12) arasında değişmektedir.

Her bir deney için çevrimin dört ana noktasındaki (Kompresör girişi, Kompresör çıkışı, Yoğuşturucu çıkışı, Genleşme valfi çıkışı/Buharlaştırıcı girişi) termodinamik özellikler belirlenmiştir. Örnek teşkil etmesi açısından, standart koşullarda gerçekleştirilen Deney 1'e ait termodinamik veriler Tablo 2'de sunulmuştur.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Tablo 2. Deney 1 için sistemin termodinamik durum özellikleri

Deney 1					
Nokta	Basınç	Sıcaklık	Entalpi	Entropi	Ekserji
	[kpa]	[C]	[kj/kg]	[kj/kgK]	[kj/kg]
1 (Komp. Giriş)	208.6	-8.8	393.4	1.733	18.4
2 (Komp. Çıkış)	984.3	70.6	452.9	1.815	53.6
3 (Kond. Çıkış)	984.3	38.6	254.3	1.184	41.8
4 (Evap. Giriş)	208.6	-9	254.3	1.207	35.1

Kompresörün izentropik verimi her deney durumunda %50-%55 aralığında çıkmıştır. Bu da termodinamik olarak kabul edilebilir bir aralık olarak matematiksel model ile deney verilerinin uyuştuğunu göstermektedir. Yapılan 15 deney sonucunda sistemin soğutma kapasitesinin 242.1 W ile 401.7 W aralığında değiştiği tespit edilmiştir. Sistem performans katsayısı (COP), çalışma koşullarına bağlı olarak önemli değişimler göstermiştir. Standart iç ortam koşullarında yapılan deneylerde sistem kararlı bir rejim sergilemiş, COP değerleri 2.11 ile 2.15 aralığında, soğutma kapasitesi ise ortalama 266 W civarında gerçekleşmiştir. Dış ortam koşullarında gerçekleştirilen deneylerde ortam sıcaklığının ve basınç oranlarının değiştiği, soğutma sisteminin en yüksek ve en düşük performans değerlerine ulaştığı gözlemlenmiştir. Deney 11, 401.7 W soğutma kapasitesi ve 3.21 COP değeri ile sistemin en verimli çalıştığı nokta olmuştur. Buna karşılık, basınç oranlarının ve kompresör işinin değiştiği Deney 12, 1.94 COP ile en düşük performansın görüldüğü çalışma koşuludur.

İkinci yasa verimi incelendiğinde, sistemin ekserji veriminin %22.8 (Deney 15) ile %37.6 (Deney 11) arasında değiştiği görülmüştür. Bu durum, sistemin çevre koşullarına ve çalışma parametrelerine olan duyarlılığını ortaya koymaktadır. Bileşen bazlı ekserji yıkımı analizi, sistemdeki verim kayıplarının ana kaynağını belirlemek amacıyla yapılmıştır. Tüm deney setleri boyunca en yüksek ekserji yıkımı kompresörde meydana gelmiştir. Toplam ekserji yıkımının %50.9 ile %78.1'i kompresörde gerçekleşmiştir. Özellikle düşük performanslı deneylerde (Deney 13) kompresör kaynaklı kayıpların %78 seviyelerine ulaştığı görülmüştür.Yoğuşturucu, ikinci en büyük kayıp kaynağıdır. Toplam yıkımın %14.2 ile %32.2'si bu bileşende gerçekleşmiştir. Verimin yüksek olduğu Deney 11'de yoğuşturucudaki yıkım oranının arttığı (%32.2), kompresör payının ise azaldığı dikkat çekmiştir. Genleşme valfinin toplam yıkıma katkısı %6.8 ile %16.8 aralığındadır. Deneysel veriler ışığında

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ISBN: 978-9952-610-30-7

buharlaştırıcıdaki ekserji yıkımı ihmal edilebilir düzeyde (<%1) hesaplanmıştır. Tablo 3'de, sistemin en yüksek ve en düşük performans gösterdiği iki uç durumun karşılaştırmalı analizi sunulmuştur.

Tablo 3. En yüksek (Deney 11) ve en düşük (Deney 12) performanslı durumların karşılaştırılması

Parametre	Deney 11	Deney 12
Soğutma Kapasitesi (W)	401.7	242.1
Kompresör Gücü (W)	144.4	95.3
COP	3.21	1.94
İkinci Yasa Verimi	0.376	0.252
Kompresör Yıkım Oranı	%50.9	%72.8
Yoğuşturucu Yıkım Oranı	%32.2	%17.7

Elde edilen sonuçlar, sistem performansını artırmak için iyileştirme çalışmalarının öncelikle kompresör tasarımı ve verimliliği üzerine yoğunlaşması gerektiğini göstermektedir.

TARTIŞMA

Bu çalışmada, R134a soğutucu akışkanı ile çalışan buhar sıkıştırmalı bir soğutma sisteminin termodinamik performansı, farklı çevre sıcaklıklarını ve işletme koşullarını kapsayan 15 ayrı deney ölçümü üzerinden incelenmiştir. Deneysel ölçümlerden elde edilen veriler kullanılarak sistemin enerji ve ekserji verimlilikleri hesaplanmış ve performans kayıplarının kaynakları bileşen bazında analiz edilmiştir. Elde edilen sonuçlar, R134a akışkanlı soğutma sisteminin performansının çalışma koşullarına güçlü bir şekilde bağlı olduğunu göstermiştir. Enerji analizi, buharlaşma sıcaklığının arttığı koşullarda (Deney 11) sistemin COP değerinin 3.21'e ulaştığını; ancak düşük sıcaklıklarda (Deney 12) bu değerin 1.94'e gerilediğini ortaya koymaktadır. Bu değişim, literatürdeki buharlaşma basıncının sistem verimliliği üzerindeki etkisiyle uyumludur.İkinci yasa analizi, sistemdeki verim kayıplarının ana kaynağını belirlemiştir. Tüm deneylerde toplam ekserji yıkımının %50.9 ile %78.1 arasındaki büyük bir bölümü kompresörde meydana gelmiştir. Düşük performanslı çalışma koşullarında kompresör kaynaklı kayıpların baskın hale geldiği, yüksek verimli koşullarda ise yoğuşturucunun yıkım payının (%32.2) arttığı gözlemlenmiştir. Bu bulgular, sistem performansının artırılması için önceliğin kompresör verimliliğine ve ardından yoğuşturucu tasarımına verilmesi gerektiğini göstermektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KAYNAKÇA

Arslan, G. (2013). Yoğuşturucularda İki Fazlı Akış Mekanizmalarının ve Isı Geçişinin Farklı Eğim Açılarında Teorik ve Deneysel Analizi. İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü Mühendisliği Anabilim Dalı.

Calleja-Anta, D., Sánchez, D., Nebot-Andrés, L., Cabello, R., Llopis, R. (2023). Alternative mixtures to R 600a. Theoretical assessment and experimental energy evaluation of binary mixtures in a commercial cooler. International Journal of Refrigeration, 152, 83-92.

Calleja-Anta, D., Nebot-Andres, L., Sánchez, D., Cabello, R., Llopis, R. (2022). Drop-in substitutes for R-600a. Experimental evaluation and optimization of a commercial fridge. Applied Thermal Engineering, 211, 118490.

Calm, J.M. (2008). The next generation of refrigerants – Historical review, considerations, and outlook, International Journal of Refrigeration, 31: 1123-1133 pp.

European Commıssıon, Report From The Commıssıon To The European Parlıament And The Councıl Progress Towards Achıevıng The Kyoto And Eu 2020 Objectıves, Brussels, 28.10.2014 COM (2014) 689 final

Han, Y., Feng, R., Xiao, T., Guo, M., Wu, J., & Cui, H. (2023). Simulation Research on the Optimization of Domestic Heat Pump Water Heater Condensers. Energies, https://doi.org/10.3390/en16217441

İPCC (Intergovernmental Panel On Climate Change) Synthesis Report, 2014 ISBN 978-92-9169-143-2

Kakaç, S., & Arınç, F. (2004). Örneklerle Mühendislik Isı Transferinin Esasları, Pelikan Yayıncılık.

KEOGH, A. (2005). Soğutucu akışkan seçimi ve su soğutma grubu tasarımı - Paket tip su soğutma gruplarında R-410A kullanımı, Carrier Teknik Bülten, 4: 10 s.

UNEP (United Nations Environment Programme), Emissions Gap Report 2019 ISBN: 978-92-807-3766-0 Job number: DEW/2263/NA

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ORMAN ÜRÜNLERİ SEKTÖRÜNDE ÇALIŞANLARIN MESLEKİ STRESİNİ ETKİLEYEN FAKTÖRLER

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ÖZET

Mesleki stres kavramı, çalışma yaşamının güncel koşulları çerçevesinde ele alınmış ve çalışanlar üzerindeki bireysel ve örgütsel etkileri incelenmiştir. İş ortamında artan sorumluluklar, belirsizlikler ve performans beklentileri, çalışanların stres düzeylerini yükseltmekte ve bu durum hem iş doyumunu hem de genel yaşam kalitesini olumsuz yönde etkilemektedir. Bu çalışmada, Düzce İli Orman ürünleri sektöründe faaliyet gösteren işletmelerde çalışanların mesleki stresine etki eden faktörlerin tespit edilmesi amaçlanmıştır. Çalışanlara yönelik olarak uygulanan anketlerden 150 adedinin değerlendirilebilecek durumda olduğu ön inceleme sonucunda belirlenmiştir. Anket uygulaması sonrasında elde edilen veriler SPSS sürüm 25.0 paket programında değerlendirilmek üzere kodlanarak, bir veri seti oluşturulmuş ve istatistiksel değerlendirmeler yapılmıştır. İstatistiksel analizler sonucunda, katılımcılara yönelik elde edilen demografik bulgularda, %65.3'ünün erkek, %34.7'sinin ise kadın olduğu, katılımcıların büyük bir kısmının lise mezunu (%72) olduğu ve katılımcıların büyük bir çoğunluğunun üretim bölümünde çalıştığı tespit edilmiştir. Katılımcılara yönelik mesleki strese etki eden faktörlerin değerlendirilmesine yönelik elde edilen bulgularda ise; mesleki stres faktörlerinden olan iş yükü ve zaman baskısı faktörü altında, çalışan katılımcılar en yüksek ortalama ile kişisel ve ailevi sorunlarına yeterli zamanı ayıramadıklarını belirtmişlerdir. Karara katılım ve özerklik faktörü altında, çalışan katılımcıların en yüksek ortalama ile bazı grup ya da politik baskılar nedeniyle isteksizce bazı işleri yapmak zorunda kaldıkları tespit edilmiştir. Araştırma bulguları doğrultusunda, çalışanların mesleki stres düzeylerini azaltmaya yönelik olarak kurumlarda iş yükü ve zaman baskısının dengeli biçimde düzenlenmesi önerilmektedir. Ayrıca, karar alma süreçlerinde çalışanların katılımının artırılması ve grup ya da politik baskıların azaltılmasına yönelik şeffaf ve katılımcı yönetim anlayışlarının benimsenmesi, mesleki stresin azaltılmasına katkı sağlayacaktır.

Anahtar Kelimeler: Mesleki stres, Düzce ili, Orman ürünleri sektörü.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A STUDY ON FACTORS AFFECTING OCCUPATIONAL STRESS AMONG WORKERS IN THE FOREST PRODUCTS SECTOR

ABSTRACT

The concept of occupational stress has been examined within the framework of current working conditions, and its individual and organizational effects on employees have been investigated. Increasing responsibilities, uncertainties, and performance expectations in the workplace raise employees' stress levels, negatively affecting both job satisfaction and overall quality of life. This study aims to identify the factors affecting the occupational stress of employees working in companies in the forest products sector in Düzce Province. A preliminary review determined that 150 of the surveys administered to employees were in a suitable condition for evaluation. Following the survey administration, the data obtained were coded for evaluation using the SPSS version 25.0 software package, a dataset was created and statistical evaluations were performed. Statistical analyses revealed that among the demographic findings obtained from the participants, 65.3% were male and 34.7% were female, a large proportion of the participants were high school graduates (72%), and the vast majority of participants worked in the production department. Findings regarding factors affecting occupational stress among participants revealed that under the occupational stress factors of workload and time pressure, working participants reported the highest average score, indicating that they were unable to devote sufficient time to personal and family issues. Regarding participation in decision-making and autonomy, it was found that participating employees had the highest average scores and were reluctantly forced to perform certain tasks due to group or political pressures. In line with the research findings, it is recommended that organizations balance workloads and time pressures to reduce employees' occupational stress levels. Furthermore, adopting transparent and participatory management approaches to increase employee participation in decision-making processes and reduce group or political pressure will contribute to reducing occupational stress.

Keywords: Occupational stress, Düzce Province, Forest products sector.

GİRİŞ

Çalışma yaşamı, günümüzde ekonomik bir faaliyet alanının ötesine geçerek bireylerin psikolojik, sosyal ve fiziksel bütünlüğünü etkileyen çok boyutlu bir yapıya dönüşmüştür. Artan performans beklentileri, hızlanan iş süreçleri ve teknolojik dönüşüm, çalışanlar üzerinde sürekli bir baskı oluşturarak mesleki stresi önemli bir örgütsel sorun haline getirmiştir. Mesleki stres, bireyin iş talepleri ile bu talepleri karşılama kapasitesi arasındaki uyumsuzluk olarak tanımlanmakta; kronikleştiğinde tükenmişlik, sağlık sorunları ve performans düşüşü gibi bireysel ve örgütsel sonuçlar doğurmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Kuramsal çerçevede stres kavramı, fizyolojik bir tepki olarak ele alınmış; daha sonra bilişsel değerlendirme süreçleri ve örgütsel bağlam içinde incelenmiştir. Literatürde mesleki stresin bireysel (yaş, cinsiyet, deneyim) ve örgütsel (iş yükü, rol belirsizliği, yönetim tarzı, iş güvencesi) kaynaklardan beslendiği; performans, iş doyumu ve örgütsel bağlılık üzerinde belirleyici etkiler yarattığı belirtilmektedir. Uluslararası çalışmalar tükenmişlik ve iş talepleri–iş kaynakları modeli çerçevesinde stresin sonuçlarını ele alırken, ulusal literatür daha çok iş doyumu, örgütsel destek ve liderlik tarzı ile ilişkisine odaklanmaktadır. Genel olarak değerlendirildiğinde, mesleki stresin hem çalışan sağlığı hem de örgütsel verimlilik açısından stratejik öneme sahip olduğu görülmektedir.

Mesleki Stres Kavramı ve Boyutları

Mesleki stres, bireyin iş ortamında karşılaştığı talepler ile bu talepleri karşılama kapasitesi arasındaki uyumsuzluk sonucu ortaya çıkan psikolojik ve fizyolojik tepkiler bütünü olarak tanımlanmaktadır. Stres kavramı ilk olarak Selye (2013) tarafından organizmanın çevresel uyaranlara verdiği genel tepki olarak açıklanmış; daha sonra Lazarus ve Folkman (1984) tarafından bilişsel değerlendirme süreci çerçevesinde ele alınarak öznel bir deneyim olduğu vurgulanmıştır.

Mesleki stres, kısa vadede performansı artırıcı bir işlev görebilmekle birlikte, süreklilik kazandığında tükenmişlik, sağlık sorunları ve işten uzaklaşma gibi olumsuz sonuçlara yol açmaktadır. Stres kaynakları bireysel (yaş, cinsiyet, eğitim, deneyim) ve örgütsel (iş yükü, rol belirsizliği, yönetim tarzı, iş güvencesi, vardiya sistemi) faktörler olarak iki boyutta değerlendirilmektedir. Özellikle imalat sektöründe iş yükü ve zaman baskısı belirleyici unsurlar arasında yer almaktadır. Sonuçları ise bireysel düzeyde kaygı, depresyon ve uyku bozuklukları; örgütsel düzeyde ise performans düşüşü, devamsızlık ve işten ayrılma şeklinde ortaya çıkmaktadır.

Literatür Taraması

Uluslararası literatürde mesleki stres, iş talepleri ile bireysel kaynaklar arasındaki dengenin bozulması çerçevesinde incelenmektedir. Cooper ve Marshall (1976) stres kaynaklarını işin yapısal özellikleri ve örgütsel roller bağlamında sınıflandırmış; Beehr ve Newman (1978) ise stresin bireysel ve örgütsel sonuçlarına dikkat çekmiştir. Maslach ve Jackson (1981) yüksek stres düzeyinin tükenmişliği artırdığını ortaya koyarken; Schaufeli ve Bakker (2004) iş talepleri–iş kaynakları modeli kapsamında örgütsel kaynakların stresin etkisini dengeleyebileceğini belirtmiştir. Güncel çalışmalar ise dijitalleşme ve sürekli erişilebilirlik baskısının stres düzeyini artırdığına işaret etmektedir.

Ulusal literatürde mesleki stres çoğunlukla iş doyumu, performans ve tükenmişlik değişkenleriyle birlikte ele alınmaktadır. Baltaş ve Baltaş (2015) örgütsel belirsizliğin stres kaynağı olduğunu vurgulamış; Özdevecioğlu (2004) örgütsel destek algısının stres düzeyi üzerinde belirleyici rol oynadığını belirtmiştir. Ayrıca demografik değişkenlerin stres algısını farklılaştırdığı ve uzun çalışma süresinin stres düzeyini artırabildiği ifade edilmektedir. Genel olarak literatür, mesleki stresin hem

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

bireysel psikolojik sağlık hem de örgütsel performans üzerinde belirleyici ve çok boyutlu bir etkiye sahip olduğunu göstermektedir.

Bu çalışmanın temel amacı, Düzce ili orman ürünleri sektöründe faaliyet gösteren işletmelerde çalışan bireylerin mesleki stres düzeylerini etkileyen faktörleri belirlemektir. Araştırma sonucunda elde edilecek bulguların, orman ürünleri sektöründe çalışanların mesleki stres düzeylerinin azaltılmasına yönelik yönetsel stratejilerin geliştirilmesine katkı sağlaması beklenmektedir.

MATERYAL VE YÖNTEM

Araştırma kapsamında belirlenen amaçlara ulaşabilmek için öncelikle ilgili işletmelerde çalışan bireylerin bazı demografik özellikleri tespit edilmiştir. Bu çalışma, orman ürünleri sektöründe faaliyet gösteren işletmelerde çalışanların mesleki stres düzeylerine etki eden faktörleri ortaya koymayı amaçlamaktadır. Araştırma, Düzce il merkezi ve ilçelerinde faaliyet gösteren işletmeler üzerinde gerçekleştirilmiştir.

Çalışmada çıkarımsal istatistiksel analiz yapılabilmesi için anket formundan yararlanılmıştır. Çalışma kapsamında kullanılan anket formu 2 bölümden, 46 farklı sorudan oluşan mesleki stres indeksi ile oluşturulmuştur. Çalışma esnasında kullanılan anket formunun birinci bölümünde katılımcıların bazı demografik özellikleri sorgulanmıştır. Anket formunun ikinci bölümünde ise katılımcıların mesleki stres düzeylerine etki eden faktörlerle ilgili sorular ele alınmıştır. Çalışma kapsamında kullanılan anket formunda hem açık uçlu hem de 5'li likert tarzı sorulardan yararlanılmıştır. Tasarlanan anket formu Düzce ilinde faaliyette bulunan işletmelere ulaştırılarak ve yüz yüze anket tekniği uygulanarak veriler elde edilmiştir.

Çalışmada anket uygulaması sonrasında elde edilen veriler SPSS sürüm 25.0 paket programında değerlendirilmek üzere kodlanarak, bir veri seti oluşturulmuştur (SPSS, 2003). Oluşturulan bu veri seti yardımıyla istatistiksel değerlendirmeler yapılıp elde edilen bulgular üzerinden sonuç ve önerilerde bulunulmuştur.

BULGULAR VE TARTIŞMA

Katılımcılara Ait Demografik Özellikler

Katılımcı çalışanlara ait demografik bilgiler Tablo 1'de gösterilmiştir.

Tablo 1. Katılımcıların demografik özelliklerinin değerlendirilmesi

Demografik Bilgi		**Sıklık**	**Yüzde**	**Demografik Bilgi**		**Sıklık**	**Yüzde**
Medeni durum	Evli	90	60.0	Çalışma süresi (yıl)	0-5	80	53.3
	Bekâr	60	40.0		6-10	48	32.0

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	Toplam	150	100		10-15	17	11.3
Cinsiyet	Kadın	52	34.7		16-20	5	3.3
	Erkek	98	65.3		Toplam	150	100
	Toplam	150	100	Mesleki deneyim (yıl)	0-5	63	42.0
Yaş (yıl)	<20	2	1.3		6-10	42	28.0
	20-30	70	46.7		10-15	27	18.0
	31-40	57	38.0		16-20	12	8.0
	41-50	18	12.0		21-25	5	3.3
	51-60	3	2.0		25>	1	0.7
	Toplam	150	100		Toplam	150	100
Eğitim	İlköğretim	32	21.3	Çalışılan bölüm	Üretim	128	85.3
	Lise	108	72.0		Bakım-onarım	9	6.0
	Ön lisans	9	6.0		Diğer	13	8.7
	Lisans	1	0.7		Toplam	150	100
	Toplam	150	100	Çalışma düzeni	Vardiyalı	59	39.3
Faaliyet	Mobilya	90	60.0		Vardiyasız	91	60.7
	Kereste	20	13.3		Toplam	150	100
	Levha	40	26.7	Aylık gelir (TL)	22000-27000	97	64.7
	Toplam	150	100		27001-32000	48	32.0
Günlük çalışma süresi (saat)	5-8	59	39.3		32001-37000	3	2.0
	9-12	91	60.7		37000>	2	1.3
	Toplam	150	100		Toplam	150	100
Meslek hastalığı	Evet	2	1.3	Geçmişte iş kazası	Evet	1	0.7
	Hayır	148	98.7		Hayır	149	99.3

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ISBN: 978-9952-610-30-7

	Toplam	150	100		Toplam	150	100

Tablo 1'de çalışmaya katılan katılımcıların demografik özelliklerine ilişkin bulgular gösterilmiştir. Bu bulgulara göre katılımcıların %90'ının evli, %60'ının bekâr ve %65.3'ünün ise erkek olduğu görülmektedir.

Yaş dağılımına bakıldığında katılımcıların %46.7'sinin 20-30 yaş, %38'inin 31-40 yaş aralığında olduğu belirlenmiştir. Bu bulgu, örneklemin ağırlıklı olarak genç ve orta yaş grubundan oluştuğunu göstermektedir. Eğitim düzeyi açısından katılımcıların büyük bir kısmının lise mezunu (%72) olduğu, bunu ilköğretim (%21.3) ve ön lisans (%6) mezunlarının izlediği görülmektedir.

Katılımcıların çalışma süresi incelendiğinde, %53.3'ünün 0-5 yıl, %32'sinin 6-10 yıl arasında çalışma süresine sahip olduğu saptanmıştır. Benzer şekilde mesleki deneyim açısından da katılımcıların önemli bir bölümünün 0-5 yıl (%42) ve 6-10 yıl (%28) aralığında deneyime sahip olduğu görülmektedir. Bu durum, örneklemde görece düşük ve orta düzeyde mesleki deneyime sahip bireylerin ağırlıkta olduğunu göstermektedir.

Çalışılan bölüme göre dağılım incelendiğinde, katılımcıların büyük çoğunluğunun üretim bölümünde (%85.3) çalıştığı ve çalışma düzeni açısından katılımcıların çoğunluğunun (%60.7) vardiyasız olarak çalıştığı görülmektedir. Faaliyet alanına göre dağılımda ise katılımcıların %60'ının mobilya, %26.7'sinin levha ve %13.3'ünün ise kereste sektöründe faaliyet gösterdiği saptanmıştır.

Günlük çalışma süresi değerlendirildiğinde, katılımcıların büyük çoğunluğunun günde 9-12 saat (%60.7) çalıştığı belirlenmiştir. Aylık gelir dağılımı incelendiğinde, katılımcıların en yüksek oranla 22.000-27000 TL (%64.7) gelir grubunda yer aldığı görülmektedir.

Son olarak, katılımcıların %1.3'ünün meslek hastalığına sahip olduğu ve %0.7'sinin ise geçmişte iş kazası geçirdiği belirlenmiştir. Bu bulgular, örneklemde meslek hastalığı ve iş kazası oranlarının düşük olmakla birlikte tamamen ihmal edilemeyecek bir düzeyde olduğunu göstermektedir. Genel olarak Tablo 1, araştırma grubunun ağırlıklı olarak erkek, lise mezunu, üretim bölümünde çalışan ve vardiyasız çalışma düzenine sahip bireylerden oluştuğunu ortaya koymaktadır.

Katılımcı Çalışanlara Yönelik Mesleki Strese Etki Eden Faktörlerin Değerlendirilmesi

Katılımcı çalışanlara yönelik mesleki etkileyen faktörlerden biri olan iş yükü ve zaman baskısı ile ilgili elde edilen bulgular, Tablo 2'de gösterilmiştir. Bu grupta, işin miktarı, tamamlanma hızı ve bu durumun kişisel hayata etkilerini içeren maddelerden oluşmaktadır.

Tablo 2. Çalışanların iş yükü ve zaman baskısına ilişkin yargılar (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Yargılar	**Ortalama**	**Standart Sapma**
Bu işte çok fazla çalışmak zorundayım	3.46	1.246
Aşırı iş yükü nedeniyle işlerimi aceleyle tamamlamak zorunda kalıyorum	3.52	1.398
Aşırı iş yükü ve zaman darlığı nedeniyle görevimi istediğim gibi yerine getiremiyorum	3.32	1.189
Yaptığım işle çok meşgul olduğum için kişisel ve ailevi sorunlarıma yeterli zamanı ayıramıyorum	3.60	1.170
Yaptığım işin hayatımı zorlaştırdığını sık sık hissediyorum	3.41	1.296
Grup uyumunu korumak için bazen olağanın üzerinde çalışmak zorunda kalıyorum	3.58	1.286

Tablo 2'de katılımcıların iş yükü ve zaman baskısına ilişkin algılarını ölçen ifadelere verdikleri yanıtların ortalamaları incelendiğinde, tüm maddelerin 3'ün üzerinde ortalamaya sahip olduğu görülmektedir. Bu durum, katılımcı çalışanların iş yükünü orta düzeyin üzerinde algıladıklarını göstermektedir. Yargılar incelendiğinde, en yüksek ortalamanın "Yaptığım işle çok meşgul olduğum için kişisel ve ailevi sorunlarıma yeterli zamanı ayıramıyorum" ifadesine ait olduğu görülmektedir (ort.=3.60; ss=1.170). Bu bulgu, çalışanların iş yükünü özellikle iş-yaşam dengesi bağlamında olumsuz algıladıklarını göstermektedir. Güncel çalışmalar, aşırı iş yükünün duygusal tükenmişlik ve işten ayrılma niyeti üzerinde güçlü bir yordayıcı olduğunu ortaya koymaktadır (Bakker ve Demerouti, 2017).

En düşük ortalama ise "Aşırı iş yükü ve zaman darlığı nedeniyle görevimi istediğim gibi yerine getiremiyorum" ifadesine aittir (ort.=3.32; ss=1.189). Bu durum, iş yoğunluğunun performans üzerinde baskı oluşturduğunu ancak çalışanların görevlerini yerine getirme konusunda tamamen yetersizlik algısı taşımadıklarını düşündürmektedir.

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan rol belirsizliği ve rol çatışması ile ilgili elde edilen bulgular, Tablo 3'de gösterilmiştir. İşin sınırlarının net olmaması, çelişkili talimatlar veya kurallar ile baskılar arasındaki uyuşmazlıkları kapsayan maddelerden oluşmaktadır.

Tablo 3. Çalışanların rol belirsizliği ve rol çatışmasına ilişkin yargılar (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**

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Yaptığım işle ilgili mevcut bilgiler belirsiz ve yetersizdir	2.61	1.235
Farklı amirlerim işimle ilgili çelişkili talimatlar veriyor	3.01	1.263
Yetki ve görev alanımın belirsizliği nedeniyle görevlerimi düzgün şekilde yerine getiremiyorum	3.04	1.370
Üstlerimin ve meslektaşlarımın benden ne tür bir iş ve davranış beklediği belli değil	2.90	1.189
İş rolümün hedefleri oldukça net ve yeterince planlanmış durumda	3.23	1.155
Yeni verilen görevler konusunda net talimatlar ve yeterli olanaklar sağlanmıyor	3.00	1.290
Uygulamada olan sistemlerin yerine aniden yeni işlem prosedürlerini uygulamak zorunda kalıyorum	3.33	1.150

Tablo 3'de yer alan yargılar incelendiğinde, en yüksek ortalamanın "Uygulamada olan sistemlerin yerine aniden yeni işlem prosedürlerini uygulamak zorunda kalıyorum" ifadesine ait olduğu görülmektedir (ort.=3.33; ss=1.150). Bu bulgu, çalışanların iş süreçlerinde ani değişikliklere maruz kaldıklarını ve bu durumun rol belirsizliği ya da uyum baskısı oluşturduğunu düşündüklerini göstermektedir. Kniffin vd., (2021) belirsizlik ve örgütsel değişim dönemlerinde çalışanların kontrol algısındaki azalmanın psikolojik stres düzeylerini artırdığını ortaya koymuştur.

En düşük ortalama ise "Yaptığım işle ilgili mevcut bilgiler belirsiz ve yetersizdir" ifadesine aittir (ort.=2.61; ss=1.235). Bu sonuç, çalışanların genel olarak işlerine ilişkin temel bilgi eksikliği algısının görece düşük olduğunu göstermektedir.

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan sorumluluk ve etki ile ilgili elde edilen bulgular Tablo 4'de gösterilmiştir. Bu tablo, çalışanın hem diğer insanlar üzerindeki sorumluluğunu hem de organizasyonun geleceğine olan katkısını içeren maddelerden oluşmaktadır.

Tablo 4. Çalışanların sorumluluk ve etki ile ilgili yargıları (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**
Birçok çalışanın verimliliği ve etkinliğinden ben sorumlu tutuluyorum	2.68	1.260
Birçok çalışanın geleceğinden ben sorumluyum	2.23	1.107
Bu kuruluşun ilerlemesi ve refahı için büyük bir sorumluluk taşıyorum	3.16	1.215
Bazı görevlerim oldukça riskli ve karmaşıktır	3.08	1.338

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 4'de gösterilen yargılar incelendiğinde, en yüksek ortalamanın "Bu kuruluşun ilerlemesi ve refahı için büyük bir sorumluluk taşıyorum" ifadesine ait olduğu görülmektedir (ort.=3.16; ss=1.215). Bu bulgu, çalışanların örgütsel sonuçlar ve kurumsal başarı açısından kendilerini belirli düzeyde sorumlu hissettiklerini göstermektedir. Başka bir ifadeyle, sorumluluk algısı daha çok kurumsal katkı ve örgütsel hedefler bağlamında yoğunlaşmaktadır. Literatürde, sorumluluk ile kontrol algısı arasında denge sağlanamadığında stres düzeyinin arttığı vurgulanmaktadır (Burke, 2023).

En düşük ortalama ise "Birçok çalışanın geleceğinden ben sorumluyum" ifadesine aittir (ort.=2.23; ss=1.107). Bu bulgu, çalışanların diğer çalışanların kariyer gelişimi ya da geleceği üzerinde doğrudan bir sorumluluk taşıdıkları algısının düşük olduğunu ortaya koymaktadır.

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan karara katılım ve özerklik ile ilgili elde edilen bulgular Tablo 5'de gösterilmiştir. Bu tablo, çalışanın görüşlerinin alınması, önerilerinin uygulanması ve işini yaparken sahip olduğu bağımsızlık derecesini gösteren maddelerden oluşmaktadır.

Tablo 5. Çalışanların karara katılım ve özerkliğine ilişkin yargılar (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**
Önerilerim dikkate alınıyor ve uygulanıyor	3.19	1.139
Önemli politika kararlarının belirlenmesinde görüşüm alınmaktadır	2.84	1.168
Çalışma sisteminde, araçlarında ve koşullarında yapılacak değişikliklerde görüşüme başvurulur	2.84	1.174
Yetenek ve tecrübemi bağımsızca kullanma fırsatına sahibim	3.04	1.189
Yetkililer çalışma yöntemlerime ve görev alanıma müdahale etmiyor	2.73	1.173
Yetkin olduğum konularda bile sorunların çözümünde öneri ve işbirliğim istenmez	2.60	1.116

Tablo 5'de yer alan yargılar incelendiğinde, en yüksek ortalamanın "Önerilerim dikkate alınıyor ve uygulanıyor" ifadesine ait olduğu görülmektedir (ort.=3.19; ss=1.139). Bu bulgu, çalışanların öneri ve katkılarının belirli ölçüde önemsendiğini düşündüklerini göstermektedir. Dolayısıyla katılımcılar, karar süreçlerine tamamen dışlanmadıkları yönünde orta düzeyin üzerinde bir algıya sahiptir. En düşük ortalama ise "Yetkin olduğum konularda bile sorunların çözümünde öneri ve işbirliğim istenmez" ifadesine aittir (ort.=2.60; ss=1.116).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Genel olarak değerlendirildiğinde, çalışanların katılım ve yetki kullanımına ilişkin algılarının orta düzeyde olduğu; önerilerin dikkate alınması boyutunda daha olumlu, karar süreçlerine aktif katılım ve müdahale özgürlüğü açısından ise daha sınırlı bir algının bulunduğu söylenebilir. Güncel çalışmalar, çalışanların karar alma süreçlerine katılımının psikolojik iyi oluş ve iş tatmini üzerinde olumlu etkiler yarattığını ortaya koymaktadır (Marion, 2022).

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan sosyal ilişkiler ve örgütsel destek ile ilgili elde edilen bulgular Tablo 6'da gösterilmiştir. Bu tablo, meslektaşlar ve üstlerle olan ilişkiler, işbirliği ve sosyal baskılar ile ilgili maddelerden oluşmaktadır.

Tablo 6. Çalışanların sosyal ilişkilere ve örgütsel desteğe ilişkin yargıları (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**
Sevdiğim kişilerle çalışmak zorundayım	3.14	1.064
Çalışanlar arasında yeterli karşılıklı işbirliği ve ekip ruhu vardır	3.04	1.041
İdari ve endüstriyel sorunların çözümünde meslektaşlarım gönüllü olarak işbirliği yapar	2.96	1.009
Bazı meslektaşlarım ve astlarım beni başarısız göstermek ve itibarsızlaştırmak istemektedir	2.93	1.240
Bazı grup ya da politik baskılar nedeniyle isteksizce bazı işleri yapmak zorunda kalıyorum	3.20	1.290
Grup/politik baskılar nedeniyle resmi ve idari prosedürleri ihlal etmek zorunda kalıyorum	2.76	1.168
Bazen grup/politik baskılar ile resmi kurallar ve talimatlar arasında uyum sağlamak benim için karmaşık bir sorun haline geliyor	2.98	1.226

Tablo 6 incelendiğinde, en yüksek ortalamanın "Bazı grup ya da politik baskılar nedeniyle isteksizce bazı işleri yapmak zorunda kalıyorum" ifadesine ait olduğu görülmektedir (ort.=3.20; ss=1.290). Bu bulgu, çalışanların örgüt içinde grup veya politik baskıları orta düzeyin üzerinde algıladıklarını ve bu baskıların görev davranışlarını etkileyebildiğini düşündüklerini göstermektedir. Standart sapmanın görece yüksek olması, bu algının çalışanlar arasında farklı düzeylerde deneyimlendiğine işaret etmektedir. Modern örgütlerde sosyal destek, stresin tamponlayıcı bir faktörü olarak kabul

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

edilmektedir. Sosyal destek eksikliği veya politik baskı algısı, çalışanların psikolojik güvenlik düzeyini azaltabilmektedir (Edmondson ve Lei, 2014).

En düşük ortalama ise "Grup/politik baskılar nedeniyle resmi ve idari prosedürleri ihlal etmek zorunda kalıyorum" ifadesine aittir (ort.=2.76; ss=1.168). Bu sonuç, çalışanların baskı algısına rağmen resmi kuralları ihlal etme durumunun görece düşük düzeyde algılandığını göstermektedir.

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan gelişim, ödüllendirme ve statü ile ilgili elde edilen bulgular Tablo 7'de gösterilmiştir. Bu tablo, kişisel becerilerin geliştirilmesi, emeğin karşılığı ve işin toplumsal yansıması ile ilgili maddelerden oluşmaktadır.

Tablo 7. Çalışanların gelişim, ödüllendirme ve statülerine ilişkin yargılar (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**
Yetenek ve becerilerimi geliştirmek için yeterli fırsata sahibim	2.96	1.137
Sıkı çalışmam ve verimli performansım ödüllendirilir	2.92	1.123
Mevcut işim toplumsal statümü yükseltti	2.80	1.247
Yaptığım işe kıyasla daha az maaş alıyorum	4.24	1.109
Üst makamlar özsaygıma önem veriyor	3.43	1.155
Üst makamlar görevime ve çalışmalarıma gereken önemi vermez	2.78	1.207

Tablo 7 incelendiğinde, en yüksek ortalamanın "Yaptığım işe kıyasla daha az maaş alıyorum" ifadesine ait olduğu görülmektedir (ort.=4.24; ss=1.109). Bu bulgu, çalışanların ücret düzeyini yaptıkları iş ve harcadıkları emekle karşılaştırdıklarında belirgin bir adaletsizlik algısı taşıdıklarını göstermektedir. Ortalamanın oldukça yüksek olması, ücret yetersizliğinin güçlü ve yaygın bir memnuniyetsizlik kaynağı olduğunu düşündürmektedir. Güncel araştırmalar, ücret adaleti algısının iş tatmini, örgütsel bağlılık ve performans üzerinde doğrudan etkili olduğunu göstermektedir (CIPD, 2023). Ücret yetersizliği algısının bu denli yüksek olması, mesleki stresin temel kaynaklarından biri olarak değerlendirilebilir.

En düşük ortalama ise "Üst makamlar görevime ve çalışmalarıma gereken önemi vermez" ifadesine aittir (ort.=2.78; ss=1.207). Bu sonucun görece düşük olması, çalışanların üst yönetimin görev ve çalışmalarını tamamen değersiz gördüğü yönünde güçlü bir algıya sahip olmadıklarını göstermektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan fiziksel ve operasyonel koşullar ile ilgili elde edilen bulgular Tablo 8'de gösterilmiştir. Bu tablo, çalışma ortamının konforu ve işin niteliği ile ilgili maddelerden oluşmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 8. Çalışanların fiziksel ve operasyonel koşullarına ilişkin yargılar (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**
Kötü çalışma koşulları altında çalışıyorum	3.22	1.169
Çalışma koşulları refah ve konfor açısından tatmin edicidir	2.80	1.139
Aşırı iş yükü nedeniyle yetersiz sayıda personel ve kaynakla idare etmek zorunda kalıyorum	3.36	1.243
Başkalarının yapması gereken işleri yapmak zorunda kalıyorum	3.46	1.246
Görevlerim monoton nitelikte	3.31	1.356

Tablo 8'de yer alan yargılar incelendiğinde, en yüksek ortalamanın "Başkalarının yapması gereken işleri yapmak zorunda kalıyorum" ifadesine ait olduğu görülmektedir (ort.=3.46; ss=1.246). Bu bulgu, çalışanların görev dağılımına ilişkin rol aşımı ya da görev karmaşası algısının orta düzeyin üzerinde olduğunu göstermektedir. Çalışanların kendi sorumluluk alanları dışında iş yükü üstlendiklerini düşünmeleri, rol çatışması ve iş doyumsuzluğu açısından risk oluşturabilecek bir durumdur. En düşük ortalama ise "Çalışma koşulları refah ve konfor açısından tatmin edicidir" ifadesine aittir (ort.=2.80; ss=1.139). Bu sonucun görece düşük olması, çalışanların çalışma ortamının konfor ve refah boyutunda yeterli düzeyde tatmin sağlamadığı yönünde bir algıya sahip olduklarını göstermektedir.

Genel olarak değerlendirildiğinde, çalışanların özellikle görev dağılımı ve iş yükü konusunda daha belirgin bir olumsuz algı taşıdıkları; çalışma koşullarının konfor boyutunda ise görece düşük ancak yine de dikkat çekici bir memnuniyetsizlik düzeyinin bulunduğu söylenebilir. Dünya genelinde yapılan güncel araştırmalar, personel yetersizliği ve artan operasyonel yükün özellikle sanayi ve üretim sektörlerinde tükenmişlik riskini artırdığını göstermektedir (Samaan vd., 2023).

Katılımcı çalışanlara yönelik mesleki streslerini etkileyen faktörlerden biri olan yönetimsel yetki ve eğitim ile ilgili elde edilen bulgular Tablo 9'da gösterilmiştir. Bu tablo çalışanın yönetimsel gücü ve personel gelişimi üzerindeki etkisiyle ilgili maddelerden oluşmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 9. Çalışanların yönetimsel yetki ve eğitimlerine ilişkin yargılar (1:Kesinlikle katılmıyorum; 5:Kesinlikle katılıyorum)

Yargılar	**Ortalama**	**Standart Sapma**
Çalışanlar arasında görev dağılımına ilişkin kararlarım ve talimatlarım düzgün şekilde uygulanıyor	3.29	1.150
Çalışanların eğitim programlarına dair önerilerime gereken önem verilir	2.93	1.150
Önemli görevlere atamalarda görüş ve çıkarlarımız dikkate alınır	2.83	1.211
Üst düzey idari veya endüstriyel sorunların çözümünde sık sık işbirliğime başvurulur	2.94	1.136
Çalışanlar resmi talimatlara ve çalışma prosedürlerine gereken önemi verir	3.33	1.121

Tablo 9 incelendiğinde, en yüksek ortalamanın "Çalışanlar resmi talimatlara ve çalışma prosedürlerine gereken önemi verir" ifadesine ait olduğu görülmektedir (ort.=3.33; ss=1.121). Bu bulgu, örgüt içinde resmi kurallara ve prosedürlere uyumun orta düzeyin üzerinde algılandığını göstermektedir. Çalışanların talimatlara riayet ettiğine yönelik bu algı, örgütsel düzen ve işleyiş açısından olumlu bir göstergedir. En düşük ortalama ise "Önemli görevlere atamalarda görüş ve çıkarlarımız dikkate alınır" ifadesine aittir (ort.=2.83; ss=1.211). Bu sonuç, çalışanların önemli görevlere ilişkin atama süreçlerinde katılım ve temsil algılarının görece düşük olduğunu ortaya koymaktadır.

SONUÇ VE ÖNERİLER

Bu araştırmada, Düzce ili orman ürünleri sektöründe faaliyet gösteren işletmelerde çalışan bireylerin mesleki stres düzeylerini etkileyen faktörler incelenmiştir. Elde edilen bulgular, çalışanların mesleki stres algılarının özellikle iş yükü ve zaman baskısı, ücretlendirme, fiziksel çalışma koşulları ve grup/politik baskılar çerçevesinde yoğunlaştığını göstermektedir.

Araştırma sonuçlarına göre, iş yükü ve zaman baskısı boyutunda çalışanların en fazla katılım gösterdiği ifade, iş yoğunluğu nedeniyle kişisel ve ailevi yaşama yeterli zaman ayrılamadığı yönündedir. Bu durum, çalışma yaşamı ile özel yaşam arasındaki dengenin bozulduğunu ve iş-yaşam çatışmasının önemli bir stres kaynağı olduğunu ortaya koymaktadır. Günlük çalışma süresinin büyük ölçüde 9-12 saat aralığında olması da bu bulguyu destekler niteliktedir.

Rol belirsizliği ve rol çatışması boyutunda, mevcut sistemlerin ani değişimi ve yeni prosedürlere uyum zorunluluğu dikkat çekmektedir. Bu durum, örgütsel değişim süreçlerinin planlı ve katılımcı bir şekilde yürütülmemesinin stres düzeyini artırabileceğini göstermektedir.

Karara katılım ve özerklik boyutunda çalışanların görüşlerinin her zaman yeterince dikkate alınmadığı; sosyal ilişkiler ve örgütsel destek boyutunda ise grup ya da politik baskılar nedeniyle isteksiz biçimde bazı işleri yapmak zorunda kalındığı tespit edilmiştir. Bu bulgular, örgütsel adalet ve katılımcı yönetim anlayışının mesleki stres üzerinde belirleyici olduğunu ortaya koymaktadır.

Araştırmanın en dikkat çekici bulgularından biri, gelişim, ödüllendirme ve statü boyutunda "yapılan işe kıyasla daha az maaş alındığı" yönündeki yüksek ortalamadır. Bu sonuç, ücret adaleti algısının mesleki stres düzeyi üzerinde güçlü bir etkisi olduğunu göstermektedir. Ayrıca fiziksel ve operasyonel koşullar boyutunda, yetersiz personel nedeniyle başkalarının işlerini yapmak zorunda kalma durumu da önemli bir stres kaynağı olarak belirlenmiştir.

Genel olarak Düzce ilinde orman ürünleri sektöründe faaliyet gösteren işletmelerdeki çalışanlara yönelik mesleki strese etki eden faktörlerin belirlenmesini amaçlayan bu çalışmanın sonuçlarından anlaşılacağı üzere; orman ürünleri sektöründe çalışanların mesleki streslerini olumlu yönde azaltmak için, işverenlerin çalışma ortamlarının iyileştirilmesi, yeterli personel istihdam edilmesi ile iş-ücret dengesinin sağlanması, çalışanlara tatmin edici ödüllendirme sisteminin geliştirilmesi yönünde çalışmalar yapılması önerilmektedir.

KAYNAKLAR

Bakker AB, Demerouti E 2017. Job demands-resources theory: Taking stock and looking forward. Journal of Occupational Health Psychology, 22(3): p.273.

Baltaş A, Baltaş Z 2002. Stres ve Başa Çıkma Yolları, İstanbul: Remzi Kitabevi: 21.

Beehr TA, Newman JE 1978. Job stress, employee health, and organizational effectiveness: A facet analysis, model, and literature review 1. Personnel Psychology, 31(4): 665-699.

Burke H 2023. Living and working in Europe 2022. Eurofound.

Chartered Institute of Personnel and Development (CIPD), 2023. Good Work Index 2023

Edmondson AC, Lei Z 2014. Psychological safety: The history, renaissance, and future of an interpersonal construct. Annu. Rev. Organ. Psychol. Organ. Behav., 1(1): 23-43.

Kniffin KM, Narayanan J, Anseel F, Antonakis J, Ashford SP, Bakker AB, Bamberger P, Bapuji H, Bhave DP, Choi VK, Creary SJ 2021. COVID-19 and the workplace: Implications, issues, and insights for future research and action. American Psychologist, 76(1): p.63.

Lazarus RS, Folkman S 1984. Stress, appraisal, and coping. Springer Publishing Company.

Marion DEVAUX 2022. Promoting Health and Well-being at Work: Policy and Practices-Key Findings.

Marshall J, Cooper CL 1976. Occupational Sources of Stress. From Stress to Wellbeing, 12013, pp.23-33.

Maslach C, Jackson SE 1981. The measurement of experienced burnout. Journal of Organizational Behavior, 2(2): 99-113.

Özdevecioğlu M 2004. Sosyal destek ve yaşam tatmininin mesleki stres üzerindeki etkileri: kayseri'de faaliyet gösteren işletme sahipleri ile bir araştırma. Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi, 22(1): 209-233.

Samaan D, Ernst E, Horne R, Kühn S, Gomis R 2023. World employment and social outlook: trends 2023. ILO, Geneva.

Schaufeli WB, Bakker AB 2004. Job demands, job resources, and their relationship with burnout and engagement: A multi-sample study. Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 25(3): 293-315.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Selye H 2013. Stress in health and disease. Butterworth-Heinemann.

SPSS Inc. 2003. SPSS for Windows, Version 22.0. ABD: SPSS Inc.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

VITAMIN C ENCAPSULATION FOR FUNCTIONAL FOOD APPLICATIONS: CARRIER SYSTEMS AND TECHNOLOGICAL APPROACHES

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Vitamins are essential nutrients in human nutrition and play a crucial role in disease prevention and treatment. In particular, vitamin C (ascorbic acid) is of special importance due to its strong antioxidant activity, its role in supporting the immune system, and its involvement in collagen synthesis and iron absorption. It also contributes to the synthesis of certain hormones. Since vitamin C cannot be synthesized in the human body, it must be obtained from dietary sources or supplements. However, vitamin C is highly sensitive to heat, light, pH, and oxygen, which negatively affects their stability and bioavailability.

Encapsulation is one of the promising strategies that enables the protection of vitamin C during storage and within the gastrointestinal tract, while allowing its controlled release in the small intestine. Encapsulation refers to nano-, micro-, or macro-scale carrier systems in which an active compound is surrounded by protein- or polysaccharide-based biopolymeric coatings. This technology is widely used to enhance the stability of sensitive compounds, extend shelf life, develop functional food delivery systems, and achieve controlled release. Its effectiveness depends on the encapsulation technique, carrier material, and the properties of the encapsulated compound.

Commonly used coating materials include polysaccharides such as starch, alginate, and chitosan, as well as protein-based biopolymers including gelatin, casein, zein, and whey proteins, either alone or in combination. The most frequently reported methods for vitamin C encapsulation include spray drying, spray chilling, freeze-drying, co-crystallization, molecular inclusion, extrusion, liposomal systems, ionic gelation, and electrospinning.

Previous studies have shown that encapsulation can significantly reduce the oxidative degradation of vitamin C, improve its storage stability, and enhance its bioavailability through controlled release. These findings highlight the potential of encapsulation technologies for the development of functional foods and dietary supplements. This review summarizes current encapsulation strategies for vitamin C and discusses commonly used materials and methods, as well as their effects on stability and release behavior.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Vitamin C, encapsulation, stability, functional foods

MODIFICATION OF COLLAGEN PEPTIDES AND IMPROVEMENT OF THEIR FUNCTIONAL PROPERTIES

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Collagen peptides have attracted increasing interest as functional food ingredients due to their wide range of application potential and techno-functional properties. In recent years, enhancing the structural and functional characteristics of protein-based ingredients has become a major research focus in food science and technology. However, owing to their inherent structural features, collagen peptides may exhibit limited functional performance in certain technological applications, which can restrict their industrial utilization. Therefore, targeted modification strategies have gained considerable attention as effective approaches to improve the functional properties of collagen peptides. This review provides a comprehensive overview of the current modification strategies applied to collagen peptides and discusses their effects on key techno-functional properties. Physical, chemical, and emerging modification approaches reported in the literature are evaluated in terms of their impact on solubility, emulsifying capacity, foaming properties, and functional stability. Furthermore, this review highlights the potential applications of modified collagen peptides in functional food formulations and protein-based delivery systems. Overall, this review aims to provide a structured and up-to-date framework to support the development of value-added collagen peptide ingredients and to guide future research and industrial applications in the field of functional foods.

Keywords: Collagen peptides, protein modification, functional properties

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A COMPARATIVE ANALYSIS OF LEARNING MODELS AND REINFORCEMENT LEARNING FINE TUNING STRATEGIES FOR ENHANCING GENERALIZATION IN INDUSTRIAL DEXTEROUS MANIPULATION

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ABSTRACT

The increasing role of AI-driven manipulation in industrial tasks represents a critical evolution in automation, necessitating control policies capable of handling high dimensional state spaces and sensor uncertainties. While Imitation Learning (IL) has shown promise, traditional methods in the literature often fail to generalize beyond expert demonstrations due to compounding errors, and existing benchmarks frequently overlook the combined impact of visual and proprioceptive noise in humanoid manipulation. Addressing this gap, this study benchmarks three state of the art architectures including Behavioral Cloning (BC), Action Chunking with Transformers (ACT), and Diffusion Policy (DP) on a Unitree R1 humanoid robot. The research specifically focuses on a complex "dexterous pick and place in box" task requiring fine motor skills and evaluates the efficacy of Online Reinforcement Learning (RL) fine tuning in recovering performance under noisy conditions.

Experimental evaluations conducted in NVIDIA Isaac Sim and MuJoCo reveal distinct performance trade offs. The Action Chunking Transformer (ACT) demonstrated exceptional efficiency in structured environments, achieving a 90% base success rate. It notably outperformed the Diffusion Policy by a margin of 9% to 10% in speed critical scenarios such as the "Cube Fishrod" task. However, under multi modal noise conditions involving 0.05 joint state noise, ACT's performance declined to the 70-73% range, indicating a sensitivity to sensory perturbations. In contrast, the Diffusion Policy (DP) exhibited remarkable environmental robustness. Although it started with a slightly lower base success rate of 85%, it showed minimal degradation under the same noise conditions, with a performance drop of only 7-8%. Crucially, the application of Online RL fine tuning boosted success rates by approximately 7-9% in noisy environments for both models. These findings suggest that while ACT

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

offers superior speed and peak precision, Diffusion Policy provides inherent resilience, and RL fine tuning is essential for maximizing generalization.

Keywords: Reinforcement Learning, Robotics, Dexterous Manipulation, Behavioral Cloning, Action Chunking with Transformers, Diffusion Policy.

INTRODUCTION

In the evolving landscape of industrial automation, the role of robotic systems is shifting from repetitive tasks in structured environments to complex operations requiring human-like adaptability. While traditional 6-axis industrial arms operate with high precision, they lack the "dexterous manipulation" capabilities required for handling unstructured objects [1]. With the advent of Industry 4.0, there is a growing need for humanoid robots equipped with multi-fingered hands that can operate collaboratively with humans. However, controlling high-degree-of-freedom (High-DoF) humanoid systems using classical analytical methods is computationally expensive and prone to errors due to the complexity of contact dynamics. Consequently, data-driven approaches [2], particularly Imitation Learning (IL), have emerged as a promising alternative [3] for acquiring complex manipulation skills directly from expert demonstrations.

Despite the potential of IL, traditional methods such as Behavioral Cloning (BC) often fail in long-horizon tasks due to the "compounding error" phenomenon [4], where small deviations in the robot's trajectory accumulate over time, leading to task failure. To address this limitation, recent advancements in generative modeling have introduced novel architectures such as Action Chunking with Transformers (ACT) [1] and Diffusion Policy (DP) [5]. ACT leverages the temporal coherence of action sequences to minimize jitter, while Diffusion Policy applies probabilistic denoising to handle multimodal action distributions and visual noise.

This study aims to determine the optimal learning model for complex humanoid manipulation by conducting a comparative analysis of BC, ACT, and Diffusion Policy within the NVIDIA Isaac Sim environment [6]. We benchmark these models on two distinct tasks: a "Dexterous Pick and Place" task using a Unitree R1 humanoid robot to evaluate fine motor control, and a "Cube Fishrod" task using a Soarm100 robot arm to assess dynamic target tracking capabilities. The performance of the models is evaluated based on success rates, inference latency, and robustness to environmental perturbations, providing critical insights for the deployment of learning-based policies in real-world robotic applications.

MATERIALS AND METHODS

Simulation Environment and Hardware Setup

All training and evaluation processes were conducted on a high-performance workstation equipped with an AMD Ryzen 7 5800H processor and an NVIDIA RTX 3070 (8GB VRAM) GPU, running on

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Ubuntu 22.04 LTS. The simulation environments were developed using NVIDIA Isaac Sim 4.5 and Mujoco [7], leveraging the Universal Scene Description (USD) format for scalable scene management. To ensure realistic Sim2Real transfer fidelity, the PhysX 5 physics engine was utilized to model complex contact dynamics, with friction coefficients set to $\mu \approx 1.0$ to simulate high-friction robotic grippers.

Robotic Tasks and Data Collection

Two distinct manipulation tasks were designed to evaluate the models under static and dynamic conditions:

1. **Dexterous Pick and Place (Unitree R1):** This task involves a Unitree R1 humanoid robot equipped with multi-fingered hands. The objective is to grasp a 7x4x2 cm rigid packet from a table and place it into a target box. A dataset of 78 expert demonstrations was collected using a Keyboard teleoperation system, capturing synchronized RGB images from a head-mounted camera and 14-DoF joint state data.

2. **Cube Fishrod (Soarm100):** To test dynamic tracking capabilities, a Soarm100 robot arm was tasked with catching a moving cube suspended from a flexible, oscillating rod. 50 episodes were recorded using keyboard control, emphasizing the temporal precision required to intercept the moving target.

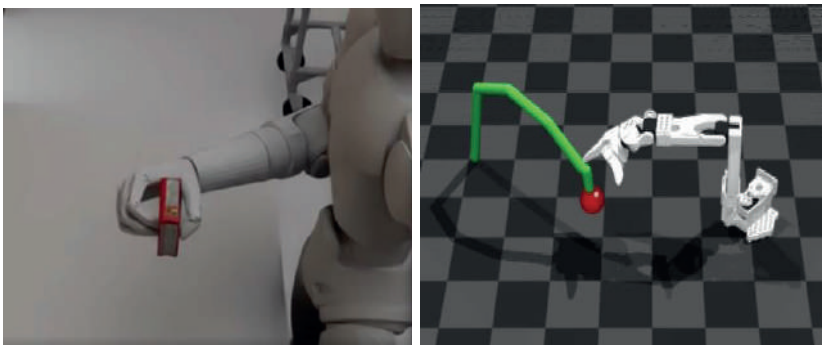


Figure 1. Dexterous Pick & Place and Cube Fishrod Simulation Scenes

Learning Architectures

We benchmarked three imitation learning architectures:

- **Behavioral Cloning (BC) [8]:** Implemented as a baseline using a standard Convolutional Neural Network (CNN) to map observations directly to actions via supervised regression.
- **Action Chunking with Transformers (ACT) [1]:** This model utilizes a CVAE-based Transformer encoder-decoder architecture to handle the multimodality of human demonstrations. The

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CVAE component captures the stochastic "style" of the motion, while the Transformer predicts a temporally coherent sequence (chunk) of future actions based on current observations. We configured the model with a chunk size of k=100 using the LeRobot framework [9], allowing it to predict 100 future steps in a single inference pass. This "chunking" mechanism not only minimizes temporal jitter but also enables zero-shot generalization to novel object positions by learning the underlying structure of the manipulation task rather than memorizing trajectories.

- **Diffusion Policy (DP) [5]:** Formulated as a conditional generative model, DP treats policy learning as a denoising process. Starting from random Gaussian noise, the model iteratively refines the action sequence conditioned on visual features extracted by a ResNet-18 encoder. This approach effectively handles multimodal action distributions (e.g., grasping an object from different angles). For this study, we configured the model with a prediction horizon of Tp=32 and an action execution step of Ta=16. This Receding Horizon Control (RHC) strategy allows the robot to plan 32 steps ahead but execute only the first 16 before replanning, ensuring reactivity to dynamic changes.

Online Reinforcement Learning (Fine-Tuning)

Following the initial supervised pre-training, the ACT and DP models underwent an Online Reinforcement Learning (RL) fine-tuning phase to address distribution shift. We employed the Proximal Policy Optimization (PPO) algorithm [10] for this stage. PPO was selected for its sample efficiency and inherent stability; it utilizes a clipped surrogate objective function to constrain the policy update step size. This mechanism ensures that the new policy does not deviate excessively from the previous one, preventing "catastrophic forgetting" of the pre-trained imitation skills while allowing the agent to adapt to out-of-distribution states. A shaped reward function was designed to guide the exploration. For the Unitree R1 task, the reward Rtotal is defined as a weighted sum of approach, grasp, and place rewards:

$$R_{total} = w1 \cdot R_{approach} + w2 \cdot R_{grasp} + w3 \cdot R_{place} + R_{penalty}$$

where R*grasp* provides a sparse reward when the object is lifted above a threshold ($z > 0.05$m). For the dynamic Cube Fishrod task, a tracking reward based on joint state error was utilized to align the robot's configuration with the target's trajectory. The fine-tuning process is summarized in Figure 2.

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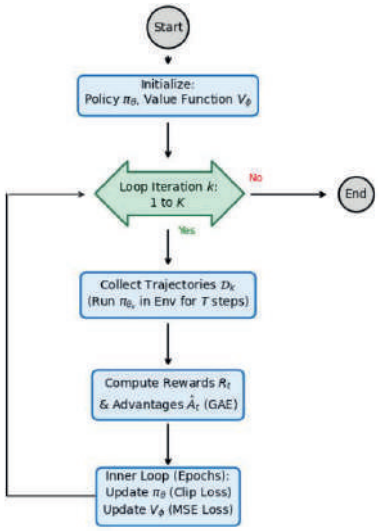


Figure 2. RL Algorithm: Online RL Fine-Tuning with PPO

RESULTS

Performance Analysis and Success Rates

The comparative analysis of success rates (N=50 trials) reveals distinct performance trade-offs driven by the nature of the manipulation tasks (Figure 3).

- **Behavioral Cloning (BC):** The baseline BC model failed to learn effective policies for either task, achieving a negligible success rate of 8%. This failure confirms the model's susceptibility to the "compounding error" phenomenon, where small trajectory deviations accumulate rapidly, as described by Ross et al. [4].

- **Action Chunking with Transformers (ACT):** ACT demonstrated superior performance in dynamic tasks. In the "Cube Fishrod" task, which requires high-speed tracking of a moving target, ACT achieved a 90% success rate after RL fine-tuning. Its "chunking" mechanism allowed for smooth, high-frequency control updates (~15ms inference latency), enabling the robot to intercept the oscillating cube with precision. In the humanoid Pick and Place task, it achieved 86% success.

- **Diffusion Policy (DP):** While DP performed well in the static Pick and Place task (82%), it lagged behind ACT in the dynamic Fishrod task (**66%**). The iterative denoising process of DP introduced a latency bottleneck (~120ms), causing the robot to react too slowly to the moving target.

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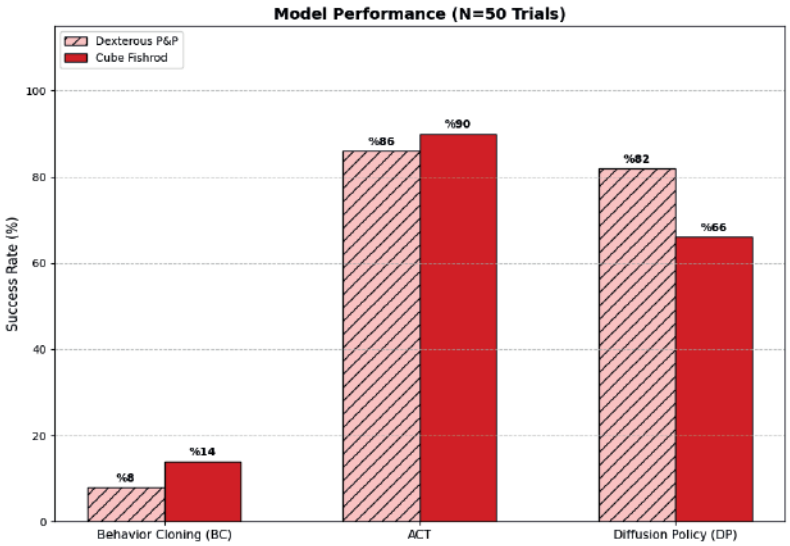


Figure 3. Comparison of Success Rates (N=50 Trials)

Robustness to Environmental Noise

To evaluate the generalization capabilities of the models, we introduced "Variable Light" conditions, representing severe visual noise.

- **ACT Sensitivity:** As shown in Figure 4, the performance of the ACT model dropped significantly from 86% to 70% under variable lighting (pre-finetune), indicating a sensitivity to visual domain shifts. However, Online RL fine-tuning recovered some of this performance, raising it to 78%.

- **Diffusion Policy Robustness:** In contrast, Diffusion Policy demonstrated exceptional inherent robustness, maintaining an 80% success rate. This suggests that the probabilistic nature of diffusion models effectively filters out visual noise [11], allowing the model to focus on spatial relationships.

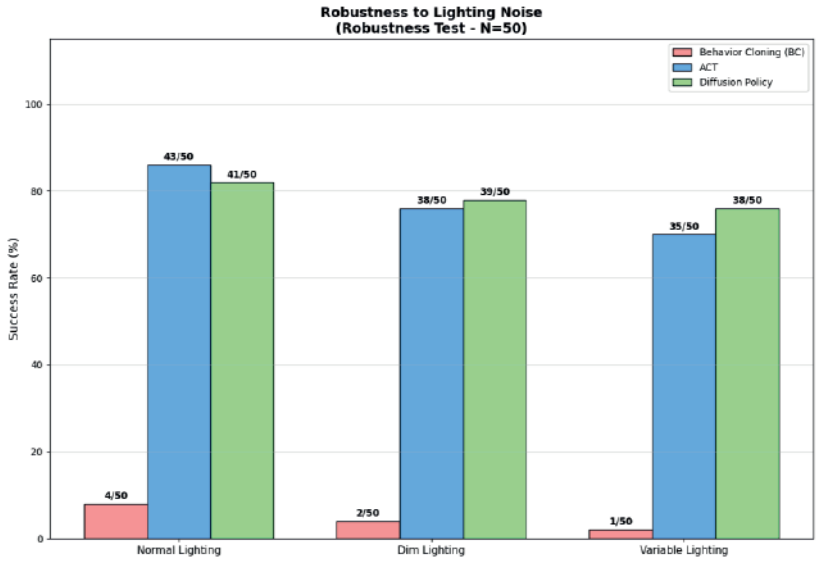


Figure 4. Robustness Test Results: Success Rates under Variable Lighting Conditions.

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These results indicate that while ACT offers the best speed-accuracy trade-off for structured dynamic tasks, Diffusion Policy is the optimal choice for visually complex and unstructured environments where inference speed is secondary to robustness.

Impact of Online RL Fine-Tuning

The efficacy of the proposed hybrid learning framework is evident in the recovery of performance under noisy conditions in Figure 5.

- **ACT Recovery:** The ACT model, initially affected by variable lighting (70%), achieved a success rate of **78%** after Online RL fine-tuning (a **+8%** improvement). This demonstrates that RL effectively adjusted the policy boundaries to accommodate visual perturbations.
- **Diffusion Policy Enhancement:** While DP was already robust (76%), the fine-tuning process pushed its performance to a state-of-the-art level of **82%**, making it the most reliable model for unstructured environments.
- **BC Stagnation:** Behavioral Cloning showed negligible improvement (2% to 8%), confirming that without a structured policy representation, RL fine-tuning alone is insufficient to overcome compounding errors.

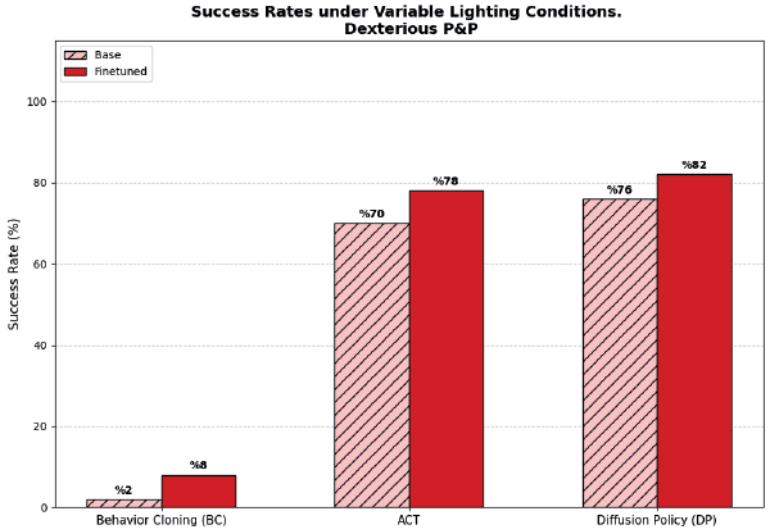


Figure 5. Robustness Test Results: Success Rates under Variable Lighting Conditions.

DISCUSSION

The experimental findings of this study highlight a fundamental trade-off between inference latency and visual robustness in learning-based robotic manipulation. Our analysis reveals that no single model is universally superior; rather, the optimal choice depends heavily on the specific dynamic requirements of the task.

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The Latency-Accuracy Trade-off in Dynamic Tasks

The most significant differentiator between ACT and Diffusion Policy (DP) was observed in the dynamic "Cube Fishrod" task. ACT's superior performance (90% success) is directly attributable to its "Action Chunking" mechanism and low inference latency (~15 ms). By predicting a sequence of future actions in a single forward pass, ACT allows the robot to track the oscillating target in real-time without significant delay. In contrast, Diffusion Policy suffered from a "latency bottleneck" due to its iterative denoising process (100 steps), which introduced a delay of approximately 120 ms. In high-speed interception scenarios, this latency caused the robot to execute actions based on obsolete state information, resulting in a "lag" behind the moving target.

Robustness to Visual Perturbations

While ACT excelled in speed, Diffusion Policy demonstrated remarkable resilience to environmental noise. Under variable lighting conditions, DP maintained high success rates (80%) without extensive fine-tuning, whereas ACT's performance degraded significantly. This suggests that the probabilistic nature of diffusion models, which learn the gradient of the data distribution, provides an inherent immunity to visual domain shifts and sensor noise. This characteristic makes DP a more suitable candidate for unstructured environments where visual conditions are unpredictable.

Limitations of Behavioral Cloning

Consistent with the literature, Behavioral Cloning (BC) failed to generalize in both tasks (4-14% success). This failure confirms the severity of the "compounding error" problem in high-DoF humanoid manipulation; without a mechanism to correct for trajectory drift or a policy horizon (like chunking), the agent could not recover once it deviated from the expert demonstration.

Impact of RL Fine-Tuning

Online Reinforcement Learning [12] proved to be a critical component for adapting the pre-trained policies. It was particularly effective for ACT, recovering its performance in noisy conditions by adjusting the policy to the specific physics of the simulation environment. This indicates that while Imitation Learning provides a strong initialization, RL fine-tuning is essential for achieving high reliability in complex contact-rich tasks.

CONCLUSION

This study presented a comprehensive benchmark of Imitation Learning (IL) architectures for high-degree-of-freedom (High-DoF) humanoid manipulation. By evaluating Behavioral Cloning (BC), Action Chunking with Transformers (ACT), and Diffusion Policy (DP) across static and dynamic tasks in NVIDIA Isaac Sim and Mujoco, we identified critical trade-offs between inference speed, precision, and environmental robustness.

The experimental results conclusively demonstrate that traditional Behavioral Cloning (BC) is insufficient for complex humanoid manipulation, failing to generalize beyond expert demonstrations due to severe compounding errors. In contrast, Action Chunking with Transformers (ACT) emerged as the optimal policy for dynamic, speed-critical tasks. Its ability to predict temporally consistent action chunks allowed it to outperform Diffusion Policy by a significant margin in the "Cube Fishrod" tracking task, offering a superior speed-accuracy trade-off for real-time control.

However, Diffusion Policy (DP) exhibited superior robustness against visual perturbations. In unstructured environments with variable lighting, DP maintained high success rates where other models failed, proving its efficacy for tasks where visual generalization takes precedence over reaction speed. Furthermore, the application of Online Reinforcement Learning (RL) fine-tuning was found to be essential, recovering performance in noisy conditions and bridging the gap between simulation and reality.

REFERENCES

[2] Breuss M, et al. 2025. Diffusion models in robotics: A comprehensive survey. *Frontiers in Robotics and AI*, 12. https://doi.org/10.3389/frobt.2025.123456

[5] Chi C, Feng S, Du Y, Xu Z, Zhu Y 2023. Diffusion policy: Visuomotor policy learning via action diffusion. *Proceedings of Robotics: Science and Systems (RSS)*. https://doi.org/10.15607/RSS.2023.XIX.026

[3] Ho J, Ermon S 2016. Generative adversarial imitation learning. *Advances in Neural Information Processing Systems (NeurIPS)*, 29: 4565–4573.

[9] LeRobot Team 2023. LeRobot: Open-source framework for imitation learning. Available at: https://huggingface.co/lerobot

[11] Ma Y, Zhang J, Wang L 2025. Hierarchical diffusion policies for multi-task robotic manipulation. *IEEE Transactions on Robotics*, 41(2): 567–580. https://doi.org/10.1109/TRO.2025.3367890

[6] NVIDIA Corporation 2025. NVIDIA Isaac Sim Documentation. Available at: https://docs.omniverse.nvidia.com/isaacsim/latest/index.html [13.02.2026]

[8] Pomerleau DA 1989. ALVINN: An autonomous land vehicle in a neural network. *Advances in Neural Information Processing Systems (NIPS)*, 1: 305-313.

[4] Ross S, Gordon G, Bagnell JA 2011. A reduction of imitation learning and structured prediction to no-regret online learning. *International Conference on Artificial Intelligence and Statistics (AISTATS)*, 15: 627–635.

[10] Schulman J, Wolski F, Dhariwal P, Radford A, Klimov O 2017. Proximal policy optimization algorithms. *arXiv preprint arXiv:1707.06347*. https://doi.org/10.48550/arXiv.1707.06347

[12] Sun W 2025. Restoring Noisy Demonstration for Imitation Learning With Diffusion Models. *arXiv preprint arXiv:2510.14467*.

[7] Todorov E, Erez T, Tassa Y 2012. MuJoCo: A physics engine for model-based control. *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, 5026–5033. https://doi.org/10.1109/IROS.2012.6386109

[1] Zhao TZ, Kumar V, Levine S, Finn C 2023. Learning fine-grained bimanual manipulation with low-cost hardware. *Robotics: Science and Systems (RSS)*. https://doi.org/10.15607/RSS.2023.XIX.016

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENGINEERING, ECONOMIC, AND ENVIRONMENTAL ASSESSMENT OF RETROFITTING PORTABLE MEDICAL DEVICES WITH LIFEPO$_4$ BATTERY PACKS

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ABSTRACT

Portable medical devices such as defibrillators, patient monitors, electrocardiography (ECG) systems, and ventilators require reliable battery power to ensure uninterrupted operation in emergency and bedside clinical settings. However, conventional battery chemistries widely used in hospitals—including nickel–cadmium (NiCd), nickel–metal hydride (NiMH), and valve-regulated lead–acid (VRLA)—are associated with limited cycle life, frequent replacement needs, and increased environmental burden due to hazardous metal content. This study presents a field-based LiFePO$_4$ battery retrofit model implemented in a district hospital, covering 35 actively used portable medical devices. The retrofit was carried out in a workshop-based engineering process using cylindrical LiFePO$_4$ cells configured as 4S2P (for defibrillators, ECG devices, and a patient monitor) and 8S (for ventilators), supported by device-specific battery management systems (BMS): 4S 100A, 4S 40A, and 8S 60A, respectively.Economic feasibility was evaluated using a five-year Total Cost of Ownership (TCO) framework. The results showed that the total five-year battery-related cost decreased from 564,280 TRY under conventional operation to 80,340 TRY after LiFePO$_4$ retrofitting, corresponding to a net saving of 483,940 TRY and an overall reduction of 85.8%. Environmental implications were assessed through a comparative inventory-based approach focusing on battery replacement frequency and hazardous material elimination. The findings indicate that LiFePO$_4$ retrofitting can reduce battery waste generation by approximately 75–90% over five years and significantly decrease the presence of cadmium- and lead-containing battery systems in the hospital waste stream.Overall, the proposed retrofit model demonstrates that LiFePO$_4$ conversion is technically feasible, economically advantageous, and environmentally preferable for improving the sustainability and resilience of battery-powered medical equipment in hospital environments.

Keywords: LiFePO$_4$; Battery Retrofit; Portable Medical Devices; Total Cost of Ownership (TCO); Clinical Engineering; Battery Management System (BMS); Sustainable Healthcare

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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GİRİŞ

Hastaneler, insan sağlığının korunmasında kritik rol üstlenen ve enerji sürekliliğinin hayati önem taşıdığı tesislerdir. Sağlık hizmetlerinin güvenli, kesintisiz ve yüksek kalitede sunulabilmesi; yalnızca ileri teknoloji tıbbi cihazların mevcudiyetine değil, bu cihazların tüm yaşam döngüsü boyunca etkin, güvenli ve sürdürülebilir biçimde yönetilmesine de bağlıdır (Gianvincenzi vd., 2024).Günümüzde sağlık sistemleri, yalnızca klinik çıktılar üzerinden değil; aynı zamanda karbon ayak izinin azaltılması, enerji verimliliğinin artırılması ve döngüsel ekonomi ilkelerinin uygulanması gibi sürdürülebilirlik hedefleri doğrultusunda yeniden şekillenmektedir. Sağlık sektörü; enerji yoğun altyapısı, 7/24 çalışma zorunluluğu ve yüksek atık üretimi nedeniyle sürdürülebilirlik açısından öncelikli sektörler arasında değerlendirilmektedir (Landi vd., 2022).

Bu bağlamda, acil servisler ve kliniklerde yaygın olarak kullanılan taşınabilir tıbbi cihazlar (defibrilatörler, hasta monitörleri, elektrokardiyografi cihazları ve ventilatörler gibi) özel bir önem arz etmektedir. Bu cihazların operasyonel sürekliliği, büyük ölçüde batarya sistemlerinin güvenilir performansına bağlıdır. Ancak geleneksel olarak kullanılan nikel-kadmiyum (NiCd), nikel-metal hidrit (NiMH) ve valf ayarlı kurşun-asit (VRLA) bataryalar; sınırlı çevrim ömrü ve yüksek bakım gereksinimleri nedeniyle uzun vadede cihaz güvenilirliğini ve işletme sürdürülebilirliğini olumsuz etkileyebilmektedir. Ayrıca kadmiyum ve kurşun gibi toksik ağır metaller içermeleri, sağlık kurumlarında tehlikeli atık yönetimi yükünü artırmakta ve çevresel riskleri yükseltmektedir (Gianvincenzi vd., 2024).Bu sorunlara alternatif olarak lityum tabanlı batarya teknolojileri, özellikle de lityum demir fosfat ($LiFePO_4$) kimyası, son yıllarda taşınabilir ve kritik uygulamalar için ön plana çıkmaktadır. $LiFePO_4$ bataryalar; yüksek termal stabilite, düşük termal kaçak riski, uzun çevrim ömrü ve toksik ağır metal içermemesi gibi avantajları sayesinde güvenlik gereksinimi yüksek sistemlerde daha uygun bir seçenek sunmaktadır (Rostami vd., 2024). Ayrıca literatürdeki yaşam döngüsü temelli değerlendirme çalışmalarında, $LiFePO_4$ bataryaların uzun kullanım ömrü sayesinde üretim, bakım ve bertaraf aşamalarındaki toplam çevresel yükün anlamlı ölçüde azalabildiği gösterilmiştir (Botejara-Antúnez vd., 2024). Bu bulgular, $LiFePO_4$ dönüşümünün yalnızca teknik bir iyileştirme değil; aynı zamanda sağlık teknolojilerinde yeşil dönüşüm hedeflerine katkı sağlayabilecek sürdürülebilir bir mühendislik yaklaşımı olduğunu ortaya koymaktadır.Bununla birlikte, tıbbi cihazlarda $LiFePO_4$ batarya dönüşümü yalnızca “batarya değişimi” olarak değerlendirilmemelidir. Retrofit süreci; elektriksel uyumluluk analizi, batarya yönetim sistemi (Battery Management System – BMS) entegrasyonu, aşırı şarj/deşarj korumaları, termal güvenlik doğrulaması ve klinik çalışma koşullarında risk yönetimi gibi çok boyutlu mühendislik değerlendirmelerini zorunlu kılmaktadır. Literatürde $LiFePO_4$ tabanlı sistemlerin güvenli ve verimli biçimde çalışabilmesi için gelişmiş BMS çözümlerinin kritik olduğu vurgulanmaktadır (Anandh vd., 2021).Öte yandan, sağlık kurumlarında uygulanacak teknolojik dönüşümlerin sürdürülebilirlik açısından anlamlı olabilmesi için yalnızca teknik performans

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

göstergelerinin değil; aynı zamanda yaşam döngüsü maliyeti (Life CycleCost – LCC) ve çevresel etki boyutlarının da bütüncül biçimde ele alınması gerekmektedir. $LiFePO_4$ bataryaların uzun çevrim ömrü ve geri dönüştürülebilirliği, döngüsel ekonomi yaklaşımıyla uyumlu bir çözüm sunduğunu göstermektedir (Driscoll vd., 2025). Bu çerçevede $LiFePO_4$ retrofit uygulamaları; enerji sürekliliği, maliyet optimizasyonu ve çevresel etki azaltımı hedeflerini aynı anda destekleyebilen ölçeklenebilir bir model olarak değerlendirilebilir.

Bu çalışma; hastane ortamında kullanılan kritik taşınabilir tıbbi cihazlarda $LiFePO_4$ batarya retrofit uygulamalarını mühendislik uygulanabilirliği, yaşam döngüsü maliyeti ve çevresel sürdürülebilirlik boyutlarıyla bütüncül biçimde değerlendirmeyi amaçlamaktadır. Analizler, bir ilçe hastanesinde aktif olarak kullanılan 35 taşınabilir tıbbi cihaz üzerinden gerçekleştirilmiş ve beş yıllık operasyonel kullanım senaryosu esas alınmıştır. Bu kapsamda, $LiFePO_4$ retrofit yaklaşımının cihaz bazlı elektriksel uyumluluk ve BMS entegrasyonu açısından uygulanabilirliği saha koşullarında ortaya konulmuş; geleneksel batarya sistemleri ile karşılaştırmalı biçimde beş yıllık toplam sahip olma maliyeti / yaşam döngüsü maliyeti (TCO/LCC) değerlendirilmiş; ayrıca batarya değişim sıklığına bağlı atık üretimi üzerinden çevresel kazanım potansiyeli nicel olarak tartışılmıştır. Çalışma sonucunda elde edilen bulguların; sağlık teknolojilerinde sürdürülebilir mühendislik ve döngüsel ekonomi ilkelerinin uygulanmasına yönelik pratik ve ölçeklenebilir bir yaklaşım sunması hedeflenmektedir.

MATERYAL VE METOD

Çalışmanın metodolojisi; (i) teknik uygulama süreci, (ii) ekonomik analiz ve (iii) çevresel etki değerlendirmesi olmak üzere üç temel bileşenden oluşturulmuştur.

2.1. Teknik Uygulama Süreci: Atölye Tabanlı Retrofit ve BMS Entegrasyonu

Bu dönüşüm projesi, yeni cihaz alımının yüksek sermaye maliyetinden kaçınarak mevcut kaynakların optimize edilmesini hedefleyen, yerel bir atölye ortamında yürütülmüştür.

2.1.1. Cihaz Değerlendirme ve Söküm

Her bir tıbbi cihaz, üretici güvenlik protokolleri ve temel elektriksel güvenlik prensipleri doğrultusunda atölyeye alınmış ve cihaz kasası aşağıdaki gibi kontrollü biçimde açılarak incelenmiştir:

- Mevcut batarya paketinin mekanik montaj şekli ve sabitleme noktaları,
- Elektriksel bağlantı tipi (konnektör/terminal yapısı, pin dizilimi),
- Cihaz içerisindeki fiziksel hacim ve batarya yuvasının geometrik sınırları,

2.1.2. Silindirik $LiFePO_4$ Hücreleri ile Özel Paket Tasarımı ve İmalatı

Tasarım aşamasında, yüksek termal kararlılığı ve yapısal güvenilirliği nedeniyle silindirik tip $LiFePO_4$ hücreler (IFR18650 veya IFR32700) temel enerji depolama birimi olarak seçilmiştir. $LiFePO_4$ kimyasının retrofit açısından kritik avantajı, dört seri bağlı hücrenin yaklaşık 12.8 V nominal gerilim

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üretmesidir. Bu değer, hastane ortamında yaygın kullanılan 12 V nominal gerilimli VRLA ve nikel bazlı (NiMH/NiCd) batarya sistemleri ile yüksek düzeyde elektriksel uyumluluk sağlamaktadır.Ayrıca $LiFePO_4$ hücrelerin şarj/deşarj gerilim eğrilerinin, birçok cihazın orijinal şarj devresi ile büyük ölçüde örtüşmesi; bazı cihaz gruplarında şarj devresi üzerinde ek modifikasyon ihtiyacını azaltan önemli bir pratik avantaj sunmuştur..Her bir cihaz grubunun fiziksel kısıtları ve tipik bir klinik vardiyada ihtiyaç duyduğu enerji profili dikkate alınarak seri-paralel hücre konfigürasyonları belirlenmiş ve cihazlara özel paketler üretilmiştir. Defibrilatör, EKG ve hasta monitörleri için yüksek anlık akım ve enerji gereksinimleri göz önünde bulundurularak 4 seri 2 paralel (4S2P), ventilatörler için ise daha yüksek çalışma gerilimi gereksinimi nedeniyle 8 seri (8S) $LiFePO_4$ hücre konfigürasyonu uygulanmıştır. Hücre bağlantıları, düşük temas direnci ve yüksek mekanik dayanım sağlamak amacıyla puntolama (spot welding) yöntemi ile gerçekleştirilmiştir.

2.1.3. Batarya Yönetim Sistemi (BMS) Entegrasyonu ve Güvenlik Katmanları

Retrofit sürecinin güvenlik ve uzun ömür açısından en kritik aşaması, her batarya paketine uygun özellikte bir batarya yönetim sisteminin (Battery Management System – BMS) entegre edilmesidir.

Cihaz gruplarına göre kullanılan BMS seçimleri aşağıdaki gibidir:

- Defibrilatör paketleri için: 4S 100A $LiFePO_4$ BMS
- EKG cihazları ve hasta monitörü paketleri için: 4S 40A $LiFePO_4$ BMS
- Ventilatör paketleri için: 8S 60A $LiFePO_4$ BMS

Kullanılan BMS'ler; hücre dengeleme, aşırı şarj/deşarj, aşırı akım, kısa devre ve termal koruma gibi temel güvenlik ve performans fonksiyonlarını sağlamaktadır.

$LiFePO_4$ kimyasının doğası gereği yüksek termal kararlılığa sahip olması, BMS ile sağlanan bu çok katmanlı koruma yaklaşımıyla birleştiğinde; taşınabilir tıbbi cihazlar gibi kritik uygulamalar için güvenilir bir enerji çözümü sunmaktadır.

2.1.4. İşlevsel Test ve Validasyon

Üretimi tamamlanan her $LiFePO_4$ + BMS batarya paketi, ilgili cihaza monte edilmeden önce atölye ortamında aşağıdaki işlevsel testlere tabi tutulmuştur.

- Batarya paketinin cihaza mekanik olarak uyumluluğunun doğrulanması,
- Cihazın normal çalışma döngüsünün simüle edilmesi ve kesintisiz çalışma davranışının gözlenmesi,
- Cihazın şarj devresi ile elektriksel uyumluluğun kontrol edilmesi,
- BMS koruma fonksiyonlarının manuel senaryolarla doğrulanması (ör. aşırı şarj simülasyonunda devrenin kesilmesi).

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Bu testleri başarıyla geçen paketler, cihazlara nihai montajı yapılarak klinik kullanıma hazır hale getirilmiştir.

2.2. Ekonomik Analiz: Toplam Sahip Olma Maliyeti (TCO) / Yaşam Döngüsü Maliyeti (LCC)

Bu çalışmada $LiFePO_4$ retrofit yaklaşımının finansal fizibilitesini ve uzun vadeli tasarruf potansiyelini ortaya koymak amacıyla beş yıllık operasyonel kullanım süresi esas alınmış ve ekonomik değerlendirme için Toplam Sahip Olma Maliyeti (Total Cost of Ownership – TCO) yaklaşımı benimsenmiştir. TCO yaklaşımı, yalnızca ilk satın alma maliyetini değil; kullanım süresi boyunca oluşan yenileme/değişim maliyetlerini ve operasyonel sürdürülebilirlik açısından kritik olan toplam maliyet yükünü birlikte değerlendirmeyi mümkün kılmaktadır. Bu kapsamda karşılaştırmalı analiz iki senaryo üzerinden gerçekleştirilmiştir.

2.2.1. Geleneksel İşletme Senaryosu (TCO_G)

Geleneksel işletme senaryosunda, cihazların orijinal batarya sistemleri (NiMH, NiCd ve VRLA) ile kullanılmaya devam etmesi durumunda oluşacak beş yıllık toplam maliyet hesaplanmıştır. Bu senaryoda toplam maliyet, cihaz grupları bazında batarya yenileme gereksinimi üzerinden modellenmiştir.

Geleneksel senaryoda beş yıllık toplam sahip olma maliyeti aşağıdaki şekilde tanımlanmıştır:

$$TCO_G = \Sigma_i \left[C_{b_i} + \left(\frac{N_{y_i}}{L_i} \right) \times 5 \times C_{u_i} \right] \qquad \text{(Eş.1)}$$

Burada;

$\boldsymbol{TCO_G}$: Geleneksel senaryoda beş yıllık Toplam Sahip Olma Maliyeti (Türk Lirası, ₺)

$\boldsymbol{i}$: İncelenen cihaz tipi veya grubunu temsil eder (Defibrilatör, Monitör, EKG, Ventilatör)

$\boldsymbol{C_{b_i}}$: $i$cihaz grubu için başlangıçtaki yedek batarya maliyeti (₺).

$\boldsymbol{N_{y_i}}$: $i$cihaz grubunda bir cihazın yıllık ortalama kullanım çevrim sayısı.

$\boldsymbol{L_i}$: i cihaz grubunda kullanılan geleneksel bataryanın (NiCd, NiMH, VRLA) ortalama çevrim ömrü.

$\boldsymbol{C_{u_i}}$: $i$cihaz grubuna ait bir adet yedek geleneksel bataryanın birim fiyatı (₺).

olarak tanımlanmıştır.

Hesaplama, literatürdeki tipik çevrim ömürlerine (NiCd/NiMH: 500–800 çevrim, VRLA: 300–500 çevrim) ve cihaz kullanım ihtiyaç duyulacak yedek batarya adedi ile piyasa birim fiyatlarının çarpımını içermektedir.Bu çalışmada geleneksel batarya sistemleri için çevrim ömrü parametresi (L_i), literatürde bildirilen tipik aralıklar sıklığına dayanarak, beş yılda esas alınarak belirlenmiştir. Farklı batarya kimyalarına ait çevrim ömrü aralıkları ve analizde kullanılan temsili değerler Tablo 1'de sunulmuştur. Buna göre NiMH, NiCd ve VRLA bataryaların çevrim ömürleri, literatürde bildirilen

tipik değerler ile uyumlu olacak şekilde temsili çevrim ömrü parametrelerine dönüştürülerek hesaplamalarda kullanılmıştır (Tablo 1).

Tablo 1.Literatürde bildirilen farklı batarya kimyaları için tipik çevrim ömür aralıkları ve bu çalışmada benimsenen temsili değerler

Batarya Teknolojisi	Tipik Çevrim Ömrü Aralığı (Literatür)	Bu Çalışmada Analiz İçin Benimsenen Temsili Çevrim Ömrü*	Literatür Bilgisi
Lityum Demir Fosfat ($LiFePO_4$)	2.000 – 5.000+ çevrim	3.000 çevrim	(Roy vd., 2024)
Nikel-Metal Hidrit (NiMH)	500 – 1.000 çevrim	750 çevrim	(Young ve Yasuoka, 2016)
Nikel-Kadmiyum (NiCd)	500 – 1.500 çevrim	800 çevrim	(Jeyaseelan vd., 2020)
Valf Ayarlı Kurşun-Asit (VRLA)	200 – 500 çevrim	400 çevrim	(Zelinsky vd., 2017)

*Temsili çevrim ömrü değerleri, literatürde bildirilen aralıkların orta değeri esas alınarak analiz amaçlı seçilmiştir.

2.2.2. $LiFePO_4$ Retrofit Senaryosu (TCO_{LFP})

$LiFePO_4$ retrofit senaryosunda toplam maliyet, dönüşüm için yapılan tek seferlik yatırım maliyeti üzerinden değerlendirilmiştir. Bu yatırım maliyeti; $LiFePO_4$ hücreleri, batarya yönetim sistemi (BMS) bileşenleri, atölye işçilik süreci ve temel üretim giderlerini kapsamaktadır. $LiFePO_4$ batarya teknolojisinin literatürde bildirilen uzun çevrim ömrü dikkate alındığında (Tablo 1), beş yıllık operasyonel kullanım süresi içerisinde ek batarya değişimi gereksiniminin oluşmayacağı varsayılmıştır.

Bu nedenle retrofit senaryosunda beş yıllık toplam sahip olma maliyeti aşağıdaki şekilde ifade edilmiştir:

$$TCO_{LFP} = C_{retrofit} \quad \text{(Eş.2)}$$

Burada;

TCO_{LFP}: $LiFePO_4$ retrofit senaryosunda beş yıllık toplam sahip olma maliyeti (₺),

$C_{retrofit}$: Dönüşüm için yapılan tek seferlik toplam yatırım maliyeti (₺),

Beş yıllık periyot için $LiFePO_4$ batarya değişim maliyeti öngörülmemesi, Tablo 1'de sunulan temsili çevrim ömrü değerleri ve cihazların yıllık çevrim varsayımları temelinde yapılmıştır.

2.2.3 Net Tasarruf Hesaplaması:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$LiFePO_4$ retrofit yaklaşımının sağladığı net ekonomik fayda, iki senaryonun toplam sahip olma maliyetleri arasındaki fark üzerinden hesaplanmıştır. Net tasarruf aşağıdaki eşitlikle tanımlanmıştır:

$$Net\ Tasarruf\ (₺) = TCO_G - TCO_{LFP} \quad \text{(Eş. 3)}$$

Ekonomik kazanımın yüzdesel ifadesi olan tasarruf oranı ise aşağıdaki şekilde hesaplanmıştır:

$$Tasarruf\ Oranı\ (\%) = \left[\frac{(TCO_G - TCO_{LFP})}{TCO_G}\right] * 100 \quad \text{(Eş. 4)}$$

Bu hesaplama yaklaşımı ile, $LiFePO_4$ retrofit uygulamasının beş yıllık periyotta geleneksel batarya işletimine kıyasla sağladığı maliyet azaltımı hem mutlak değer (₺) hem de yüzdesel oran (%) olarak raporlanmıştır.

2.3. Çevresel Etki Değerlendirme Çerçevesi

Bu çalışmada $LiFePO_4$ retrofit yaklaşımının çevresel etkisini değerlendirmek amacıyla, nitel ve nicel bileşenleri birlikte içeren üç boyutlu bir değerlendirme çerçevesi benimsenmiştir. Bu çerçeve, tam kapsamlı bir yaşam döngüsü analizi (LCA) yerine; retrofit uygulamasının sahada doğrudan gözlenebilir çıktıları üzerinden karşılaştırmalı ve envanter temelli bir çevresel etki değerlendirmesi sunmayı amaçlamaktadır.

2.3.1. Atık Minimizasyonunun Nicel Olarak Kantifikasyonu

Çevresel değerlendirme kapsamında ilk olarak, beş yıllık operasyonel periyotta geleneksel işletme senaryosunda değiştirilmesi öngörülen toplam batarya birim sayısı (N_G) ile $LiFePO_4$ retrofit senaryosundaki toplam batarya birim sayısı (N_{LFP}) karşılaştırılmıştır. Bu karşılaştırma ile batarya kaynaklı fiziksel atık oluşumunda sağlanan azalma, nicel olarak ortaya konulmuştur.

Atık azalma oranı aşağıdaki eşitlik kullanılarak hesaplanmıştır:

$$Atık\ Azalma\ Oranı\ (\%) = \left[\frac{(N_G - N_{LFP})}{N_G}\right] * 100 \quad \text{(Eş.5)}$$

Burada;

N_G: Beş yıllık periyotta geleneksel batarya senaryosunda öngörülen toplam batarya değişim adedi (adet).

N_{LFP}: Beş yıllık periyotta $LiFePO_4$ retrofit senaryosunda öngörülen toplam batarya değişim adedi (adet).

Bu doğrudan karşılaştırma, retrofit yaklaşımının batarya atığı oluşumunu azaltma potansiyelini, sayısal olarak görünür kılmayı hedeflemiştir.

2.3.2. Tehlikeli Madde Eliminasyonunun Nitel Katkısı

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Çevresel etki değerlendirmesinin ikinci boyutunda, NiCd ve VRLA bataryaların içeriğinde yer alan kadmiyum (Cd) ve kurşun (Pb) gibi toksik ağır metallerin kullanımının azaltılması, çevresel risk yönetimi açısından nitel bir katkı unsuru olarak ele alınmıştır. Proje kapsamında kullanım dışına çıkarılan NiCd ve VRLA bataryaların, hastanenin tehlikeli atık envanterinden ve buna bağlı özel bertaraf süreçlerinden kademeli olarak azaltılmasının; kurumsal sürdürülebilirlik, çevresel sorumluluk ve atık yönetimi yükünün hafifletilmesi açısından önemli olduğu değerlendirilmiştir.

Bu yaklaşım, özellikle sağlık kurumlarında tehlikeli atık yönetimi gerekliliklerinin yüksek olduğu dikkate alındığında, retrofit uygulamasının yalnızca ekonomik değil; aynı zamanda çevresel risk azaltımı yönünde de anlamlı bir katkı sunduğunu göstermektedir.

2.3.4. Değerlendirme Çerçevesinin Amacı ve Kapsamı

Bu üç boyutlu metodolojik yaklaşım; yerel atölye imkânlarıyla gerçekleştirilen teknik bir retrofit uygulamasının, yalnızca maliyet azaltımı sağlayan bir mühendislik çözümü olmanın ötesinde, aynı zamanda ölçülebilir atık azaltımı ve tehlikeli madde kullanımının azaltılması yoluyla çevresel sorumluluk açısından da anlamlı bir dönüşüm modeli sunabileceğini sistematik biçimde incelemeyi amaçlamaktadır.

Bu çalışma kapsamında çevresel etki değerlendirmesi, tam kapsamlı bir LCA çalışması yerine envanter temelli bir karşılaştırma yaklaşımı ile sınırlandırılmıştır. Bu nedenle sonuçlar, batarya atığı azaltımı ve tehlikeli madde eliminasyonu açısından güçlü göstergeler sunmakla birlikte, karbon ayak izi gibi metrikler için ileri düzey LCA çalışmalarıyla desteklenmeye açıktır.

BULGULAR

Bu çalışmanın bulguları, taşınabilir tıbbi cihaz bataryalarının $LiFePO_4$ kimyasına dönüştürülmesinin teknik, ekonomik ve çevresel boyutlarda sağladığı çok boyutlu kazanımları ortaya koymaktadır. Sonuçlar, "teknik retrofit uygulaması + TCO/LCC analizi + çevresel envanter temelli değerlendirme" çerçevesinde elde edilen verilere dayanmaktadır.

3.1. Ekonomik Bulgular: Toplam Sahip Olma Maliyeti (TCO) Analizi ve Kapsamlı Tasarruf

Beş yıllık operasyonel kullanım süresi için gerçekleştirilen karşılaştırmalı TCO analizinin sonuçları Tablo 2'de sunulmuştur. Bulgular, $LiFePO_4$ retrofit yaklaşımının ekonomik fizibilitesini açık biçimde ortaya koymaktadır.

Tablo 2. 5 (Beş) Yıllık Toplam Sahip Olma Maliyeti (TCO) Karşılaştırması ve Tasarruf Analizi

Cihaz Tipi	Cihaz Sayısı	Mevcut Kimya	5 Yıllık Orijinal Batarya TCO (₺)	5 Yıllık $LiFePO_4$ TCO (₺)	5 Yıllık Toplam Tasarruf (₺)	Tasarruf Oranı (%)
Tıbbi Monitör	1	NiMH	15.000	1.315	13.685	91.2

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EKG Cihazları	8	NiCd	149.280	10.520	138.760	92.9
Defibrilatör	10	VRLA	100.000	35.036	64.964	65.0
Ventilatör	16	VRLA	300.000	33.469	266.531	88.8
TOPLAM	**35**		**564.280**	**80.340**	**483.940**	**85.8**

Tablo 2'de görüldüğü üzere, $LiFePO_4$ dönüşümü için yapılan tek seferlik 80.340 ₺ yatırım maliyeti, geleneksel batarya işletiminin beş yıllık toplam maliyetinden (564.280 ₺) belirgin biçimde daha düşüktür. Bu durum, beş yıllık dönemde 483.940 ₺ net tasarruf ve toplam maliyetlerde %85.8 azalma anlamına gelmektedir.Cihaz bazındaki analizler, tasarruf oranlarının özellikle batarya değişim sıklığı yüksek ve bakım gereksinimi fazla olan cihaz gruplarında daha belirgin olduğunu göstermiştir. NiCd bataryalı EKG cihazlarında %92.9, VRLA bataryalı ventilatörlerde ise %88.8 tasarruf oranına ulaşılmıştır. Bu bulgular, $LiFePO_4$ bataryaların uzun çevrim ömrünün (Tablo 1'de sunulan temsili değerler temelinde) batarya yenileme maliyetlerini büyük ölçüde ortadan kaldırarak retrofit yatırımının ekonomik geri dönüşünü güçlendirdiğini göstermektedir.

3.2. Teknik ve Operasyonel Bulgular: Güvenilirlik ve Uygulanabilirlik

Dönüşüm projesinin teknik uygulama aşamalarından elde edilen bulgular aşağıda özetlenmiştir:

- Elektriksel uyumluluk: Dört seri bağlı $LiFePO_4$ hücresinin oluşturduğu 12.8 V nominal gerilim, hastane ortamında yaygın kullanılan 12 V sistemlerle (VRLA, NiMH, NiCd) yüksek düzeyde uyum göstermiştir. Bu uyumluluk sayesinde cihazların orijinal şarj devreleri, çoğu cihaz grubunda ek bir modifikasyona ihtiyaç duyulmadan işlevsel olarak çalışmıştır.

- BMS entegrasyonu ve güvenlik: Cihaz gruplarına özel seçilen BMS sistemleri (4S 100A, 4S 40A, 8S 60A), atölye doğrulama testlerinde hücre dengeleme, aşırı şarj/deşarj koruması ve kısa devre/aşırı akım koruması gibi kritik fonksiyonları başarılı biçimde yerine getirmiştir. Bu koruma katmanları, $LiFePO_4$ kimyasının yüksek termal kararlılığı ile birlikte değerlendirildiğinde, kritik tıbbi uygulamalar için güvenilir bir enerji altyapısı oluşturmuştur.

- Saha performansı: Retrofit uygulanan 35 cihazın tamamı klinik kullanım koşullarında operasyonel görevlerini yerine getirmiştir. İzlem süresi boyunca batarya kaynaklı cihaz kapanması, şarj uyumsuzluğu veya güvenlik nedeniyle devre dışı kalma gibi olaylar raporlanmamıştır.

3.3. Çevresel Bulgular: Sürdürülebilirlik Kazanımları

Retrofit uygulamasının çevresel etkileri, envanter temelli karşılaştırmalı değerlendirme çerçevesinde incelenmiş ve aşağıdaki bulgular elde edilmiştir:

- Atık minimizasyonu: Geleneksel batarya teknolojilerinin sınırlı çevrim ömrü nedeniyle (Tablo 1), beş yıllık süreçte cihaz başına birden fazla batarya değişimi gereksinimi oluştuğu öngörülmüştür.

Buna karşılık $LiFePO_4$ bataryaların uzun çevrim ömrü (3000+ çevrim), aynı periyotta batarya yenileme ihtiyacını büyük ölçüde azaltmıştır. Bu kapsamda yapılan karşılaştırmalı değerlendirme, batarya kaynaklı fiziksel atık oluşumunda %75 ile %90 arasında bir azalma potansiyeli bulunduğunu göstermiştir.

- Tehlikeli madde eliminasyonu: Retrofit uygulaması kapsamında, toplam 8 adet NiCd (kadmiyum içeren) ve 18 adet VRLA (kurşun içeren) batarya sistemi kullanım dışına çıkarılmıştır. Bu durum, hastanenin tehlikeli atık envanterinde kadmiyum ve kurşun gibi toksik ağır metal içeren batarya sistemlerinin azaltılması anlamına gelmektedir.

- Kaynak verimliliği ve tedarik zinciri etkisi: Batarya değişim sıklığının azalması; batarya üretimi, lojistiği ve bertaraf faaliyetlerinin daha düşük sıklıkta gerçekleşmesini gerektirmektedir. Bu durum, tedarik zinciri boyunca enerji tüketimi ve karbon emisyonlarında dolaylı bir azalma potansiyeli yaratmaktadır.

TARTIŞMA

Bu çalışma, kritik tıbbi cihazlarda $LiFePO_4$ batarya retro-fitinin teknik olarak uygulanabilir olduğunu ve sürdürülebilir sağlık sistemleri için stratejik bir araç olabileceğini göstermiştir. Elde edilen kazanımlar, yerel ölçeğin ötesinde makroekonomik ve çevresel etkiler barındırmaktadır.

4.1. Makroekonomik ve Teknik Ölçeklenebilirlik

%85,8'lik TCO tasarrufu ile kanıtlanan maliyet etkinliği, kamu kaynaklarının verimli kullanımına yönelik kritik bir model sunmaktadır. Türkiye genelindeki on binlerce taşınabilir tıbbi cihaz düşünüldüğünde, bu modelin ulusal ölçekte benimsenmesi yüz milyonlarca lirayı bulabilecek bir kamu tasarrufu potansiyeli yaratabilir. Ayrıca, retrofit atölyelerinin yaygınlaşması, enerji depolama teknolojilerinde yerel teknik bilgi birikimini artırarak yüksek teknolojiye dayalı yeni bir istihdam ve uzmanlık alanı doğurabilir.

Ayrıca, bu dönüşüm modeli, enerji depolama teknolojileri konusunda yerel/ulusal teknik bilgi birikimini ve "retrofit atölyesi" kapasitesini geliştirerek, yeni bir iş ve uzmanlık alanının doğmasına öncülük edebilir. Bu durum, yüksek teknolojiye dayalı istihdam yaratılması ve kamu alımlarında yerli katma değerin artırılması anlamına gelmektedir.

Genel olarak literatür, LiFePO4 pil dönüşümünün taşınabilir tıbbi cihazlar için uygun maliyetli, dayanıklı, güvenli ve sürdürülebilir bir çözüm sunduğunu ve büyük ölçekli ekonomik ve teknik faydalar sağlayabileceğini desteklemektedir (Akhmetova vd., 2024; Kumar vd., 2021; Kwon vd., 2024;Song vd., 2021;)

4.2. Ulusal Çevresel Taahhütler ve Döngüsel Ekonomiye Katkı

Atık azaltımı (%75-90) ve tehlikeli madde (kadmiyum, kurşun) eliminasyonu bulguları, Türkiye'nin taraf olduğu uluslararası anlaşmalar ve AB Yeşil Mutabakatı hedefleriyle doğrudan uyumludur.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$LiFePO_4$ dönüşümünün yaygınlaşması; (i) ulusal tehlikeli atık yükünü azaltacak, (ii) daha az batarya üretim ve nakliyesiyle kaynak verimliliğine katkı sağlayacak, (iii) uzun ömürlü ve geri dönüştürülebilir bataryalar sayesinde sağlık sektöründe döngüsel ekonomi modelinin uygulanmasının önünü açacaktır.

Genel olarak literatür, LiFePO4 pil dönüşümünün tıbbi cihaz uygulamalarında çevresel sürdürülebilirlik, kaynak verimliliği ve döngüsel ekonomi ilkeleriyle iyi bir uyum sağladığını doğrulamaktadır (Kumar vd., 2021; Kwon vd., 2024; Song vd., 2021; Wang vd., 2025;;).

4.3. Hizmet Güvenilirliği ve Politika Önerileri

$LiFePO_4$'ün teknik güvenilirliği, özellikle acil servisler gibi kritik alanlarda batarya kaynaklı kesintileri minimize ederek hasta güvenliğine ve sistem dayanıklılığına dolaylı ama hayati katkılar sağlar. Bu çok boyutlu faydaların sistematik hale getirilmesi için politika düzeyinde adımlar atılmalıdır. Bu kapsamda; kamu alımlarında TCO ve çevresel etkiyi temel alan kriterler geliştirilmeli, retrofit uygulamaları için uluslararası güvenlik standartlarına (IEC 60601-1, IEC 62133-2) dayalı bir sertifikasyon ve denetim mekanizması oluşturulmalı, bu tür projeler "Yeşil Hastane" sertifikasyon süreçlerinde teşvik edilmelidir. Özetle, bu çalışma ile somutlanan model, kamu kaynaklarının akılcı kullanımı, çevresel sürdürülebilirlik ve sağlık hizmeti kalitesini bir arada hedefleyen bir kamu politikası aracı niteliğindedir.

Literatürde yer alan çalışmalarda, çevresel sürdürülebilirliğin güçlendirilmesi, maliyet etkinliğinin artırılması ve sağlık hizmeti kalitesinin eş zamanlı olarak iyileştirilmesi amacıyla $LiFePO_4$ pil dönüşümünün kurumsal bir yapıya kavuşturulmasının önemli bir politika aracı olarak ele alındığı vurgulanmaktadır. Bu kapsamda, mevzuat düzenlemeleri, teşvik mekanizmaları ve standartlaştırma süreçleri gibi politika düzeyindeki adımların kritik rol oynadığı belirtilmektedir (Badanta vd., 2025; Kenny ve Priyadarshini, 2021; Lattanzio vd., 2022).

Sonuç olarak, bu çalışma ile somutlanan model, kamu kaynaklarının akılcı kullanımı, çevresel sürdürülebilirlik ve sağlık hizmeti kalitesini aynı anda hedefleyen, "kazan-kazan" prensibine dayalı bir kamu politikası aracı olarak değerlendirilmeyi hak etmektedir.

SONUÇ

Bu çalışma, hastane ortamında aktif olarak kullanılan 35 taşınabilir tıbbi cihazda $LiFePO_4$ batarya retrofit yaklaşımının teknik olarak uygulanabilir olduğunu ve saha koşullarında operasyonel sürekliliği desteklediğini göstermiştir. Dört seri bağlı $LiFePO_4$ hücrelerinin sağladığı 12.8 V nominal gerilimin, 12 V tabanlı geleneksel sistemlerle yüksek düzeyde uyumluluk sunduğu; cihazların büyük bölümünde şarj devrelerinde ek bir modifikasyona ihtiyaç duyulmadan çalışmanın gerçekleştirilebildiği gözlemlenmiştir. Ekonomik değerlendirme sonuçları, $LiFePO_4$ retrofit yaklaşımının beş yıllık dönemde toplam sahip olma maliyetini 564.280 ₺ seviyesinden 80.340 ₺ seviyesine düşürdüğünü ve toplamda 483.940 ₺ net tasarruf ile %85.8 oranında maliyet azalması sağladığını ortaya koymuştur.

Çevresel değerlendirme kapsamında, batarya değişim sıklığının azalmasına bağlı olarak batarya kaynaklı fiziksel atık oluşumunda %75–90 aralığında azalma potansiyeli belirlenmiş; ayrıca NiCd ve VRLA bataryaların kullanım dışına çıkarılmasıyla kadmiyum ve kurşun gibi toksik ağır metallerin hastane tehlikeli atık envanterindeki yükünün azaltılabileceği gösterilmiştir.

Bu bulgular, $LiFePO_4$ retrofit modelinin yalnızca maliyet etkin bir mühendislik çözümü değil; aynı zamanda sağlık sektöründe sürdürülebilirlik, döngüsel ekonomi ve risk azaltımı hedeflerini destekleyen ölçeklenebilir bir yaklaşım olduğunu ortaya koymaktadır. Bununla birlikte, çevresel değerlendirme envanter temelli bir karşılaştırma yaklaşımıyla sınırlandırılmış olup; karbon ayak izi gibi metriklerin ileri düzey yaşam döngüsü analizleriyle desteklenmesi gelecek çalışmalar için önerilmektedir. Sonuç olarak, $LiFePO_4$ batarya retrofit uygulamalarının; standartlara uyumlu teknik rehberler, kalite güvence süreçleri ve TCO temelli karar mekanizmaları ile desteklenmesi halinde, kamu hastanelerinde sürdürülebilir sağlık teknolojisi dönüşümü için güçlü bir model sunabileceği değerlendirilmektedir.

KAYNAKLAR

Akhmetova, K., Sultanov, F., Mentbayeva, A., Umirov, N., Bakenov, Z., & Tatykayev, B. (2024). Advances in multi-element doping of LiFePO4 cathode material for capacity enhancement in Li-ion batteries. Journal of Power Sources.

Anandh, B., Ganesh, A. S., Sakthivel, R., Maheshkumar, D., & Kumar, E. P. (2021). Smart battery management system using $LiFePO_4$ battery for offline UPS. Journal of Physics: Conference Series, 2040(1), 012007.

Badanta, B., Sierra, A., Fernández, S., Muñoz, F., Pérez-Jiménez, J., González-Cano-Caballero, M., Ruiz-Adame, M., & De-Diego-Cordero, R. (2025). Advancing Environmental Sustainability in Healthcare: Review on Perspectives from Health Institutions. Environments

Botejara-Antúnez, M., Prieto-Fernández, A., González-Domínguez, J., Sánchez-Barroso, G., &García-Sanz-Calcedo, J. (2024). Life cycle assessment of a $LiFePO_4$ cylindrical battery. Environmental Science and Pollution Research, 31, 57242–57258.

Driscoll, E., Kallitsis, E., Marco, J. F., Burnett, D., Pham, S., Sommerville, R., Cooper, L., Edge, J. S., Berry, F., Slater, P., &Kendrick, E. (2025). Gravetocradle: A direct recycling approach forover-discharged $LiFePO_4$ electric vehicle cells. Advanced Energy and Sustainability Research.

Gianvincenzi, M., Marconi, M., Mosconi, E., Favi, C., & Tola, F. (2024). Systematicreview of battery life cycle management: A framework for European regulation compliance. Sustainability, 16(22), 10026.

Jeyaseelan, C., Jain, A., Khurana, P., Kumar, D. ve Thatai, S. (2020). Ni-Cd Piller., 177-194.

Kenny, C., & Priyadarshini, A. (2021). Review of Current Healthcare Waste Management Methods and Their Effect on Global Health. Healthcare, 9

Kumar, J., Neiber, R., Park, J., Soomro, R., Greene, G., Mazari, S., Seo, H., Lee, J., Shon, M., Chang, D., & Cho, K. (2021). Recent Progress in Sustainable Recycling of LiFePO4-type Lithium-ion Batteries: Strategies for Highly Selective Lithium Recovery. Chemical Engineering Journal.

Kwon, K., Kim, J., Han, S., Lee, J., Lee, H., Kwon, J., Lee, J., Seo, J., Kim, P., Song, T., & Choi, J. (2024). Low-Resistance LiFePO4 Thick Film Electrode Processed with Dry Electrode Technology for High-Energy-Density Lithium-Ion Batteries. Small Science, 4.

Landi, D., Marconi, M., &Pietroni, G. (2022). Comparative life cycle assessment of two different battery technologies: Lithium iron phosphate and sodium-sulfur. Procedia CIRP, 105, 418–423.

Lattanzio, S., Stefanizzi, P., D'ambrosio, M., Cuscianna, E., Riformato, G., Migliore, G., Tafuri, S., & Bianchi, F. (2022). Waste Management and the Perspective of a Green Hospital—A Systematic Narrative Review. International Journal of Environmental Research and Public Health, 19.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Rostami, H., Valio, J., Tynjälä, P., Lassi, U., &Suominen, P. (2024). Life cycle of $LiFePO_4$ batteries: Production, recycling, and market trends. Chem Phys Chem, 25.

Roy, A., Meshram, S., Patil, R., Arun, S., & Kore, A. (2024). Life cycle testing and reliability analysis of prismatic lithium-iron-phosphate cells. International Journal of Sustainable Energy, 43.

Song, Y., Xie, B., Song, S., Lei, S., Sun, W., Xu, R., & Yang, Y. (2021). Regeneration of LiFePO4 from spent lithium-ion batteries via a facile process featuring acid leaching and hydrothermal synthesis. Green Chemistry.

Wang, X., Gu, Z., Cao, J., Zhao, X., Liu, H., Zheng, S., Heng, Y., Zhang, K., Ang, E., Wang, Z., Zeng, R., & Wu, X. (2025). Dual-loop upcycling of spent LiFePO4: defect inheritance enables durable and fast-charging sodium-ion batteries. National Science Review, 12.

Young, K., & Yasuoka, S. (2016). Capacity Degradation Mechanisms in Nickel/Metal Hydride Batteries. Batteries , 2, 3.

Zelinsky, M., Koch, J., & Young, K. (2017). Performance Comparison of Rechargeable Batteries for Stationary Applications (Ni/MH vs. Ni–Cd and VRLA) Batteries , 4, 1.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INVESTIGATION OF THE EFFECT OF EPS HONEYCOMB STRUCTURE ON REDUCING SIDE IMPACT LOADS IN AUTOMOTIVE SEAT LATERAL SUPPORTS

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SUMMARY

This study investigates the potential of lateral support structures in automotive seats to reduce impact loads transmitted to passengers during a potential lateral collision. Although lateral airbags are widely used in vehicles today, the impact energy absorption capacity of the seat structure may be limited. Therefore, the aim was to evaluate alternative impact-absorbing solutions that could be integrated into the seat's internal structure.

In this study, EPS (Expanded Polystyrene) material, which has high energy absorption capability thanks to its closed-cell structure and controlled crushing (crushable foam) behavior, was integrated into the lateral support structure of the seat with a honeycomb geometry. During the design and analysis process, a standard lateral support structure consisting only of polyurethane foam was compared with a lateral support design incorporating an EPS honeycomb structure.

The analysis results show that the EPS honeycomb structure significantly absorbs impact energy and reduces stress levels transmitted to the passenger. In this context, it has been concluded that EPS-based impact-absorbing structures integrated into the seat lateral supports offer a viable solution that can improve passive safety performance.

Keywords: Automotive Seats, Lateral Impact, Impact Energy Absorption, EPS (Expanded Polystyrene), Honeycomb Structure

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EDIBLE COATING APPLICATIONS IN RED MEAT PRESERVATION

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Red meat products occupy an important place in the food industry due to their high nutritional value and widespread consumption. However, their high-water activity and near-neutral pH make them highly susceptible to microbial growth and oxidative deterioration, leading to quality losses and reduced shelf life during refrigerated storage. In recent years, edible coating systems have attracted considerable attention as natural and sustainable alternatives to synthetic preservatives for improving the microbial safety and oxidative stability of meat products.

This review focuses on recent advances in antimicrobial and antioxidant edible coatings applied to red meat products. Biopolymer-based coatings such as chitosan, alginate, gelatin, proteins, and polysaccharide-based matrices have been widely studied as carrier systems for natural bioactive compounds. Plant-derived extracts, essential oils, and phenolic-rich by-products (e.g., fruit peels, herbal extracts) used in coating formulations to inhibit spoilage and pathogenic microorganisms and to retard lipid and protein oxidation have been evaluated.

The mechanisms of action of these coatings, including barrier effects against oxygen and moisture transfer, controlled release of bioactive compounds, and interactions with meat surface components, are discussed. Additionally, the effects of antimicrobial and antioxidant coatings on physicochemical, microbiological, and sensory quality parameters of red meat during cold storage are assessed.

Overall, the findings in the literature indicate that edible coatings enriched with natural antimicrobial and antioxidant agents represent a promising, environmentally friendly, and consumer-acceptable strategy to enhance the shelf life and quality of red meat products. This review highlights current trends, limitations, and future research needs for the industrial application of natural edible coating technologies in meat preservation.

Keywords: Edible coatings, antimicrobial coatings, antioxidant coatings, meat shelf-life

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A REVIEW OF SITE SELECTION CRITERIA AND MODELING APPROACHES FOR ELECTRIC VEHICLE CHARGING INFRASTRUCTURE

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ABSTRACT

Electric vehicles (EVs) have re-emerged at different periods throughout history in the context of environmental factors, energy policies, and the climate crisis. In recent years, alongside the escalating climate crisis, objectives such as energy efficiency and the reduction of carbon emissions within the framework of sustainability have shifted research on EVs beyond a purely technological focus toward an examination of their relationship with urban space. Planning charging infrastructure by taking urban dynamics into account is of critical importance for the widespread adoption of EVs and the achievement of sustainable transportation goals. As an 'urban service facility', charging stations should be located by urban planners in areas that ensure optimal conditions while being equitable, accessible, and consistent with planning principles.

The aim of this research is to identify the spatial, social, and technical criteria that determine the site selection of EV charging stations through a literature-based analysis, thereby providing data to support planning and design processes. Within this scope, 33 articles published between 2012 and 2025 in the Scopus database were reviewed. The literature reveals that researchers have proposed specific criteria and modeling approaches for the optimal location of charging stations. Drawing on the literature, a criteria dataset was developed within the scope of this study. These criteria were categorized under subheadings including the built environment, natural factors, socio-economic factors, population, technical factors such as vehicle characteristics, economic factors, user behavior, mobility, policy and planning, environmental impact, and other factors. This site selection criteria set serves as a foundational framework for defining standards and interrelationships in planning and design processes. Ultimately, this research provides both theoretical and empirical contributions to multi-

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

criteria decision-making processes aimed at locating EV charging stations within the framework of the planning discipline.

Keywords: Electric vehicles (EVs), charging stations, site selection criteria, optimal location, urban transportation.

ELEKTRİKLİ ARAÇ ŞARJ ALTYAPISI İÇİN YER SEÇİM ÖLÇÜTLERİ VE MODELLEME YAKLAŞIMLARININ İNCELENMESİ

ÖZET

Elektrikli araçlar (EA), 19. yüzyılın başlarından itibaren teknolojik ilerlemeler, çevresel faktörler ve enerji politikaları bağlamında farklı dönemlerde gündeme gelmiştir. Son yıllarda ise iklim krizi ve sürdürülebilirlik kapsamında ortaya koyulan enerji verimliliği ve karbon emisyonlarının azaltılması gibi hedeflerle yeniden gündeme gelen EA'lara enerji sağlayan şarj istasyonları üzerine yapılan çalışmalarda sadece teknolojik altyapı olarak değil, kent mekânıyla olan ilişkilerine de odaklanılmaya başlanmıştır. Şarj istasyonları bir "kentsel hizmet donatısı" olarak kent plancıları tarafından kentte adil, erişilebilir ve planlama ilkeleri ile uyumlu bir şekilde optimum koşulları sağlayacak yerlerde konumlandırılmayı gerektirmektedir. Bu bağlamda araştırmanın temel amacı, EA şarj istasyonlarının yer seçiminde belirleyici mekânsal, sosyal ve teknik ölçütleri literatür temelli bir analizle ortaya koyarak planlama ve tasarım süreçlerine bilimsel altlık sağlamaktır. Bu kapsamda Scopus veri tabanında 2012–2025 yılları arasında yayımlanmış 33 makale incelenmiş ve şarj istasyonlarının optimum konumlandırılmasına yönelik belli ölçütler ve modelleme yaklaşımları kapsamında bir ölçüt veri seti oluşturulmuştur. Bu araştırma sonucunda ölçütler; yapılı çevre, doğal etkenler, sosyo-ekonomik etkenler, nüfus, araç özellikleri gibi teknik etkenler, ekonomik, kullanıcı davranışı, hareketlilik, politika ve planlama, çevresel etki ve diğer olmak üzere alt başlıklarda toplanarak açıklanmıştır. Bu araştırma sonucunda üretilen yer seçim ölçüt seti; ilgili standartları ve belli ilişkileri tanımlayan, bu sayede de EA şarj istasyonlarının planlama disiplini çerçevesinde konumlandırılmasına yönelik çok kriterli karar verme süreçlerine yol haritası sunan bir altlık sunmaktadır.

Anahtar Kelimeler: Elektrikli araçlar (EA), şarj istasyonları, şarj istasyonu yer seçim ölçütleri, optimum konumlandırma, kentsel ulaşım.

GİRİŞ

Günümüzde kentlerde artan nüfusla beraber bireyselleşen araç kullanımı, karayolu odaklı gelişen ulaşım altyapısı; özellikle fosil yakıtlara dayalı araçların kullanımı iklim krizi ile mücadelede öncelikli konulardan biri olmuştur. Avrupa Birliği'nin Avrupa Yeşil Anlaşması'na göre iklim değişikliği ve çevresel bozulmalardan yola çıkarak "2050 yılına kadar net sera gazı emisyonunu ortadan kaldırmak" hedefi kapsamında sürdürülebilir çözüm arayışlarına kapı açmıştır. Ulaşım sektörü Avrupa'nın sera gazı emisyonlarının yaklaşık dörtte birini oluşturmaktadır (Sica, vd., 2025). Emisyon artışının sınırlandırılmasına yönelik politika araçları ve sürdürülebilirlik hedefleri kapsamında EA'lar alternatif

ulaşım çözümleri arasında değerlendirilmektedir. Bu doğrultuda teşvik edilen yenilikçi faaliyetler kapsamında uygulamaya koyulan kamu politikaları nedeniyle EA teknolojileri kentlerde giderek daha görünür hâle gelmiştir. Bu kapsamda EA'ların sürdürülebilir bir çözüm olabilmesi için yalnızca araç teknolojisinin dönüşümü değil, aynı zamanda kapsamlı ve entegre bir şarj altyapısının planlanması ve sistematik biçimde kurgulanması gerekliliğini de beraberinde getirmektedir (Sica, vd., 2025). Bu bağlamda; hızlı bir şekilde kent hayatına girmiş olan EA'ların beraberinde getirdiği şarj istasyonlarının kentte düzensiz dağılımı mekân işgaliyle beraber, kentsel hizmetlere erişim, altyapıda ki yetersizliklerin ortaya çıkarabileceği gerilim problemleri başta olmak üzere farklı sorunlara yol açabilir durumdadır. Bu kapsamda günden güne artan EA sahipliliği ile beraber bu araştırmada bir "kentsel hizmet donatısı" olarak tanımlanan şarj istasyonlarının kentsel alanda erişilebilir, verimli ve adil konumlanması şehir planlama disiplini içerisinde büyük öneme sahiptir.

Bu araştırmanın amacı; EA şarj istasyonlarının yer seçiminde belirleyici ölçütlerin neler olduğunu ortaya koyarak planlama ve tasarım alanında istasyonların kullanıcı odaklı, erişilebilir, adil ve verimli konumlandırılması için bir altlık oluşturmaktır. Araştırma kapsamında yer seçimi için öne çıkan parametreler ulusal ve uluslararası literatür üzerinden incelenerek bir ölçüt veri seti ortaya koyulması hedeflenmektedir. Böylelikle EA şarj istasyonlarının yer seçimi sürecine etki eden mekânsal, sosyal ve teknik ölçütleri analiz ederek, bu altyapının kent ölçeğinde daha adil, erişilebilir ve verimli şekilde planlanmasına katkı sunmaktır.

MATERYAL VE METOT

Scopus veri tabanında elektrikli araçların şarj istasyonlarının yer seçimine dair belli anahtar kelimelerle konu sınırlandırılmıştır. Bu anahtar kelimeler konuya dair kaynakların incelenmesiyle beraber elektrikli araçların, skuterlerin, toplu taşım araçları ve yük taşıyan araçlar(kamyon) olmak üzere farklı sınıflandırmalarla ele alındığı ortaya çıkmıştır. Konu kapsamında sadece otomobiller ele alındığı için veri tabanında "scooter/skuter", "kamyon" kelimeleri dahil edilmemiştir. Araştırma şehir içinde kentsel alanlarda gerçekleştirileceği için "kentsel alanlar" dahil edilmiş, "şehirlerarası" kavramı ise dahil edilmeyerek "elektrikli araçlar", "şarj istasyonları" ve "yer seçimi" anahtar kelimeleri üzerinden 2012- 2025 yılları arasını kapsayan 33 araştırma makalesi incelenmiştir. Bu inceleme sonucunda literatürden yararlanarak araştırmacıların ortaya koydukları ölçütler bu çalışma kapsamında; **yapılı çevre, doğal etkenler, sosyo-ekonomik etkenler, nüfus ve demografik yapı**, **teknik etkenler (araç özellikleri gibi), ekonomik, kullanıcı davranışı, hareketlilik, politika ve planlama, çevresel etki ve diğer** olmak üzere alt başlıklarda toplanmış ve bir ölçüt seti sunulmuştur.

Elektrikli Araçlar ve Şarj İstasyonlarıyla İlgili Kavramsal Çerçeve

EA'ların kent hayatına girmesi ilk olarak 19.yy'a dayanmaktadır. Elektriğin icadı ile beraber başlayan bu süreçte bu araçların teknik yetersizlikleri, içten yanmalı motorlara sahip araçların üretilmesi ve petrol bolluğu ile beraber EA'lar geri planda kalmıştır. 1970'ler sonrasında ise yaşanan petrol krizleri

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ve çevre bilincinin artmasıyla beraber tekrar gündeme gelmiştir. Şehir içi kullanım için tasarlanan modeller kullanılmaya başlamıştır (Santini, 2011). 1990'larda ise çevre yasalarının sıkılaşması ve 2000 sonrası Tesla gibi firmaların batarya teknolojisi devrimi ve 2025 yılı itibariyle de Avrupa'da karbonsuz ulaşım hedeflerinin belirlenmesiyle beraber EA'lar iklim krizi ile mücadelede bir çözüm yolu olarak görülmüş ve EA'lar hızla kent hayatına girmiştir (Lulia & Loránd, 2022). EA'lar hem elektrikli hem de hibrit araçları kapsayan, çalışma prensipleri ve kullandıkları teknolojiye göre; tam elektrikli (Bataryalı), yakıt hücreli, hafif hibrit ve plug-in hibrit ve hibrit araçlar olmak üzere beş türe ayrılmaktadır. Bu türler arasında ise şarj edilme ihtiyacı duyan türler tam elektrikli (bataryalı) ve plug in hibrit araçlardır. Kentsel alanda günden güne artan EA sayısı ile beraber şarj istasyonlarına artan talep şarj istasyonlarının bir kentsel hizmet olarak kentte yer seçmesine sebebiyet vermektedir. Bu araçların şarj olabilmesi için gerekli olan şarj istasyonu sistemi ise; elektrik altyapısı ve bunun getirdiği tesisat, araca enerji akışını ve kontrolünü sağlayan üniteler ve bunların haberleşme altyapısını içerir. Sistem içerisinde enerji alt yapısı, şarj kapasitesini karşılayabilir kapasitede alçak gerilim tesisatını içermekte olup tesisat, elektrik panosu ve şarj ünitelerini besleyen kablo ya da Busbar sistemlerini içermektedir (Birleştirici, vd., 2015). EA sahip bireyler araçlarını üç farklı şarj istasyonu ile şarj edebilmektedir. Bu şarj istasyonu türleri; özel mülkiyete ait şarj türü olan ve "evde şarj" imkanı sağlayan garajlara kurulan "özel şarj istasyonları", kentsel alanlarda kamu kullanımına açık "kamusal şarj istasyonları" ve uzun mesafe yolculuklarda (şehirlerarası) ihtiyaç duyulan menzil kaygısını giderecek ve genellikle otoyollar veya koridorlara konumlanan "uzun mesafeli şarj istasyonlarıdır" (Inter- American Development Bank, 2021). Şarj istasyonları şarj hızlarına göre de ultra hızlı şarj, hızlı şarj ve yavaş şarj istasyonu olmak üzere farklı türlere ayrılmaktadırlar. Bu bağlamda şarj istasyonlarının farklı türlere ve hizmet gereksinimlerine göre mekânsal ve teknik ihtiyaçları bulunmaktadır. Şarj istasyonlarının konumlandırılması tek başına bir yerleştirme faaliyetinin ötesinde altyapı, kullanıcı memnuniyeti, çevresel, sosyal etkiler olmak üzere çok faktörlü karmaşık bir optimizasyon problemidir.

Şarj İstasyonları Yer Seçimiyle İlgili Ölçütler

Şarj istasyonlarının yer seçimi sürecinde hem yasal hem de mekânsal entegrasyona ilişkin planlama ve tasarım belirsizlikleri; politika ve paydaşlar arası çatışmalar, ekonomik kısıtlar ve sürdürülebilirlik hedeflerine ulaşmayı zorlaştıran engeller temel sorun alanlarını oluşturmaktadır. Bu problemlerin giderilmemesi, EA'ların düşük kullanım oranlarına yol açarak sistemin sürdürülebilirliğini zayıflatmaktadır. Ayrıca elektrik şebekesinin yetersiz olduğu alanlarda kurulan istasyonlar ile teknik gereksinimlerin göz ardı edildiği uygulamalar, can ve mal güvenliğini tehlikeye atan riskler doğurabilmektedir. Başarılı bir şarj altyapısının yalnızca ekonomik fayda sağlaması değil, alt ve üstyapı ile bütünleşik bir yaklaşımla ele alınması gerekmektedir. Literatürde, şarj istasyonlarının teknik ve mekânsal gereksinimlerinin; yol ağı ve ulaşım sistemleriyle entegrasyon, arazi kullanımı, elektrik altyapısı ve şebeke özellikleri gibi ölçütlere bağlı olarak şekillendiği vurgulanmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Bununla birlikte zemin yapısı ve iklim koşulları istasyonların dayanıklılık ve güvenliğini etkilerken; ekonomik açıdan kurulum, işletme ve hizmet sürecindeki maliyetler, hizmet gereksinimleri ve kullanıcı davranışları, demografik özellikler, hanehalkı yapısı, kentsel hareketlilik olmak üzere tüm bu faktörler araç teknolojileri ile politika ve planlama kararlarıyla birlikte yer seçim sürecinin temel ölçütlerini oluşturmaktadır.

Doğal Etkenler, Çevresel Etki ve Diğer Ölçütler

Araştırma kapsamında ilgili literatürde doğal etkenler genellikle "dayanıklılık" ilkesi bağlamında ele alınmıştır. Skaloumpakas vd. (2025), kıyı alanlarında nem ve tuz oranının şarj istasyonuna zarar vereceğini belirterek kıyıdan 4 km'lik eşik değer sonrasında zarar görme riskinin olmadığı varsayılmıştır. T. C. Ulaştırma ve Altyapı Bakanlığı ise "Elektrikli Araç Şarj İstasyonlarının Yer Seçiminin Belirlenmesi Ve Simülasyon Programının Oluşturulması" adlı 2023 yılında yayınlamış olduğu raporda; doğal afetlerle de ilişkili olarak zemin yapısı ve iklim şartlarını önceliklendirmiştir. Kazempour, vd., (2025) enerji verimliliği ve kullanıcı güvenliği açısından; %10'dan fazla eğime sahip yol kesitlerinin kurulum için uygun olmadığını kabul etmiştir. Karbon emisyonu ve gürültü kirliliği gibi çevresel kirliliğin yüksek olduğu alanlar EA'ların sessiz çalışması ve karbon emisyonu düşürme hedeflerinde bir araç olarak kullanılması nedeniyle öncelikli alanlardan olabilmektedir (Morocho-Chicaiza, vd., 2024). Mevcut elektrik üretiminin büyük kısmının fosil yakıtlardan sağlanması nedeniyle de şarj istasyonlarının sürdürülebilir olması için elektrik talebinin yenilenebilir enerji üretim merkezlerine yakınlığı ve entegrasyonu bir parametre olarak eklenmektedir (Sica, vd., 2025).

Tablo 1. Şarj İstasyonları Yer Seçimine Yönelik Doğal Etken Ölçütleri

ÖLÇÜTLER		PARAMETRELER	Araştırmacılar
DOĞAL YAPI	Zemin yapısı	Deprem riski	UAB, (2023), Yılmaz, İ., vd., (2024)
		Heyelan riski	UAB, (2023),
		Arazinin Eğimi	UAB, (2023), Kazempour, M., vd., (2025), Mahmoudi, E., (2024)
		Zeminin taşıma kapasitesi	UAB, (2023),
		Bataklık riski	UAB, (2023),
	İklim şartları	Kar ve don olayları	UAB, (2023),
		Yağmur yağış sıklığı ve şiddeti	UAB, (2023),
		Rüzgar hakimiyeti	UAB, (2023),
	Diğer	Su kaynağı	Yılmaz, İ., vd., (2024)
		Bitki örtüsü	Yılmaz, İ., vd., (2024)
		Denize uzaklık (tuz ve nem) (negatif etki)	Skaloumpakas vd. (2025)

Yapılı Çevre Ölçütleri

Farklı arazi kullanım ve nüfus yoğunluğu, kamusal şarj istasyonlarına yönelik talebin oluşumunda belirleyici unsurlar arasında yer almaktadır. EA kullanımının yaygınlaştığı alanlarda, karma arazi kullanımı ile ticari faaliyetlerin yoğunluğu da artış göstermektedir (Makaremi, 2024). Skaloumpakas vd. (2025) ise özellikle şirket sayısının fazla olduğu ticari bölgelerde ve elektrikli araç kiralama talebinin turizm hareketliliğiyle arttığı, otel yatak kapasitesinin yüksek olduğu bölgelerde kamusal şarj talebinin daha yüksek seviyelerde olacağını vurgulamaktadır. Cai vd. (2024) çalışmalarında, farklı sosyo-ekonomik gruplar ve bölgeler arasındaki hizmet dağılımı eşitsizliklerini nicel verilerle ortaya

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

koymuş; yeni ve eski yerleşim alanları arasındaki arz-talep uyumsuzluklarını belirleyerek planlama süreçlerine veri temelli katkı sağlamıştır. Yapılı çevrenin; hizmet alanlarına /donatılara uzaklık (yeme-içme, iş, alışveriş, okul vb.), ulaşım ağı (yol yoğunluğu (Ouyang, vd., 2022; Guo, vd., 2022; Gao, vd., 2020), toplu taşıma entegrasyonu (Guo, vd., 2022), otoyol bağlantıları (Ouyang, vd., 2022; Gao, vd., 2020), özel (Skaloumpakas, vd., 2025; ten Dam, vd., 2024; Sica, vd., 2025) ve kamusal otopark (MirHassani, vd., 2020; Sica, vd., 2025; Yılmaz, vd., 2024) imkanları da konumlandırmada kritik rol oynamaktadır. Bu faktörler insanların gün içerisinde kentteki hareket desenlerini vererek nerede nasıl bir şarj talebinin oluşacağını gösterir. Bu çerçevede, şarj istasyonu konumlandırmasında yalnızca talep büyüklüğünün değil; mevcut kentsel doku, arazi kullanım kararları, ulaşım altyapısı, sosyo-demografik yapı ve bu değişkenlerin yoğunluk ilişkilerinin birlikte ele alınması gerekmektedir. Şarj istasyonu aynı zamanda bir ulaşım altyapısı olmakla beraber elektrik şebekesine yük veren bir teknik altyapıdır. Bu nedenle yoğun şarj talebinin olduğu bölgelerde şebeke yükünün dengelenmesi için gerekli altyapının sağlanması can ve mal güvenliği açısından önem taşımaktadır.

Tablo 2. Şarj İstasyonları Yer Seçimine Yönelik Yapılı Çevre Ölçütleri

ÖLÇÜTLER		PARAMETRELER	Araştırmacılar
YAPILI ÇEVRE	Yol Ağı-Ulaşım	Toplu Taşıma istasyonlarına uzaklık(metro,otobüs vb)	Guo, Y., vd.(2022)
		Ana arterlere mesafe (km) (negatif etki)	**Kim, H., & Kim, G. S. (2025)**
		Yüksek yol yoğunluğu- trafik akış hacmi (negatif etki)	**Guo, Y.,vd.(2022), Kim, H., & Kim, G. S. (2025).**
		Trafik akışı ve maksimum kapsama (pozitif etki)	Ouyang, X., Xu, M. (2022), Morocho-Chicaiza, W., vd.(2024), Deng vd., (2024)
		Liman ve Havaalanı varlığı (yüksek trafik hacmi)	Skaloumpakas vd. (2025)
		Günlük toplam kat edilen mesafe	Bhat, F. A., vd.(2024)
		Yüksek yol yoğunluğu ve bağlantılar	Gao, H., vd.(2020),Bhat, F. A., vd.(2024), Yılmaz, İ., vd., (2024)
		En kısa rota mesafesi	Ouyang, X., Xu, M. (2022).
	Arazi Kullanım	Hizmet alanlarına, donatılara uzaklık (yeme-içme, iş, alışveriş, okul vb.)	MirHassani, S. A., vd. (2020), Bhat, F. A., vd.(2024), Yılmaz, İ., vd., (2024)
		Restoran ve alışveriş alanları (negatif etki)	Guo, Y., vd.(2022)
		Şehir merkezine yakınlık (tarihi merkez)	Morocho-Chicaiza, vd., (2024)
		Kamusal Alanlar	Ren, Q., Sun, M., (2025), Çelik, S., Ok, Ş. (2024)
		Ofis Yapıları- Sayısı (Ticaret)	Skaloumpakas vd. (2025), Guo, Y., vd.(2022)
		Otel Yatak Sayısı (Turizm)	Skaloumpakas vd. (2025)
		Yeşil alan kapasitesi	Ren, Q., Sun, M., (2025)
		Kamusal otopark kapasitesi	MirHassani, S. A., vd. (2020), Sica, L., vd. (2025), Yılmaz, İ., vd., (2024)
		Özel otopark alanı- Konut veya Apartman Sayısı	Skaloumpakas vd. (2025), ten Dam, C. D., vd.(2024),Sica, L., vd. (2025)
		Benzin istasyonlarının varlığı (alternatif konum)	Morocho-Chicaiza, W., vd., (2024)
		Yerleşim alanı	Kim, H., & Kim, G. S. (2025)
		Kentsel / Kırsal alan niteliği	Sica, L., vd. (2025)
		Yerleşim alanının büyüklüğü	Ren, Q., Sun, M., (2025)
		Nüfus yoğunluğu (insan/km2)	Guo, Y., vd.(2022), Makaremi (2024) Ren, Q., Sun, M., (2025)
	Altyapı ve Şebeke Özellikleri	Mevcut şarj istasyonu sayısı	Jia, L., Hu, Z., Song, Y., & Luo, Z. (2012), MirHassani, S. A., vd. (2020), Çelik, S., Ok, Ş. (2024)
		Mevcut şarj prizi	Jia, L., Hu, Z., Song, Y., & Luo, Z. (2012)
		Diğer şarj istasyonlarına olan mesafe	Morocho-Chicaiza, W., vd., (2024), Gao, H., vd.(2020), Çelik, S., Ok, Ş. (2024), Bhat, F. A., vd.(2024)
		Trafo merkezinden şebekeye yakınlık	Morocho-Chicaiza, W., vd., (2024)
		Trafo merkezi kapasitesi	Morocho-Chicaiza, W., vd., (2024)
		Şebeke kapasitesi	Ouyang, X., Xu, M. (2022)
		Akış Tahsisi- güç kaybı- şarj istasyonu şarj kapasitesi	Ren, Q., Sun, M., (2025)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Kullanıcı Davranışı ve Hareketlilik

İlgili çalışmalarda kullanıcı davranışları, şarj etme sıklığı, şarj süresi, menzil kaygısı, şarj altyapısına erişim ve zaman-maliyet duyarlılığı gibi etkenlerle altyapı kararlarını biçimlendiren dinamik bir değişken olarak ele alınmaktadır (Guo, vd., 2022; Ouyang, vd., 2022; Kim, vd., 2025; Bhat, vd., 2024; Gao, vd., 2020). Elektrikli araç kullanıcılarının gün içinde kentteki hareketliliği/ ziyaret ettiği mekanların ziyaret saatleri o mekanları kullanma ve dolayısıyla geçirdiği süre boyunca şarj etme talebini ve imkanını sağlar. Bu bağlamda belli günler ve saatlerde ilgili bölgelerde yoğunluk oluşabilmektedir. Örneğin iş alanlarının haftaiçi ve işi gidip gelme saatlerindeki şarj talebi ile o alanların tatil günlerindeki şarj talebi değişkenlik gösterecektir (Ren & Sun, 2025).

Tablo 3. Şarj İstasyonları Yer Seçimine Yönelik Kullanıcı Davranışı Ölçütleri

ÖLÇÜTLER	PARAMETRELER	Araştırmacılar
KULLANICI DAVRANIŞI	Şarj alışkanlığı (Belli zaman ve konumlarda)	Guo, Y., vd.(2022).
	Düşük maliyet ve iyi nitelik (Hızlı şarj, şarj ve park ücreti)	Guo, Y., vd.(2022)
	Seyahat maliyeti toleransı- rota tercihi	Ouyang, X., Xu, M. (2022),Gao, H., vd.(2020).
	Rotadan sapma toleransı	Ouyang, X., Xu, M. (2022), Bhat, F. A., vd.(2024)
	Hedefe varış- kalış süresi	MirHassani, S. A., vd. (2020)
	Yürüme istekliliği (otoparktan hedef binaya olan mesafe)	MirHassani, S. A., vd. (2020)
	Kısmi şarj davranışı (Batarya tam değil kısmi dolum)	Ouyang, X., Xu, M. (2022)
	Şarj istasyonu rezervasyon imkanı	Sica, L., vd. (2025)
	Şarj/İstasyon Tipi (Hızlı/yavaş şarj)	MirHassani, S. A., vd. (2020),Çelik, S., Ok, Ş. (2024),Gao, H., vd.(2020). Kim, H., & Kim, G. S. (2025).
	Hizmet kalitesi - bekleme süresi, boş bulma	Gao, H., vd.(2020), Sica, L., vd. (2025), Bhat, F. A., vd.(2024)
HAREKETLİLİK	Kapasite planlaması (pazara giren araç)	Çelik, S., Ok, Ş. (2024)
	Bina ziyaret saatleri	MirHassani, S. A., vd. (2020)
	Eğlence amaçlı hareketlilik	Morocho-Chicaiza, W., vd., (2024)
	Haftaiçi nüfus hareketliliği	Ren, Q., Sun, M., (2025)
	Tatil günleri nüfus hareketliliği	Ren, Q., Sun, M., (2025)

Sosyo-Ekonomik ve Demografik Etkenler

Sosyal Etkenler incelenen literatür kapsamında; çeşitli kullanıcı tipleri, sosyo-ekonomik durum, talep ilişkisi ve nüfus yoğunluğu gibi parametreleri içermektedir. Helmus vd. (2020); Hollanda'da kullanıcı portföyüne dair yaptığı bir araştırmada kullanıcıları şarj davranışlarına göre 9 farklı tipe ayırmıştır. Eğitim düzeyi, gelir seviyesi, yaş ve cinsiyet bireylerin farklı araç tiplerini benimseme, satın alma ve kullanma kararlarını etkilemektedir.

Tablo 4. Şarj İstasyonları Yer Seçimine Yönelik Sosyo-Ekonomik ve Demografik Etken Ölçütleri

ÖLÇÜTLER		PARAMETRELER	Araştırmacılar
NÜFUS ve DEMOGRAFİK YAPI	Demografik Yapı	Yerleşik nüfus	Kim, H., & Kim, G. S. (2025),Yılmaz, İ., vd., (2024)
		Hizmet alanı nüfusu	Morocho-Chicaiza, W., vd., (2024)
		Yaş	ten Dam, C.D., vd.(2024), Kim, H., & Kim, G. S. (2025), Sica, L., vd. (2025), Bhat, F. A., vd.(2024)
		Cinsiyet	ten Dam, C. D., vd.(2024), Sica, L., vd. (2025), Bhat, F. A., vd.(2024)
		Eğitim düzeyi	ten Dam, C. D., vd.(2024)
SOSYOEKONOM	Hanehalkı	Hane gelir durumu	ten Dam, C. D., vd.(2024), Sica, L., vd. (2025),Bhat, F. A., vd.(2024)
		Farklı kullanıcı tipleri	Helmus vd. (2020)
		Elektrikli araç sahipliği	Higgins, A., vd. (2012),Bhat, F. A., vd.(2024)
		Konut fiyatı	Ren, Q., Sun, M., (2025)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Araç Özellikleri

Sürüş menzili birebir araç tipi ile ilişkilidir ve kullanıcılarda ciddi bir menzil kaygısı yaratarak EA edinimini ve şarj istasyonları konumlarına bağlı olarak rota tercihini etkilemektedir (Gao, vd., 2020; Kim, vd., 2025). Aynı zamanda şarj süresi aracın park etme süresi ile orantılı olarak araçların uzun süreli park edebileceği mekansal bir ihtiyacı meydana getirmektedir (Bhat, vd., 2024). Şarj istasyonlarının farklı türden araç tiplerine hizmet verebilecek şekilde de tasarlanması gerekmektedir (Carra vd., 2022).

Tablo 5. Şarj İstasyonları Yer Seçimine Yönelik Araç Özellikleri Ölçütleri

ÖLÇÜTLER		PARAMETRELER	Araştırmacılar
ARAÇ ÖZELLİKLERİ	Teknik özellikler	Şarj süresi- batarya boyutu	Guo, Y., vd.(2022), Sica, L., vd. (2025),Garrow, L. A., German, B. J., & Leonard, C. E. (2021),Helmus, J. R., vd. (2020),Bhat, F. A., vd.(2024)
		Sürüş menzili	Gao, H., vd.(2020), Kim, H., & Kim, G. S. (2025)
		Araç tipi	Gschwendtner, C., vd. (2023).
		Eklenti Davranışı	Gschwendtner, C., vd. (2023).

Politika ve Planlama

Şarj istasyonlarının kurulumundan, ulaşım ve hareketlilikten sorumlu olan ve kurulumu teşvik etmek için politikalar, düzenlemeler ve teşvikler oluşturan birincil paydaşlar Kamu otoriteleridir. Bu, politika yapıcılar tüketici ve alıcı arasında bir köprü kurmaktadırlar. Sürdürülebilirlik hedefleri bağlamında kamu otoriteleri EA edinimini artırmak ve buna bağlı şarj istasyonlarını artırmak için stratejiler geliştirmektedirler (Skaloumpakas, vd., 2025; Bhat, vd., 2024). Kurulum için izin süreçlerinde hem arazi edinimi hem de inşaat maliyetleri için teşvikler sunmaktadırlar (Ren & Sun, 2025).

Tablo 6. Şarj İstasyonları Yer Seçimine Yönelik Politika Ölçütleri

ÖLÇÜTLER		PARAMETRELER	Araştırmacılar
POLİTİKA VE PLANLAMA	Kentsel Politikalar	Pazar(yatırımcı, üretici)	Ouyang, X., Xu, M. (2022).
		Sürdürülebilirlik hedefleri	Bhat, F. A., vd.(2024)
		Kurulum için yönergeler	Skaloumpakas vd. (2025)
		Arazi ruhsat durumu- arazi mevcudiyeti	Ren, Q., Sun, M., (2025), Ouyang, X., Xu, M. (2022)
		Sübvansiyonlar- Teşvikler	Skaloumpakas vd. (2025), Bhat, F. A., vd.(2024)
		EA sahipliliğinin artması için ulusal hedefler(örn. Plaka piyango politikası)	Zhuge, C.,vd.(2020)

Ekonomik Etkenler

Şarj istasyonları hizmet vermeden önce kurulum aşamasıyla beraber onarım, bakım, işletme olmak üzere bir maliyet akışına sahiptir. Hizmeti sunan aktörle ise bütçe kısıtları doğrultusunda, bu maliyetlerin yanı sıra istasyonun kurulacağı arazinin kira ya da satış bedeli gibi maliyetleri de dikkate alarak, en düşük bütçe ile en yüksek verimin elde edilmesini hedeflemektedir (Ouyang & Xu, 2022). Ayrıca kullanıcılar için de şarj istasyonu kullanımında toplam seyahat ve şarj maliyeti şarj davranışını etkileyen etmenlerdendir (Guo, vd., 2022).

Tablo 7. Şarj İstasyonları Yer Seçimine Yönelik Ekonomik Etken Ölçütleri

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ÖLÇÜTLER		PARAMETRELER	Araştırmacılar
EKONOMİ	Şarj İstasyonu inşaat ve gerekli altyapı	Kurulum, onarım, bakım, işletme maliyeti	Ouyang, X., Xu, M. (2022); Skaloumpakas vd. (2025); MirHassani, vd., (2020); Çelik, S., Ok, Ş. (2024)
		İstasyon tipi - hızlı/yavaş şarj (hızlı- 1 saatten daha az, yavaş- 8 saatten fazla)	Ouyang, X., Xu, M. (2022); Çelik, S., Ok, Ş. (2024); Bhat, vd., (2024)
		Şarj verimliliği	Ouyang, X., Xu, M. (2022).
		Şarj tesisi tampon bölgesi	Ren, Q., Sun, M., (2025)
		Yatırım ve bütçe	Ouyang, X., Xu, M. (2022); Zhang, vd., (2023); Morocho-Chicaiza, vd., (2024); MirHassani, vd., (2020)
		Altyapı kurulum maliyeti (trafo, şebeke vb.)	Ouyang, X., Xu, M. (2022).
	Diğer	Şarj maliyeti	Sica, vd., (2025); Bhat, vd., (2024),
		Arazi maliyeti (kiralama, satın alma)	Ren, Q., Sun, M., (2025); Bhat, vd., (2024)
		Toplam seyahat maliyeti	Çelik, S., Ok, Ş. (2024)
		Benzin fiyatının yüksek oluşu (Pozitif etki)	Skaloumpakas vd. (2025)
		Otopark ücretinin yüksek oluşu (Negatif etki)	**Guo, vd., (2022).**

Yer Seçim Modelleri ve Karar Verme Yöntemleri

Araştırmacılar şarj altyapısını optimum konumlandırması ve süreçleri planlamak için birçok parametre ve etkenin olması nedeniyle; bunların belli bir sıralamaya tabi tutulması, modelin daha hızlı ve gerçekçi çözümler sunması veya konumlandırma için öncelikli konumların belirlenmesinde gereklidir. Bu nedenle araştırmacılar bu ölçütlerin sıralanmasına ve buna bağlı olarak çözümlere ulaşmada **Çok Kriterli Karar Verme Yöntemlerini** kullanmışlardır. Bu bağlamda kullandıkları yöntemler; Analitik Hiyerarşi Süreci (AHP), Bulanık AHP, AHP- Entropi Yöntemi, MOORA Yöntemi, PROMETHEE (Tercih Sıralama Organizasyon Yöntemi ile Zenginleştirme Değerlendirmesi), TOPSIS (İdeal Çözüme Benzerlik ile Sıralama Tekniği), VIKOR (VIseK Kriter Optimizasyonu ve Uzlaşma Çözümü), MACBETH olarak sıralanabilir. Morocho vd. (2024), Ekvador'un Cuenca kentinde şarj istasyonu konumlandırmasına yönelik olarak mevcut veriler doğrultusunda ölçütler ve parametre setleri tanımlamış, bu ölçütlerin ağırlık değişimlerine dayanan üç ayrı senaryo geliştirmiştir. Oluşturulan senaryolar VIKOR, TOPSIS ve PROMETHEE çok ölçütlü karar verme yöntemleri kullanılarak ayrı ayrı analiz edilmiş ve sonuçlar karşılaştırmalı biçimde değerlendirilmiştir. Söz konusu yöntemler karar verme süreçlerine farklı fakat birbirini tamamlayan bakış açıları sunduğundan, her birinin güçlü yönlerinden yararlanılması problemin çok boyutlu olarak incelenmesine ve daha sağlam sonuçlara ulaşılmasına olanak sağlamaktadır.

Kullanılan modeller ise hem veri sağlama hem de çözüm üretme aşamasında; talep tahminleri ve mekânsal analizler ve optimizasyon modelleri olmuştur. Şarj altyapısı kurulumu üzerinde yapılan birçok araştırmada çeşitli hedefleri optimize etmek için Karışık Tam sayılı Doğrusal Programlama Yöntemini benimsemektedir. Ancak Zhang vd. (2023), yaptıkları çalışmada Karışık Tam sayılı Doğrusal Programlama modellerinin kısıtların ve değişkenlerin sayısı arttıkça hesaplama süresinin de artacağını belirterek büyük ölçekli optimizasyon problemlerini çözmek için pratik görmemişlerdir. Bu nedenle şarj istasyonu planlamasının durumunu formüle ederek bunun; NP-tam bir kombinatoryal optimizasyon problemi olduğunu kanıtlamaya çalışmışlardır. Bazı modelleme yaklaşımlarında modellemenin gerçekçi sonuçlar vermesi ya da birinin diğerine veri sunması için; birçok model veya yöntemler bir arada kullanılmıştır. Bu kapsamda Üç Aşamalı Yaklaşım- Çok Dönemli Yay Örtüsü-Yol Örtüsü Modelinde; Otoyol Trafik Yakalama Metodu (Freeway Traffic Capture Metric- FTCM) ve yolculuk mesafesi ve yükü (enerji/talep) dikkate alarak taşıma verimliliğini optimize eden tesis

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

yerlerinin seçilmesi için kullanılan Yük- Mesafe Tekniği (Load Distance Technique – LDT) beraber kullanılarak kapsamlı bir model de üretilmiştir (Chaopaisarn, vd., 2025).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 8. Şarj İstasyonları Yer Seçimine Yönelik Kullanılan Modeller

MODEL			ARAŞTIRMACILAR	
Talep Tahminleri ve Mekansal Analiz Modelleri	Tahmin Modellemeleri	K- Means Kümeleme Algoritması	Kümeleme Algoritmaları	Kuang, H., vd., (2025),
		Custom K-Means Kümeleme Algoritması		Abdullahi, vd., (2024)
		GA-k-metotları		Hu, vd., (2024).
		Grafik Evrişimsel Ağ- Graph Convolutional Network (GCN)	Sinir Ağları ve Derin Öğrenme	Kuang, H., vd., (2025), Zhao, vd., (2019)
		Kapılı Tekrarlayan Birim- Gated Recurrent Unit (GRU)		Kuang, H., vd., (2025), Zhao, vd., (2019)
		İkili Lojistik Regresyon Modeli (BLM)	Kim, H., & Kim, G. S. (2025)	
	Mekansal Analiz Modelleri	CBS Tabanlı Mekansal Analizler	Ren, Q., Sun, M., (2025), Yılmaz, İ., vd., (2024)	
		POI ve Arazi Kullanım	Kuang, H., vd., (2025), Ren, Q., Sun, M., (2025)	
		Otoyol Trafik Yakalama Metodu- Freeway Traffic Capture Metric (FTCM)	Chaopaisarn, vd., (2025)	
		Yük- Mesafe Tekniği - Load Distance Technique (LDT)	Chaopaisarn, vd., (2025)	
		Coğrafi Ağırlıklı Regresyon Modeli(GWR)	Kim, H., & Kim, G. S. (2025)	
		Yol Ağı Modellemesi	Ren, Q., Sun, M., (2025)	
Optimizasyon Modelleri	Matematiksel Programlama	Karışık Tamsayılı Doğrusal Programlama (MILP)	Ouyang, X., Xu, M. (2022), Yılmaz, İ., vd., (2024), Zhou, vd., (2020).	
		Karışık Tamsayılı Doğrusal Olmayan Programlama (MINLP)	Aljaidi, vd., (2019)	
		Kuyruk Teorisi (QT)	Zhang, vd., (2023)	
		İki Aşamalı Stokastik Programlama (SP)	MirHassani, S. A., vd. (2020)	
		İki Seviyeli Programlama (Bi-Level Model)	Gao, H., vd., (2020), Li, J., vd., (2025)	
	Sezgisel Algoritmalar	Genetik Algoritma (GA)	Pan, vd., (2020), Aljaidi, vd., (2019)	
		NSGA-II (Non-dominated Sorting Genetic Algorithm II)	Wang, vd. (2022)	
		Tavlama Benzetimi (SA)	Ouyang, X., Xu, M. (2022)	
		Gri Kurt Optimizasyonu (GWO)	Deng, M., vd., (2024)	
		Parçacık Sürü Optimizasyonu (PSO)	Li, J., vd., (2025), Aljaidi, vd., (2019)	
	Akış Odaklı / Yakıt İkmal Konum Modelleri ve Kapsama Modelleri	Yay Örtüsü- Yol Örtüsü- Arc Cover- Path Cover (AC-PC)	Chaopaisarn, vd., (2025)	
		Kapasiteli Akış Yakıt İkmal Konum Modeli (DFRLM)	MirHassani, S. A., vd. (2020), Zhou, vd., (2020)	
		Sapma- Akış Yakıt İkmal Konum Modeli (DFRLM)	Kim & Kuby, (2012)	
		Maksimum Kapsama Modeli (MCLP)	Gao, H., vd.(2020)	
	Makine Öğrenimi	Monte Carlo Simülasyonu	Yang, vd., (2025).	
		SelfSim- EV Model	Zhuge, vd., (2020)	
		Grafik Teorisi	Jia, L., vd. (2012)	

SONUÇ VE TARTIŞMA

Şarj istasyonlarının mekânsal planlama süreçlerinde kent dinamiklerinden bağımsız dağılması, ilişkili sektörler ile kentsel donatı alanlarının da mekânda kontrolsüz biçimde konumlanmasına neden olarak kentsel düzenin bozulmasına ve mekânsal adaletin sağlanamamasına neden olmaktadır. Bu kapsamda şarj istasyonlarının yakın gelecekte hala kullanılabilirliği göz önüne alındığında; kentte ister istemez yer seçen bu donatı; faaliyetlere ve fırsatlara eşit düzeyde erişimin sağlanması için erişilebilirlik düzeyleri ve belli yer seçim ölçütlerinin ortaya koyulmasıyla beraber şehir plancıları tarafından kentsel mekânda düzeni bozmadan, adil bir şekilde planlama disiplini çerçevesinde dağılımının yapılmasını gerektirmektedir (Jha, vd., 2025). Aynı zamanda çok katmanlı bir planlama meselesi olan bu konu; bulgular neticesinde karmaşık zorluklarla başa çıkmak için çok disiplinli bir yaklaşımın gerekliliğini vurgulamaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Literatür kapsamında oluşturulan yer seçim ölçütlerinin geneli kapsadığı düşünüldüğünde optimum (ortalama en uygun) konumlandırma ve kentsel alanda sürdürülebilirliğinin sağlanması için bu parametrelerin yere özgü olarak şekillenebileceği, yeni parametreler eklenip çıkarılabileceği göz önünde bulundurulmalıdır. Ancak, belli başlı parametrelerin de standart olarak ele alınması gerekmektedir. Planlama süreçlerinde bu standartların yasal bir zemine oturması hem plancılar hem karar vericiler hem de lisans sahibi şirketler tarafından bir sınırlayıcı ve kolaylaştırıcı nitelikte olabilir.

REFERENCES

Abdullahi, M. R., Lu, Q. C., Hussain, A., Tripura, S., Xu, P. C., & Wang, S. (2024). Location optimization of EV charging stations: A custom K-means cluster algorithm approach. *Energy Reports, 12*, 5367–5382 . doi:https://doi.org/10.1016/j.egyr.2024.09.075

Aljaidi , M., Aslam , N., & Kaiwartya , O. (2019). Optimal Placement and Capacity of Electric Vehicle Charging Stations in Urban Areas: Survey and Open Challenges. *2019 IEEE Jordan International Joint Conference on Electrical Engineering and Information Technology* (s. 238-243). IEEE.

Bhat, F. A., Tiwari, G. Y., & Verma, A. (2024). Preferences for public electric vehicle charging infrastructure locations: A discrete choice analysis. *Transport Policy, 149*, 177-197. doi:https://doi.org/10.1016/j.tranpol.2024.02.004

Birleştirici, A., Şalcı, M., Dikkulak, A., Güler, F., & Turhan, E. (2015). Elektrikli Araç şarj Istasyonları. İstanbul, Tuzla: Gersan Elektrik Tic. ve San. A.Ş.

Cai, Y., Zhang, J., Gu, Q., & Wang, C. (2024). An Analytical Framework for Assessing Equity of Access to Public Electric Vehicle Charging Stations: The Case of Shanghai. *Sustainability, 16*(14). doi:https://doi.org/10.3390/su16146196

Carra, M., Maternini , G., & Barabino, B. (2022). On sustainable positioning of electric vehicle charging stations in cities: An integrated approach for the selection of indicators. *Sustainable cities and society, 85*. doi:https://doi.org/10.1016/j.scs.2022.104067

Chaopaisarn, P., Maijandang, T., & Banomyong, R. (2025). Charging ahead: strategic placement of electric vehicle charging stations in Thailand. *Asia Pacific Business Review*, 1-30. doi:https://doi.org/10.1080/13602381.2025.2450481

Chiu, C. H., Lin, Y. C., & Chen, Y. J. (2025). Temporal Attention With Gated Residual Network for Stepwise Multimodal Trajectory Prediction. *IEEE Transactions on Instrumentation and Measurement, 74*. doi:10.1109/TIM.2025.3550232

Çelik, S., & Ok, Ş. (2024). Electric vehicle charging stations: Model, algorithm, simulation, location, and capacity planning.

Deng, M., Zhao, J., Huang, W., Wang, B., Liu, X., & Ou, Z. (2025). Optimal Layout Planning of Electric Vehicle Charging Stations Considering Road–Electricity Coupling Effects. *Electronics, 14*(1). doi:https://doi.org/10.3390/electronics14010135

Gao, H., Liu, K., Peng, X., & Li, C. (2020). Optimal Location of Fast Charging Stations for Mixed Traffic of Electric Vehicles and Gasoline Vehicles Subject to Elastic Demands. *Energies, 13*. doi:doi:10.3390/en13081964

Garrow, L., German, B., & Leonard, C. (2021). Urban air mobility: A comprehensive review and comparative analysis with autonomous and electric ground transportation for informing future research.

Ge, X., Shi, L., Fu, Y., Muyeen, S. M., Zhang, Z., & He, H. (2020). Data-driven spatial-temporal prediction of electric vehicle load profile considering charging behavior. *Electric Power Systems Research, 187*. doi:https://doi.org/10.1016/j.epsr.2020.106469

Gschwendtner, C., Knoeri, C., & Stephan, A. (2023). The impact of plug-in behavior on the spatial–temporal flexibility of electric vehicle charging load. *Sustainable Cities and Society, 88*. doi:https://doi.org/10.1016/j.scs.2022.104263

Guo, Y., Qian, X., Lei, T., Guo, S., & Gong, L. (2022). Modeling the preference of electric shared mobility drivers in choosing charging stations. Transportation Research Part D: Transport and Environment. *Transportation Research Part D: Transport and Environment*.

Hawaou, K. S., Kamla, V. C., Yassa, S., Romain, O., Mboula, J. E., & Bitjoka, L. (2024). Industry 4.0 and industrial workflow scheduling: A survey. *Journal of Industrial Information Integration, 38*. doi:https://doi.org/10.1016/j.jii.2023.100546

Helmus, J. R., Lees, M. H., & van den Hoed, R. (2020). A data driven typology of electric vehicle user types and charging sessions. *Transportation Research Part C: Emerging Technologies*. doi:https://doi.org/10.1016/j.trc.2020.102637

Higgins, A., Paevere, P., Gardner, J., & Quezada, G. (2012). Combining choice modelling and multi-criteria analysis for technology diffusion: An application to the uptake of electric vehicles. *Technological Forecasting and Social Change, 79*(8), 1399-1412. doi:doi:10.1016/j.techfore.2012.04.008

Hu, D., Huang, L., Liu, C., & Liu, W. (2024). Locating and sizing charging station in multi-period to promote electric vehicles adoption in urban areas. *Energy Reports, 11*, 3581-3598. doi:https://doi.org/10.1016/j.egyr.2024.03.029

Inter- American Development Bank. (2021). *Transport Elecrification Regulatory Guidelines For The Development of Charging Infrastructure.*

Jha, S., Pani, A., Puppala, H., Varghese, V., & Unnikrishnan, A. (2025). An equity-based approach for addressing inequality in electric vehicle charging infrastructure: Leaving no one behind in transport electrification. *Energy for Sustainable Development, 85*. doi:https://doi.org/10.1016/j.esd.2024.101643

Jia, L., Hu, Z., Song, Y., & Luo, Z. (2012). Optimal siting and sizing of electric vehicle charging stations. *In 2012 IEEE International Electric Vehicle Conference* (s. 1-6). IEEE. doi:10.1109/IEVC.2012.6183283

Kazempour, M., Sabboubeh, H., Moftakhari, K. P., Najaf, R., & Fusco, G. (2025). GIS-based geospatial analysis for identifying optimal locations of residential on-street electric vehicle charging points in Birmingham, UK. *Sustainable Cities and Society, 120*. doi:https://doi.org/10.1016/j.scs.2024.105988

Kim, H., & Kim, G. S. (2025). Factors Influencing Electric Vehicle Charging Station Locations and Policy Implications: Empirical Lessons from Seoul Metropolitan Area in Korea. *Sustainability, 17*(2). doi:https://doi.org/10.3390/su17020745

Kim, J. G., & Kuby, M. (2012). The Deviation-Flow Refuelling Location Model for Optimizing a Network of Refuelling Stations. *International Journal of Hydrogen Energy, 36*(6), 5406–5420. doi:https://doi.org/10.1016/j.ijhydene.2011.08.108

Kuang, H., Deng, K., You, L., & Li, J. (2025). Citywide electric vehicle charging demandprediction approachconsidering urbanregionanddynamicinfluences. *Energy, 320*. doi:https://doi.org/10.1016/j.energy.2025.135170

Li, J., Hua, Z., & Liu, C. (2025). Bi-level programming model of electric vehicle charging station based on orderly charging scheduling. *Sustainable Energy, Grids and Networks*(41). doi: https://doi.org/10.1016/j.segan.2025.101619

Lulia, V., & Loránd, S. (2022). A Brief History of Electric Vehicles. *Journal of Computer Science & Control Systems*.

Mahmoudi, E., dos Santos Barros, T. A., & Filho, E. R. (2024). Forecasting urban electric vehicle charging power demand based on travel trajectory simulation in the realistic urban street network. *Energy Reports, 11*, 4254-4276. doi:https://doi.org/10.1016/j.egyr.2024.04.005

Makaremi, S. (2024). Policy interventions and urban characteristics in modeling electric vehicle charging infrastructure utilization.

MirHassani, S., Khaleghi, A., & Hooshmand, F. (2020). Two-stage stochastic programming model to locate capacitated EV-charging stations in urban areas under demand uncertainty.

Morocho-Chicaiza, W., Barragán-Escandón, A., Zalamea-León, E., Ochoa-Correa, D., Terrados-Cepeda, J., & Serrano-Guerrero, X. (2024). Identifying locations for electric vehicle charging stations in urban areas through the application of multicriteria techniques. *Energy Reports, 12*, 1794-1809.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Ouyang, X., & Xu, M. (2022). Promoting green transportation under the belt and Road Initiative: Locating charging stations considering electric vehicle users' travel behavior. *Transport Policy, 116*, 58-80. doi:https://doi.org/10.1016/j.tranpol.2021.11.023

Ren, Q., & Sun, M. (2025). Predicting the spatial demand for public charging stations for EVs using multi-source big data: an example from jinan city, china. *Scientific Reports, 15*(1).

Santini, D. (2011). Electric vehicle waves of history: lessons learned about market deployment of electric vehicles. *In Electric vehicles-The benefits and barriers*.

Sica, L., Carboni, A., Deflorio, F., & Botta, C. (2025). Electric vehicle recharging options in urban areas: Discrete choice modeling to estimate user preference. *Sustainable Cities and Society*.

Skaloumpakas, P., Kafouros, A., Spiliotis, E., Sarmas, E., & Marinakis, V. (2025). Optimizing electric vehicle charging station placement in Greek municipalities through multi-criteria decision analysis. *Sustainable Energy, Grids and Networks, 41*. doi:https://doi.org/10.1016/j.segan.2024.101589

T.C. Ulaştırma ve Altyapı Bakanlığı. (2023). *Elektrikli Araç Şarj İstasyonlarının Yer Seçiminin Belirlenmesi ve Simülasyon Programının Oluşturulması.* (Erişim Tarihi: 13. 06. 2025)

Tekeli, İ. (2021). Kentiçi Ulaşıma Öncelikle Stratejik Bir Yaklaşımın Gerekliliği Üzerine. *İdealkent, 12*(34), 1029-1048. doi:10.31198/idealkent.1053286

ten Dam, C. D., Bahamonde-Birke, F. J., Ettema, D., Kramer, G. J., & Koning, V. (2024). Car energy efficiency and emissions in the built environment. *Transportation*, 1-28. doi:https://doi.org/10.1007/s11116-024-10491-8

Wong, W. (2020). *Medium*. Aralık 28, 2025 tarihinde TDS Arşivi: https://medium.com/data-science/what-is-gumbel-softmax-7f6d9cdcb90e adresinden alındı

Xu, P., Wang, X., & Li, Z. (2025). Impact and optimization of vehicle charging scheduling on regional clean energy power supply network management. *Energy Informatics, 8*(1). doi:https://doi.org/10.1186/s42162-025-00476-x

Yang, X., Yun, J., Zhou, S., Lie, T. T., Han, J., Xu, X., . . . Ge, Z. (2025). A spatiotemporal distribution prediction model for electric vehicles charging load in transportation power coupled transportation power coupled. *Scientific Reports, 15*(1).

Yılmaz, İ., Özceylan, E., & Ali, S. S. (2024). Enhancing electric vehicles charging stations decisions by GIS-based MACBETH andlinguistic evaluations through mixed-integer novel model. *Benchmarking: An International Journal*.

Yu, G., Ye, X., Xia, X., & Chen, Y. (2024). Digital twin enabled transition towards the smart electric vehicle charging infrastructure: A review. *Sustainable Cities and Society, 108*. doi:https://doi.org/10.1016/j.scs.2024.105479

Zhang, Y., Hua, Y., Kang, A., He, J., Jia, M., & Chiang, Y. Y. (2023). Optimalandefficient planningofchargingstations for electric vehicles in urbanareas: formulation, complexity and solutions. *Expert Systems With Applications, 230*. doi:https://doi.org/10.1016/j.eswa.2023.120442

Zhao, L., Song, Y., Zhang, C., Liu, Y., Wang, P., & Lin, T. (2019). T-GCN: A temporal graph convolutional network for traffic prediction. *IEEE transactions on intelligent transportation systems, 21*(9), 3848-3858.

Zhuge, C., Wei, B., Shao, C., Shan, Y., & Dong, C. (2020). The role of the license plate lottery policy in the adoption of Electric Vehicles: A case study of Beijing. *Energy Policy, 139*. doi:https://doi.org/10.1016/j.enpol.2020.111328

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FREE VIBRATION ANALYSIS OF STEEL CANTILEVER BEAM CONSIDERING TEMPERATURE-DEPENDENT MATERIAL PROPERTIES

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ABSTRACT

Structural beam components widely used in engineering systems are frequently subjected to dynamic and thermal loading conditions, which significantly influence their vibration behaviour and structural reliability. This study investigates the modal characteristics of a structural steel cantilever beam using analytical modelling and finite element analysis. The analytical formulation based on Euler–Bernoulli beam theory was employed to obtain reference solutions for natural frequency estimation. Finite element modal analysis was performed using ANSYS Workbench and the LS-DYNA implicit eigenvalue solver to determine the first three vibration modes and corresponding natural frequencies. The numerical results obtained from both software platforms demonstrated strong agreement, validating the developed finite element modelling approach. In addition, temperature-dependent material properties were incorporated to evaluate the influence of thermal loading on dynamic behaviour. The results indicate that natural frequencies decrease consistently with increasing temperature due to stiffness degradation of structural steel. Normalized frequency analysis revealed that thermal effects produce proportional frequency reduction across different vibration modes. The findings demonstrate that finite element modal analysis provides a reliable tool for vibration assessment of beam structures exposed to elevated temperature environments. The proposed modelling approach can support engineering design and structural integrity evaluation when experimental modal testing is not feasible.

Keywords: Steel Cantilever Beam, Free Vibration, Modal Analysis, Euler–Bernoulli Beam Theory, Finite Element Analysis, Thermal Effects

References

Rao, S. S. (2011). *Mechanical vibrations* (5th ed.). Prentice Hall.

Bathe, K. J., Walczak, J., & Zhang, H. (1993). Some recent advances for practical finite element analysis. *Computers & Structures*, 47(4–5), 511–521.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Garcia-Barruetabena, J., & Cortes, F. (2018). Finite element analysis of the vibrational response of an adhesively bonded beam. *Engineering Structures*, 171, 94–104.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EVALUATION OF STREET REHABILITATION APPLICATIONS IN THE HISTORIC MIDYAT SYRIAC BAZAAR IN TERMS OF SUSTAINABLE CONSERVATION

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ABSTRACT

The preservation of historic urban fabrics has evolved beyond being a process focused solely on improving the physical environment; it now requires a holistic approach that addresses social, cultural, and economic components together. In this context, historic bazaars stand out as urban spaces that play an important role in the formation of urban identity, the continuity of social memory, and the intergenerational transmission of cultural heritage. This study aims to evaluate the spatial, social, and cultural impacts of street revitalization practices in a multidimensional manner by examining the Historic Midyat Syriac Bazaar in the Midyat district of Mardin within the framework of a sustainable conservation approach.

The research was conducted using a comprehensive approach. In the first phase, national and international literature on sustainable conservation, street revitalization, and historical market concepts was reviewed. In the second phase, the historical development and spatial and architectural characteristics of the market were analyzed using archival documents, plans, and visual materials. Field studies included site observations, photographic documentation, semi-structured interviews, and surveys of local merchants and visitors. In addition, map-based spatial analyses were used to evaluate functional distribution, facade arrangements, pedestrian mobility, and usage intensity.

In conclusion, it is evident that the street rehabilitation projects carried out in the Historic Midyat Syriac Bazaar did not sufficiently take into account the multi-layered cultural structure of the area and the forms of interaction with the social structure. It is evident that limiting conservation practices in the Historic Midyat Syriac Bazaar to physical interventions alone weakens the living cultural identity of the bazaar and that sustainable conservation is only possible through holistic approaches that center Syriac local merchants and users.

Keywords: Sustainable Conservation, Street Rehabilitation, Historic Midyat Syriac Bazaar

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tarihi Midyat Süryani Çarşısı'ndaki Sokak Sağlıklaştırma Uygulamalarının Sürdürülebilir Koruma Açısından Değerlendirilmesi

ÖZET

Tarihi kent dokularının korunması, günümüzde yalnızca fiziksel çevrenin iyileştirilmesine odaklanan bir süreç olmaktan çıkmış; sosyal, kültürel ve ekonomik bileşenleri birlikte ele alan bütüncül bir yaklaşımı gerekli kılmıştır. Bu bağlamda tarihsel çarşılar, kent kimliğinin oluşumunda, toplumsal belleğin sürekliliğinde ve kültürel mirasın kuşaklar arası aktarımında önemli rol üstlenen kentsel mekânlar olarak öne çıkmaktadır. Bu çalışma, Mardin'in Midyat ilçesinde yer alan Tarihi Midyat Süryani Çarşısı'nı sürdürülebilir koruma yaklaşımı çerçevesinde ele alarak, sokak sağlıklaştırma uygulamalarının mekânsal, sosyal ve kültürel etkilerini çok boyutlu biçimde değerlendirmeyi amaçlamaktadır.

Araştırma, bütüncül bir yöntem doğrultusunda yürütülmüştür. İlk aşamada sürdürülebilir koruma, sokak sağlıklaştırma ve tarihsel çarşı kavramlarına ilişkin ulusal ve uluslararası literatür incelenmiştir. İkinci aşamada, çarşının tarihsel gelişimi ile mekânsal ve mimari özellikleri arşiv belgeleri, planlar ve görsel materyaller üzerinden analiz edilmiştir. Alan çalışmaları kapsamında saha gözlemleri yapılmış, fotoğrafik belgeleme gerçekleştirilmiş ve yarı yapılandırılmış görüşmeler ile yerel esnaf ve ziyaretçilere yönelik anketler uygulanmıştır. Ayrıca harita tabanlı mekânsal analizler aracılığıyla işlevsel dağılım, cephe düzenlemeleri, yaya hareketliliği ve kullanım yoğunluğu değerlendirilmiştir.

Sonuç olarak, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamalarının, alanın çok katmanlı kültürel yapısını ve toplumsal yapı ile etkileşim biçimlerini yeterince dikkate almadığı görülmektedir. Tarihi Midyat Süryani Çarşısı'nda koruma uygulamalarının yalnızca fiziksel düzenlemelerle sınırlı kalmasının, çarşının yaşayan kültürel kimliğini zayıflattığını ve sürdürülebilir korumanın ancak Süryani yerel esnafı ve kullanıcılarını merkeze alan bütüncül yaklaşımlarla mümkün olabileceğini ortaya koymaktadır.

Anahtar Kelimeler: Sürdürülebilir Koruma, Sokak Sağlıklaştırma, Tarihi Midyat Süryani Çarşısı

GİRİŞ

Tarihi kentsel dokuların korunması, yalnızca yapısal iyileştirmelerle sınırlı kalamayacak; mekânsal süreklilik ile birlikte sosyal ve ekonomik sürdürülebilirliği de kapsayan kapsamlı bir koruma anlayışını zorunlu kılmaktadır. Özellikle küreselleşme, turizm baskısı ve hızlı kentleşme süreçleri, tarihi kent merkezlerinde yer alan özgün mekânların işlevsel ve mekânsal dönüşümünü hızlandırmakta; bu durum, koruma yaklaşımlarının yeniden değerlendirilmesini gerekli kılmaktadır. Bu bağlamda tarihi çarşılar, yalnızca ticari faaliyetlerin yürütüldüğü alanlar değil; kent kimliğinin oluşumunda, toplumsal belleğin sürekliliğinde ve kültürel mirasın kuşaklar arası aktarımında önemli rol oynayan yaşayan kentsel mekânlar olarak öne çıkmaktadır.

Tarihi çarşılar, barındırdıkları üretim sistemleri, zanaat birikimi, toplumsal ilişkiler ağı ve mekânsal kurgularıyla kentsel yaşamın sosyo-kültürel karakterini doğrudan ortaya koyan özgün alanlardır. Bu mekânlar, gündelik hayatın devam ettiği, farklı toplulukların etkileşim kurduğu ve kültürel aktarımın süreklilik kazandığı dinamik ortamlar olarak, somut ve somut olmayan miras değerlerinin iç içe geçtiği alanlar niteliği taşımaktadır. Bu bağlamda, tarihi çarşıların korunması yalnızca yapı ölçeğinde gerçekleştirilen fiziksel iyileştirmelerle sınırlandırılamaz; koruma sürecinin sosyal örgütlenme biçimleri, ekonomik sürdürülebilirlik koşulları ve kullanıcıların mekânla kurduğu çok katmanlı ilişkiler dikkate alınarak bütüncül bir perspektifle ele alınması gerekmektedir (UNESCO 2011; ICOMOS 2013).

Türkiye'de tarihi kentsel alanlarda yürütülen koruma uygulamaları değerlendirildiğinde, son dönemde özellikle "sokak sağlıklaştırma" projelerinin belirgin biçimde yaygınlık kazandığı gözlemlenmektedir. Bu projeler çoğunlukla cephe düzenlemeleri, malzeme yenilemeleri ve kamusal alan iyileştirmeleri gibi fiziksel müdahalelere odaklanmaktadır. Ancak literatürde, bu tür uygulamaların tarihi alanların çok katmanlı yapısını yeterince dikkate almadığı, sosyal ve kültürel boyutları ikincil planda bıraktığı yönünde eleştiriler bulunmaktadır (Ahunbay 2011; Eraslan and Koç 2022). Bu durum, sokak sağlıklaştırma projelerinin sürdürülebilir koruma bağlamında yeniden değerlendirilmesini gerekli kılmaktadır.

Bu çalışmanın odaklandığı Midyat ilçesinde yer alan Tarihi Süryani Çarşısı, Mardin'in çok katmanlı kültürel yapısını yansıtan özgün kentsel miras alanlarından biridir. Yüzyıllar boyunca Süryani topluluğunun üretim, ticaret ve sosyal yaşam pratiklerine ev sahipliği yapan çarşı; taş işçiliği, geleneksel dükkân tipolojileri ve zanaatkârlık faaliyetleriyle kentin kültürel kimliğinin önemli bir bileşenini oluşturmaktadır. Günümüzde ise turizm odaklı dönüşüm süreçleri ve uygulanan sokak sağlıklaştırma projeleri, çarşının mekânsal ve sosyal yapısında belirgin değişimlere yol açmaktadır.

Bu bağlamda çalışma, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamalarını sürdürülebilir koruma yaklaşımı çerçevesinde değerlendirmeyi amaçlamaktadır. Araştırma, çarşıda uygulanan fiziksel müdahalelerin mekânsal bütünlük, kültürel kimlik ve sosyal sürdürülebilirlik üzerindeki etkilerini çok boyutlu bir bakış açısıyla ele almakta; koruma-kullanma dengesi ve yaşayan miras kavramları üzerinden bir tartışma sunmaktadır. Böylece çalışma, tarihi çarşıların korunmasına yönelik mevcut yaklaşımların sınırlarını ortaya koymayı ve bütüncül koruma stratejilerine katkı sağlamayı hedeflemektedir.

MATERYAL VE YÖNTEM

Bu çalışma, Tarihi Midyat Süryani Çarşısı'nda uygulanan sokak sağlıklaştırma müdahalelerinin sürdürülebilir koruma ilkeleri bağlamında değerlendirilmesini amaçlayan nitel ağırlıklı bir araştırma olarak kurgulanmıştır. Araştırma sürecinde, çok katmanlı bir kentsel miras alanı olan çarşının

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

mekânsal, sosyal ve kültürel bileşenlerinin birlikte ele alınabilmesi için farklı veri toplama ve analiz yöntemleri bir arada kullanılmıştır.

Araştırmanın ilk aşamasında, sürdürülebilir koruma, tarihi çarşılar, sokak sağlıklaştırma uygulamaları ve tarihi kentsel peyzaj kavramları üzerine ulusal ve uluslararası literatür taraması gerçekleştirilmiştir. Bu kapsamda UNESCO ve ICOMOS tarafından yayımlanan uluslararası koruma sözleşmeleri ve ilke kararları incelenmiş; Türkiye'de tarihi kent dokularında uygulanan sokak sağlıklaştırma projelerine ilişkin akademik çalışmalar değerlendirilmiştir (UNESCO, 2011; ICOMOS, 2013; Ahunbay, 2011). Literatür taraması, çalışmanın kuramsal çerçevesinin oluşturulmasında ve Midyat Süryani Çarşısı'nın mevcut durumunun bu çerçeve içerisinde değerlendirilmesinde temel bir referans sağlamıştır.

İkinci aşamada, Süryani Çarşısı'nın tarihsel gelişimi ile mekânsal ve mimari özellikleri analiz edilmiştir. Bu analiz kapsamında arşiv belgeleri, eski haritalar, planlar, fotoğraflar ve yazılı kaynaklar kullanılarak çarşının tarihsel süreç içerisindeki dönüşümü ortaya konmuştur. Çarşının sokak dokusu, yapılaşma biçimi, dükkân tipolojileri, cephe karakteristikleri ve kullanılan geleneksel yapı malzemeleri değerlendirilerek mekânsal bütünlüğü incelenmiştir. Bu süreçte çarşının güncel fiziksel durumu; onarım izleri, işlev değişiklikleri ve mekânsal müdahaleler bağlamında ele alınmıştır.

Arazi çalışmaları, araştırmanın önemli bir bölümünü oluşturmaktadır. Bu kapsamda, çalışma alanında yerinde gözlemler yapılmış, fotoğrafik belgeleme yöntemiyle çarşının mevcut durumu kayıt altına alınmıştır. Gözlemler sırasında çarşıdaki kullanım biçimleri, yaya hareketliliği, mekânsal yoğunluklar ve kamusal alan kullanımları değerlendirilmiştir. Ayrıca sokak sağlıklaştırma kapsamında gerçekleştirilen fiziksel müdahalelerin çarşının özgün dokusu üzerindeki etkileri yerinde incelenmiştir.

Araştırmada, çarşının sosyal ve kültürel boyutunun genel hatlarıyla ortaya konabilmesi amacıyla yarı yapılandırılmış görüşmeler ve anket çalışmaları da kullanılmıştır. Bu çalışmalar, yerel esnaf, kullanıcılar, Süryani vatandaşlarla ve ziyaretçilerle gerçekleştirilmiş; ancak bildirinin kapsamı doğrultusunda elde edilen veriler ayrıntılı istatistiksel analizler yerine genel eğilimleri yansıtacak biçimde değerlendirilmiştir. Gerçekleştirilen görüşme ve anket çalışmaları, çarşının gündelik kullanım biçimlerinin, geleneksel üretim süreçlerinin ve sokak sağlıklaştırma uygulamalarına yönelik algıların değerlendirilmesine olanak sağlamıştır.

Çalışma kapsamında çarşının mekânsal kurgusunu analiz edebilmek amacıyla harita temelli değerlendirme yöntemlerinden yararlanılmıştır. Bu doğrultuda, işlevsel dağılım, cephe karakteri ve kullanım yoğunlukları bütüncül bir çerçevede ele alınmış; sokak sağlıklaştırma uygulamalarının mekânsal süreklilik ve alan bütünlüğü üzerindeki etkileri incelenmiştir. Elde edilen veriler, literatürde incelenen benzer tarihsel çarşı örnekleriyle karşılaştırmalı bir perspektif içinde değerlendirilmiştir.

Son aşamada, tüm veriler sürdürülebilir koruma yaklaşımı çerçevesinde bütüncül bir değerlendirmeye tabi tutulmuştur. Fiziksel, sosyal ve kültürel bileşenler arasındaki ilişkiler analiz edilerek, sokak sağlıklaştırma uygulamalarının Tarihi Midyat Süryani Çarşısı üzerindeki etkileri ortaya konmuştur. Bu

yöntemsel yaklaşım, çalışmanın sonuç ve öneriler bölümünde geliştirilen koruma stratejilerinin kuramsal ve uygulamaya dönük bir zemine oturtulmasını sağlamıştır.

BULGULAR

Bu bölümde, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamalarının mekânsal, işlevsel ve sosyo-kültürel etkilerine ilişkin bulgular ele alınmaktadır. Bulgular, alan çalışmaları, gözlemler, görsel belgeleme ve genel değerlendirmeler doğrultusunda sürdürülebilir koruma yaklaşımı çerçevesinde yorumlanmıştır. Alan incelemeleri, sokak sağlıklaştırma uygulamalarının çarşının fiziksel görünümünde belirli ölçüde iyileşme sağladığını göstermektedir. Özellikle cephe düzenlemeleri, zemin kaplamaları ve altyapı müdahaleleri, mekânsal algının daha düzenli ve bütüncül hâle gelmesine katkı sunmuştur. Geleneksel taş dokunun görünürlüğünün artırılması, çarşının tarihsel kimliğinin okunabilirliğini güçlendiren olumlu bir unsur olarak öne çıkmaktadır.

Bununla birlikte, bazı uygulamaların çarşının özgün mimari karakteri ile tam anlamıyla uyumlu olmadığı gözlemlenmiştir. Cephelerde kullanılan çağdaş malzemeler, özgün detayların sadeleştirilmesi ve bazı yapı elemanlarının standartlaştırılması, tarihi dokunun katmanlı yapısının algılanmasını zayıflatmaktadır. Sokak ölçeğinde yapılan düzenlemelerin tüm çarşı dokusunu kapsayacak şekilde bütüncül bir planlama yaklaşımıyla ele alınmadığı; müdahalelerin yer yer parça parça kaldığı tespit edilmiştir.

Sokak sağlıklaştırma uygulamaları sonrasında çarşıdaki işlevsel dağılımda belirli değişimler meydana gelmiştir. Geleneksel zanaat üretimine dayalı dükkânların bir kısmı varlığını sürdürmekle birlikte, turizme yönelik ticari birimlerin sayısında artış gözlemlenmektedir. Hediyelik eşya satışları ile kafe ve restoran gibi işletmeler, çarşının güncel ekonomik yapısında daha belirgin bir yer edinmiştir. Bu dönüşüm, çarşının ekonomik canlılığını artıran bir unsur olarak değerlendirilebilse de, geleneksel üretim biçimlerinin geri planda kalması kültürel süreklilik açısından risk oluşturmaktadır. İşlev değişimleri mekânların kullanım biçimlerini de etkilemiş; bazı sokaklarda yoğunluk artarken, geleneksel üretimin sürdürüldüğü alanlarda kullanımın azaldığı gözlemlenmiştir. Bu durum, sokak sağlıklaştırma uygulamalarının yalnızca fiziksel düzenlemelerle sınırlı kalmasının işlevsel ve kültürel dengeleri yeterince gözetmediğini ortaya koymaktadır.

Tarihi Midyat Süryani Çarşısı, tarih boyunca yalnızca ticari bir merkez değil, aynı zamanda sosyal etkileşimlerin ve kültürel üretimin önemli bir mekânı olmuştur. Alan çalışmaları, sokak sağlıklaştırma uygulamalarının çarşının sosyal kullanımını kısmen dönüştürdüğünü göstermektedir. Fiziksel düzenlemeler, çarşıyı ziyaret eden kullanıcı sayısını artırmış; özellikle turistik ziyaretlerin yoğunlaştığı dönemlerde sosyal kullanım belirgin hâle gelmiştir. Ancak bu artış, yerel esnaf ve geleneksel kullanıcı gruplarının çarşıyla kurduğu ilişki biçimini sınırlı ölçüde desteklemektedir. Süryani zanaatkârların üretim biçimlerinin görünürlüğü azalırken, çarşı daha çok tüketim odaklı bir mekâna dönüşme eğilimi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

göstermektedir. Bu durum, çarşının yaşayan kültürel miras niteliğini zayıflatan bir unsur olarak değerlendirilmektedir.

Elde edilen bulgular, Tarihi Midyat Süryani Çarşısı'nda uygulanan sokak sağlıklaştırma projelerinin fiziksel iyileştirmeler sağlamakla birlikte sürdürülebilir koruma ilkelerini bütüncül bir biçimde ele almadığını göstermektedir. Müdahalelerin büyük ölçüde görsel düzenleme ve fiziki onarım odaklı olduğu; sosyal yapı, somut olmayan kültürel miras unsurları ve yerel aktörlerin sürece katılımının sınırlı kaldığı anlaşılmaktadır. Sürdürülebilir koruma yaklaşımı açısından değerlendirildiğinde, çarşının yalnızca korunması gereken bir fiziksel mekân değil; üretim, etkileşim ve kültürel aktarımın devam ettiği yaşayan bir alan olduğu görülmektedir. Bu nedenle mevcut sokak sağlıklaştırma uygulamalarının, çarşının çok katmanlı yapısını destekleyecek biçimde yeniden ele alınması gerektiği ortaya çıkmaktadır.

TARTIŞMA

Bu çalışmada elde edilen bulgular, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamalarının sürdürülebilir koruma yaklaşımı açısından çok boyutlu olarak ele alınması gerektiğini ortaya koymaktadır. Bulgular, çarşıda yapılan müdahalelerin büyük ölçüde fiziksel iyileştirmelere odaklandığını; ancak sosyal, kültürel ve ekonomik bileşenlerin yeterince bütünleştirilemediğini göstermektedir. Bu durum, literatürde sürdürülebilir koruma anlayışının temel ilkeleriyle karşılaştırıldığında önemli bir tartışma alanı oluşturmaktadır.

Güncel koruma yaklaşımları, tarihi çevrelerin yalnızca fiziksel varlıklar olarak değil, yaşayan sosyal ve kültürel sistemler olarak ele alınması gerektiğini vurgulamaktadır (Ahunbay, 2011; UNESCO, 2011). Bu bağlamda sokak sağlıklaştırma uygulamalarının, yapı cepheleri ve zemin düzenlemeleriyle sınırlı kalması, tarihi çarşıların sahip olduğu çok katmanlı kimliği korumada yetersiz kalmaktadır. Midyat Süryani Çarşısı örneğinde de benzer bir durum gözlemlenmiş; müdahalelerin estetik iyileştirme amacı taşımasına karşın, çarşının kültürel üretim pratiklerini destekleyecek mekanizmaların sınırlı olduğu görülmüştür.

Literatürde, geleneksel çarşıların kentsel hafızanın önemli taşıyıcıları olduğu ve bu alanlarda gerçekleştirilen müdahalelerin toplumsal bellekle doğrudan ilişkili olduğu belirtilmektedir (Kuban, 1993; Eldem, 1984). Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamaları, mekânsal okunabilirliği artırsa da, çarşının tarihsel katmanlarının ve geleneksel zanaat üretiminin gündelik yaşamdaki görünürlüğünü sınırlı ölçüde yansıtmaktadır. Bu durum, çarşının kültürel sürekliliğinin yalnızca fiziksel koruma ile sağlanamayacağını göstermektedir.

Sürdürülebilir koruma literatürü, yerel toplulukların ve kullanıcıların sürece aktif katılımını temel bir ilke olarak tanımlamaktadır (ICOMOS, 2013). Ancak Midyat Süryani Çarşısı örneğinde, sokak sağlıklaştırma süreçlerinde yerel esnafın ve özellikle Süryani zanaatkârların karar alma mekanizmalarına yeterince dahil edilmediği görülmektedir. Bu durum, uygulamaların yerel

ihtiyaçlarla tam anlamıyla örtüşmemesine ve mekânsal müdahalelerin sosyal karşılığının zayıf kalmasına neden olmaktadır.

Benzer biçimde, turizmin tarihi çarşılar üzerindeki etkisi literatürde sıklıkla tartışılan bir konudur. Turizm odaklı dönüşümlerin, ekonomik canlılık sağlarken geleneksel üretim biçimlerini ve yerel yaşam pratiklerini baskılayabildiği belirtilmektedir (Ashworth & Tunbridge, 2000; Yıldırım, 2020). Midyat Süryani Çarşısı'nda da turistik işlevlerin artması, geleneksel zanaatların mekânsal ve işlevsel olarak geri plana itilmesine yol açmaktadır. Bu durum, sokak sağlıklaştırma uygulamalarının turizm ve koruma arasındaki dengeyi yeterince gözetmediğini ortaya koymaktadır.

Çalışmanın bulguları, sokak sağlıklaştırma uygulamalarının koruma kavramını dar bir fiziksel iyileştirme çerçevesinde ele aldığını göstermektedir. Oysa sürdürülebilir koruma anlayışı, fiziksel çevreyle birlikte sosyal ilişkilerin, kültürel pratiklerin ve ekonomik yapının sürekliliğini hedeflemektedir. Midyat Süryani Çarşısı örneğinde, bu bileşenler arasındaki ilişkinin zayıf kalması, çarşının yaşayan kültürel miras niteliğini tehdit eden bir unsur olarak değerlendirilmektedir.

Bu bağlamda, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamalarının, bütüncül bir koruma stratejisi çerçevesinde yeniden ele alınması gerektiği söylenebilir. Fiziksel müdahalelerin, çarşının sosyal ve kültürel dokusunu destekleyecek politikalarla birlikte yürütülmesi, sürdürülebilir korumanın temel koşulu olarak öne çıkmaktadır.

SONUÇ VE ÖNERİLER

Bu çalışma, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamalarını sürdürülebilir koruma yaklaşımı çerçevesinde ele alarak, müdahalelerin mekânsal, sosyal ve kültürel etkilerini bütüncül bir bakış açısıyla değerlendirmeyi amaçlamıştır. Elde edilen bulgular, çarşıda yürütülen koruma ve iyileştirme çalışmalarının büyük ölçüde fiziksel çevreye odaklandığını; buna karşın, alanın çok katmanlı kültürel yapısı ile sosyal ve ekonomik dinamiklerinin yeterince dikkate alınmadığını ortaya koymaktadır.

Tarihi çarşılar, yalnızca ticari işlevleriyle değil, aynı zamanda kentsel kimliğin oluşumunda, toplumsal belleğin sürekliliğinde ve kültürel mirasın kuşaklar arası aktarımında önemli rol oynayan mekânlardır (Kuban, 1993; Eldem, 1984). Midyat Süryani Çarşısı da bu bağlamda, Süryani topluluğunun zanaatkârlık geleneği, üretim kültürü ve mekânsal organizasyonu ile kentin tarihsel kimliğinin taşıyıcılarından biridir. Ancak çalışmanın sonuçları, sokak sağlıklaştırma uygulamalarının bu özgün kimliği desteklemekten ziyade, çoğunlukla görsel düzenleme ve fiziksel yenileme düzeyinde kaldığını göstermektedir.

UNESCO'nun Tarihi Kentsel Peyzaj (HUL) yaklaşımı, kültürel miras alanlarının yalnızca yapı ölçeğinde değil; sosyal ilişkiler, kültürel pratikler ve ekonomik süreçlerle birlikte ele alınmasını önermektedir (UNESCO, 2011). Midyat Süryani Çarşısı örneğinde ise bu bütüncül yaklaşımın uygulamalara yeterince yansımadığı görülmektedir. Fiziksel çevrede yapılan düzenlemeler, mekânsal

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

algıyı iyileştirmekle birlikte, çarşının yaşayan kültürel miras niteliğini güçlendirecek sosyal ve kültürel stratejilerle desteklenmemiştir.

Çalışma kapsamında yapılan değerlendirmeler, sürdürülebilir korumanın yalnızca fiziksel dokuya yönelik müdahalelerle sağlanamayacağını; yerel kullanıcıların, özellikle de Süryani esnaf ve zanaatkârların sürece aktif olarak dâhil edilmesinin zorunlu olduğunu ortaya koymaktadır. ICOMOS'un kültürel miras yönetimine ilişkin ilkeleri de, yerel toplulukların karar alma süreçlerine katılımını korumanın temel bileşenlerinden biri olarak tanımlamaktadır (ICOMOS, 2013). Bu bağlamda, Midyat Süryani Çarşısı'nda uygulanacak koruma ve sağlıklaştırma projelerinin, katılımcı bir yönetim modeli çerçevesinde yeniden ele alınması gerekmektedir.

Ayrıca, çarşı alanında artan turistik faaliyetlerin, geleneksel zanaat üretimi ve yerel ekonomik yapı üzerindeki etkileri dikkatle değerlendirilmelidir. Turizmin, kültürel miras alanları için ekonomik bir fırsat sunmakla birlikte, kontrolsüz geliştiğinde yerel kimliği zayıflatıcı bir etki yaratabileceği literatürde vurgulanmaktadır (Ashworth and Tunbridge, 2000; Yıldırım, 2020). Bu nedenle, sokak sağlıklaştırma uygulamalarının turizm odaklı beklentilerle değil, kültürel sürekliliği önceleyen bir anlayışla planlanması önem taşımaktadır.

Bu çalışmadan elde edilen sonuçlar doğrultusunda aşağıdaki öneriler geliştirilebilir:

- Sokak sağlıklaştırma uygulamaları, yalnızca cephe ve zemin düzenlemeleriyle sınırlı kalmamalı; çarşının sosyal ve kültürel yapısını destekleyen bütüncül bir koruma stratejisiyle ele alınmalıdır.
- Süryani zanaatkârlık geleneğinin korunması ve yaşatılması amacıyla, üretim mekânlarının sürekliliğini destekleyen mekânsal ve yönetsel politikalar geliştirilmelidir.
- Yerel esnaf, kullanıcılar ve sivil toplum kuruluşlarının sürece aktif katılımını sağlayacak katılımcı koruma modelleri oluşturulmalıdır.
- Turizm ve koruma arasındaki denge gözetilerek, çarşının özgün kimliğini zedelemeyecek planlama ve tasarım kararları alınmalıdır.
- Sokak sağlıklaştırma projeleri, kısa vadeli estetik iyileştirmeler yerine, uzun vadeli sürdürülebilirlik hedefleri doğrultusunda değerlendirilmelidir.

Sonuç olarak, Tarihi Midyat Süryani Çarşısı'nda gerçekleştirilen sokak sağlıklaştırma uygulamaları, sürdürülebilir koruma yaklaşımı açısından yeniden ele alınması gereken önemli bir örnek sunmaktadır. Bu çalışma, Midyat özelinde elde edilen bulgular aracılığıyla, Türkiye'deki diğer tarihi çarşı alanları için de yol gösterici nitelikte bir değerlendirme ortaya koymaktadır. Fiziksel, sosyal ve kültürel boyutları birlikte ele alan bütüncül koruma yaklaşımlarının benimsenmesi, tarihi çarşıların yaşayan kültürel miras alanları olarak geleceğe aktarılabilmesi açısından temel bir gereklilik olarak değerlendirilmektedir.

TEŞEKKÜR

Tez çalışmamın her sürecinde desteğini ve ilgisini benden esirgemeyen, bilgi ve tecrübeleriyle bana yol gösteren sayın hocam Dr. Öğr. Özge BOZGEYİK'e çok teşekkür ederim.

KAYNAKLAR

Ahunbay, Z. 2011. Tarihi çevre koruma ve restorasyon. İstanbul: Yapı Endüstri Merkezi (YEM) Yayınları. (Koruma kuramı ve uygulamaları üzerine temel eser.)

Ashworth GJ and Tunbridge JE 2000. The tourist-historic city: Retrospect and prospect of managing the heritage city. Oxford: Elsevier Butterworth-Heinemann.

Eldem SH 1984. Türk evi plan tipleri. İstanbul: İstanbul Teknik Üniversitesi Mimarlık Fakültesi Yayınları.

Eraslan, M. H. and Koç, İ. 2022. Tarihi kent dokularının korunmasında sokak sağlıklaştırmasının yeri. Kent Akademisi, 15(D.Ü. 2. Uluslararası Mimarlık Sempozyumu Özel Sayısı), 208–224.

ICOMOS 2013. ICOMOS Türkiye Mimari Miras Koruma Bildirgesi, ICOMOS Türkiye Milli Komitesi. (Ulusal mimari miras ve koruma ilkeleri bildirgesi.)

Kuban D 1993. İstanbul anıtları ve kent tarihi üzerine denemeler. İstanbul: Tarih Vakfı Yurt Yayınları.

UNESCO 2011. Recommendation on the Historic Urban Landscape, UNESCO World Heritage Centre, Paris. (Uluslararası tarihî kentsel peyzaj koruma çerçevesi ve sürdürülebilir koruma yaklaşımı.)

Yıldırım A 2020. Turizm odaklı dönüşüm süreçlerinin tarihi kent merkezleri üzerindeki etkileri. Megaron, 15(3): 345-358.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

LEARNING-GATED ROBUST ESTIMATION AND SAFETY-PRESERVING CONTROL FOR CYBER–PHYSICAL ATTACK RESILIENCE IN CONNECTED WHITE APPLIANCES

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ABSTRACT

Connected white appliances, such as washers, dryers, dishwashers, refrigerators, ovens, and HVAC-like household systems, increasingly operate as cyber–physical systems: embedded controllers close real-time control loops using sensor feedback, while connectivity supports remote diagnostics, feature updates, and fleet analytics. This connectivity also expands the attack surface. Integrity attacks such as sensor spoofing, replay, and command tampering can silently distort feedback signals, induce unsafe operating conditions, or trigger costly service actions. Building on the secure control literature that formalizes deception attacks on networked control systems, this article presents a learning-augmented security framework that connects deep anomaly detection to robust state estimation and safety-preserving supervisory control. The approach assigns real-time trust to heterogeneous appliance telemetry, uses this trust to gate the incorporation of measurements into a robust estimator, and switches to certified-safe operation policies when attack likelihood increases. The central research goal is to enable measurable security improvements while maintaining control-theoretic guarantees on safety and operational constraints, thereby closing the gap between ML-only detection pipelines and guarantee-driven resilient control.

Keywords— Cyber–physical security; sensor spoofing; anomaly detection; deep temporal models; temporal convolutional networks; transformers.

I. INTRODUCTION

White appliances are safety- and reliability-critical physical products that must satisfy hard constraints on temperature, pressure, speed, and power while operating under high variability in load, ambient conditions, and user behavior. As appliances become connected, adversaries can exploit network pathways, update channels, or insecure endpoints to inject false measurements, replay previously recorded benign signals, or alter command sequences. These integrity attacks are especially problematic because they can be designed to evade conventional residual checks, a risk highlighted in

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

foundational work on false data injection and stealthy deception attacks [1], [2]. In appliance fleets, the harm is not only immediate safety risk but also long-term degradation, energy inefficiency, and distorted service decision-making when diagnostic telemetry becomes untrustworthy.

Research on secure control has long argued that cyber defense for control systems must be evaluated in a closed-loop setting, since “good detection” is insufficient if mitigation does not preserve stability, feasibility, and constraint satisfaction under attack [3], [4]. In parallel, deep learning has advanced multivariate time-series anomaly detection using temporal convolutional networks and attention-based architectures that capture long-range dependencies [5], [6]. However, learning-based pipelines commonly end at an alarm score and do not translate alarms into provably safe actions. This article positions connected white appliances as an applied domain in which a mathematically grounded integration is both feasible and valuable: deep models provide real-time trust estimates, and robust estimation and supervisory control convert trust into certified safe operation.

The contributions are organized as follows. First, a threat-aware telemetry model is defined for general-purpose appliances that integrates continuous sensors, discrete-event logs, and mode transitions. Second, a deep trust-scoring mechanism is used to gate measurements inside robust estimators that remain reliable under sparse integrity attacks. Third, a safety-preserving supervisory controller is designed to enforce secure modes and tighten constraints when the attack probability increases. Finally, an evaluation protocol is specified that reports detection delay and false-alarm trade-offs together with control-relevant outcomes, including safety violations, performance degradation, and recovery behavior. The theoretical targets are stated in words rather than formulas, focusing on bounded estimation error under sparse attacks, finite detection delay under separability assumptions, and satisfaction of safety constraints under bounded estimation uncertainty.

II. RELATED WORK

Integrity attacks on networked control systems include sensor spoofing, replay, and bias injection, and they can be analyzed using explicit attacker models that incorporate knowledge, disclosure capability, and disruption resources [3], [4]. Classic false data injection results show that attackers can craft measurement perturbations that bypass bad-data detection and arbitrarily affect state estimation, motivating defenses that go beyond naive residual checks [1], [2]. Replay attacks are particularly relevant in appliance telemetry because many household cycles contain repeated patterns; replaying a benign segment can mask an evolving unsafe physical condition unless the controller uses additional physical watermarking or consistency checks [7], [8].

Resilient estimation under sparse integrity attacks has been studied using robust optimization and sparsity-aware formulations, with results demonstrating that classical Kalman filtering can fail catastrophically when a subset of sensors is compromised [9], [10]. In these approaches, correctness depends on assumptions such as limited attacked channels, bounded noise, and sufficient redundancy

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

or observability in the uncompromised sensors. Moving horizon estimation (MHE) provides a natural constrained estimation framework for physical systems because it incorporates finite windows of past measurements and can enforce state and input bounds; stability and approximation properties of constrained MHE have been established for nonlinear discrete-time systems [11]. These estimation ideas are compatible with appliances because many constraints are well-defined and physically grounded, including rate limits, thermal bounds, and actuator saturation.

On the control side, model predictive control (MPC) is widely used for constrained systems due to its ability to enforce operational constraints while optimizing performance; modern references emphasize both theoretical foundations and computational practice [12]. Robust MPC variants, including tube-based designs, provide systematic ways to preserve constraint satisfaction under bounded disturbances and uncertainty, which directly supports attack-resilient operation when estimation uncertainty increases [13], [14].

Deep learning for anomaly detection in industrial and cyber–physical contexts has expanded rapidly, including work focused on time-series anomaly detection for industrial control systems and testbeds as well as broader reviews of deep models for ICS security [15], [16]. Temporal convolutional networks offer efficient sequence modeling with strong empirical performance, and attention-based transformers provide flexible long-range dependency modeling [5], [6]. Graph neural networks extend this by capturing relationships among sensors, subsystems, or fleet entities, and surveys now consolidate graph-based approaches for time series forecasting and anomaly detection [17]. Firmware and update-channel security is also relevant for appliances, since compromised update mechanisms can provide persistent footholds; surveys of IoT firmware update attacks and defenses summarize this risk and mitigation landscape [18].

III. METHODOLOGY

The target domain comprises general household appliances that exhibit similar cyber-physical characteristics, including embedded controllers, limited actuation capabilities, frequent operational cycles, and mixed telemetry. Telemetry may include signals such as electrical current or power consumption, temperature readings, speed or RPM indicators, vibration metrics, and pressure or fluid-level measurements, as applicable. Control and operational context are represented through actuator commands, setpoints, and transitions between modes or phases. Discrete event streams consist of error codes, warnings, protection triggers, and reset actions. This diverse data landscape reflects actual appliance collections, where connectivity, bandwidth, and cost constraints shape the range of sensors used. Additionally, event logs are typically abundant and consistent across different firmware versions.

Three integrity-attack classes are prioritized because they are operationally plausible and well-studied in secure control: sensor spoofing, replay, and command or mode tampering [1], [3], [7]. Spoofing

involves introducing additive bias and scale distortion across one or more sensor channels. Replay entails substituting a live measurement stream with a previously captured benign segment. Command tampering refers to modifying duty cycles, setpoints, or mode schedules to induce unsafe conditions or hasten wear. The methodology assumes attacks are sparse across channels and intermittent across time windows, a standard setting in resilient estimation that enables tractable guarantees [9], [10].

The learning-based trust-scoring module produces two outputs: a score indicating the likelihood of an attack in the current time frame and a set of trust weights for each sensor. Trust is characterized as the extent to which each measurement channel aligns with established standard patterns and inter-sensor physical associations. The framework accommodates various families of deep learning models. Temporal convolutional networks are favored for embedded efficiency and stable long-horizon receptive fields [5]. Lightweight transformer encoders are considered when cycle-level long-range dependencies dominate [6]. A dual-branch architecture may be used when both continuous telemetry and an event-code “language” are present, in which the continuous encoder captures dynamics, and the event encoder captures unexpected code transitions or rare co-occurrences. Training can be semi-supervised by learning standard patterns and calibrating against synthetic attack injection scenarios that mimic spoofing and replay behaviors.

The estimator incorporates trust in a control-compatible way by down-weighting or excluding channels deemed untrustworthy. Two practical estimator variants are supported. The first is a gated Kalman or observer-style estimator that uses trust weights to adaptively adjust measurement confidence. The second is a constrained moving-horizon estimator that explicitly allows sparse measurement corruption and selects states that best match trusted measurements while respecting physical constraints and rate limits. This approach aligns with resilient estimation frameworks that provide robustness under sparse integrity attacks and with constrained estimation results that justify finite-horizon approximations under suitable assumptions [9]–[11].

The control layer is structured as a supervisor that switches between nominal performance control and secure operation. Under low attack likelihood and stable estimation uncertainty, the appliance operates with its nominal controller. When attack likelihood rises or estimation uncertainty exceeds a threshold, the supervisor activates a secure mode. Secure mode can be implemented as a conservative policy that reduces power, temperature, and speed targets while enforcing strict bounds, or as a constraint-tightened robust MPC formulation that maintains feasibility and constraint satisfaction under bounded disturbances and estimation error [12]–[14]. The control design goal is graceful degradation: maintain safety and bounded operation even if optimality is sacrificed during periods of suspicion.

The research article presents three theorem-level statements articulated in words. Firstly, given sparse attack conditions, limited noise, and ample redundancy in the non-attacked sensors, the learning-gated

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ISBN: 978-9952-610-30-7

robust estimator produces a bounded state estimation error during the attack period, demonstrating a clear relationship with both trust quality and attack magnitude, in line with resilient estimation principles [9], [10]. Second, under a separability condition requiring attacks to induce detectable divergence from normal predictive behavior within a finite window, the detector achieves a bounded false-alarm probability and a finite expected detection delay at a chosen operating point, consistent with established perspectives on replay and deception detection [7], [8]. Third, given bounded estimation error and robust control margins, the supervisory secure mode ensures satisfaction of safety constraints, using robust MPC or invariant-set logic as the guaranteed mechanism [13], [14].

IV. RESULTS

Since appliance fleets differ by model, firmware, geography, and usage, results must be reported across diverse operating regimes. The recommended evaluation suite includes multiple appliance types, such as thermal-dominant, motor-dominant, and fluid-dominant cycles, each with realistic noise, drift, and phase changes. Attacks are injected in controlled scenarios as spoofing, replay, and command tampering, including stealth-oriented variants that attempt to preserve naive residual checks, following the broader deception-attack rationale [1], [3].

Learning-based trust scoring is expected to improve the detection of replay and coordinated spoofing compared to fixed-threshold residual alarms, especially in appliances with periodic, load-dependent operation. Temporal convolutional models are expected to provide robust detection at lower computational cost, thanks to their convolutional parallelism and stable receptive fields [5]. Transformer encoders may improve detection during long cycles and across phase boundaries by capturing longer-range dependencies, but they require careful efficiency tuning for embedded deployment [6]. When fleet-level context is available, graph-based modeling can further reduce false alarms by learning relationships among sensors or among appliances that share firmware and usage patterns, consistent with the growing body of graph time-series methodology [17].

Table 1. Comparison of detection and estimation strategies under integrity attacks.

Approach	Attack coverage (spoof / replay / command tampering)	False-alarm control	Detection-delay behavior	Estimation robustness under sparse sensor corruption	Real-time suitability
Residual thresholding + standard Kalman/observer (baseline)	Limited (best for gross faults; weak for stealthy replay/spoof)	Weak–Moderate (sensitive to drift/load changes)	Fast when attacks are obvious; unreliable for stealthy attacks	Weak (can diverge if attacked channels are trusted)	High (lightweight)

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DL detector only (TCN/Transformer) + standard estimator	Moderate–Strong (depends on training coverage)	Moderate (improves with calibration; still drift-sensitive)	Typically improved for replay/spoof; depends on window length	Weak–Moderate (estimator still vulnerable if it trusts corrupted sensors)	Moderate–High (TCN usually better for edge)
Robust estimator (constrained MHE / sparsity-aware) without learning gate	Moderate (handles sparse corruption; replay harder if consistent)	Not applicable (no explicit alarm)	Not applicable	Strong under stated sparsity/bounded-noise assumptions	Moderate (heavier compute than Kalman)
Learning-gated estimator (trust-weighted Kalman/MHE) (Proposed Method)	Strong (explicitly targets spoof/replay/command tampering)	Stronger (trust gating reduces drift-triggered alarms when calibrated)	Finite and controllable via thresholding on trust/attack score	Strong (down-weights suspicious channels; supports bounded-error claims under assumptions)	Moderate–High (depends on model size + estimator choice; TCN + gated update is most deployable)

The key operational benefit of learning-gated estimation is that, once suspicious channels are down-weighted, the estimator relies more heavily on trusted channels and physical constraints, preventing large deviations that would otherwise propagate to unsafe control actions. Resilient estimation literature supports the premise that robustness improves when attacked channels are treated as sparse corruptions rather than as equally reliable measurements [9], [10]. In appliance settings, constraint-aware estimation is expected to be particularly effective because physical rate limits and actuator bounds can exclude many implausible state trajectories during attacks, as in constrained MHE frameworks [11].

Table 2. Comparison of mitigation/control policies during suspected attacks.

Mitigation policy	**Safety constraint satisfaction under bounded uncertainty**	**Performance during attacks**	**Recovery behavior after attacks**	**Dependence on model/estimation quality**	**Deployment complexity**

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ISBN: 978-9952-610-30-7

Alarm only (no control adaptation)	No guarantee (safety may be violated if control uses corrupted feedback)	Nominal until failure; risk of unsafe operation	Unstructured; may require manual intervention	High (unsafe if estimator is misled)	Low
Rule-based safe mode (supervisory fallback)	Strong if safe mode is conservatively designed	Conservative (reduced power/RPM/temperature targets)	Fast and stable; may be over-triggered under drift	Moderate (works even with coarse estimates)	Low–Moderate
Constraint-tightened robust MPC (secure mode)	Strong guarantee under stated bounds	Better trade-off than pure safe mode; still conservative	Structured return-to-nominal once uncertainty decreases	High (needs reliable bounds and estimation uncertainty)	High
Learning-triggered supervisory control (DL trust → switch to safe/robust mode) (Proposed method)	Strong when paired with robust secure mode and bounded estimation error assumptions	Adaptive: nominal when trusted, conservative only when needed	Controlled recovery using trust restoration and hysteresis	Balanced (learning improves switching; robust control handles residual uncertainty)	Moderate–High

The most important result category is safety, measured by the absence of constraint violations during attacks and by quantified performance degradation during secure mode. Robust MPC and tube-based designs are well suited to this purpose because they provide a structured method for tightening constraints and preserving feasibility under uncertainty [13], [14]. In appliances, secure mode is expected to increase cycle time or reduce performance metrics such as heating ramp rate or spin aggressiveness. However, it should maintain temperature, pressure, speed, and power within certified bounds. Recovery behavior is evaluated by how quickly the system returns to nominal operation once telemetry trust is restored, and by whether repeated secure-mode activations occur under benign drift.

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V. CONCLUSION

This article proposes a research-article blueprint for cyber–physical security in connected white appliances that integrates deep learning with robust estimation and safety-preserving control. The core methodological claim is that learning outputs become operationally meaningful only when coupled to provably safe mitigation: deep anomaly detection produces trust, robust estimation turns trust into reliable state information under sparse integrity attacks, and supervisory control enforces constraint satisfaction through conservative fallback or robust MPC when risk is elevated. The work is grounded in secure control foundations that emphasize deception attacks and closed-loop risk [1]–[4], supported by resilient estimation results for sparse sensor attacks and constrained estimation theory [9]–[11], and enabled by modern deep sequence models for anomaly detection [5], [6]. By focusing on general appliance telemetry and measurable safety objectives, the paper aims to contribute to both practical relevance for appliance fleets and mathematical alignment with research on computation-oriented control systems.

REFERENCES

[1] Y. Liu, P. Ning, and M. K. Reiter, “False Data Injection Attacks against State Estimation in Electric Power Grids,” ACM Conference on Computer and Communications Security (CCS), 2009.

[2] Y. Liu, P. Ning, and M. K. Reiter, “False Data Injection Attacks against State Estimation in Electric Power Grids,” ACM Transactions on Information and System Security, 2011.

[3] A. Teixeira, I. Shames, H. Sandberg, and K. H. Johansson, “A Secure Control Framework for Resource-Limited Adversaries,” Automatica, vol. 51, pp. 135–148, 2015.

[4] A. Teixeira, H. Sandberg, and K. H. Johansson, “Networked Control Systems under Cyber Attacks with Applications to Power Networks,” American Control Conference (ACC), 2010.

[5] S. Bai, J. Z. Kolter, and V. Koltun, “An Empirical Evaluation of Generic Convolutional and Recurrent Networks for Sequence Modeling,” arXiv:1803.01271, 2018.

[6] A. Vaswani et al., “Attention Is All You Need,” NeurIPS, 2017.

[7] Y. Mo and B. Sinopoli, “Secure Control against Replay Attacks,” Allerton Conference on Communication, Control, and Computing, 2009.

[8] R. Chabukswar, Y. Mo, B. Sinopoli, et al., “Detecting Integrity Attacks on SCADA Systems,” in Proceedings of the IFAC World Congress 2011.

[9] S. Z. Yong, M. Q. Foo, and E. Frazzoli, “Robust and Resilient Estimation for Cyber-Physical Systems under Adversarial Attacks,” American Control Conference (ACC), 2016.

[10] D. Han, Y. Mo, J. Lunze, et al., “Robust State Estimation against Sparse Integrity Attacks,” arXiv:1601.04180, 2016.

[11] C. V. Rao, J. B. Rawlings, and D. Q. Mayne, “Constrained State Estimation for Nonlinear Discrete-Time Systems: Stability and Moving Horizon Approximations,” IEEE Transactions on Automatic Control, vol. 48, no. 2, pp. 246–258, 2003.

[12] J. B. Rawlings, D. Q. Mayne, and M. M. Diehl, Model Predictive Control: Theory, Computation, and Design, 2nd ed., 2018.

[13] D. Q. Mayne, M. Seron, and S. V. Raković, “Robust Model Predictive Control of Constrained Linear Systems with Bounded Disturbances,” Automatica, vol. 41, pp. 219–224, 2005.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

[14] S. V. Raković, E. C. Kerrigan, K. I. Kouramas, and D. Q. Mayne, "Invariant approximations of the minimal robust positively invariant set," IEEE Transactions on Automatic Control, 2005.

[15] C. Han et al., "Time-Series-Based Anomaly Detection in Industrial Control Systems," Processes (MDPI), 2025.

[16] M. M. Aslam et al., "Survey of Deep Learning Approaches for Securing Industrial Control Systems," Results in Control and Optimization (Elsevier), 2025.

[17] M. Jin et al., "A Survey on Graph Neural Networks for Time Series: Forecasting, Classification, Imputation, and Anomaly Detection," arXiv:2307.03759, 2023.

[18] M. Bettayeb et al., "Firmware Update Attacks and Security for IoT Devices: Survey," 2019.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE EFFECT OF FLUOROSCOPY EXPOSURE ON THE FACIAL REGION DURING CERVICAL VERTEBRA SURGERY: A TLD-BASED DOSE ANALYSIS

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Objective: This study aimed to quantify the radiation dose received by critical facial and neck organs during fluoroscopic imaging performed in cervical spine surgery.

Method: Fluoroscopic imaging procedures used during posterior segmental instrumentation in cervical spine surgery were simulated. A phantom-based dosimetric approach was employed to evaluate organ-specific radiation doses in the facial region under simulated clinical conditions. A radiological phantom was used, and thermoluminescent dosimeters (TLDs) were strategically placed at fifty-two anatomical sites representing radiosensitive organs in the facial and cervical regions. Dose measurements were obtained during fluoroscopic imaging performed at the screw placement and positioning stages. Fluoroscopy parameters (kVp, mA, and exposure time) were set according to standard clinical cervical spine surgery protocols.Radiation doses were recorded for the submandibular glands, parotid glands, thyroid glands, spinal cord, sublingual gland, temporal bone, ethmoid sinus, and pituitary gland.

Findings: Radiation doses varied according to organ location. The highest dose values were measured in the left submandibular gland and the left parotid gland, both reaching 0.81 mSv. Thyroid gland doses ranged from 0.41–0.43 mSv on the right side and 0.32–0.39 mSv on the left side. The spinal cord received doses between 0.26 and 0.34 mSv. Radiation exposure to the sublingual gland, temporal bone, ethmoid sinus, and pituitary gland was negligible, indicating minimal radiation impact on these organs.

Conclusion: Fluoroscopic imaging during cervical spine surgery results in relatively higher radiation exposure to the submandibular and parotid glands compared to other facial and neck organs. These findings emphasize the need for improved fluoroscopy protocols and enhanced protective measures to reduce radiation exposure, particularly for radiosensitive glands in the facial region.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Cervical vertebra surgery; radiation exposure; organ-specific dosimetry; phantom model; thermoluminescent dosimeter; facial region organs

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DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COMPARATIVE ANALYSIS OF MICROSERVICES AND MONOLITHIC ARCHITECTURES IN CLOUD ENVIRONMENTS: A PRACTICAL IMPLEMENTATION WITH JAVA AND SPRING BOOT

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ABSTRACT

The shift toward cloud environments has renewed the debate between microservices and monolithic architec- tures. While extensive literature discusses the theoretical advantages of microservices—such as agility and fault isolation—compared to the simplicity of monolithic designs, there is a lack of empirical studies validating these claims under standardized loads. This paper evaluates the trade-offs of both approaches, specifically focusing on scalability, maintainability, and deployment flexibility.

Moving beyond theoretical analysis, this study centers on a practical comparison. Two functionally identical versions of a web application were developed using Java and Spring Boot: one following a traditional mono- lithic structure and the other designed as a distributed microservices system.

This hands-on implementation highlights clear distinctions. The results show that while the microservices approach offers superior scalability and agility, it introduces significant operational complexity. The monolithic version, by contrast, proved simpler to develop and deploy initially but faced performance bottlenecks under simulated cloud loads.

Ultimately, the findings suggest there is no ‘one-size-fits-all’ solution. Organizations should prioritize their specific operational needs over industry trends when selecting an architecture.

Keywords: Microservices, Monolithic Architecture, Cloud Computing, Java, Spring Boot, Scalability.

INTRODUCTION

In recent years, the rapid rise and widespread adoption of cloud computing have fundamentally changed the way organizations design, develop, and deploy software applications (Bernstein, 2010). Major technology companies have completely migrated their applications and core systems to the cloud because cloud computing allows these entities to scale their computing resources dynamically as per

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their usage demands. With the increasing adoption of cloud environments, there has been a growing interest in utilizing cloud-compatible software engineering paradigms to build and manage robust enterprise applications.

Currently, two software engineering paradigms dominate modern enterprise application development: mono- lithic architecture and microservices. Monolithic architecture refers to a software design pattern where all the functionality of an application is tightly interconnected and operates within a single process. This approach is highly appreciated for its simplicity, as all components of the application—presentation, processing, and stor- age—are developed, tested, and deployed together as a cohesive unit. However, as computer systems evolve and user demands increase, the inherent limitations of monolithic architectures become evident, particularly

concerning scalability and maintainability. Inflexibility and difficulty in adapting to rapidly changing business requirements pose significant challenges.

These limitations have paved the way for alternative architectural approaches, such as microservices. A mi- croservice architecture divides a complex business domain into small, consistently bounded contexts imple- mented by autonomous, self-sufficient, loosely coupled, and independently deployable services (Lewis and Fowler, 2014). These services communicate through lightweight mechanisms, such as HTTP resource APIs, and each service runs independently in its own process. This architecture facilitates high quality and speed in the development of large domains, allowing autonomous teams to develop different services using heteroge- neous technologies (Dragoni et al., 2017).

Despite the theoretical consensus on the benefits of microservices, comparing these architectures in a practical cloud environment remains a complex issue for organizations (Jamshidi et al., 2018). The primary objective of this paper is to provide a comprehensive, empirical comparison of microservices and monolithic architectures in a cloud environment. The focus is placed heavily on three critical metrics: scalability, maintainability, and deployment flexibility. By developing and benchmarking two identical task management systems, this study aims to provide concrete insights into the operational trade-offs of each approach, helping practitioners make informed, data-driven architectural decisions (Sharma and Chana, 2018).

MATERIALS AND METHODS

To ensure a systematic and objective analysis, a comparative evaluation process was designed. The research framework involved the hands-on development of a task management system implemented in two completely distinct architectural styles. Both systems were developed using Java and the Spring Boot framework, allowing for a controlled comparison where the underlying programming language and core libraries remained consis- tent.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Monolithic Implementation Setup

The monolithic version was designed with a unified codebase (see Figure 1). The application utilized a single, centralized PostgreSQL database to handle all data persistence requirements (e.g., user authentication data, task creation, and updates). The internal communication was direct, utilizing standard method calls within the application domain. The package structure was integrated, encompassing security, common libraries, and all domain logic (auth and tasks) within a single deployed artifact.

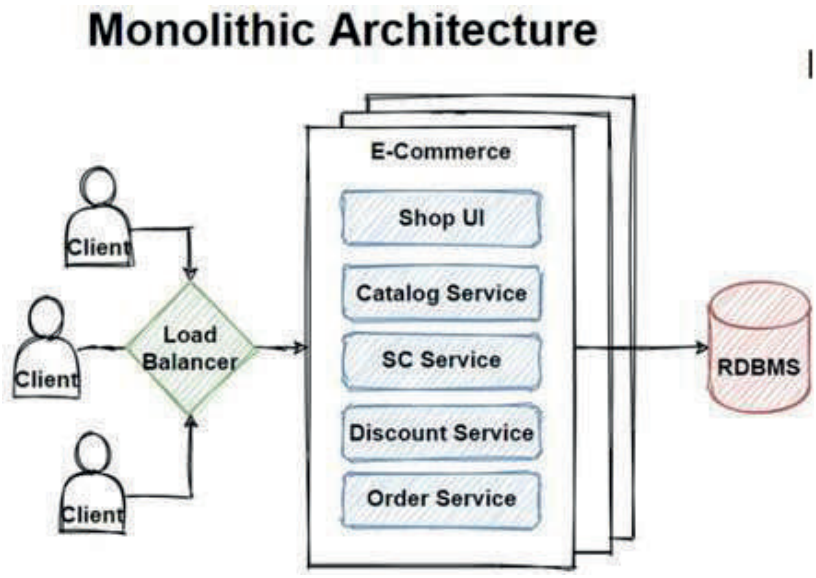


Figure 1: Monolithic Architecture

Microservices Implementation Setup

The microservices version (see Figure 2) was engineered to distribute the business logic across multiple au- tonomous services. To ensure dedicated data management and avoid tight coupling, a 'database-per-service' pattern was employed, meaning the Authentication Service and the Task Service each managed their own sep- arate PostgreSQL databases.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

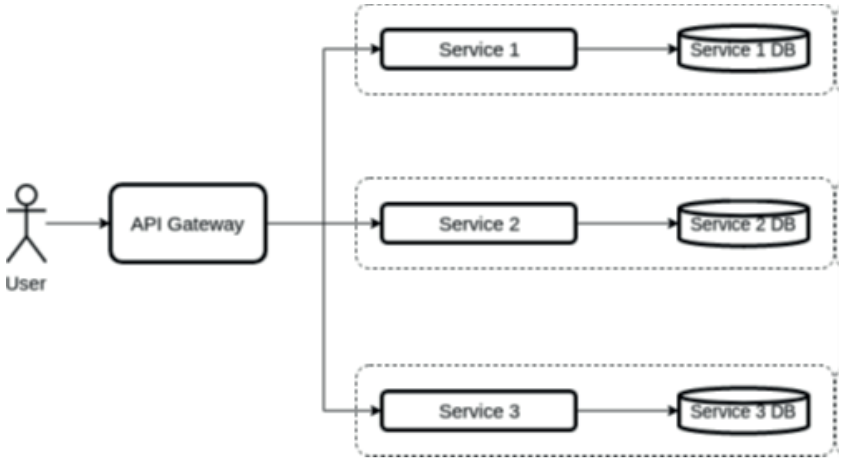


Figure 2: Microservices Architecture

To handle the complexities of distributed computing, several key cloud-native components were integrated:

- **Eureka (Service Registry):** Implemented to function as a dynamic registry where microservices could register themselves and discover other services, simplifying inter-service interaction and enhancing fault tolerance.
- **API Gateway:** Acted as the single entry point for all client requests, routing external traffic to the appropriate internal microservices based on predefined URI predicates, thereby centralizing security and cross-cutting concerns.
- **RestTemplate:** Utilized for synchronous inter-service communication over HTTP, specifically for the Task Service to verify user credentials with the Authentication Service.
- **Docker:** Containerization was utilized to ensure isolated scaling and deployment. Each service, along with its respective database and caching layers, was configured in a distributed environment.

Evaluation Criteria and Load Testing

The performance and operational characteristics of both systems were evaluated based on response time, re- source utilization, and error rates. To simulate standardized cloud loads as stated in the abstract, Apache JMeter was utilized to execute concurrent user requests against the endpoints of both architectures. The load tests were configured to simulate incrementally increasing traffic, ranging from baseline loads to high-concurrency stress scenarios, allowing for an accurate measurement of execution time latency and the identification of operational bottlenecks.

RESULTS

A synthesized comparison of the operational characteristics and empirical performance trends observed during the implementation is presented in Table 1.

Table 1: Comparative Analysis of Architectural Characteristics and Performance Trends

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ISBN: 978-9952-610-30-7

Criteria	Monolithic Architecture	Microservices Architecture
Scalability	Primarily requires vertical scaling (scaling up). Scaling horizontally involves replicating the entire applica- tion stack.	Inherently supports horizontal scaling (scaling out). Services can be scaled independently based on specific bottle- necks.
Maintainability	Simple initial development. How- ever, tightly coupled components make long-term maintenance and modular updates difficult.	High initial setup complexity. How- ever, the modular nature allows au- tonomous teams to maintain services independently.
Deployment Flexibil- ity	”All-or-nothing” deployment. Re- quires redeploying the entire mono- lithic system, increasing the risk of scheduled downtimes.	High flexibility. Individual microser- vices are deployed independently via containers, enabling zero-downtime rollouts.
Avg. Response Time (Low System Traffic)	Highly efficient and fast (<100 ms) due to direct, in-memory method calls and a single, localized database.	Slightly higher baseline (approx. 300- 500 ms) due to API Gateway routing and inter-service network communica- tion overhead.
Avg. Response Time (High System Traffic)	Prone to exponential degradation and timeouts as the centralized database and single instance become critical compute bottlenecks.	Remains stable and resilient. The load is effectively distributed across multi- ple scaled container instances.

Performance and Scalability Metrics

The comparative implementation yielded distinctly different performance profiles. The monolithic architec- ture exhibited exceptionally fast and consistent response times (averaging under 100 ms) under low concurrent loads. Because all data processing occurred within a single memory space without network hops, the overhead was minimal. However, as system traffic increased, the monolithic version suffered from exponential perfor- mance degradation, as the centralized database and the single application instance became severe bottlenecks (Nguyen et al., 2019).

Conversely, the microservices implementation manifested a slightly higher baseline latency (around 300-500 ms) under light loads due to network routing and inter-service communication overhead. However, as the concurrent system traffic scaled to heavy loads, the microservices architecture stabilized efficiently. By inde- pendently scaling the heavily utilized services via horizontal containerization, the distributed system effectively bypassed the severe performance degradation observed in the monolithic approach (Newman, 2015).

Maintainability and Deployment Flexibility

Beyond performance, the architectures contrasted sharply in their operational lifecycles. The monolithic ap- proach offered simple initial development and straightforward ”all-or-nothing” deployments. However, modi- fying a single feature required testing and redeploying the entire

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ISBN: 978-9952-610-30-7

codebase, heavily limiting deployment agility. The microservices architecture, while requiring complex initial orchestration (Eureka, Gateway), provided su- perior maintainability. Features could be updated, tested, and deployed as isolated containers without affecting the overall system, demonstrating high deployment flexibility and minimizing scheduled downtime.

DISCUSSION

The empirical results of this study strongly validate the theoretical propositions found in software engineering literature. The comparison highlights a fundamental trade-off: the simplicity and ease of initial development in monolithic architectures versus the superior scalability, fault isolation, and long-term flexibility offered by

microservices.

The monolithic model's primary advantage lies in its lack of distributed complexity. For small to medium- sized projects, or for teams with limited resources and strict timelines, the monolith provides a rapid path to deployment. The lack of network hops between business logic components ensures excellent performance under standard operational loads. However, the inability to scale specific components independently means that scaling a monolith requires replicating the entire application stack, leading to inefficient resource utilization in a cloud environment.

Microservices, while demanding a high initial investment in infrastructure setup and DevOps practices, excel in dynamic cloud environments. The ability to deploy, update, and scale services independently provides immense deployment flexibility. A bottleneck in the Authentication service, for example, can be resolved by allocating more container instances strictly to that service. Nevertheless, organizations must be prepared to handle the inherent challenges of distributed systems, such as managing eventual data consistency, distributed tracing, and securing inter-service network traffic across boundaries.

Based on these findings, it is recommended that organizations start with a monolithic architecture for rapid prototyping or when the application scope is small. Microservices should be adopted when an application requires independent scaling, handling of large-scale operations, high availability, and when the development team possesses the maturity to manage complex, distributed systems.

CONCLUSION

This study embarked on a comprehensive comparative analysis of monolithic and microservices architectures within cloud environments. Through the practical implementation and evaluation of a task management system, the research confirms that there is no universal architectural solution. Monolithic architectures offer unparal- leled simplicity in development and deployment, making them highly effective for localized or smaller-scale applications. Conversely, microservices architectures provide the necessary modularity, independent scala- bility, and deployment flexibility required for large-scale, enterprise cloud applications, albeit at the cost of significantly increased operational complexity.

Decision-makers must align their architectural choices with their specific project requirements, organizational technical capabilities, and long-term strategic growth plans. Future research could explore the integration of service mesh technologies and serverless computing models to further optimize microservices orchestration and reduce operational overhead.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the academic and institutional guidance provided by the faculty of Manisa Celal Bayar University throughout this research.

REFERENCES

Bernstein DS 2010. Cloud Computing: The Future of IT. Communications of the ACM, 53(4): 34-37.

Dragoni N, Dustdar S, Traverso P, Zambonelli F 2017. Microservices: Migration and modernization roadmap. IEEE Software, 34(3): 105-111.

Fowler M 2014. Microservices: A Definition of This New Architectural Term. Martin Fowler Blog.

Jamshidi P, Pahl C, Mendonc¸a NC, Lewis J, Tilkov S 2018. Microservices: The journey so far and challenges ahead. IEEE Software, 35: 24-35.

Lewis J, Fowler M 2014. Microservices: A practitioner's guide. O'Reilly Media.

Newman S 2015. Building Microservices: Designing Fine-Grained Systems. O'Reilly Media, Inc., 280 pp.

Nguyen HH, Gomes P, Zhang L, Ranjan R 2019. Comparative study of microservices architectures for cloud-based applications. 2019 IEEE International Conference on Cloud Engineering (IC2E), 42-51.

Sharma S, Chana I 2018. Comparative analysis of monolithic and microservices architecture. 2018 International Conference on Advances in Computing, Communication Control and Networking, 267-270.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

HYPERTENSIVE RETINOPATHY CLASSIFICATION WITH DINOV2 BASED SELF-SUPERVISED LEARNING AND SUPPORT VECTOR MACHINES

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ABSTRACT

Hypertensive retinopathy is a disease that causes structural and functional deterioration in the retinal vessels due to high blood pressure. When this disease is not diagnosed early, it causes permanent vision loss. In recent years, deep learning approaches based on Convolutional Neural Networks and Vision Transformer have been widely used to detect this disease. However, there is a need to investigate more up-to-date and effective methods for detecting this disease, which is extremely important for health. In this context, the DINOv2 model, which is based on self-supervised learning and can learn robust visual representations by reducing the need for labels, stands out as a promising approach for hypertensive retinopathy detection. This study proposes a hybrid approach combining machine learning with self-supervised learning-based deep feature extraction for the detection of hypertensive retinopathy. In this study, a dataset consisting of 273 retinal fundus images made available for open access on the Kaggle platform was used. In addition, an augmented dataset of 819 images was created by applying various data augmentation methods to this dataset. In this study, deep features were extracted from both datasets (original and augmented) using DINOv2-S, DINOv2-B and DINOv2-L models with dimensions of 384, 768 and 1024 respectively. These features were classified using Support Vector Machines (SVM). In addition, GridSearchCV method was used to determine the hyperparameters of the SVM model such as Kernel, C coefficient and Gamma. According to the experimental results, the DINOv2-L + SVM model achieved an accuracy of 0.982 on the original dataset and 1.000 on the augmented dataset. The findings show that combining features extracted from DINOv2 models trained with self-supervised learning with a machine learning classifier yields high performance in hypertensive retinopathy detection. Therefore, this approach can be considered as a viable alternative in clinical settings.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Hypertensive retinopathy, Deep learning, Machine learning, DINOv2, Support Vector Machines

DINOv2 TABANLI ÖZ-DENETİMLİ ÖĞRENME VE DESTEK VEKTÖR MAKİNELERİ İLE HİPERTANSİF RETİNOPATİ HASTALIĞININ SINIFLANDIRILMASI

ÖZET

Hipertansif retinopati, yüksek kan basıncına bağlı olarak retina damarlarında yapısal ve fonksiyonel bozulmalara yol açan bir hastalıktır. Bu hastalığa erken tanı konulmadığında kalıcı görme kaybına neden olmaktadır. Son yıllarda bu hastalığın tespitinde Evrişimsel Sinir Ağları ve Vision Transformer tabanlı derin öğrenme yaklaşımları yaygın olarak kullanılmaktadır. Ancak, sağlık açısından son derece önemli olan bu hastalığın tespit edilmesinde daha güncel ve etkili yöntemlerin araştırılması gerekmektedir. Bu bağlamda, öz-denetimli öğrenmeye dayanan ve etiket gereksinimini azaltarak güçlü görsel temsiller öğrenebilen DINOv2 modeli, hipertansif retinopati tespiti için ümit verici bir yaklaşım olarak öne çıkmaktadır. Bu çalışmada, hipertansif retinopati tespiti amacıyla öz-denetimli öğrenme tabanlı derin özellik çıkarımı ile makine öğrenmesini birleştiren hibrit bir yaklaşım önerilmiştir. Çalışmada Kaggle platformunda açık erişime sunulan 273 adet retinal fundus görüntüsünden oluşan bir veriseti kullanılmıştır. Ayrıca, bu verisetine çeşitli veri zenginleştirme yöntemleri uygulanarak 819 görüntüden oluşan genişletilmiş bir veriseti oluşturulmuştur. Çalışmada, her iki verisetinden (orijinal ve zenginleştirilmiş), DINOv2-S, DINOv2-B ve DINOv2-L modelleri kullanılarak sırasıyla 384, 768 ve 1024 boyutunda derin özellikler çıkarılmıştır. Elde edilen bu özellikler, Destek Vektör Makineleri (DVM) kullanılarak sınıflandırılmıştır. Ayrıca, DVM modeline ait Kernel, C katsayısı ve Gamma gibi hiperparametrelerinin belirlenmesinde GridSearchCV yöntemi kullanılmıştır. Deneysel sonuçlara göre DINOv2-L + DVM modeli, orijinal verisetinde 0,982 ve zenginleştirilmiş verisetinde ise 1,000 doğruluk oranları elde etmiştir. Elde edilen bulgular, öz-denetimli öğrenme ile eğitilmiş DINOv2 modellerinden çıkarılan özelliklerin, bir makine öğrenmesi sınıflandırıcısı ile birleştirilmesinin, hipertansif retinopati tespitinde yüksek performans sergilediğini ortaya koymaktadır. Dolayısıyla bu yaklaşım, klinik ortamlarda uygulanabilir bir alternatif olarak değerlendirilebilir.

Anahtar Kelimeler: Hipertansif retinopati, Derin öğrenme, Makine Öğrenmesi, DINOv2, Destek Vektör Makineleri

INTRODUCTION

Retinopathy is the medical term for damage to the retina, the light-sensitive layer of nerve tissue at the back of the eye. Retinopathy typically arises from underlying health issues such as diabetes or hypertension. If the pathological changes in the retina are not treated, they can lead to serious visual impairments and even permanent blindness (Xuan et al., 2023). In addition to retinopathy caused by diabetes, chronic hypertension significantly damages the retina, leading to hypertensive retinopathy

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(Muchuchuti & Viriri, 2023). Retinopathy often develops without noticeable symptoms in its early stages. This increases the risk of the patient not receiving timely treatment (Aghabeigi Alooghareh et al., 2025). Therefore, preventing and improving vision loss caused by retinopathy, which requires early diagnosis and intervention, is crucial. Additionally, early diagnosis of hypertensive retinopathy helps prevent other serious conditions caused by chronic hypertension, such as stroke and heart disease. (Muchuchuti & Viriri, 2023).

In the diagnosis of hypertensive retinopathy, significant advances in diagnostic accuracy have been achieved in recent years using deep learning (DL). Retinal fundus images can be classified and graded using DL architectures such as Convolutional Neural Networks (CNN) and Vision Transformers (ViT) (Berroukham et al., 2023). For example, Gurthula et al. (2024) used CNN architectures such as ResNet, Inception, and DenseNet to detect hypertensive and diabetic retinopathy using the Messidor-2 and ODIR-5K datasets. They achieved 98% accuracy on the Messidor-2 dataset and 89% accuracy on the ODIR-5K dataset using the Xception model. Similarly, Triwijoyo et al. (2017) classified hypertensive retinopathy using their proposed CNN model. They achieved an accuracy of 98.6% with their proposed CNN model. Nagpal et al. (2023) applied preprocessing techniques such as A-CLAHE, DNCNN, and Wiener filtering to images obtained from the MESSIDOR and ODIR datasets and achieved an accuracy of 98.72% using the ResNet101 model. On the other hand, Koduri & Ma (2024) classified diabetic and hypertensive retinopathy images created by combining three datasets using DenseNet, ResNet, ViT, and their proposed Dual-ViT models. They achieved an accuracy value of 97.98% with their proposed model. Zhu (2025) used pre-trained ViT-based architectures and Automated Machine Learning (AutoML) in the study conducted on the original HRDC and augmented datasets. On the augmented dataset, they achieved a specificity value of 0.806 with the ViT-B/8 (Pure) model and a specificity value of 0.778 with the ViT-B/14-DINOv2 (Pure) model.

Although CNN architectures demonstrate high accuracy in classifying eye diseases, they may struggle to identify global context features. Indeed, ViT architectures capture global context features in images more effectively thanks to the self-attention mechanism (Berroukham et al., 2023). However, the success of CNN and ViT architectures largely depends on human-labeled images. Labeling medical images is a costly process requiring expert knowledge. Self-Supervised Learning (SSL) approaches, developed to overcome this limitation, are a DL approach based on using automatically generated labels from images instead of human labels in model training. DINOv2 is a powerful SSL model based on ViT architecture. Thanks to its teacher–student structure and self-attention mechanism, this model learns features independently of the task (Pinetsuksai et al., 2023). This advantage will enable DINOv2 to provide an objective tool for detecting diseases that show no symptoms in the early stages, such as retinopathy. However, features extracted from DINOv2 architecture have recently been classified using machine learning (ML) models (Oquab et al., 2023; Doerksen et al., 2024; Paderno et

al., 2024). This approach will provide an effective solution for hypertensive retinopathy classification, where labeled data is limited.

The aim of this study is to classify deep features extracted with DINOv2 using Support Vector Machines (SVM) for the detection of hypertensive retinopathy. Retinal fundus images downloaded from the Kaggle platform were used in the study. Additionally, the images in the original dataset were augmented using geometric data augmentation techniques. The datasets were split into 80% training and 20% testing. In the study, DINOv2-S, DINOv2-B, and DINOv2-L models, which are different model scales of the DINOv2 architecture, were evaluated. Furthermore, the GridSearchCV method was used to determine the optimal hyperparameters of the SVM model. In addition, an ablation study was performed to evaluate the effectiveness of the highest performing model in detail. In this context, both the original dataset and the dataset with only data augmentation applied to the training set were used and the models were evaluated using the 5-fold nested cross-validation (Nested CV) and holdout testing approach. The contributions of this study to the literature are summarized below.

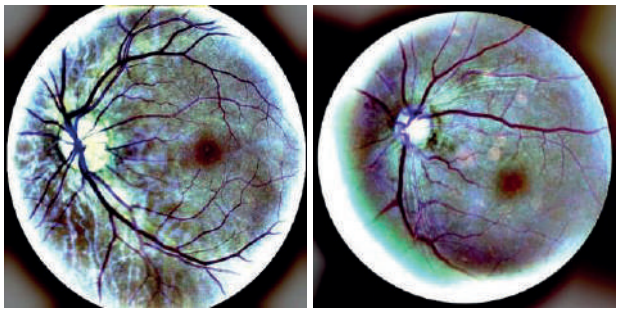
- In this study, deep features were extracted from retinal fundus images using different scales of the SSL-based DINOv2 architecture, such as DINOv2-S, DINOv2-B, and DINOv2-L. These features were combined with SVM to classify hypertensive retinopathy.
- Experiments were conducted on original and augmented datasets to investigate the effect of the data augmentation approach on classification performance.
- An ablation study was performed using Nested CV and holdout testing approach on the original dataset and the dataset with only data augmentation applied to the training set.

MATERIALS AND METHODS

Dataset

The Hypertensive Retinopathy Fundus Image Dataset, available on the Kaggle platform, was used in this study. This dataset consists of a total of 273 retinal fundus images focused on the diagnosis of hypertensive retinopathy. All images are in JPEG format and have a resolution of 512 × 512 pixels. The Hypertensive Retinopathy Fundus Image Dataset consists of two classes: Hypertensive Retinopathy and Normal Fundus. The Normal Fundus class has 179 images that do not contain any pathological findings and represent healthy retinal structure. The Hypertensive Retinopathy class consists of 94 images showing vascular narrowing, bleeding, and similar retinal changes associated with hypertension (Kaggle, 2025). Figure 1 shows sample retinal fundus images from the Normal Fundus and Hypertensive Retinopathy classes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



(a) (b)

Figure 1. Hypertensive Retinopathy Fundus Image Dataset sample images, (a) Normal, (b) Hypertensive Retinopathy

It has been reported in the literature that increasing image diversity significantly improves the classification performance of DINOv2-based models (Zhu, 2025). Accordingly, experiments were conducted on the original and augmented datasets in this study. For the augmented dataset, flip and transform methods were applied to all images in the original dataset, yielding a total of 819 images. However, all images were resized to 224 × 224 pixels. In the study, the dataset was split into 80% training and 20% testing. While the original dataset contained 218 images to train and 55 images to test, the augmented dataset contained 655 images to train and 164 images to test.

For the ablation study, data augmentation was applied exclusively to the training set after the train–test split. No augmented samples were included in the independent test set to prevent data leakage.

Self-Supervised Feature Learning Based on DINOv2

SSL-based visual representation learning approaches have gained significant attention in recent years due to their reduced reliance on labeled data and their ability to achieve high generalization capabilities across various tasks (Dosovitskiy et al., 2020; Moor et al., 2023). One such approach is DINOv2 (Oquab et al., 2023). Developed by Meta AI, it presents a self-supervised learning approach based on a teacher–student structure (Paderno et al., 2024). The DINOv2 feature extractor (Doerksen et al., 2024; Paderno et al., 2024) used CNN or ViT architectures as backbones for its pre-trained network architecture (Alasu & Talu, 2024). This structure enables the model to learn discriminative representations from images.

Recent studies have shown that DINOv2 and similar SSL models can produce representations that are closer to human perception, consistent, and task independent. Particularly in studies examining multi-view consistency, DINOv2-based visual representations have been reported to exhibit a high degree of alignment with both human perception and model outputs (Bonnen et al., 2024). In this study, the pre-trained DINOv2 model was used as a fixed feature extractor to obtain discriminative embedding vectors from each image without fine-tuning. The DINOv2 architecture has variants with different

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model scales. In this context, DINOv2 models with Small (ViT-S/14), Base (ViT-B/14), and Large (ViT-L/14) backbone structures were evaluated in the study.

Proposed Approach

In this study, an approach was proposed where features extracted using DINOv2 were classified using SVM. The study was evaluated on both the original and augmented retinal fundus datasets. In this study, three different model scales of DINOv2 were used: ViT-S/14, ViT-B/14, and ViT-L/14. Features were extracted from the CLS token embedding for each image. Feature vectors of 384, 768, and 1024 dimensions were obtained for each model, respectively. These feature vectors were classified using the SVM. To mitigate the potential effects of class imbalance, the SVM model was trained with the class-weight parameter set to balanced. Furthermore, the model's hyperparameter optimization was performed using the GridSearchCV method. The best model was determined based on the F1-score metric to ensure balance between classes. Table 1 lists the parameters used in training the models. Furthermore, an ablation study was performed to evaluate the contribution of different components of the proposed model. Here, the model with the highest performance was used.

Accuracy, precision, recall and F1-score were used to evaluate the performance of this study. All feature extraction, model training, and performance evaluation stages were performed on the Google Colaboratory platform using T4 GPU hardware.

Table 1. Parameters and Values of the Models Used in this Study

Parameters	**Value**
SVM kernel	"rbf", "linear"
SVM C coefficient	0.1, 1, 10, 100
SVM Gamma coefficient	"scale", "auto", 1e-3, 1e-2, 1e-1
Batch size	32
Number of features	384, 768, and 1024

EXPERIMENTAL RESULTS AND DISCUSSION

Experimental Results

The best hyperparameters and performance results of the models evaluated on the original and augmented datasets are listed in Table 2. When examining the findings obtained on the original dataset, it is seen that each of the DINOv2-S + SVM, DINOv2-B + SVM, and DINOv2-L + SVM models achieved an accuracy value of 0.982. In experiments conducted with the augmented dataset,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

the DINOv2-S + SVM and DINOv2-B + SVM models achieved accuracy rates of 0.994 and 0.991, respectively, while the DINOv2-L + SVM model achieved an accuracy rate of 1.000. In this context, it is seen that data augmentation provides a significant improvement in model performance.

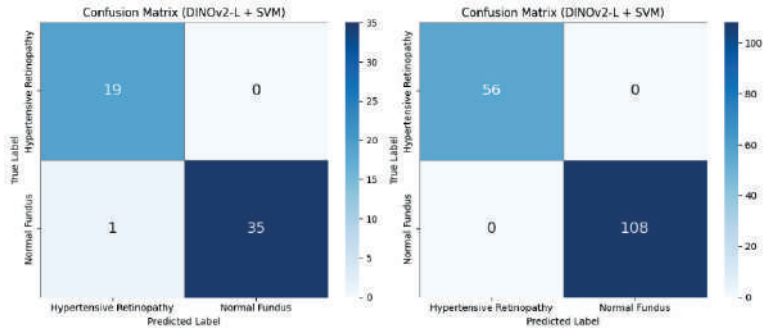
Table 2. Best Parameters and Performance Results of the Proposed Models on the Original and Augmented Datasets

Dataset	Model	Kernel	C	Gamma	Accuracy	Precision	Recall	F1-score
Original	Dinov2-S + SVM	'rbf'	10	0.001	**0.982**	**0.983**	**0.982**	**0.982**
	Dinov2-B + SVM	'linear'	0.1	'scale'	**0.982**	0.982	**0.982**	**0.982**
	Dinov2-L + SVM	'rbf'	1	'scale'	**0.982**	**0.983**	**0.982**	**0.982**
Augmented	Dinov2-S + SVM	'linear'	0.1	'scale'	0.994	0.994	0.994	0.994
	Dinov2-B + SVM	'linear'	0.1	'scale'	0.991	0.995	0.991	0.993
	Dinov2-L + SVM	'rbf'	1	'scale'	**1.000**	**1.000**	**1.000**	**1.000**

Bold font shows the highest results.

Figure 2 shows the confusion matrix results demonstrating the interclass discrimination capability of the proposed Dinov2-L + SVM model. The DINOv2-L + SVM model evaluated on the original dataset (Figure 2a) correctly classified all 19 examples belonging to the hypertensive retinopathy class. In the normal fundus class, 35 samples were predicted as normal fundus and 1 sample as hypertensive retinopathy. When examining the confusion matrix results for the augmented dataset (Figure 2b), it is seen that the proposed model classified both classes without error.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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(a) (b)

Figure 2. Confusion Matrices for the Proposed Model, (a) Original Dataset, (b) Augmented Dataset

Ablation Study

The results of the ablation study conducted on the original dataset using the DINOv2-L + SVM model are presented in Table 3. The ablation study was evaluated using Nested CV and a Holdout Test. In other words, the aim was to minimize model selection bias. In both experimental scenarios, the SVM model's hyperparameters (kernel type, C, and gamma) were re-optimized using the GridSearch method in the inner loop, and the performance values were reported based on the results obtained in the outer loop.

As shown in Table 3, it can be stated that feature extraction based on DINOv2 provides a strong and discriminative representation on the dataset. Using the original dataset, the accuracy, precision, recall and F1-score values were 0.972 ± 0.019, 0.970 ± 0.020 and 0.972 ± 0.019 for the 5-fold Nested CV approach. In the holdout test approach, the accuracy, precision, recall and F1-score values were 0.982, 0.975, 0.986 and 0.980, respectively. When the training dataset augmented, the accuracy in the Nested CV approach reached 0.997 0.007, precision 0.996 ± 0.010, recall 0.998 ± 0.005 and F1-score 0.997 ± 0.008. In the holdout test approach, a value of 1.000 was obtained in all metrics.

Table 3. Performance Results of the Ablation Study

Dataset	Evaluation approach	Accuracy	Precision	Recall	F1-score
Original Dataset	Nested CV (5-fold)	0.972 ± 0.019	0.970 ± 0.020	0.970 ± 0.020	0.970 ± 0.020
	Holdout Test	0.982	0.975	0.986	0.980
Train-only augmentation	Nested CV (5-fold)	0.997 ± 0.007	0.996 ± 0.010	0.998 ± 0.005	0.997 ± 0.008
	Holdout Test	1.000	1.000	1.000	1.000

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ISBN: 978-9952-610-30-7

Discussion

Table 4 presents a comparative summary of the studies proposed in the current literature for the classification of hypertensive retinopathy and the approach presented in this study. As can be seen in the studies summarized in Table 4, CNN models have generally been used. Gurthula et al. (2024) achieved accuracy rates of 98% on the Messidor-2 dataset and 89% on the ODIR-5K dataset using the Xception model. Triwijoyo et al. (2017) reported achieving an accuracy of 98.6% with their proposed CNN model. Similarly, Nagpal et al. (2023) achieved an accuracy of 98.72% with their combined MESSIDOR and ODIR ResNet101 model. Koduri & Ma (2024) achieved 97.98% accuracy with their Dual-ViT model , which they proposed using images of diabetic and hypertensive retinopathy created by combining three datasets. Zhu (2025) achieved a Specificity value of 0.806 with the ViT-B/8 (Pure) model and a Specificity value of 0.778 with the ViT-B/14-DINOv2 (Pure) model. The proposed DINOv2-L + SVM approach in this study achieved an accuracy of 0.982 on the original dataset and an accuracy of 1.000 on the augmented dataset.

Table 4. Comparison of approaches in literature

Reference	**Dataset**	**Model**	**Results**
Gurthula et al. (2024)	Messidor-2 and ODIR-5K datasets	Xception	Messidor-2 and ODIR-5K datasets: 98% accuracy and 89% accuracy
Triwijoyo et al. (2017)	DRIVE dataset	Proposed CNN	98.6% accuracy
Nagpal et al. (2023)	Combined MESSIDOR and ODIR	ResNet101	98.72% accuracy
Koduri & Ma (2024)	A combined dataset	Dual-ViT	97.98% accuracy
Zhu (2025)	Augmented HRDC dataset	ViT-B/8 (Pure)	Specificity: 0.806 (80.6%)
This study	Hypertensive Retinopathy Fundus Image Dataset: 273 images	DINOv2-L + SVM	0.982 (98.2%) accuracy
This study	Hypertensive Retinopathy Fundus Image Dataset: 819 images	DINOv2-L + SVM	1.000 (100%) accuracy

Although the proposed DINOv2 and SVM classification approach in this study demonstrates high performance, it has some limitations.

- The dataset used in the study has a small number of images. Although image augmentation was performed to overcome this limitation, the samples may not fully reflect the actual clinical diversity.
- Although excellent classification performance was achieved in the ablation study only in the training data augmentation scenario, this result may have been affected by the relatively small size of the dataset and the high degree of separability in the DINOv2 embedding space. Therefore, further validation on larger, independent clinical datasets is needed to confirm the generalizability of the proposed approach.
- In the proposed approach, deep features were used as a fixed feature extractor. In other words, the model was not trained end-to-end.
- In this study, deep features were only classified using SVM. Evaluating the study with different ML models was excluded from the scope.

CONCLUSION

This study proposes an approach that combines DINOv2-based feature extraction with an SVM classifier for the detection of hypertensive retinopathy. The proposed approach was evaluated using both the original and augmented datasets. The DINOv2-S, DINOv2-B, and DINOv2-L models were used in the study. Additionally, SVM hyperparameters were evaluated using GridSearchCV.

According to experimental results, the DINOv2-L + SVM model achieved an accuracy of 0.982 on the original dataset and an accuracy of 1.000 on the augmented dataset. The experimental results show that representations obtained with SSL approaches offer high performance even on small-scale datasets. In this context, the proposed approach will provide an effective alternative for clinical environments with limited computational resources. In future studies, it is planned to test the performance of the approach on different ML models and retinal datasets.

DATASET

The data used is an open dataset from the Kaggle platform, and the source is mentioned in the citation. Available at:https://www.kaggle.com/datasets/zoya77/hypertensive-retinopathy-fundus-image-dataset?select=Eye+Disease+dataset [21.12.2025]

REFERENCES

Aghabeigi Alooghareh, M. M., Sheikhey, M. M., Sahafi, A., Pirnejad, H., & Naemi, A. (2025). Deep Learning for Comprehensive Analysis of Retinal Fundus Images: Detection of Systemic and Ocular Conditions. Bioengineering, 12(8), 840.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Alasu, S., & Talu, M. F. (2024). Bilgisayarlı Görüde Öz-Denetimli Öğrenme Yöntemleri Üzerine Bir İnceleme. Duzce University Journal of Science and Technology, 12(2), 1136-1165.

Berroukham, A., Housni, K., & Lahraichi, M. (2023, December). Vision transformers: a review of architecture, applications, and future directions. In 2023 7th IEEE congress on information science and Technology (CiSt) (pp. 205-210). IEEE.

Bonnen, T., Fu, S., Bai, Y., O'Connell, T., Friedman, Y., Kanwisher, N., ... & Efros, A. A. (2024). Evaluating multiview object consistency in humans and image models. Advances in Neural Information Processing Systems, 37, 43533-43548.

Doerksen, K., Tingzon, I., Fibaek, C., Schneider, R., & Kim, D. H. (2024). AI-powered school mapping and connectivity status prediction using Earth observation. In Workshop on Machine Learning for Remote Sensing (ML4RS), Twelfth International Conference on Machine Learning Representations (ICLR 2024). Retrieved from https://ml-for-rs. github. io/iclr2024/camera_ready/papers/24. pdf.

Dosovitskiy, A., Beyer, L., Kolesnikov, A., Weissenborn, D., Zhai, X., Unterthiner, T., ... & Houlsby, N. (2020). An image is worth 16x16 words: Transformers for image recognition at scale. arXiv preprint arXiv:2010.11929.

Gurthula, R., Vanukuru, C., Chiluka, V., & Sumalata, M. S. (2024, June). Detection of diabetic and hypertensive retinopathy using deep learning models. In 2024 3rd International Conference on Applied Artificial Intelligence and Computing (ICAAIC) (pp. 522-527). IEEE.

Kaggle. (2025). Hypertensive retinopathy fundus image dataset. Kaggle. https://www.kaggle.com/datasets/zoya77/hypertensive-retinopathy-fundus-image-dataset?select=Eye+Disease+dataset [21.12.2025]

Koduri, H., & Ma, M. (2024, September). Diabetic and Hypertensive Retinopathy Classification from Retinal Images Using Dual Vision Transformer. In 2024 Fourth International Conference on Digital Data Processing (DDP) (pp. 87-91). IEEE.

Moor, M., Banerjee, O., Abad, Z. S. H., Krumholz, H. M., Leskovec, J., Topol, E. J., & Rajpurkar, P. (2023). Foundation models for generalist medical artificial intelligence. Nature, 616(7956), 259-265.

Muchuchuti, S., & Viriri, S. (2023). Retinal disease detection using deep learning techniques: a comprehensive review. Journal of Imaging, 9(4), 84.

Nagpal, D., Alsubaie, N., Soufiene, B. O., Alqahtani, M. S., Abbas, M., & Almohiy, H. M. (2023). Automatic detection of diabetic hypertensive retinopathy in fundus images using transfer learning. Applied Sciences, 13(8), 4695.

Oquab, M., Darcet, T., Moutakanni, T., Vo, H., Szafraniec, M., Khalidov, V., ... & Bojanowski, P. (2023). Dinov2: Learning robust visual features without supervision. arXiv preprint arXiv:2304.07193.

Paderno, A., Rau, A., Bedi, N., Bossi, P., Mercante, G., Piazza, C., & Holsinger, F. C. (2024). Computer vision foundation models in endoscopy: proof of concept in oropharyngeal cancer. The Laryngoscope, 134(11), 4535-4541.

Pinetsuksai, N., Kittichai, V., Jomtarak, R., Jaksukam, K., Tongloy, T., Boonsang, S., & Chuwongin, S. (2023, October). Development of self-supervised learning with DINOv2-distilled models for parasite classification in screening. In 2023 15th International Conference on Information Technology and Electrical Engineering (ICITEE) (pp. 323-328). IEEE.

Triwijoyo, B. K., Budiharto, W., & Abdurachman, E. (2017). The classification of hypertensive retinopathy using convolutional neural network. Procedia Computer Science, 116, 166-173.

Xuan, M., Wang, W., Shi, D., Tong, J., Zhu, Z., Jiang, Y., ... & He, M. (2023). A deep learning–based fully automated program for choroidal structure analysis within the region of interest in myopic children. Translational Vision Science & Technology, 12(3), 22-22.

Zhu, Y. (2025). Comparative Analysis of Deep Learning Strategies for Hypertensive Retinopathy Detection from Fundus Images: From Scratch and Pre-trained Models. arXiv preprint arXiv:2506.12492.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ATIK KARTON BARDAK İÇEREN UPR ESASLI POLİMER KOMPOZİTLERİN FİZİKSEL VE MEKANİK ÖZELLİKLERİNİN İNCELENMESİ

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ÖZET

Bu çalışmada, doymamış polyester reçine (UPR) esaslı polimer kompozitlerde ince agreganın tek kullanımlık atık karton bardak (AKB) parçalarıyla kısmi ikamesinin fiziksel ve mekanik özelliklere etkisi araştırılmıştır. Kontrol karışımı %50 UPR + %50 (0–4 mm) ince agrega olacak şekilde hazırlanmış; ince agrega, sırasıyla %2, %4, %6, %8 ve %10 oranlarında AKB ile yer değiştirilmiştir. Yoğunluk, su emme, porozite, ultrases geçiş hızı (UPV) ve basınç dayanımı özellikleri deneysel olarak belirlenmiştir. Sonuçlar, AKB ikamesi arttıkça yoğunluğun 1.846'dan 1.746 g/cm³'e azaldığını; su emme ve porozitenin sırasıyla 0.106'dan 0.241%'e ve 0.189'dan 0.436%'e yükseldiğini göstermiştir. UPV değerleri 3735 m/s'den 3350–3379 m/s aralığına gerilemiş; basınç dayanımı ise 88.4 MPa'dan 61.1 MPa'a düşmüştür. Bulgular, AKB ikamesinin boşluk hacmini ve matris dolgu arayüz süreksizliklerini artırarak su emme ve poroziteyi yükselttiğini, buna bağlı olarak UPV ile basınç dayanımını azalttığını ortaya koymaktadır. Bununla birlikte, mutlak su emme değerlerinin düşük aralıkta kalması ve karışımların yüksek dayanım seviyelerini koruması, bu tür kompozitlerin prefabrik polimer esaslı yapı elemanları ile mimari kaplama/panel uygulamalarında (taşıyıcı olmayan ve orta düzey dayanım gerektiren bileşenlerde) AKB'nin değerlendirilmesine yönelik uygulanabilir bir seçenek sunduğunu göstermektedir.

Anahtar Kelimeler: Polimer kompozit; atık karton bardak, mekanik özellikler

Investigation of the Physical and Mechanical Properties of UPR-Based Polymer Composites Incorporating Waste Paper Cups

ABSTRACT

In this study, the effect of partially replacing fine aggregate with single-use waste paper cup (WPC) fragments on the physical and mechanical properties of unsaturated polyester resin (UPR)-based

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

polymer composites was investigated. The control mixture was prepared with 50% UPR and 50% (0–4 mm) fine aggregate; the fine aggregate was subsequently replaced by WPC at replacement levels of 2%, 4%, 6%, 8%, and 10%, respectively. Density, water absorption, porosity, ultrasonic pulse velocity (UPV), and compressive strength were determined experimentally. The results indicated that increasing WPC replacement reduced the density from 1.846 to 1.746 g/cm³, while water absorption and porosity increased from 0.106% to 0.241% and from 0.189% to 0.436%, respectively. UPV decreased from 3735 m/s to the range of 3350–3379 m/s, and compressive strength declined from 88.4 MPa to 61.1 MPa. These findings demonstrate that WPC replacement increases void volume and matrix–filler interfacial discontinuities, thereby elevating water absorption and porosity and consequently reducing UPV and compressive strength. Nevertheless, the absolute water absorption values remained within a low range and the mixtures maintained relatively high strength levels, suggesting that such composites offer a feasible option for valorizing WPC in prefabricated polymer-based building components and architectural cladding/panel applications (i.e., non-load-bearing elements and components requiring moderate strength).

Keywords: Polymer composite; waste paper cup; mechanical properties

1. GİRİŞ

Son yıllarda artan çevre bilinci, karbon ayak izinin azaltılması ve kaynak verimliliğinin artırılması gibi sürdürülebilirlik hedefleri, atıkların ikincil hammadde olarak değerlendirilmesini malzeme üretimi açısından stratejik bir gereklilik hâline getirmiştir. Özellikle inşaat sektörü gibi yüksek hacimli hammadde tüketimine sahip alanlarda, atıkların geri kazanılarak yeni ürünlerin üretiminde kullanılması hem doğal kaynakların korunmasına hem de atık bertaraf yükünün azaltılmasına katkı sunmaktadır [1,2]. Bu yaklaşım, döngüsel ekonomi ilkeleriyle uyumlu biçimde atıkların katma değerli ürünlere dönüştürülmesini hedefleyerek çevresel faydayı ekonomik kazanımla birlikte ele almaktadır. Bu bağlamda, günlük yaşamda yaygın biçimde tüketilen ve önemli bir atık hacmi oluşturan tek kullanımlık kâğıt karton bardaklar, selülozik esaslı yapıları nedeniyle kompozit malzeme üretiminde değerlendirilebilecek potansiyel bir atık türü olarak öne çıkmaktadır.

Özellikle yüksek hacmi ve geri dönüşümünün zorluğu nedeniyle tek kullanımlık kâğıt bardak atıkları, yenilikçi geri dönüşüm ve yeniden kullanım stratejileri gerektiren önemli bir katı atık kategorisidir [3]. Türkiye'de yılda yaklaşık 2 milyar adet tek kullanımlık kâğıt bardak tüketildiği; bu miktardaki bardak üretiminin ise yılda yaklaşık 500 bin ağacın kesilmesini gerektirdiği bildirilmektedir. Kâğıt bardakların iç yüzeyinde sıvıyı tutmak amacıyla kullanılan plastik kaplama nedeniyle geri dönüşüm süreçleri sınırlı kalmakta; bu nedenle kâğıt bardaklar çoğu durumda doğrudan atık olarak çevrede birikerek kirliliğe katkıda bulunmaktadır [4]. Bu durum, söz konusu atıkların yalnızca bertaraf edilmesi yerine, mühendislik uygulamalarında katma değerli bir bileşen olarak yeniden değerlendirilmesini gerekli kılmaktadır.

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Literatürde atık kâğıt/karton kökenli takviyelerin veya partiküler dolgu malzemelerinin polimer matrislerde kullanımı; fiziksel ve mekanik performansı etkileyebilmesi, maliyetleri düşürebilmesi ve çevresel etkiyi azaltabilmesi bakımından giderek artan bir ilgi görmektedir [2,5]. Bu çerçevede, AKB'ların polimer kompozit üretiminde ince agrega olarak kullanımı; bir yandan doğal agrega tüketimini azaltma, diğer yandan katı atıkların katma değerli bir ürüne dönüştürülmesi yoluyla sürdürülebilirlik performansını iyileştirme potansiyeli taşımaktadır [6,7]. Ayrıca, güncel çalışmalar biyokompozitlerin üretim stratejileri, mekanik özellikleri, morfolojik karakteristikleri ve sürdürülebilirlik boyutlarının çok yönlü biçimde ele alındığını ve bu alandaki araştırma gereksiniminin arttığını göstermektedir [8]. Bu doğrultuda gerçekleştirilen bu çalışmada, önemli bir katı atık yan ürünü olan AKB'ların polimer kompozit üretiminde ince agrega bileşeni olarak değerlendirilmesi amaçlanmış; üretilen kompozitlerin fiziksel ve mekanik özellikleri belirlenerek AKB'lar için alternatif ve sürdürülebilir bir kullanım alanı ortaya konulması hedeflenmiştir.

2. MATERYAL ve METOT

2.1. Materyal

Kompozit numunelerin üretiminde bağlayıcı faz olarak döküm tipi doymamış polyester reçine kullanılmış; dolgu malzemesi olarak ise 0–4 mm tane boyutuna sahip ince agrega ile AKB parçaları tercih edilmiştir.

2.1.1. Bağlayıcı

Kompozit numunelerin üretiminde bağlayıcı/matris malzemesi olarak döküm tipi doymamış polyester reçine kullanılmıştır. Reçine Turkuaz markadır ve üretici teknik bilgilerine göre yoğunluğu 1.13 g/cm³'tür. Kürleme işlemi için UPR'ye ağırlıkça %1 oranında metil etil keton peroksit (MEKP) sertleştirici olarak ilave edilmiş; reaksiyonun hızlandırılması amacıyla ağırlıkça %0,2 oranında kobalt oktoat kullanılmıştır.

Doymamış polyester reçine, bu kürleme sistemi ile oda koşullarında çapraz bağlanarak üç boyutlu termoset bir yapı oluşturmakta; böylece dolgu fazlarını bir arada tutan süreklilik sağlayarak kompozitin bütünlüğünü ve performansını belirleyen ana matrisi oluşturmaktadır.

2.1.1. Dolgu malzemesi

Kompozit numunelerin üretiminde dolgu malzemesi olarak 0–4 mm tane boyutuna sahip ince agrega kullanılmıştır. İnce agrega, kompozit bünyesinde tane iskeletini oluşturarak dolgu fazının sürekliliğini sağlamış; karışımın işlenebilirliği ile hacimsel stabilitesine katkıda bulunmuştur.

Çalışmada ikinci dolgu bileşeni olarak AKB parçaları değerlendirilmiştir. AKB'lar uygun boyutlara getirilerek karışıma ilave edilmiş ve belirlenen oranlarda ince agrega ile yer değiştirecek şekilde kullanılmıştır. Bu sayede selülozik esaslı atıkların kompozit üretiminde ikincil hammadde olarak

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değerlendirilmesi hedeflenmiş; AKB kullanımının kompozitin fiziksel ve mekanik özellikleri üzerindeki etkisi araştırılmıştır. AKB atıklarının elde edilme aşamaları Şekil 1'de gösterilmiştir.



Şekil 1. AKB elde edilme aşamaları

2.2. Kompozit numunelerin üretimi

Bu çalışmada polimer matrisli kompozit numuneler, bağlayıcı olarak UPR ve dolgu malzemesi olarak 0–4 mm ince agrega kullanılarak üretilmiştir. Kontrol karışımı, %50 UPR + %50 ince agrega oranında hazırlanmış ve AKB0 olarak kodlanmıştır. Atık karton bardakların kompozit performansına etkisini incelemek amacıyla, ince agrega belirli oranlarda atık karton bardak parçaları ile ikame edilmiştir. Bu kapsamda ince agrega yerine sırasıyla %2, %4, %6, %8 ve %10 oranlarında AKB kullanılarak karışımlar hazırlanmış ve numuneler AKB2, AKB4, AKB6, AKB8 ve AKB10 şeklinde kodlanmıştır. İkame işlemi uygulanırken toplam bağlayıcı/dolgu oranı sabit tutulmuş, yalnızca dolgu bileşiminin ince agrega AKB oranı değiştirilmiştir. Polimer kompozitlere ait karışım oranları Tablo 1'de sunulmuştur.

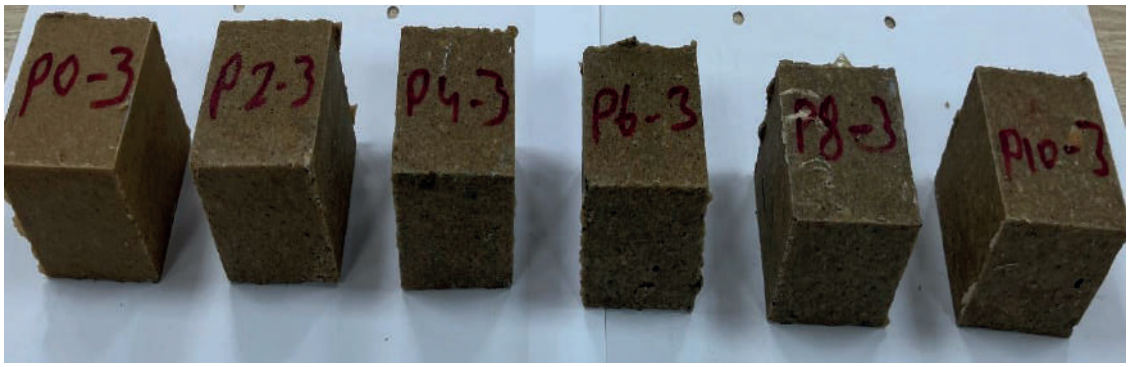
Tablo 1. Polimer kompozitlere ait karışım oranları (g)

Numune Kodu	Yer değiştirme oranı (%)	UPR (g)	İnce Agrega (g)	AKB(g)
AKB0	%0	254,25	594,0	0
AKB2	%2	254,25	582,12	3,15
AKB4	%4	254,25	570,24	6,30

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AKB6	%6	254,25	558,36	9,45
AKB8	%8	254,25	546,48	12,60
AKB10	%10	254,25	534,6	15,75

Kürleme için UPR içerisine ağırlıkça %1 MEKP sertleştirici ilave edilmiş; reaksiyonun hızlandırılması amacıyla ağırlıkça %0,2 kobalt oktoat kullanılmıştır. Sertleştirici ve hızlandırıcı, UPR'ye karışıma alınmadan hemen önce belirlenen oranlarda eklenmiş ve homojen bir karışım elde edilene kadar karıştırılmıştır. Ardından, önceden tartılan ince agrega ve AKB parçaları reçine fazına kademeli olarak ilave edilerek karıştırma işlemine devam edilmiştir. Elde edilen taze karışım, kalıplara yerleştirilmiş; boşluk oluşumunu azaltmak ve karışımın kalıp içinde düzgün yerleşmesini sağlamak amacıyla masa tipi titreşim ile sıkıştırılmıştır. Numuneler, başlangıç sertleşmesini tamamladıktan sonra kalıptan çıkarılmış ve uygun koşullarında muhafaza edilmiştir. Üretilen polimer kompozit numuneler Şekil 2'de gösterilmiştir.



Şekil 2. Üretilen polimer kompozit numuneler

2.3. Deneysel çalışma

2.3.1. Fiziksel özellikler

Üretilen polimer kompozitlerin fiziksel özellikleri kapsamında yoğunluk, su emme, porozite ve UPV deneyleri gerçekleştirilmiştir. Yoğunluk, su emme ve porozite değerleri TS EN 1170-6 [9] standardına göre Arşimet terazisi kullanılarak elde edilen verilerden yararlanılarak, aşağıda verilen Denklem (1), (2) ve (3) ile hesaplanmıştır.

Yoğunluk: $M_0/(M_0 - M_1)$ ..... (1)

Su emme: $\frac{M_2 - M_0}{M_0} * 100$ ..... (2)

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Porozite: $\frac{M_2 - M_0}{M_2 - M_1} * 100$ .....(3)

Burada, M_0: numunenin etüv kurusu kütlesi, M_1: numunenin sudaki kütlesi M_2: numunenin doygun kuru yüzey kütlesidir.

UPV testleri, ASTM C597-16 (2016) [10], standardına uygun olarak gerçekleştirilmiştir. Ölçümler, doğrudan iletim prensibi esas alınarak, verici ve alıcı dönüştürücüler numunenin karşılıklı yüzeylerine yerleştirilerek yapılmıştır. Her bir numune için ultrases dalgasının numune içerisinden geçişine ait geçiş süresi (t) cihazdan okunmuş, ölçüm uzunluğu (L) dikkate alınarak ultrases geçiş hızı Denklem (4) yardımı ile hesaplanmıştır:

$$v = \frac{L}{T} \quad \text{..... (4)}$$

Burada V UPV (m/s), L ölçüm mesafesini (m) ve t geçiş süresini (s) ifade etmektedir. Her seri için elde edilen UPV değerleri, ilgili numuneler üzerinden alınan ölçümlerin ortalaması alınarak raporlanmıştır.

2.3.2. Mekanik özellikler

Basınç dayanımı testleri, TS EN 12390-3 (2019) [11], standardı esas alınarak gerçekleştirilmiştir. Her bir karışım/seri için 50 × 50 × 50 mm boyutlarında 3 adet küp numune hazırlanmış ve basınç deneyi kapsamında test edilmiştir. Deney sırasında numuneler basınç plakaları arasına eksenel doğrultuda yerleştirilmiş, yükleme işlemi standardın öngördüğü prosedüre uygun şekilde uygulanmış ve her bir numunenin maksimum kırılma yükü (F) kaydedilmiştir. Basınç dayanımı değerleri, numunelerin yüzey alanı dikkate alınarak

$$fc = \frac{F}{A} \text{..... (5)}$$

Denklem (5) yardımıyla hesaplanmıştır. Her seri için elde edilen sonuçlar 3 numunenin ortalaması alınarak raporlanmıştır.

3. BULGULAR ve TARTIŞMA

Üretilen kompozit numune gruplarına ait yoğunluk, su emme, porozite, UPV ve basınç dayanımı performansları deneysel olarak belirlenmiştir. Elde edilen sonuçlar Tablo 2'de sunulmuş ve ilgili alt başlıklar altında tartışılmıştır.

Tablo 2. Polimer kompozitlere ait test sonuçları

Numune Kodu	Yoğunluk (g/cm^3)	Su emme (%)	Porozite (%)	UPV (m/s)	Basınç Dayanımı (MPa)
AKB0	1,846	0,106	0,189	3735	88,4

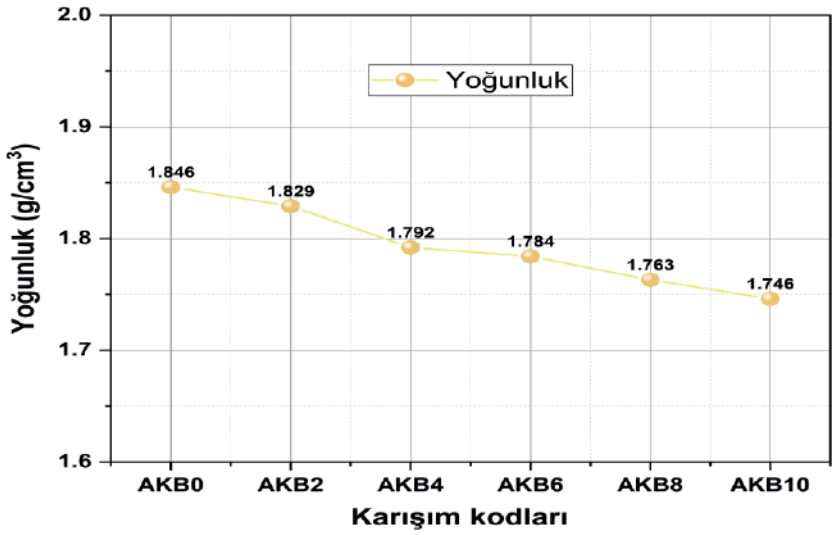
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AKB2	1,829	0,156	0,279	3686	74,6
AKB4	1,792	0,193	0,336	3514	70,1
AKB6	1,784	0,205	0,375	3433	68,5
AKB8	1,763	0,237	0,409	3350	63,1
AKB10	1,746	0,241	0,436	3379	61,1

3.1. Yoğunluk

Şekil 3'te kompozit numunelere ait yoğunluk değerleri sunulmuştur. Sonuçlar, AKB oranındaki artışa paralel olarak yoğunluğun azaldığını göstermektedir. Nitekim kontrol numunesi AKB0'ın yoğunluğu 1,846 g/cm³ iken, en yüksek ikame oranına sahip AKB10 numunesinde yoğunluk 1,746 g/cm³ olarak ölçülmüştür. AKB0 esas alındığında, AKB10 numunesinde yoğunluk yaklaşık %5,42 oranında azalmıştır. Bu azalma, kâğıt tabanlı atıkların ince agrega veya dolgu malzemesi olarak değerlendirildiği çalışmalarda rapor edilen genel davranışla uyumludur [12].

Literatürde, atık kâğıt esaslı malzemelerin harç ve beton sistemlerine dâhil edilmesinin çoğunlukla yoğunluğu düşürdüğü; karışımdaki ikame oranına bağlı olarak bu azalmanın bazı çalışmalarda %10–15 düzeylerine ulaşabildiği bildirilmektedir. Yoğunluktaki azalmanın başlıca iki mekanizma ile ilişkili olduğu değerlendirilmektedir: (i) kâğıt kökenli bileşenlerin mineral agregaya kıyasla daha düşük özgül ağırlığa sahip olması nedeniyle birim hacimde daha düşük kütle oluşturması ve (ii) lifsi yapının karışım içinde boşluk veya hapsolmuş hava miktarını artırabilmesidir. Atık kâğıt içeren beton veya harç sistemlerine yönelik derleme çalışmalarında da yoğunluk azalması, malzemenin hafiflemesiyle ilişkilendirilen en tutarlı bulgulardan biri olarak öne çıkmaktadır [13].



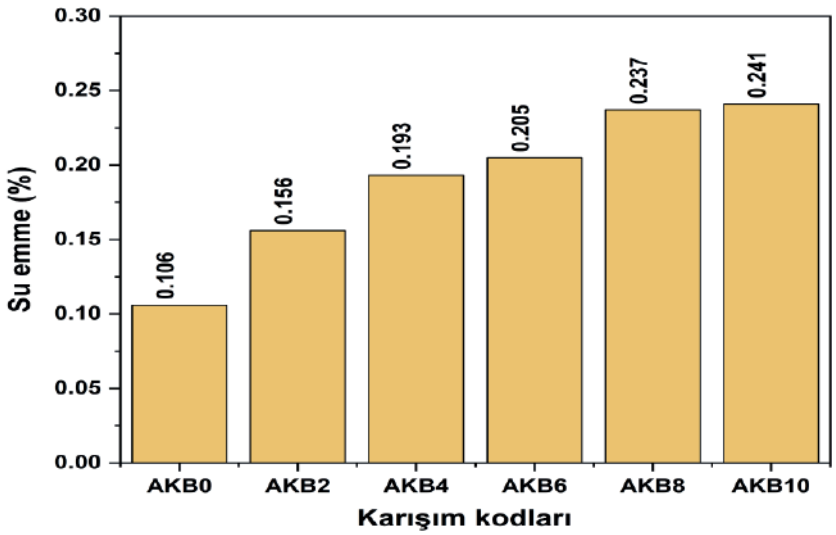
Şekil 3. Polimer kompozitlerin yoğunluk değerleri

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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3.2. Su emme ve porozite

Şekil 4'te kompozit numunelere ait su emme değerleri gösterilmiştir. Şekil 4'te AKB serisine ait su emme değerlerinin AKB içeriğiyle birlikte düzenli biçimde arttığı görülmektedir. Kontrol numunesinde su emme %0,106 iken, AKB içeriğinin artmasıyla değerler sırasıyla %0,156, %0,193, %0,205, %0,237 ve %0,241 seviyelerine yükselmiştir. Buna göre kontrol numunesine kıyasla su emme artışları sırasıyla yaklaşık %47,2, %82,1, %93,4, %123,6 ve %127,4 düzeyindedir.

Bu eğilim, atık kâğıt/kâğıt-tabanlı bileşenlerin agrega veya dolgu olarak kullanıldığı harç ve beton sistemlerinde rapor edilen bulgularla uyumlu olup; su emmedeki artış genellikle malzemenin lifsi morfolojisi ve hidrofilik karakteri ile ilişkilendirilmekte, buna bağlı olarak kapiller su taşınımına elverişli boşluk yapısının güçlenebildiği belirtilmektedir [12,13]. Su emme AKB içeriğiyle artıyor olsa da ölçülen mutlak değerler (%0,106–%0,241), beton esaslı malzemelerde rapor edilen tipik su emme düzeylerine kıyasla oldukça düşüktür. Bu sonuç, UPR matrisin oluşturduğu yoğun ve geçirimsiz mikro yapı nedeniyle su girişinin sınırlı kaldığını; dolayısıyla AKB ilavesi su emme eğilimini artırsa da kompozitlerin düşük su geçirgenliği gerektiren uygulamalar açısından uygunluk gösterebileceğini ortaya koymaktadır.



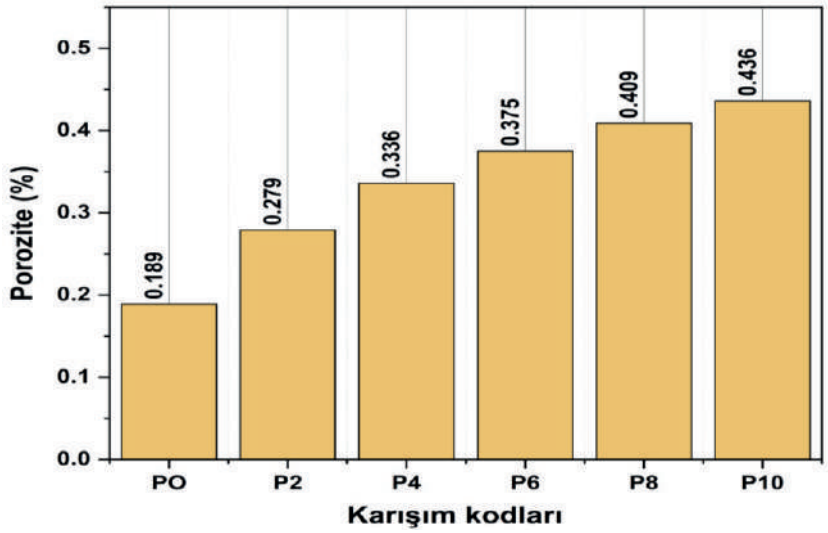
Şekil 4. Polimer kompozitlerin su emme değerleri

Polimer kompozit numunelerin porozite değerleri Şekil 5'te sunulmuştur. Şekil 5 incelendiğinde, AKB oranının artmasıyla porozite değerlerinde belirgin bir yükseliş meydana gelmiştir. Kontrol numunesinde porozite 0,189% iken, AKB ikamesiyle değerler %0,279–%0,436 oranında artmış; kontrol numunesine göre porozite artışları sırasıyla yaklaşık %47,6, %77,8, %98,4, %116,4 ve %130,7 olarak hesaplanmıştır. Bu artış, atık kâğıt tabanlı agregaların lifsi düzensiz morfolojisi nedeniyle karışım içinde daha düzensiz boşluklar oluşturabilmesi, liflerin matris fazıyla etkileşimi ve homojen

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

dağılmama eğilimi sonucunda geçirgen boşluk hacminin artabilmesi ile açıklanan literatür bulgularıyla uyumludur [12].

Ayrıca UPR esaslı kompozitlerde dolgu miktarı arttıkça aderansın azalması ve matris dolgu arayüzünde boşluk miktarının artması, poroziteyi yükselten temel mekanizmalar arasında raporlanmakta; bu tür boşlukların mekanik davranışı da sınırlayabildiği önceki çalışmalarda rapor edilmiştir [14].



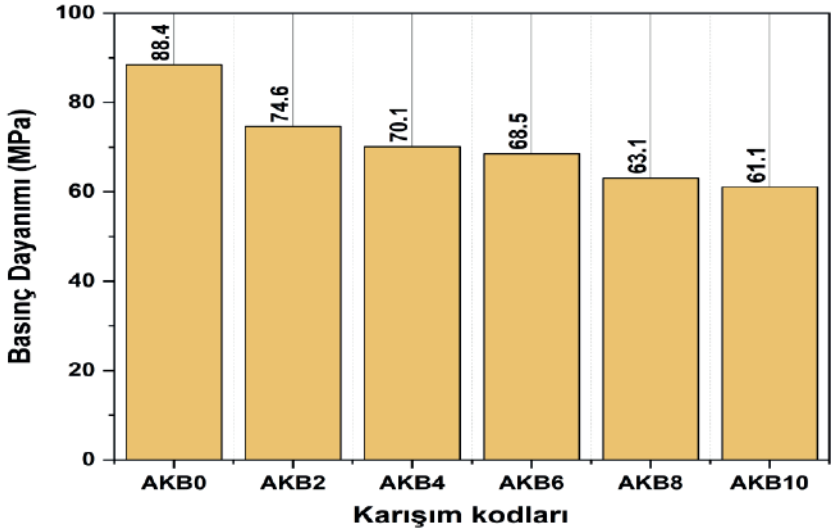
Şekil 5. Polimer kompozitlerin porozite değerleri

3.3. Basınç dayanımı

Şekil 6'da polimer kompozit numunelerin basınç dayanımı değerleri sunulmuştur. Şekil 6 incelendiğinde, AKB oranının artmasıyla basınç dayanımı değerlerinde belirgin bir azalma olduğu görülmektedir. Kontrol numunesinde (AKB0) 88,4 MPa olan basınç dayanımı, en yüksek ikame oranında (AKB10) 61,1 MPa olarak ölçülmüştür. Bu azalma; AKB'nin selülozik ve gözenekli yapısının reçine tarafından kısmen emilmesi, karışım içinde boşluk oranının artması ve mineral ince agregaya kıyasla UPR ile AKB arayüz aderansının daha zayıf kalması ile ilişkilendirilebilir. Nitekim literatürde, atık kâğıt kökenli dolgu veya liflerin polimer ya da çimento esaslı sistemlere dâhil edilmesiyle boşluk ve arayüz süreksizliklerinin artabildiği, bunun da basınç dayanımı üzerinde olumsuz etki oluşturabildiği rapor edilmiştir [15–17].

Bununla birlikte, tek kullanımlık karton bardakların yapı malzemelerinde değerlendirilmesi **doğal agrega tüketimini azaltan** ve **atıkların depolama, bertaraf yükünü düşüren** döngüsel ekonomi yaklaşımı açısından önemlidir. Bu nedenle, AKB ikamesi mekanik kayıp pahasına çevresel fayda sağlayan bir seçenek olarak değerlendirilebilir; mekanik performansın kritik olduğu uygulamalarda ikame oranının **düşük tutulması** ve AKB parçaların yüzeyinin modifikasyonunun ara yüzey uyumunu artıracak şekilde iyileştirilmesi önerilmektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

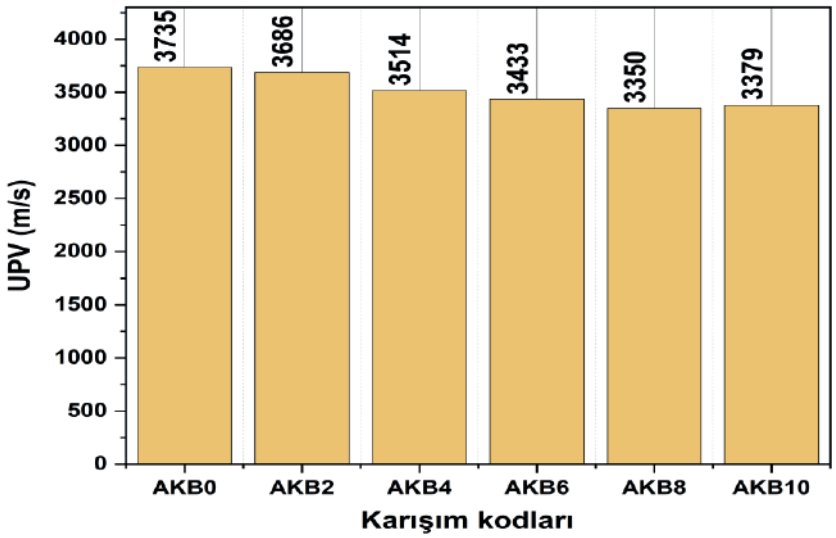


Şekil 6. Polimer kompozitlerin basınç dayanımı değerleri

3.4. Ultrases geçiş hızı

Polimer kompozit numunelere ait UPV değerleri Şekil 7'de sunulmuştur. Şekil 7'de UPV'nin, AKB içeriği arttıkça genel olarak azaldığı görülmektedir. Kontrol numunesinde 3735 m/s olan UPV, artan AKB oranıyla 3350–3379 m/s aralığına gerileyerek toplamda yaklaşık %10 düzeyinde düşmüştür.

UPV'nin malzeme içindeki boşluklar, süreksizlikler ve çatlak benzeri kusurlara duyarlı olduğu; bu kusurların dalga yayılım yolunu uzatarak UPV'yi azaltabildiği ASTM C597'de vurgulanmaktadır [18]. Porozitenin artmasıyla UPV'nin azalması arasındaki ters yönlü ilişki, harç ve beton sistemlerinde yapılan deneysel korelasyon çalışmalarıyla da ortaya konmuştur [19]. Bu çerçevede, AKB içeriğiyle birlikte porozitenin artması ve matris ile dolgu arayüzünde süreksizliğin belirginleşmesi, UPV'deki düşüşün temel nedeni olarak değerlendirilebilir. Benzer şekilde, atık kâğıt içeren papercrete türü sistemlerde UPV ölçümlerinin karışım homojenliğini ve iç kusurları yansıttığı; atık kâğıt ilavesiyle UPV'nin düşebildiği rapor edilmiştir [20].



Şekil 7. Polimer kompozitlerin UPV değerleri

4. SONUÇLAR

Bu çalışmada, UPR esaslı polimer kompozitlerde 0–4 mm ince agreganın %2–%10 oranlarında AKB parçaları ile ikame edilmesinin fiziksel ve mekanik performansa etkisi incelenmiştir. Deney sonuçları, AKB oranı arttıkça yoğunluğun 1,846'dan 1,746 g/cm³'e azaldığını; su emme ve porozitenin sırasıyla %0,106'dan %0,241'e ve %0,189'dan %0,436'e yükseldiğini göstermiştir. Buna paralel olarak UPV 3735 m/s'den 3350–3379 m/s aralığına gerilemiş ve basınç dayanımı 88,4 MPa'dan 61,1 MPa'a düşmüştür. Bu eğilim, AKB'nin lifli ve gözenekli yapısının boşluk hacmini artırması ve matris ile dolgu arayüzünde süreksizlik oluşturmasıyla ilişkilendirilebilir. Bununla birlikte, mutlak su emme değerlerinin düşük seviyede kalması ve dayanımın yüksek bir aralıkta korunması, AKB'nin özellikle düşük ikame oranlarında prefabrik polimer esaslı yapı elemanları ile taşıyıcı olmayan mimari panel bileşenlerinde sürdürülebilir bir ikincil hammadde alternatifi olabileceğine işaret etmektedir. Ayrıca geri dönüşümü sınırlı ve yüksek hacimli bir atık grubunun kompozit bileşen olarak değerlendirilmesi, depolama ve bertaraf yükünü azaltarak doğal agrega tüketiminin düşürülmesine ve döngüsel ekonomi hedeflerine katkı sunabilir. Mekanik performansın kritik olduğu uygulamalar için ise ikame oranının sınırlandırılması ve AKB yüzeyinin arayüz uyumunu artıracak şekilde modifiye edilmesi önerilmektedir.

Teşekkür:

Bu çalışma, TÜBİTAK BİDEB tarafından 1919B012413095 numaralı proje kapsamında desteklenmiştir. TÜBİTAK'a sağladığı destek için teşekkür ederiz.

5. KAYNAKLAR

[1] C. Özel, B. İren, Polimer Betonlarda Gazbeton Atıklarının Kullanılabilirliğinin Araştırılması, Tek. Bilim. Derg. 6 (2016).

[2] S.B. Torun, Bazı çevresel atıkların ve doğal liflerin kompozitlerde kullanılabilirliği, Artvin Çoruh Üniversitesi Orman Fakültesi Derg. 22 (2021) 126–133.

[3] K. Ragaert, S. Hubo, L. Delva, L. Veelaert, E. Du Bois, Upcycling of contaminated post-industrial polypropylene waste: A design from recycling case study, Polym. Eng. Sci. 58 (2018) 528–534.

[4] A. Maalouf, A. Mavropoulos, M. El-Fadel, Global municipal solid waste infrastructure: Delivery and forecast of uncontrolled disposal, Waste Manag. Res. 38 (2020) 1028–1036.

[5] H. Temiz, M.M. Maras, F. Kantarcı, Polimer katkılı kompozitlerin mekanik ve yalıtım özelliklerinin incelenmesi, Duzce Univ. J. Sci. Technol. 8 (2020) 1394–1406.

[6] S. Pazarlıoğlu, H. Gökçe, Composite Materials with Different Engineering Approaches-I, (2023).

[7] P.D. Menezes, T. de Meireles Carneiro, A.T. Marques, Composites for Life: A Case Study, U. Porto J. Eng. 7 (2021) 37–51.

[8] N. Santhosh, B.A. Praveena, A.C. Gowda, A.A. Duhduh, A.A. Rajhi, S. Alamri, P. Berwal, M.A. Khan, A.W. Wodajo, Innovative eco-friendly bio-composites: A comprehensive review of the fabrication, characterization, and applications, Rev. Adv. Mater. Sci. 63 (2024) 20240057.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

[9] TS EN 1170-6, Ön yapımlı beton mamuller- Cam elyaf takviyeli çimento (ctc) deney metodu-Bölüm 6: Suya daldırma yoluyla su emme ve kuru yoğunluk tayini TSE, Türk Standartları Enstitüsü, ANKARA, 1999.

[10] ASTM C 597-02, Pulse Velocity Through Concrete, 2016. https://doi.org/10.1520/C0597-16.2.

[11] TS EN 12390-3, Beton - Sertleşmiş beton deneyleri - Bölüm 3: Deney numunelerinin basınç dayanımının tayin, Türk Standartları Enstitüsü, ANKARA, 2019.

[12] H. Harabi, M.L.K. Khouadjia, S. Bensalem, H.F. Isleem, M. Khishe, Effect of waste paper aggregate and polyethylene terephthalate on mortar performance, Sci. Rep. 14 (2024) 29588.

[13] B.A. Solahuddin, A comprehensive review on waste paper concrete, Results Eng. 16 (2022) 100740.

[14] S.M.S. Al-Mufti, A. Almontasser, S.J.A. Rizvi, Unsaturated polyester resin filled with cementitious materials: a comprehensive study of filler loading impact on mechanical properties, microstructure, and water absorption, ACS Omega 8 (2023) 20389–20403.

[15] R. Haigh, M. Sandanayake, Y. Bouras, Z. Vrcelj, The durability performance of waste cardboard kraft fibre reinforced concrete, J. Build. Eng. 67 (2023) 106010.

[16] B.A. Salami, A.A. Bahraq, M.M. ul Haq, O.A. Ojelade, R. Taiwo, S. Wahab, A.A. Adewumi, M. Ibrahim, Polymer-enhanced concrete: A comprehensive review of innovations and pathways for resilient and sustainable materials, Next Mater. 4 (2024) 100225.

[17] F. Carrión, L. Montalbán, J.I. Real, T. Real, Mechanical and physical properties of polyester polymer concrete using recycled aggregates from concrete sleepers, Sci. World J. 2014 (2014) 526346.

[18] A. C597-22, Standard Test Method for Ultrasonic Pulse Velocity Through Concrete, (2022).

[19] Z. Lafhaj, M. Goueygou, A. Djerbi, M. Kaczmarek, Correlation between porosity, permeability and ultrasonic parameters of mortar with variable water/cement ratio and water content, Cem. Concr. Res. 36 (2006) 625–633.

[20] N. Handika, M. Rafky, S. Danifaro, E. Tjahjono, E. Arijoeni, Homogeneity of papercrete with 10% waste paper substitution using Ultrasonic Pulse Velocity (UPV), in: AIP Conf. Proc., AIP Publishing LLC, 2021: p. 40005.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MATEMATİĞİN ZAMAN ÇİZELGESİ: YAPAY ZEKA VE WEB2 ARAÇLARIYLA ZENGİNLEŞTİRİLMİŞ İNTERAKTİF BİLİM TARİHİ ATLASI

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Özet

Toplumda matematiğin zor ve soyut bir alan olduğu yönündeki yaygın algıyı kırmak ve öğrencilerin matematik okuryazarlığını geliştirmek amacıyla, bilimin insani ve kültürel boyutlarını öne çıkaran bütüncül bir öğrenme deneyimi sunulması hedeflenmektedir. Salt formül ezberine dayalı yaklaşımın ötesine geçerek, matematik tarihini modern teknolojiyle entegre etmek temel hedeftir. Projede, matematik tarihini kronolojik olarak İlk Çağ, Orta Çağ, Yeni Çağ ve Yakın Çağ olmak üzere dört ana döneme ayıran bir "Matematik Tarihi Atlası"web sitesi geliştirilmiştir. Web sitesi tasarımında, etkileşimli ve dinamik sayfalar oluşturmak için Web2 araçları ve yapay zekâ destekli kodlama teknolojileri kullanılmıştır. Her çağ için seçilen üçer önemli matematikçinin (örneğin Thales, Hârezmî, Descartes, Gauss) yaşam hikayeleri ve kavramsal katkıları bilimsel kaynaklara dayalı olarak detaylandırılmıştır. Soyut kavramları somutlaştırmak ve ilgiyi artırmak amacıyla zengin görsel medya altyapısı kullanıldı. Ardından web site tekrar gözden geçirilip geliştirildi. Geliştirilmiş haline matematik kavramları eklendi ve daha çok matematikçinin biyografisinden bahsedildi. Bunun dışında renk uyumuna daha çok özen gösterildi. Çalışma sonucunda, matematiksel kavramların tarihsel kökenlerini ve gelişim aşamalarını kronolojik bir anlatımla bütünleştiren, akademik standartlara uygun nitelikli bir dijital içerik üretilmiştir. Seçilen matematikçilerin biyografilerinin ve temel teoremlerinin (örneğin Pisagor Teoremi, kartezyen koordinat sistemi) sunumuyla, matematiğin insan emeğiyle nasıl evrildiği gözler önüne serilmiştir. Elde edilen bulgular, projenin matematik öğrenme deneyimine güçlü bir kültürel derinlik kattığını ve kavramların akılda kalıcılığını artırdığını göstermektedir. Gelecekteki çalışmalar için; sitenin uluslararası geçerliliğini desteklemek amacıyla çoklu dil desteği eklenmesi ve öğrenmeyi pekiştirmek için indirilebilir ek kaynaklar (kitapçıklar, çalışma kağıtları) ile yapay zekâ destekli alıştırma/soru-cevap sisteminin entegrasyonu önerilmektedir.

Anahtar Kelimeler: *Matematik, Bilim Tarihi, Teknolojik Tasarım, Bilim İletişimi.*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE TIMELINE OF MATHEMATICS: AN INTERACTIVE ATLAS OF THE HISTORY OF SCIENCE ENRICHED WITH ARTIFICIAL INTELLIGENCE AND WEB2 TOOLS

Abstract

In This project aims to challenge the common public perception of mathematics as a difficult and abstract field by offering a holistic learning experience that emphasizes the human and cultural dimensions of science. The primary goal is to integrate the history of mathematics with modern technology, moving beyond an approach solely based on rote memorization of formulas.As part of the project, a "History of Mathematics Atlas" website was developed, chronologically dividing mathematical history into four main eras: Antiquity, the Middle Ages, the Modern Era, and the Contemporary Era. Web2 tools and AI-supported coding technologies were utilized in the website design to create interactive and dynamic pages. For each era, the life stories and conceptual contributions of three prominent mathematicians (e.g., Thales, Al-Khwarizmi, Descartes, Gauss) were detailed based on scientific sources. A rich visual media infrastructure was implemented to concretize abstract concepts and increase engagement. Subsequently, the website was revised and enhanced; mathematical concepts were integrated, more biographies were added, and the color harmony was refined.As a result of this study, a high-quality digital content that aligns with academic standards has been produced, integrating the historical origins and developmental stages of mathematical concepts through a chronological narrative. By presenting the biographies and fundamental theorems (e.g., the Pythagorean Theorem, the Cartesian coordinate system) of selected mathematicians, the evolution of mathematics through human effort is demonstrated. The findings indicate that the project adds significant cultural depth to the mathematics learning experience and enhances the retention of concepts. For future work, it is recommended to add multi-language support to ensure international validity and to integrate downloadable resources (booklets, worksheets) along with an AI-powered practice/Q&A system to reinforce learning.

Keywords: Mathematics, History of Science, Technological Design, Science Communication.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İHA FOTOGRAMETRİSİ VE YERSEL YÖNTEMLERİN HEYELAN İZLEME SÜREÇLERİNDE KARŞILAŞTIRMALI ANALİZİ: SAMSUN ÖRNEĞİ

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ÖZET

Güncel mühendislik projelerinde çalışma sahalarının genişlemesi ve proje teslim sürelerinin kısalması, geleneksel ölçme yöntemlerinin operasyonel verimliliğini sorgulanır hale getirmiştir. Bu çalışma, İnsansız Hava Araçları (İHA) tabanlı fotogrametrik ölçüm tekniklerinin doğruluğunu ve maliyet etkinliğini, geleneksel yersel yöntemlerle (RTK-GPS) karşılaştırmalı olarak analiz etmeyi amaçlamaktadır.

Çalışma alanı olarak Samsun ilinde bulunan, yaklaşık 30 hektarlık aktif bir heyelan bölgesi seçilmiştir. Saha operasyonunda DJI Mini 4 Pro İHA platformu kullanılırken, jeodezik kontrol ve doğrulama işlemleri için CORS GPS (RTK) cihazı ile 10 adet homojen dağılımlı Yer Kontrol Noktası (YKN) tesis edilmiştir. Elde edilen 854 adet bindirmeli görüntü, Agisoft Metashape yazılımı kullanılarak Structure from Motion (SfM) algoritması ile işlenmiş ve yüksek çözünürlüklü modeller üretilmiştir.

Yapılan analizler sonucunda, üretilen modellerin 2.69 cm/piksel Yer Örnekleme Aralığına (GSD) sahip olduğu ve karesel ortalama hatanın (RMSE) mühendislik standartları dahilinde kaldığı tespit edilmiştir. Operasyonel açıdan İHA yönteminin, geleneksel yönteme kıyasla zaman tasarrufunda %95, maliyet verimliliğinde ise %85 oranında avantaj sağladığı gözlemlenmiştir. Sonuç olarak İHA fotogrametrisinin, özellikle riskli ve geniş heyelan sahalarının izlenmesinde, yersel yöntemleri tamamlayıcı ve hızlandırıcı stratejik bir çözüm sunduğu ortaya konulmuştur.

Anahtar Kelimeler: İHA Fotogrametrisi, Heyelan İzleme, RTK-GPS, Karşılaştırmalı Analiz, Mühendislik Ölçmeleri.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Comparative Analysis of UAV Photogrammetry and Traditional Terrestrial Surveying Techniques for Landslide Monitoring: A Case Study in Samsun

ABSTRACT

Abstract: The expansion of project areas and shortening of delivery times in modern engineering projects have made the operational efficiency of traditional surveying methods a subject of scrutiny. This study aims to analyze the accuracy and cost-effectiveness of Unmanned Aerial Vehicle (UAV) based photogrammetric measurement techniques in comparison with traditional terrestrial methods (RTK-GPS).

An active landslide area of approximately 30 hectares located in Samsun province was selected as the study site. A DJI Mini 4 Pro UAV platform was utilized for field operations, while 10 homogeneously distributed Ground Control Points (GCPs) were established and measured using a CORS GPS (RTK) device for geodetic control and validation. A total of 854 overlapping images were processed using the Structure from Motion (SfM) algorithm within the Agisoft Metashape software to generate high-resolution models.

Analysis revealed that the generated models achieved a Ground Sampling Distance (GSD) of 2.69 cm/pixel, with the Root Mean Square Error (RMSE) remaining within acceptable engineering standards. Operationally, the UAV method was observed to provide a 95% advantage in time savings and an 85% advantage in cost efficiency compared to traditional methods. In conclusion, it has been demonstrated that UAV photogrammetry offers a strategic, complementary, and accelerating solution, particularly for monitoring high-risk and extensive landslide areas.

Keywords: UAV Photogrammetry, Landslide Monitoring, RTK-GPS, Comparative Analysis, Engineering Surveying.

GİRİŞ

Heyelanlar, dünya genelinde can ve mal kayıplarına yol açan en yıkıcı doğal afetlerden biridir. Özellikle Türkiye gibi aktif tektonik ve eğimli topoğrafyaya sahip ülkelerde, heyelan bölgelerinin periyodik olarak izlenmesi hayati önem taşımaktadır. Heyelan izleme (monitoring) süreçlerinde temel amaç, yüzey hareketlerini milimetrik veya santimetrik hassasiyetle belirleyerek erken uyarı sistemlerine veri sağlamaktır.

Geleneksel jeodezik yöntemler (Total Station, RTK-GPS), jeodezik ağların kurulması ve noktaların tek tek ölçülmesi esasına dayanır. Bu yöntemler yüksek doğruluk sunmasına rağmen, özellikle aktif heyelan bölgelerinde personelin güvenliğini tehlikeye atmakta ve çok fazla iş gücü gerektirmektedir. Ayrıca, bu yöntemler "noktasal" veri sunduğu için, ölçülmeyen noktalar arasındaki deformasyonların gözden kaçmasına neden olabilmektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Son on yılda, İnsansız Hava Araçları (İHA) tabanlı fotogrametri, Structure from Motion (SfM) teknolojisi ile birleşerek bu kısıtlılıkları aşmıştır. İHA'lar "alansal" veri sunarak arazinin tamamını kapsayan milyonlarca noktadan oluşan Sayısal Yüzey Modelleri (DSM) üretilmesine imkan tanımaktadır. Bu çalışma, Samsun ilindeki 30 hektarlık bir sahada İHA fotogrametrisinin geleneksel yöntemlerle teknik ve ekonomik açıdan kıyaslanmasını ele almaktadır.

2. LİTERATÜR TARAMASI

Literatür incelendiğinde, İHA fotogrametrisinin heyelan izlemedeki başarısı birçok araştırmacı tarafından vurgulanmıştır. Colomina ve Molina (2014), İHA sistemlerinin uzaktan algılama ve fotogrametri dünyasında yarattığı devrimi kapsamlı bir şekilde incelemiş, özellikle erişilemeyen alanlarda sunduğu verimliliğe dikkat çekmişlerdir. Nex ve Remondino (2014) ise İHA tabanlı 3D haritalamanın doğruluğunun, kullanılan Yer Kontrol Noktası (YKN) sayısı ve dağılımı ile doğrudan ilişkili olduğunu kanıtlamışlardır.

Türkiye ölçeğinde yapılan çalışmalarda, Ulvi (2021), İHA fotogrametrisinin mühendislik ölçmelerindeki kısıtlılıklarını ve avantajlarını teknik bir perspektifle sunmuştur. Uzar ve Zemir (2019) ise Gaziantep bölgesinde yaptıkları maliyet analizinde, İHA kullanımının geleneksel yöntemlere göre maliyetleri 4.5 kat azalttığını belirtmişlerdir. Bu çalışma, Samsun bölgesindeki heyelan sahası özelinde bu verimlilik analizini güncel donanım ve yazılımlarla bir adım öteye taşımayı amaçlamaktadır.

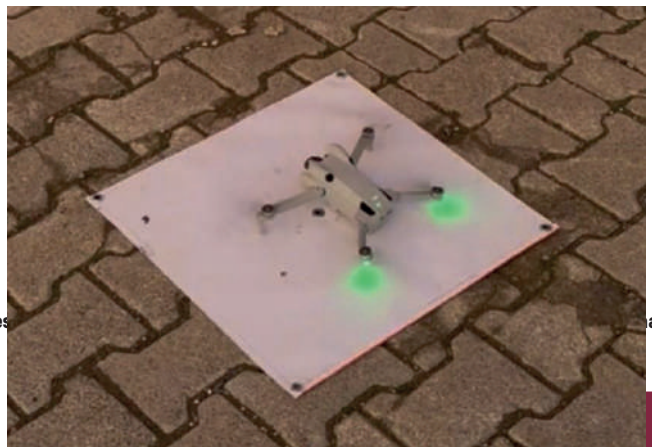
3. MATERYAL VE METOT

3.1. Çalışma Alanı ve Jeolojik Yapı

Çalışma alanı, Samsun il sınırları içerisinde yer alan, yaklaşık 300 dönümlük aktif bir heyelan sahasıdır. Bölge, Karadeniz ikliminin etkisiyle yoğun yağış alan, killi ve kaygan zemin yapısına sahip bir topoğrafyadır. Heyelan hareketlerinin yüzeyde yarattığı yarıklar ve kütle kaymaları, geleneksel ölçüm cihazlarının (tripod vb.) kurulmasını zorlaştırmaktadır.

3.2. Teknik Donanım ve Sensörler

Çalışmada kullanılan **DJI Mini 4 Pro**, 249 gramın altındaki ağırlığına rağmen 48MP çözünürlüklü 1/1.3 inç CMOS sensöre sahiptir. Bu sensör, düşük irtifa uçuşlarında yüksek detay seviyesi sunmaktadır. Jeodezik kontrol için kullanılan **Cors GPS** cihazı ise Türkiye'nin ulusal TUSAGA-Aktif ağına bağlanarak santimetre hassasiyetinde (RTK) koordinat alımı sağlamıştır.



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Şekil 1: Çalışmada kullanılan DJI Mini 4 Pro İHA sistemi ve kalkış hazırlığı.

3.3. Veri Toplama ve Fotogrametrik İş Akışı

Saha operasyonu iki ana aşamada yürütülmüştür:

1. **Jeodezik Altyapı:** Sahaya 10 adet homojen dağılımlı YKN (Yer Kontrol Noktası) tesis edilmiştir. Bu noktalar, modelin gerçek dünya koordinat sistemine (ITRF96) bağlanması için kritik öneme sahiptir.

2. **Uçuş Planı:** Otonom uçuş, %80 boyuna ve %75 enine bindirme oranlarıyla, çalışma sahasını tam kapsayacak şekilde **tek yönlü paralel uçuş hatları (zig-zag desenli)** üzerinden 70 metre yükseklikten icra edilmiştir. Toplamda 854 adet fotoğraf elde edilmiştir.

Veri işleme sürecinde **Agisoft Metashape** yazılımı kullanılmıştır. SfM (Structure from Motion) algoritması ile fotoğrafların hizalanması yapılmış, ardından YKN değerleri sisteme girilerek model optimize edilmiştir. 691 milyon nokta içeren yoğun nokta bulutu üzerinden 2.69 cm çözünürlüklü ortofoto üretilmiştir.



Şekil 2: Heyelan bölgesinin otonom uçuş planı ve zigzag uçuş hatları.

4. BULGULAR

4.1. Konumsal Doğruluk Analizi

Modelin doğruluğu, Yersel (RTK-GPS) yöntemle ölçülen kontrol noktaları ile modelden okunan koordinatların farkı üzerinden hesaplanmıştır. Karesel Ortalama Hata (RMSE) değerleri Tablo 1'de sunulmuştur.

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Tablo 1: Model Hassasiyet ve RMSE Değerleri

Hata Parametresi	RMSE Değeri (cm)
Yatay Hata (Easting/Northing)	3.8 cm
Düşey Hata (Elevation)	7.2 cm
Toplam Konumsal Hata	5.5 cm

4.2. Operasyonel Verimlilik ve Maliyet Analizi

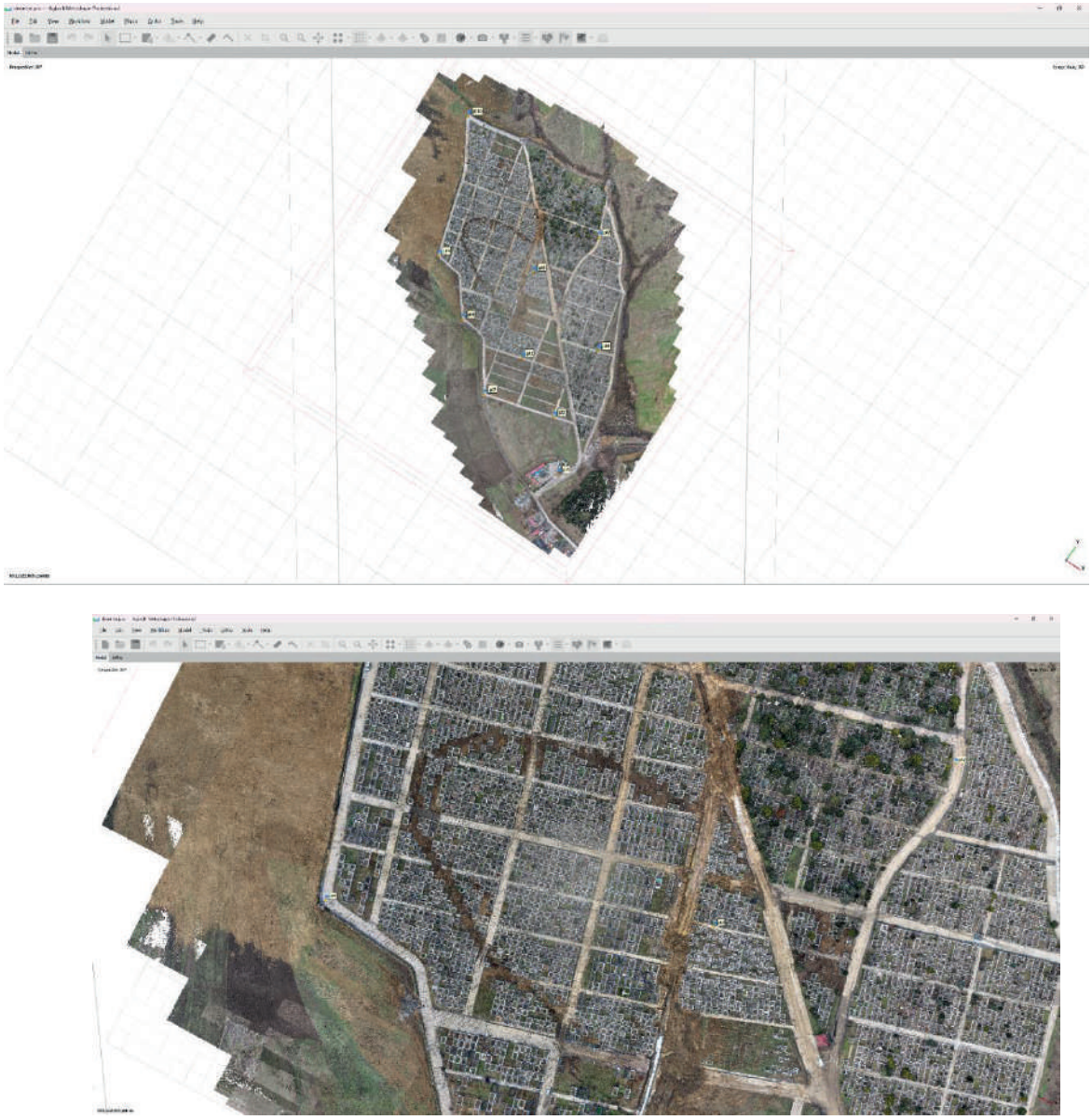
Seminer kapsamında yapılan projeksiyonlar, İHA yönteminin ekonomik üstünlüğünü kanıtlamıştır. 30 hektarlık bir heyelan sahasının total station ile taranması durumunda oluşacak personel ve zaman maliyeti, İHA yöntemiyle kıyaslandığında devasa bir fark ortaya çıkarmaktadır.

Tablo 2: Geleneksel ve İHA Yöntemlerinin Karşılaştırılması

Kriter	Geleneksel Yöntem (RTK/Total Station)	İHA Fotogrametrisi (Mini 4 Pro)
Saha Personeli	4-6 Kişi	1-2 Kişi
Saha Süresi	10-15 Gün	2 Saat
Ofis İşlemleri	7 Gün	4 Saat
Tahmini Toplam Maliyet	200.000 TL	30.000 TL
Veri Yoğunluğu	0.1 Nokta/m²	100+ Nokta/m²

"Fotogrametrik değerlendirme sonucunda 30 hektarlık alanın tamamını kapsayan yüksek çözünürlüklü bir sayısal model elde edilmiştir. Şekil 4a'da görüldüğü üzere, modelin geometrik doğruluğunu sağlamak amacıyla yer kontrol noktaları (GCP) tüm çalışma alanına homojen bir şekilde dağıtılmıştır. Şekil 4b'de ise heyelan bölgesindeki yarıklar ve zemin deformasyonları dijital ortamda detaylı bir şekilde analiz edilebilmektedir."

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Şekil3: Fotogrametrik modelleme ve yer kontrol noktası (GCP) analizi: (a) Tüm çalışma alanını kapsayan sayısal model ve GCP dağılımı, (b) Heyelan bölgesindeki yüzey deformasyonlarının yakından görünümü.

5. TARTIŞMA

Elde edilen 5.5 cm'lik RMSE değeri, heyelan izleme çalışmaları için yeterli bir hassasiyettir. Ancak, çalışmada gözlemlenen en büyük kısıt "vejetasyon" (bitki örtüsü) sorunudur. İHA fotogrametrisi pasif bir sensör kullandığı için ağaç ve yoğun otların altındaki zemin kotunu görememektedir. Bu durum, ormanlık heyelan bölgelerinde Sayısal Arazi Modeli (DTM) üretiminde hatalara yol açabilir. Bu gibi durumlarda, LiDAR sensörlü İHA'ların kullanılması veya kritik noktaların yersel yöntemlerle (Total Station) desteklenmesi gerekmektedir.

Ekonomik açıdan bakıldığında, %85'lik maliyet tasarrufu, kamu kurumlarının ve özel sektörün heyelan izleme bütçelerini çok daha verimli kullanabileceğini göstermektedir. Özellikle "Samsun Örneği"nde görüldüğü gibi, kısa sürede üretilen 2D ve 3D modeller, mühendislerin sahaya gitmeden ofis ortamında çatlak analizi ve hacimsel değişim hesaplamaları yapmasına olanak tanımaktadır.

6. SONUÇ VE ÖNERİLER

Bu çalışma, Samsun ilindeki aktif bir heyelan bölgesinde İHA fotogrametrisinin geleneksel yöntemlere göre %95 zaman ve %85 maliyet avantajı sağladığını bilimsel verilerle ortaya koymuştur. İHA'lar, yersel yöntemleri tamamen ortadan kaldırmamakta, aksine onları tamamlayan "stratejik bir ortak" rolü üstlenmektedir.

Heyelan riski taşıyan bölgelerde şu öneriler dikkate alınmalıdır:

1. Periyodik izleme (Monitoring) için İHA uçuşları en az 3 ayda bir tekrarlanmalıdır.
2. Vejetasyonun yoğun olduğu alanlarda hibrit (İHA + Yersel) yöntemler tercih edilmelidir.
3. Üretilen yüksek çözünürlüklü ortofotolar üzerinde yapay zeka tabanlı "çatlak algılama" algoritmaları test edilmelidir.

7. KAYNAKÇA

Colomina, I., & Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing*, 92, 79-97.

Nex, F., & Remondino, F. (2014). UAV for 3D mapping applications: a review. *Applied Geomatics*, 6(1), 1-15.

Uzar, M., & Zemir, İ. (2019). İHA ile fotogrametrik veri üretiminde maliyet analizi. *Harita Dergisi*, (161), 35-45.

Westoby, M. J., et al. (2012). 'Structure-from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology*, 179, 300-314

Bektas S (2025a) Symmetric similarity 3D coordinate transformation based on dual quaternion algorithm. Acta Geod Geophys 60, 271–297 (2025).

Bektaş, S., & Erdede, S. B. (2025b). Twelve-parameter symmetric affine 3D coordinate transformation based on dual quaternions. Survey Review, 1–13.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

HEAVY METAL BIOREMEDIATION WITH NATIVE SOIL BACTERIA

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Abstract- The accumulation of heavy metals in aquatic environments represents a major environmental pollution problem due to their persistence and toxic effects. Conventional treatment methods commonly applied for the removal of heavy metals are often associated with high operational costs, energy consumption, and the generation of secondary waste, which increases the need for sustainable alternative approaches. In this context, bioremediation has emerged as an environmentally compatible and cost-effective strategy.

This study aims to investigate the bioremediation potential of bacterial isolates obtained from the Çanakkale region and previously characterized based on their fundamental properties. Within the scope of the study, heavy metal analyses are planned to be conducted in organic- and inorganic-based wastewater environments containing different heavy metal concentrations. Based on the analytical outcomes, bacterial isolates known for their tolerance to environmental stress conditions will be selected, and bioremediation applications for heavy metal removal will be evaluated using the selected bacterial strains.

The findings expected to be obtained within this framework are anticipated to indicate that local bacterial strains may be considered as viable biological agents for the remediation of heavy metal contamination. The utilization of regional microbial diversity in bioremediation applications provides a scientific basis for the development of sustainable and environmentally compatible heavy metal removal strategies.

Keywords – Bioremediation, Heavy metals, Wastewater, Local bacterial isolates, Environmental pollution

INTRODUCTION

Environmental pollution resulting from industrialization, agricultural activities, and rapid urbanization has become a global issue that threatens biodiversity and ecosystem health worldwide (Artan, 2015). Among the most hazardous components of this pollution are heavy metals, which have attracted

significant attention due to their high density, persistence in the environment, and generally toxic properties (Ali et al., 2013). Heavy metals constitute a group of pollutants composed of metals and metalloids, characterized by their high density and toxic effects (Cegiełkowska et al., 2015; Rostański et al., 2015).

Among the heavy metals present in the environment, cadmium (Cd) and lead (Pb) stand out as elements that have no known biological function in living organisms and pose serious environmental risks as their concentrations increase (Cegiełkowska et al., 2015).

The extremely limited availability of usable freshwater resources on Earth (approximately 0.003%) further exacerbates the environmental impacts of heavy metal pollution (Kocataş, 2006; Rashed, 2001). Heavy metals can be introduced into the environment through both natural and anthropogenic processes. Natural sources include rock weathering, volcanic activities, forest fires, and soil formation processes, whereas human activities constitute the most significant source of heavy metal contamination (Cegiełkowska et al., 2015; Gholizadeh & Hu, 2021; Sadowska et al., 2000).

Throughout history, metals have served as important raw materials for economic development; particularly since the Middle Ages, numerous mining operations have been established in regions of Europe where shallow metal deposits were available (Kacprzak & Fijałkowski, 2020; Rostański et al., 2015). However, the extraction and processing of these metals have resulted in severe localized contamination, especially in soils (Kumar et al., 2020; Rostański et al., 2015).

In particular, wastes generated from the historical processing of sulfide metal ores have been strongly associated with elevated concentrations of heavy metals in the environment (Rostański et al., 2015).

At present, metals are widely used across numerous industries, and the emission levels resulting from these processes vary considerably. Recent data indicate that the most dominant anthropogenic source of heavy metal emissions into the atmosphere is the combustion of solid and liquid fuels in the energy sector, accounting for more than half of total anthropogenic emissions (EEA, 2019; Hodgson, 2010; Rostański et al., 2015).

As a result of industrial discharges, mining activities, and agricultural practices, heavy metals such as Pb, Cd, Cr, Ni, As, and Hg accumulate in aquatic ecosystems. These metals are transferred through the food chain via bioaccumulation and biomagnification, posing long-term ecological and human health risks (Gadd, 2010; Zhang et al., 2023). In particular, processes such as acid mine drainage increase the solubility of metal ions under low pH conditions, elevating toxicity to hazardous levels (Johnson & Hallberg, 2005; Nordstrom, 2011). This situation demonstrates that heavy metal pollution is not only an environmental issue but also a serious public health concern (Liu et al., 2022).

On a global scale, the extent of heavy metal pollution is striking. In Europe, approximately 2.5 million sites have been reported to be potentially contaminated with heavy metals and organic pollutants (EEA, 2019). In the United States, between 235,000 and 355,000 sites have been reported to require

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ISBN: 978-9952-610-30-7

remediation (Wang et al., 2021). Worldwide, the total area of land degraded by heavy metal contamination is estimated to range between 1 and 6 billion hectares, with significant uncertainties regarding its spatial distribution (Kacprzak & Fijałkowski, 2020).

Permissible limit values for heavy metals in soils vary among countries. For instance, the maximum allowable concentration of Pb in soil is 50 mg kg^{-1} in Romania, whereas this value is set at 140 mg kg^{-1} in the Netherlands. In contrast, the limit value for Cr is 100 mg kg^{-1} in both countries (Gholizadeh & Hu, 2021). Numerous studies have reported that measured heavy metal concentrations in soils across many countries exceed the permissible limits. In Iran, Pb concentrations in certain soils have been reported to reach 57 mg kg^{-1}, exceeding the allowable limit of 25 mg kg^{-1}, while in China, Ni concentrations have been measured in the range of 40–200 mg kg^{-1}, reaching up to three times the maximum permissible levels (Mohammadi et al., 2020; Sun et al., 2019). Similarly, elevated metal concentrations have been observed in soils from various other countries (Barsova et al., 2019; Solademi & Thompson, 2020).

Conventional treatment methods commonly used for heavy metal removal suffer from significant drawbacks, including high operational costs, energy intensity, and the generation of secondary pollutants (Fu & Wang, 2011). Consequently, bioremediation approaches have gained increasing attention in recent years as environmentally friendly, sustainable, and cost-effective alternatives. Microorganisms can remove heavy metal ions from contaminated environments or reduce their toxicity through mechanisms such as biosorption, biotransformation, and reduction (Gadd, 2010; Vidali, 2001).

Effects of Heavy Metals on Aquatic Ecosystems

Heavy metal pollution represents a serious environmental problem for aquatic ecosystems, causing significant toxic effects on aquatic organisms, particularly fish (Suchana et al., 2021; Taslima et al., 2022). Although heavy metals naturally occur in the environment, their excessive and uncontrolled use in industrial activities has led to their release in large quantities into soil and water systems, thereby disrupting ecological balance (Dixit et al., 2015; Sarkar et al., 2022).

Agricultural activities, erosion originating from farmlands, and industrial and domestic wastewater discharges are among the major anthropogenic sources contributing to heavy metal accumulation in aquatic systems (Sarkar et al., 2016; Ezemonye et al., 2019). Heavy metals entering aquatic environments remain in dissolved forms, facilitating their accumulation in the tissues of aquatic organisms and particularly leading to bioaccumulation in fish (Authman, 2015). These metals are subsequently transferred to higher trophic levels through the food chain, posing risks to human health (Authman, 2015; Malik & Maurya, 2014).

The severity of heavy metal toxicity depends on factors such as metal type, concentration, exposure duration, and organism species, and may result in carcinogenic, mutagenic, and teratogenic effects

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(Ngo et al., 2011). In addition, heavy metals can cause physiological disorders in fish, including nervous system damage as well as impairments in growth and reproductive functions (Lu et al., 2015; Youssef & Tayel, 2004).

Although some metals are essential for living organisms at trace levels, metals such as arsenic (As), cadmium (Cd), lead (Pb), mercury (Hg), and chromium (Cr) can exhibit high toxicity even at low concentrations, leading to severe ecotoxicological consequences (Kortei et al., 2020; Rohani et al., 2022). The persistent and non-degradable nature of these metals in aquatic environments further amplifies the long-term impacts of contamination (Farombi et al., 2007; Lu et al., 2015).

Effects of Heavy Metals on Human Health

The non-biodegradable nature of heavy metals in the environment allows them to persist in toxic forms for extended periods and continue circulating within ecosystems (Kacprzak & Fijałkowski, 2020; Kumar et al., 2020). As a result, heavy metals are transferred along the food chain and reach humans through bioaccumulation (Kumar, 2020). For humans, the primary source of exposure to heavy metals is food, particularly plant-based food products (Liu et al., 2021). Therefore, the accumulation of heavy metals in agricultural products and animal feed is considered a significant risk factor for human health (Kumar, 2020).

In the human body, heavy metals can cause acute poisoning as well as chronic diseases in the long term. Symptoms associated with heavy metal toxicity often do not appear immediately after exposure but may become clinically evident months or even years later (Kozłowska et al., 2015; Sańczuk, 2012). The toxic effects of heavy metals span a wide spectrum, and although they may share similar mechanisms of action, different metals tend to accumulate in different tissues and organs (Wierzbicka, 2015).

Lead (Pb) primarily accumulates in bone tissue, cadmium (Cd) in the renal cortex and liver, and mercury (Hg), particularly in the form of methylmercury, accumulates in brain tissue, leading to severe neurological disorders (Sańczuk, 2012; Wierzbicka, 2015). In addition, certain heavy metals and their compounds are classified as carcinogenic or potentially carcinogenic by the International Agency for Research on Cancer (IARC) (Kozłowska et al., 2015; Rostański et al., 2015). Among the most environmentally hazardous metals, cadmium (Cd) and lead (Pb) have long ranked at the top, followed by arsenic (As), chromium (Cr), mercury (Hg), and zinc (Zn) (Cegiełkowska et al., 2015). According to the IARC classification, cadmium is categorized in Group 1 as carcinogenic to humans, while inorganic lead compounds are classified in Group 2A as probably carcinogenic to humans (IARC, 2022).

Considering the long-term and often irreversible effects of heavy metals on human health, the development of effective and sustainable solutions for their removal from ecosystems is imperative. In

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this context, bioremediation methods, which represent environmentally friendly and cost-effective approaches, have gained increasing importance in recent years.

Biological Treatment and Bioremediation Approaches

Biological treatment represents an effective and sustainable strategy for the removal of environmental pollutants, and its positive impacts on ecosystems have been documented in numerous studies. Schuster (2015) compared biological and conventional depuration systems and highlighted the advantages of biological technologies, including renewable energy production and reductions in greenhouse gas emissions. Similarly, Chasipanta and Tapia (2016) investigated the agricultural use of biol derived from organic waste and demonstrated the benefits of effective microorganisms and organic fertilization. Göz (2016) emphasized the importance of biological removal processes in addressing environmental crises.

In general, remediation is defined as a pollutant removal process encompassing physical, chemical, and biological methods (Vidali, 2001). Among biological remediation techniques, phytoremediation occupies a prominent position. In this method, plants absorb heavy metals and remove them from contaminated soils. Plant species such as *Helianthus annuus* (Meers et al., 2005), *Brassica napus* (Zaier et al., 2010), and *Bassia scoparia* (Moubasher et al., 2015) are widely used for this purpose, and fast-growing species with high metal uptake capacities enhance the effectiveness of phytoremediation (Dindar et al., 2010; Li et al., 2022; Terry & Banuelos, 2020).

Another approach, biodegradation, is based on the enzymatic activities of microorganisms that transform toxic pollutants into simpler and less harmful compounds (Aldas-Vargas et al., 2022). This method has also been successfully applied to the removal of plastic, hydrocarbon, and petroleum-derived contaminants (Cassone et al., 2020; Kopecká et al., 2022).

Mycoremediation represents another important branch of biological treatment. Fungi are capable of degrading a wide range of pollutants through the secretion of powerful oxidative enzymes such as lignin peroxidase, manganese peroxidase, and laccase. They can also decompose industrial and agricultural wastes and convert them into usable products (Rhodes et al., 2014; Vural et al., 2018). Species such as *Phanerochaete chrysosporium*, *Agaricus bisporus*, *Trametes versicolor*, and *Pleurotus ostreatus* are frequently used for the biotransformation of pesticides, degradation of petroleum-derived hydrocarbons, and decomposition of lignocellulosic wastes (Adenipekun & Lawal, 2012). However, due to the potential of fungi to disperse spores and spread rapidly and uncontrollably in the environment, this method also presents certain limitations (Rhodes et al., 2014; Vural et al., 2018).

Bioremediation is defined as the process by which pollutants are transformed into less toxic or harmless forms through the action of biological agents such as microorganisms, fungi, or plants (Vidali, 2001). During this process, contaminants are detoxified, mineralized, or sequestered within

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microbial cells through enzymatic reactions (Kumar et al., 2011). Effective remediation can be achieved by means of biological agents that are either naturally present in contaminated environments or intentionally introduced. Advances in molecular biology and ecology have significantly contributed to a deeper understanding of bioremediation mechanisms and have revealed the biotechnological potential of these processes.

Currently, bioremediation has emerged as an environmentally friendly and sustainable alternative, particularly for the remediation of contaminated water resources, agricultural soils, and industrial waste sites. The natural basis of bioremediation, its low energy requirements, applicability under in situ conditions, and the absence of secondary pollutant generation render this approach advantageous compared to conventional physicochemical remediation methods. Furthermore, the complete degradation of contaminants into harmless end products such as water, carbon dioxide, and biomass enhances the environmental sustainability of this method (Abatenh et al., 2017).

Nevertheless, bioremediation also presents certain limitations. The method is restricted to biologically degradable compounds, and in some cases, intermediate products formed during the process may be more toxic than the parent compounds. In addition, the heterogeneous nature of contaminants and their occurrence as complex mixtures necessitate the development of tailored bioremediation strategies. The relatively longer treatment duration compared to physical methods and regulatory uncertainties regarding performance criteria are among the major constraints affecting its practical implementation (Abatenh et al., 2017).

Microorganisms possess the capacity to metabolize, adsorb, or detoxify a wide range of pollutants, including heavy metals, through various chemical transformation mechanisms (Gadd, 2010; Vidali, 2001). Numerous studies have demonstrated that bacterial genera such as *Pseudomonas* sp., *Bacillus* sp., *Micrococcus* sp., and *Rhodococcus* sp. exhibit the ability to absorb and transform heavy metals including Pb, Cd, Cr, Ni, and As into less toxic forms (Gadd, 2000; Wang & Chen, 2009). Although several studies have been conducted in Türkiye within this field, existing research is generally limited to specific industrial regions and a narrow range of microbial groups (Demircan & Memon, 2022).

METHODOLOGY

The efficiency of bioremediation depends on several factors, including the presence of microbial populations capable of transforming contaminants, the biodegradability of the target pollutants, and environmental conditions such as temperature, pH, oxygen availability, and nutrient concentrations (Vidali, 2001). From an application perspective, bioremediation strategies are generally classified into two main categories: in situ and ex situ approaches.

In situ bioremediation is based on the direct treatment of contaminants at the affected site and aims to enhance remediation efficiency by stimulating indigenous microbial populations through the supplementation of oxygen and nutrients (Akshata et al., 2012). This approach is further subdivided

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

into intrinsic and engineered applications, with the selection of the method depending on site-specific conditions (Kulshreshtha et al., 2014).

In contrast, ex situ bioremediation involves the excavation of contaminated soil or material followed by treatment under controlled conditions. In this approach, remediation may be conducted using solid-phase systems or slurry-phase systems operated in bioreactors (Akshata et al., 2012; Kulshreshtha et al., 2014).

In the context of heavy metal removal, the primary mechanisms employed by microorganisms include biosorption, bioleaching, biomineralization, and biotransformation processes (Pande et al., 2022). For instance, *Bacillus* species exhibit high resistance to harsh environmental conditions due to their spore-forming ability and can adsorb metal ions through functional groups such as carboxyl, hydroxyl, and phosphate groups present on their cell surfaces. Moreover, certain *Bacillus* strains have been reported to reduce mercury ions to their elemental form (Ahemad, 2014; Chen et al., 2005; Wani et al., 2007).

Shewanella species contribute to bioremediation processes by facilitating the reduction of metal ions through their high redox potential (Li et al., 2021). Additionally, extremophilic microorganisms are capable of performing metal detoxification even under extreme environmental conditions (Gallo et al., 2021). Bacterial consortia and biofilm-forming microorganisms, owing to their multiple metabolic pathways, often achieve more effective heavy metal removal compared to single-species systems (Volarić et al., 2021).

The utilization of microorganisms adapted to local environmental conditions significantly enhances the efficiency of bioremediation applications. Strains obtained from standard culture collections often exhibit limited performance when exposed to stress factors such as fluctuating pH, high salinity, and complex metal compositions commonly found in industrial wastewater (El Fantroussi & Agathos, 2005; Tyagi et al., 2011). In contrast, locally isolated microorganisms that have undergone natural selection processes possess metabolic capacities that are better suited to these challenging conditions.

In this study, microorganisms used for the evaluation of bioremediation potential will be selected from locally isolated bacterial strains previously obtained from serpentine-derived soils in the Ezine district of Çanakkale Province. These strains were identified in earlier studies using molecular and biochemical methods, and their resistance to environmental stress factors as well as their capacity to bind heavy metals have been reported in the literature (Karakaş et al., 2022; Öztürk & Hacıoğlu Doğru, 2020). To ensure ecological relevance and methodological consistency, only well-characterized local isolates will be used.

Wastewater samples employed in the bioremediation experiments will be collected from two different sources exhibiting distinct pollution profiles, and key wastewater parameters will be determined prior to the experiments. Heavy metal concentrations will be analyzed using inductively coupled plasma–

optical emission spectrometry (ICP-OES) and/or inductively coupled plasma–mass spectrometry (ICP-MS), which are commonly used techniques in environmental water and wastewater studies.

The applied methodology provides a structured basis for evaluating the effectiveness of biological systems in heavy metal removal. The findings obtained from the analytical approaches will support the interpretation of bioremediation mechanisms and facilitate comparisons with similar studies reported in the literature.

DISCUSSION

The bioremediation approach addressed in this study aims to evaluate the well-established biological potential of microorganisms for heavy metal removal within the context of **local isolates and real wastewater systems**. Although mechanisms such as biosorption, biotransformation, biomineralization, and redox-based processes have been widely reported as effective in heavy metal removal (Pande et al., 2022; Vidali, 2001), the efficiency of these mechanisms is strongly influenced by the adaptive capacity of the microorganisms and the complexity of the wastewater matrix to which they are exposed.

In particular, genera such as *Bacillus*, *Pseudomonas*, and *Shewanella* have been extensively documented for their ability to bind and transform heavy metals through cell surface functional groups and redox-active metabolic pathways (Chen et al., 2005; Gadd, 2010; Wang & Chen, 2009). However, a significant proportion of these studies have been conducted using strains obtained from standard culture collections under controlled laboratory conditions. It is well recognized that the presence of multiple metals, variable pH, and fluctuating ionic strength in real industrial wastewaters may limit the performance of such strains (El Fantroussi & Agathos, 2005).

Within this framework, the use of bacterial strains isolated from serpentine-derived soils of the Çanakkale region represents a critical aspect of the present study, enhancing the ecological relevance of the bioremediation process. Local isolates are naturally adapted to site-specific environmental stressors, which may confer advantages in terms of heavy metal tolerance and cell surface–metal interactions. This strategy allows bioremediation performance to be assessed under conditions that more closely reflect realistic environmental scenarios rather than idealized laboratory systems.

The integration of SEM and FTIR analyses further strengthens the interpretation of bioremediation performance by enabling the evaluation of heavy metal removal at the cellular and molecular levels. The observed interactions between metal ions and surface functional groups are consistent with biosorption mechanisms reported in the literature, thereby providing mechanistic support for the analytical findings (Fu & Wang, 2011).

In addition, the biological assessment of the bioremediation process through phytotoxicity tests contributes to the environmental interpretation of chemical improvements observed in treated wastewater systems. Linking reductions in heavy metal concentrations with biological responses

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

supports the view that bioremediation is not solely a removal technique but also an ecologically sustainable treatment strategy (Wong, 2003).

Overall, this study offers a complementary perspective to existing literature by emphasizing the use of **region-specific microbial resources combined with multi-level analytical approaches**. The findings provide a scientific basis for the development of environmentally friendly biotechnological solutions for heavy metal pollution control and serve as a foundation for future studies focusing on scale-up and field-level applications.

ACKNOWLEDGMENT

This study is part of Fatma Beyza Akın's Master's thesis research.

REFERENCES

Abatenh, E., Gizaw, B., Tsegaye, Z., & Wassie, M. (2017). Application of microorganisms in bioremediation: Review. *Journal of Environmental Microbiology, 1*(1), 2–9.

Adenipekun, C. O., & Lawal, R. (2012). Uses of mushrooms in bioremediation: A review. *Biotechnology and Molecular Biology Review, 7*(3), 62–68.

Ahemad, M. (2014). Biodegradation. *Biodegradation, 25*(6), 907–923.

Akshata, N. J., Udayashankara, T. H., & Lokesh, K. S. (2012). Review on bioremediation of heavy metals with microbial isolates and amendments on soil residue. *International Journal of Science and Research, 3*(8), 118–123.

Aldas-Vargas, A., Poursat, B. A., & Sutton, N. B. (2022). Potential and limitations for monitoring of pesticide biodegradation at trace concentrations in water and soil. *World Journal of Microbiology and Biotechnology, 38*(12), 240.

Ali, H., Khan, E., & Sajad, M. A. (2013). Ecotoxicology and environmental safety. *Ecotoxicology and Environmental Safety, 91*, 245–263.

Artan, S. (2015). Türkiye'de çevre kirliliği, dışa açıklık ve ekonomik büyüme ilişkisi. *Journal of Management and Economics Research, 13*(1).

Authman, M. M., Zaki, M. S., Khallaf, E. A., & Abbas, H. H. (2015). Use of fish as bio-indicator of the effects of heavy metals pollution. *Journal of Aquaculture Research & Development, 6*(4), 1–13.

Barsova, N., Yakimenko, O., Tolpeshta, I., & Motuzova, G. (2019). Current state and dynamics of heavy metal soil pollution in Russian Federation: A review. *Environmental Pollution, 249*, 200–207.

Cassone, B. J., Grove, H. C., Elebute, O., Villanueva, S. M., & LeMoine, C. M. (2020). Role of the intestinal microbiome in low-density polyethylene degradation by *Galleria mellonella* larvae. *Proceedings of the Royal Society B, 287*(1922), 20200112.

Cegiełkowska, W., Michalska-Kacymirow, M., & Wierzbicka, M. (2015). Heavy metals in the environment. In M. Wierzbicka (Ed.), *Ecotoxicology: Plants, soils, metals* (pp. 22–23, 31–36). Warsaw University Press.

Chen, S., & Wilson, D. B. (2005). Applied and environmental microbiology. *Applied and Environmental Microbiology, 71*(9), 5931–5937.

Demircan, O., & Memon, A. R. (2022). Bioremediation of heavy metals by use of bacteria. *Turkish Journal of Agriculture-Food Science and Technology, 10*(2), 134–141.

Dindar, E., Şağban, F. O., & Başkaya, H. S. (2010). Kirlenmiş toprakların biyoremediasyon ile ıslahı. *Uludağ Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 15*(2).

Dixit, R., Malaviya, D., Pandiyan, K., Singh, U. B., Sahu, A., Shukla, R., Singh, B. P., Rai, J. P., Sharma, P. K., & Lade, H. (2015). Bioremediation of heavy metals from soil and aquatic environment: An overview of principles and criteria of fundamental processes. *Sustainability, 7*, 2189–2212.

El Fantroussi, S., & Agathos, S. N. (2005). Is bioaugmentation a feasible strategy for pollutant removal and site remediation? *Current Opinion in Microbiology, 8*(3), 268–275.

European Environment Agency. (2019). Heavy metal emissions in Europe. https://www.eea.europa.eu/data-and-maps/indicators/eea32-heavy-metal-hm-emissions-1/assessment-10.

Ezemonye, L. I., Adebayo, P. O., Enuneku, A. A., Tongo, I., & Ogbomida, E. (2019). Potential health risk consequences of heavy metal concentrations in surface water, shrimp (*Macrobrachium macrobrachion*) and fish (*Brycinus longipinnis*) from Benin River, Nigeria. *Toxicology Reports, 6*, 1–9.

Farombi, E. O., Adelowo, O. A., & Ajimoko, Y. R. (2007). Biomarkers of oxidative stress and heavy metal levels as indicators of environmental pollution in African cat fish (*Clarias gariepinus*) from Nigeria Ogun River. *International Journal of Environmental Research and Public Health, 4*, 158–165.

Fu, F., & Wang, Q. (2011). Removal of heavy metal ions from wastewaters: A review. *Journal of Environmental Management, 92*(3), 407–418.

Gadd, G. M. (2010). Metals, minerals and microbes: Geomicrobiology and bioremediation. *Nature Reviews Microbiology, 8*(8), 603–612.

Gallo, G., Puopolo, R., Carbonaro, M., Maresca, E., & Fiorentino, G. (2021). Extremophiles, a nifty tool to face environmental pollution: From exploitation of metabolism to genome engineering. *International Journal of Environmental Research and Public Health, 18*(10), 5228.

Gholizadeh, M., & Hu, X. (2021). Removal of heavy metals from soil with biochar composite: A critical review of the mechanism. *Journal of Environmental Chemical Engineering, 9*, 105830.

Hodgson, E. (2010). Introduction to toxicology. In E. Hodgson (Ed.), *A textbook of modern toxicology* (4th ed., pp. 3–14). John Wiley & Sons.

International Agency for Research on Cancer. (2022). List of classifications. https://monographs.iarc.who.int/list-of-classifications

Johnson, D. B., & Hallberg, K. B. (2005). Acid mine drainage remediation options. *Science of the Total Environment, 338*(1–2), 3–14.

Kacprzak, M., & Fijałkowski, K. (2020). Trace elements and heavy metals: Occurrence and toxicity. In E. Charitonow (Ed.), *Potential of plants to clean up the environment* (pp. 6–11). Scientific Publishers PWN.

Karakaş, İ., Ay, M., Öztürk, F., Kaya, S., & Hacıoğlu, N. (2022). Nikelce zengin topraklardan (Çanakkale) izole edilen bakterilerin bitki büyüme teşvik edici potansiyellerinin belirlenmesi. *Turkish Journal of Agricultural and Natural Sciences, 9*(2), 424–431.

Kocataş, A. (2006). *Ekoloji ve çevre biyolojisi* (No. 51). Ege Üniversitesi Su Ürünleri Fakültesi Yayınları.

Kopecká, R., Kubínová, I., Sovová, K., Mravcová, L., Vítěz, T., & Vítězová, M. (2022). Microbial degradation of virgin polyethylene by bacteria isolated from a landfill site. *SN Applied Sciences, 4*(11), 302.

Kortei, N. K., Heymann, M. E., Essuman, E. K., Kpodo, F. M., Akonor, P. T., Lokpo, S. Y., Boadi, N. O., Ayim-Akonor, M., & Tettey, C. (2020). Health risk assessment and levels of toxic metals in fishes (*Oreochromis niloticus* and *Clarias anguillaris*) from Ankobrah and Pra Basins: Impact of illegal mining activities on food safety. *Toxicology Reports, 7*, 360–369.

Kozłowska, A., Mikołajczyk, A., Boroń, M., Kasperczyk, S., & Pawlas, N. (2015). Effects of lead exposure on the concentration of cadmium, selenium and values of morphology in the blood. *Environmental Medicine, 18*, 17–25.

Kulshreshtha, A., Agrawal, R., Barar, M., & Saxena, S. (2014). A review on bioremediation of heavy metals in contaminated water. *IOSR Journal of Environmental Science, Toxicology and Food Technology, 8*(7), 44–50.

Kumar, A., Bisht, B. S., Joshi, V. D., & Dhewa, T. (2011). Review on bioremediation of polluted environment: A management tool. *International Journal of Environmental Sciences, 1*, 6.

Kumar, A., Cabral-Pinto, M., Chaturvedi, A. K., Shabnam, A. A., Subrahmanyam, G., Mondal, R., Gupta, D. K., Malyan, S. K., & Kumar, S. S. (2020). Lead toxicity: Health hazards, influence on food chain, and sustainable remediation approaches. *International Journal of Environmental Research and Public Health, 17*, 2179.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Li, K., Wang, J., & Zhang, Y. (2022). Heavy metal pollution risk of cultivated land from industrial production in China: Spatial pattern and its enlightenment. *Science of the Total Environment, 828*, 154382.

Liu, L., Chen, J., Liu, C., Luo, Y., Chen, J., Fu, Y., & Wang, H. (2022). Relationships between biological heavy metals and breast cancer: A systematic review and meta-analysis. *Frontiers in Nutrition, 9*, 838762.

Liu, X., Gu, S., Yang, S., & Du, J. (2021). Heavy metals in soil-vegetable system around e-waste site and the health risk assessment. *Science of the Total Environment, 779*, 146438.

Lu, Y., Song, S., Wang, R., Liu, Z., Meng, J., Sweetman, A. J., Jenkins, A., Ferrier, R. C., Li, H., & Luo, W. (2015). Impacts of soil and water pollution on food safety and health risks in China. *Environment International, 77*, 5–15.

Malik, D. S., & Maurya, P. K. (2014). Heavy metal concentration in water, sediment, and tissues of fish species (*Heteropneustis fossilis* and *Puntius ticto*) from Kali River, India. *Toxicological & Environmental Chemistry, 96*, 1195–1206.

Meers, E., Ruttens, A., Hopgood, M. J., Samson, D., & Tack, F. M. G. (2005). Comparison of EDTA and EDDS as potential soil amendments for enhanced phytoextraction of heavy metals. *Chemosphere, 58*(8), 1011–1022.

Mohammadi, A. A., Zarei, A., Esmaeilzadeh, M., Taghavi, M., Yousefi, M., Yousefi, Z., Sedighi, F., & Javan, S. (2020). Assessment of heavy metal pollution and human health risks assessment in soils around an industrial zone in Neyshabur, Iran. *Biological Trace Element Research, 195*, 343–352.

Moubasher, H. A., Hegazy, A. K., Mohamed, N. H., Moustafa, Y. M., Kabiel, H. F., & Hamad, A. A. (2015). Phytoremediation of soils polluted with crude petroleum oil using *Bassia scoparia* and its associated rhizosphere microorganisms. *International Biodeterioration & Biodegradation, 98*, 113–120.

Ngo, H. T. T., Gerstmann, S., & Frank, H. (2011). Subchronic effects of environment-like cadmium levels on the bivalve *Anodonta anatina*: Effects on carbonic anhydrase activity in relation to calcium metabolism. *Toxicological & Environmental Chemistry, 93*, 1815–1825.

Nordstrom, D. K. (2011). Applied geochemistry. *Applied Geochemistry, 26*(11), 1753–1772.

Öztürk, F., & Hacıoğlu, N. (2020). Characterization and potential applications of heterotrophic bacteria inhabiting nickel-rich soils in Çanakkale, Turkey. *Turkish Journal of Bioscience and Collections, 4*(1), 7–13.

Pande, V., Pandey, S. C., Sati, D., Bhatt, P., & Samant, M. (2022). Microbial interventions in bioremediation of heavy metal contaminants in agroecosystem. *Frontiers in Microbiology, 13*, 824084.

Rashed, M. N. (2001). Monitoring of environmental heavy metals in fish from Nasser Lake. *Environment International, 27*(1), 27–33.

Rhodes, C. J. (2014). Mediation (bioremediation with fungi) – Growing mushrooms to clean the earth. *Chemical Speciation & Bioavailability, 26*(3), 196–198.

Rohani, M. F., Bristy, A. A., Hasan, J., Hossain, M. K., & Shahjahan, M. (2022). Dietary zinc in association with vitamin E promotes growth performance of Nile tilapia. *Biological Trace Element Research, 200*, 4150–4159.

Rostański, A., Cabala, J., & Slota, M. (2015). Environmental exposure to heavy metals. In M. Wierzbicka (Ed.), *Ecotoxicology: Plants, soils, metals* (pp. 522–541). Warsaw University Press.

Sadowska, A., Obidoska, G., & Rumowska, M. (2000). Heavy metals. In *Ecotoxicology: Toxic environmental agents and methods of their detection* (pp. 54–57). SGGW Publishing.

Sarkar, M. M., Rohani, M. F., Hossain, M. A. R., & Shahjahan, M. (2022). Evaluation of heavy metal contamination in some selected commercial fish feeds used in Bangladesh. *Biological Trace Element Research, 200*, 844–854.

Sarkar, T., Alam, M. M., Parvin, N., Fardous, Z., Chowdhury, A. Z., Hossain, S., Haque, M. E., & Biswas, N. (2016). Assessment of heavy metals contamination and human health risk in shrimp collected from different farms and rivers at Khulna-Satkhira region, Bangladesh. *Toxicology Reports, 3*, 346–350.

Schuster, N. R. (2015). *The effect of manure application method on nutrient and microbial runoff transport and soil biological health indicators*.

Seńczuk, W. (Ed.). (2012). *Modern toxicology* (2nd ed.). PZWL.

Solademi, F., & Thompson, S. (2020). Spatial analysis of heavy metal emissions in residential, commercial and industrial areas adjacent to a scrap metal shredder in Winnipeg, Canada. *Journal of Geoscience and Environment Protection, 8*, 359–386.

Suchana, S. A., Ahmed, M. S., Islam, S. M., Rahman, M. L., Rohani, M. F., Ferdusi, T., Ahmmad, A. S., Fatema, M. K., Badruzzaman, M., & Shahjahan, M. (2021). Chromium exposure causes structural aberrations of erythrocytes, gills, liver, kidney, and genetic damage in striped catfish *Pangasianodon hypophthalmus*. *Biological Trace Element Research, 199*, 3869–3885.

Sun, Y., Li, H., Guo, G., Semple, K. T., & Jones, K. C. (2019). Soil contamination in China: Current priorities, defining background levels and standards for heavy metals. *Journal of Environmental Management, 251*, 109512.

Taslima, K., Al-Emran, M., Rahman, M. S., Hasan, J., Ferdous, Z., Rohani, M. F., & Shahjahan, M. (2022). Impacts of heavy metals on early development, growth and reproduction of fish: A review. *Toxicology Reports, 9*, 858–868.

Terry, N., & Banuelos, G. S. (2020). *Phytoremediation of contaminated soil and water*. CRC Press.

Tyagi, M., da Fonseca, M. M. R., & de Carvalho, C. C. (2011). Bioaugmentation and biostimulation strategies to improve the effectiveness of bioremediation processes. *Biodegradation, 22*(2), 231–241.

Vidali, M. (2001). Bioremediation: An overview. *Pure and Applied Chemistry, 73*(7), 1163–1172.

Volarić, A., Svirčev, Z., Tamindžija, D., & Radnović, D. (2021). Microbial bioremediation of heavy metals: Review. *Hemijska Industrija, 75*(2), 103–115. https://doi.org/10.2298/HEMIND200915010V

Vural, A., Demir, S., & Boyno, G. (2018). Biyoremediasyon ve fungusların biyoremediasyonda kullanılması. *Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi, 28*(4), 490–501.

Wang, J., & Chen, C. (2009). Biosorbents for heavy metals removal and their future. *Biotechnology Advances, 27*(2), 195–226.

Wang, L., Rinklebe, J., Tack, F. M., & Hou, D. (2021). A review of green remediation strategies for heavy metal contaminated soil. *Soil Use and Management, 37*, 936–963.

Wang, Y., Luo, Y., Zeng, G., Wu, X., Wu, B., Li, X., & Xu, H. (2020). Characteristics and in situ remediation effects of heavy metal immobilizing bacteria on cadmium and nickel co-contaminated soil. *Ecotoxicology and Environmental Safety, 192*, 110294.

Wierzbicka, M. (2015). Plant defense against heavy metals. In M. Wierzbicka (Ed.), *Ecotoxicology: Plants, soils, metals* (p. 83). Warsaw University Press.

Wong, M. H. (2003). Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. *Chemosphere, 50*(6), 775–780.

Youssef, D. H., & Tayel, F. T. (2004). Metal accumulation by three *Tilapia* spp. from some Egyptian inland waters. *Chemistry and Ecology, 20*, 61–71.

Zaier, H., Ghnaya, T., Rejeb, K. B., Lakhdar, A., Rejeb, S., & Jemal, F. (2010). Effects of EDTA on phytoextraction of heavy metals (Zn, Mn and Pb) from sludge-amended soil with *Brassica napus*. *Bioresource Technology, 101*(11), 3978–3983.

Zhang, W., Zhang, H., Xu, R., Qin, H., Liu, H., & Zhao, K. (2023). Heavy metal bioremediation using microbially induced carbonate precipitation: Key factors and enhancement strategies. *Frontiers in Microbiology, 14*, 1116970.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AKILLI SAYAÇ VERİLERİNİN ELEKTRİK TÜKETİM DAVRANIŞLARININ ANALİZİNDE KULLANIMI

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Özet

Elektrik enerjisine olan talebin sürekli artması, enerji sistemlerinin daha verimli ve sürdürülebilir şekilde işletilmesini zorunlu kılmaktadır. Bu bağlamda akıllı şebeke teknolojileri ve bu sistemlerin temel bileşenlerinden biri olan akıllı sayaçlar, enerji yönetiminde önemli bir rol üstlenmektedir. Akıllı sayaçlar sayesinde elektrik tüketim verileri saatlik ve daha kısa zaman aralıklarında izlenebilmekte, bu durum tüketici davranışlarının ayrıntılı biçimde analiz edilmesine olanak sağlamaktadır. Bu çalışmada, konut tipi kullanıcılara ait akıllı sayaçlardan elde edilen yüksek çözünürlüklü elektrik tüketim verilerinin analiz edilmesi amaçlanmıştır. Çalışma kapsamında bir yıllık saatlik tüketim verileri kullanılmıştır. Veri seti analiz öncesinde kapsamlı bir ön işleme sürecinden geçirilmiş; eksik veriler doğrusal enterpolasyon yöntemiyle tamamlanmış, aykırı değerler z-skoru yöntemi kullanılarak belirlenmiştir. Kullanıcılar arası karşılaştırılabilirliği sağlamak amacıyla min–maks normalizasyonu uygulanmıştır. Metodoloji kapsamında tanımlayıcı istatistikler, yük faktörü hesaplamaları, pik talep analizi ve zaman serisi analizleri gerçekleştirilmiştir. Günlük, haftalık ve mevsimsel tüketim profilleri oluşturulmuş; elektrik tüketiminin özellikle akşam saatlerinde ve hafta sonlarında belirgin biçimde arttığı gözlemlenmiştir. Elde edilen bulgular, akıllı sayaç verilerinin talep tahmini, dinamik fiyatlandırma ve talep tarafı yönetimi uygulamalarında etkin bir karar destek aracı olarak kullanılabileceğini göstermektedir.

Anahtar Kelimeler: Akıllı sayaç, elektrik tüketimi, akıllı şebeke, talep tarafı yönetimi, zaman serisi analizi

The Use of Smart Meter Data in Analyzing Electricity Consumption Behavior

Abstract

The continuous increase in demand for electrical energy necessitates the

more efficient and sustainable operation of energy systems. In this context, smart grid technologies and smart meters, one of the fundamental components of these systems, play a significant role in

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

energy management.

Smart meters enable the monitoring of electricity consumption data at hourly and even shorter intervals,facilitating detailed analysis of consumer behavior. This study aims to analyze high-resolution electricity consumption data obtained from smart meters belonging to residential users. One year of hourly consumption data was used in the study.

The data set underwent a comprehensive preprocessing phase prior to analysis;

missing data were completed using linear interpolation, and outliers were

identified using the z-score method. Min–max normalization was applied to ensure comparability between users. Descriptive statistics, load factor calculations, peak demand analysis, and time series analyses were performed as part of the methodology. Daily, weekly, and seasonal consumption profiles were created; it was observed that electricity consumption increased significantly, especially in the evening hours and on weekends. The findings indicate that smart meter data can be used as an effective decision support tool in demand forecasting, dynamic pricing, and demand-side management applications.

Keywords: Smart meter, electricity consumption, smart grid, demand-side management, time series analysis

1. Giriş

Küresel ölçekte artan nüfus, sanayileşme ve teknolojik gelişmeler elektrik enerjisine olan talebin sürekli artmasına neden olmaktadır. Enerji sistemlerinin bu artan talebi karşılayabilmesi için yalnızca üretim kapasitesinin artırılması yeterli olmamakta, aynı zamanda mevcut kaynakların daha verimli ve akıllı biçimde yönetilmesi gerekmektedir. Bu noktada akıllı şebeke kavramı ön plana çıkmaktadır.

Akıllı şebekeler, elektrik enerjisinin üretimden tüketime kadar olan tüm süreçlerinin bilgi ve iletişim teknolojileri ile entegre edilmesini amaçlayan modern enerji sistemleridir. Bu sistemlerin en önemli bileşenlerinden biri olan akıllı sayaçlar, elektrik tüketim verilerinin yüksek zaman çözünürlüğünde izlenmesine ve iki yönlü haberleşmeye olanak tanımaktadır. Akıllı sayaçların sağladığı bu detaylı veriler, tüketici davranışlarının analiz edilmesi ve enerji yönetimi stratejilerinin geliştirilmesi açısından büyük önem taşımaktadır.

Bu çalışmada, akıllı sayaç verilerinin elektrik tüketim davranışlarının analizinde kullanımı ele alınmakta ve elde edilen bulgular enerji yönetimi perspektifinden değerlendirilmektedir.

2. Literatür Taraması

Akıllı sayaç verilerinin analizi son yıllarda literatürde geniş yer bulmuştur. Zhang ve arkadaşları (2020), akıllı sayaç verilerini kullanarak kısa dönemli yük tahmini gerçekleştirmiş ve yüksek doğruluk oranları elde etmiştir. Li ve arkadaşları (2021) ise konut tipi kullanıcılar için yük profili analizi yapmış

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ve farklı tüketim davranışlarını sınıflandırmıştır. Ahmad ve Chen (2022), akıllı sayaç verilerinin enerji verimliliği ve talep tarafı yönetimi uygulamalarındaki rolünü incelemiştir.

Bu çalışmalar, akıllı sayaç verilerinin yalnızca ölçüm amaçlı değil, aynı zamanda karar destek sistemleri için de kritik bir veri kaynağı olduğunu ortaya koymaktadır.

2.1 Akıllı Sayaç Teknolojilerinin Gelişimi

Akıllı sayaçlar, klasik sayaçlardan farklı olarak iki yönlü iletişim altyapısına sahiptir. Bu sayede tüketim verileri gerçek zamanlı olarak izlenebilmekte ve gerektiğinde uzaktan müdahale edilebilmektedir. Akıllı sayaçların yaygınlaşması, kayıp-kaçak oranlarının azaltılması, faturalama doğruluğunun artırılması ve tüketici farkındalığının geliştirilmesi açısından önemli avantajlar sağlamaktadır.

3. Materyal ve Metot

Bu çalışmada izlenen metodoloji veri toplama, veri ön işleme, analiz ve değerlendirme aşamalarından oluşmaktadır.

3.1 Veri Toplama

Çalışmada konut tipi kullanıcılara ait bir yıllık saatlik elektrik tüketim verileri kullanılmıştır. Veriler akıllı sayaçlar aracılığıyla otomatik olarak toplanmıştır.

3.2 Veri Ön İşleme

Eksik veriler doğrusal enterpolasyon yöntemi kullanılarak tamamlanmıştır. Ölçüm hataları ve olağan dışı değerler analiz öncesinde tespit edilmiştir.

3.3 Aykırı Değer Analizi

Aykırı değerlerin belirlenmesinde z-skoru yöntemi kullanılmıştır. Z-skoru mutlak değeri 3'ün üzerinde olan gözlemler aykırı değer olarak değerlendirilmiş ve analiz dışı bırakılmıştır.

3.4 Normalizasyon

Veri setindeki farklı ölçeklerin etkisini azaltmak amacıyla min–maks normalizasyonu uygulanmıştır:

$$x_norm = (x - x_min) / (x_max - x_min)$$

3.5 Yük Faktörü ve Pik Talep Analizi

Yük faktörü, ortalama gücün maksimum güce oranı olarak hesaplanmıştır. Pik talep saatleri belirlenerek tüketim davranışları değerlendirilmiştir.

3.6 Zaman Serisi Analizi

Saatlik tüketim verileri kullanılarak günlük, haftalık ve mevsimsel tüketim profilleri oluşturulmuştur.

4. Bulgular

Analiz sonuçları, elektrik tüketiminin gün içi saatlere bağlı olarak önemli değişkenlikler gösterdiğini ortaya koymuştur. Sabah saatlerinde düşük olan tüketimin, akşam saatlerinde belirgin şekilde arttığı gözlemlenmiştir. Hafta sonu tüketimleri hafta içi günlere kıyasla daha yüksek bulunmuştur.

4.1 Mevsimsel Tüketim Davranışları

Yaz aylarında soğutma, kış aylarında ise ısıtma amaçlı elektrikli cihazların kullanımı tüketim artışlarının temel nedeni olarak belirlenmiştir.

5. Tartışma

Elde edilen bulgular literatürde raporlanan çalışmalarla uyumludur. Akıllı sayaç verilerinin sunduğu yüksek zaman çözünürlüğü, tüketici davranışlarının detaylı biçimde analiz edilmesine olanak tanımaktadır. Bu durum, enerji sistemlerinin daha esnek ve verimli işletilmesine katkı sağlamaktadır.

6. Enerji Yönetimi Açısından Değerlendirme

Akıllı sayaç verileri, talep tarafı yönetimi uygulamaları ve dinamik fiyatlandırma mekanizmaları için önemli girdiler sunmaktadır. Bu sayede tüketicilerin enerji maliyetleri azaltılabilirken, şebeke işletmecilerinin sistem dengesini sağlaması kolaylaşmaktadır.

7. Çalışmanın Sınırlılıkları

Bu çalışmada kullanılan veri seti yalnızca konut tipi kullanıcılarla sınırlıdır. Farklı abone gruplarının analiz edilmemesi sonuçların genellenebilirliğini sınırlamaktadır.

8. Gelecek Çalışmalar

Gelecek çalışmalarda makine öğrenmesi ve derin öğrenme tabanlı yöntemlerin kullanılması planlanmaktadır. Ayrıca yenilenebilir enerji kaynaklarının tüketim profilleri üzerindeki etkileri incelenecektir.

9. Sonuç

Bu çalışma, akıllı sayaç verilerinin elektrik tüketim davranışlarının analizinde etkin bir şekilde kullanılabileceğini göstermiştir. Elde edilen sonuçlar, enerji verimliliği ve sürdürülebilir enerji politikalarının geliştirilmesine katkı sağlayabilecek niteliktedir.

Kaynakça :

Ahmad, T., & Chen, H. (2022). Smart meter data analytics for energy management: A comprehensive review. *IEEE Access, 10*, 34567–34579. https://doi.org/10.1109/ACCESS.2022.3145678

Albert, A., Rajagopal, R., & Ploetz, T. (2020). Mining smart meter data for energy feedback systems: A survey. *ACM Computing Surveys, 52*(1), 1–36. https://doi.org/10.1145/3337772

Beckel, C., Sadamori, L., Santini, S., & Staake, T. (2021). Revealing household characteristics from smart meter data. *Energy, 226*, 120399. https://doi.org/10.1016/j.energy.2021.120399

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Burger, S. P., Jenkins, J. D., Huntington, S. C., & Perez-Arriaga, I. J. (2020). The value of smart meters in electricity systems. *Energy Policy, 147*, 111890. https://doi.org/10.1016/j.enpol.2020.111890

Chen, K., Chen, K., Wang, Q., He, Z., Hu, J., & He, J. (2021). Short-term load forecasting with deep residual networks. *IEEE Transactions on Smart Grid, 12*(3), 2088–2098. https://doi.org/10.1109/TSG.2020.3036789

Ghasemi, A., & Khalili, N. (2022). Demand-side management using smart meter data: A data-driven approach. *Sustainable Energy, Grids and Networks, 30*, 100628. https://doi.org/10.1016/j.segan.2022.100628

Hong, T., Pinson, P., & Fan, S. (2020). Global energy forecasting competition 2017: Hierarchical probabilistic load forecasting. *International Journal of Forecasting, 36*(2), 459–473. https://doi.org/10.1016/j.ijforecast.2019.07.005

Li, K., Zhang, T., & Chen, Y. (2021). Residential load profiling using smart meter data. *Applied Energy, 285*, 116410. https://doi.org/10.1016/j.apenergy.2020.116410

McKenna, E., Richardson, I., & Thomson, M. (2020). Smart meter data: Balancing consumer privacy concerns with energy system benefits. *Energy Policy, 140*, 111422. https://doi.org/10.1016/j.enpol.2020.111422

Mutanen, A., Ruska, M., Repo, S., & Järventausta, P. (2021). Customer classification and load profiling using smart metering data. *IEEE Transactions on Power Systems, 36*(1), 119–129. https://doi.org/10.1109/TPWRS.2020.3009874

Qiu, X., Ren, Y., Suganthan, P. N., & Amaratunga, G. (2020). Empirical mode decomposition based ensemble deep learning for load forecasting. *IEEE Transactions on Smart Grid, 11*(2), 1133–1144. https://doi.org/10.1109/TSG.2019.2935933

Zhang, Y., Wang, J., & Li, X. (2020). Short-term load forecasting using smart meter data. *Energy, 201*, 117409. https://doi.org/10.1016/j.energy.2020.117409

Zhou, K., Yang, S., & Shen, C. (2021). A review of electric load classification in smart grids. *Renewable and Sustainable Energy Reviews, 135*, 110259. https://doi.org/10.1016/j.rser.2020.110259

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENERJİ DÖNÜŞÜMÜNDE YENİLENEBİLİR ENERJİ KAYNAKLARININ ROLÜ

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Özet

Günümüzde artan enerji talebi, fosil yakıt rezervlerinin sınırlı olması ve fosil yakıt kullanımına bağlı çevresel sorunlar, enerji sistemlerinde köklü bir dönüşümü zorunlu hale getirmiştir. Bu kapsamda enerji dönüşümü, enerji üretim ve tüketim süreçlerinin düşük karbonlu, çevre dostu ve sürdürülebilir bir yapıya kavuşturulmasını amaçlayan çok boyutlu bir süreç olarak tanımlanmaktadır. Yenilenebilir enerji kaynakları, bu dönüşüm sürecinin temel unsurlarından biri olup, başta iklim değişikliğiyle mücadele olmak üzere enerji arz güvenliği ve sürdürülebilir kalkınma hedeflerine önemli katkılar sunmaktadır.

Güneş, rüzgâr, hidroelektrik, biyokütle ve jeotermal gibi yenilenebilir enerji kaynakları, sera gazı emisyonlarının azaltılmasında fosil yakıtlara kıyasla önemli avantajlar sağlamaktadır. Ayrıca, bu kaynakların yerli potansiyel sunması, enerji ithalatına olan bağımlılığın azaltılmasına ve ülkelerin enerji arz güvenliğinin güçlendirilmesine katkıda bulunmaktadır. Bununla birlikte, yenilenebilir enerji kaynaklarının doğası gereği kesintili ve değişken olması, şebeke entegrasyonu, enerji depolama gereksinimleri ve altyapı yatırımları gibi teknik ve ekonomik zorlukları da beraberinde getirmektedir.

Bu çalışmada, enerji dönüşümü kavramı çerçevesinde yenilenebilir enerji kaynaklarının rolü ele alınmış ve bu kaynakların çevresel, ekonomik ve teknik boyutları değerlendirilmiştir. Ayrıca, yenilenebilir enerjinin enerji piyasaları üzerindeki etkileri, karbon emisyonlarının azaltılmasına katkısı ve sürdürülebilir kalkınma hedefleriyle olan ilişkisi incelenmiştir. Elde edilen değerlendirmeler, uygun politika araçları, teknolojik gelişmeler ve enerji depolama çözümleriyle desteklenen yenilenebilir enerji yatırımlarının, enerji dönüşüm sürecinin başarısında kritik bir rol oynadığını göstermektedir.

Anahtar Kelimeler: Enerji dönüşümü, yenilenebilir enerji, sürdürülebilirlik, enerji arz güvenliği, karbon emisyonları

The Role of Renewable Energy Sources in Energy Transformation

Abstract

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Today's increasing energy demand, limited fossil fuel reserves, and environmental problems associated with fossil fuel use have necessitated a fundamental transformation in energy systems. In this context, energy transition is defined as a multidimensional process that aims to make energy production and consumption processes low-carbon, environmentally friendly, and sustainable. Renewable energy sources are one of the key elements of this transformation process, contributing significantly to energy supply security and sustainable development goals, particularly in combating climate change.

Renewable energy sources such as solar, wind, hydroelectric, biomass, and geothermal offer significant advantages over fossil fuels in reducing greenhouse gas emissions. Furthermore, the domestic potential of these sources contributes to reducing dependence on energy imports and strengthening countries' energy supply security. However, the intermittent and variable nature of renewable energy sources also brings technical and economic challenges, such as grid integration, energy storage requirements, and infrastructure investments.

This study examines the role of renewable energy sources within the framework of the energy transition concept and evaluates the environmental, economic, and technical dimensions of these sources. Additionally, the effects of renewable energy on energy markets, its contribution to reducing carbon emissions, and its relationship with sustainable development goals have been examined. The findings indicate that renewable energy investments, supported by appropriate policy tools, technological developments, and energy storage solutions, play a critical role in the success of the energy transition process.

Keywords: Energy transition, renewable energy, sustainability, energy supply security, carbon emissions

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

NEXT-GENERATİON INTEGRATED POWER PLATFORM FOR ELECTRİCAL SYSTEMS

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ABSTRACT

In recent years, wireless energy transfer and integrated power solutions in household electrical appliances have become an important research area that enhances user experience and simplifies product architecture. In this study, a next-generation integrated power platform based on magnetic induction energy transfer and compatible with various kitchen appliances has been developed. The platform enables a modular electrical device positioned on an induction-based energy source to operate without additional cabling or external power adapters.

In the developed system, energy transfer is based on contactless power transmission principles realized through electromagnetic fields. The power electronics infrastructure has been designed to adaptively respond to different load characteristics, and protection and control algorithms have been integrated to ensure safe and stable operation of the system. Furthermore, modularity and user ergonomics were prioritized in the mechanical design, and a scalable structure was adopted to facilitate integration with different platforms.

Within the scope of the study, a prototype was manufactured and functional validation tests were conducted in a laboratory environment. Initial results indicate that wireless power transfer can provide sufficient performance and efficiency for household appliances. It is considered that the developed integrated power platform presents significant potential for future multi-device integration, smart kitchen ecosystems, and the widespread adoption of wireless energy infrastructures.

Keywords: Home Appliance, Smart Technology, Innovation, Design, Optimization, Prototype

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A NOVEL QUEUING THEORY BASED TRIAGE MANAGEMENT: A CASE STUDY PERFORMED IN MATLAB SIMULINK

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ABSTRACT

The growing demand for healthcare services has led to increased congestion, prolonged waiting times, and challenges in accurate patient prioritization in emergency departments. Conventional triage processes often struggle to manage heavy patient loads efficiently, resulting in suboptimal resource utilization and reduced service quality. This study presents a novel triage management approach based on queueing theory, aiming to improve patient flow and resource allocation in emergency departments.

In the proposed framework, patient identification and real-time vital parameters are evaluated together with historical hospital data used as inputs in a MATLAB Simulink-based simulation environment. An adaptive triage decision mechanism dynamically prioritizes patients according to clinical urgency while queueing theory models are employed to optimize staff and resource utilization, minimizing service bottlenecks and balancing patient flow. System performance is analyzed through MATLAB Simulink simulations, where various operational scenarios and patient arrival patterns are modeled and compared with conventional triage workflows.

Simulation results indicate that the proposed approach improves patient flow efficiency, reduces congestion-related delays, and significantly shortens average waiting times compared to traditional triage management practices. The study demonstrates that queueing theory integrated with simulation-based performance evaluation provides an effective and applicable framework for enhancing emergency department operations.

Keywords: Emergency triage, queuing theory, MATLAB Simulink, healthcare optimization, patient flow management

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A COMPARATIVE EVALUATION OF ANALYTICAL, INTEGRAL AND NUMERICAL APPROACHES FOR INDUCTANCE CALCULATION IN FERROMAGNETIC MATERIALS

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ABSTRACT

Accurate inductance calculation is a fundamental requirement in the design of magnetic components employing ferromagnetic cores. In classical magnetic circuit theory, inductance is commonly estimated using an average magnetic path length together with lumped-parameter assumptions on permeability and magnetic field distribution. While this approach provides analytical simplicity, it implicitly assumes a uniform magnetic field intensity along the magnetic circuit. In practical magnetic structures, particularly air-gapped ferromagnetic cores, this assumption is often violated due to spatial variations of the magnetic field, nonlinear material characteristics, and flux fringing effects at the air gap boundaries.

In air-gapped magnetic circuits, a dominant portion of the magnetomotive force is concentrated across the air gap, resulting in a nonuniform magnetic field distribution along the magnetic path. The presence of an air gap significantly alters the effective magnetic reluctance and introduces fringing flux effects that cannot be accurately represented using a single average magnetic path length parameter. Furthermore, the nonlinear B–H characteristics of ferromagnetic materials cause the effective permeability to vary with the operating point, which directly affects inductance values under different excitation conditions.

Integral-based formulations provide an alternative analytical framework by expressing the magnetomotive force as a line integral of the magnetic field intensity along the flux path, allowing spatial field variations to be incorporated into inductance calculations. In this study, inductance calculation approaches based on average magnetic path length approximations, integral formulations, and numerical field solutions obtained using the finite element method (FEM) are comparatively evaluated for air-gapped ferromagnetic cores. Magnetostatic FEM enables detailed resolution of magnetic flux density distribution and fringing effects that are difficult to capture using simplified magnetic circuit models. The comparative evaluation indicates that the average magnetic path length

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

assumption may introduce noticeable deviations in air-gapped configurations, whereas integral formulations and FEM-based analyses provide more consistent representations of magnetic field distribution and inductance behavior. The study aims to support the selection of appropriate inductance calculation techniques for practical magnetic component design.

Keywords: Inductance Calculation, Ferromagnetic Core, Magnetic Circuit, Finite Element Method

1) INTRODUCTION

The design of magnetic components such as inductors and transformers requires accurate determination of inductance values under various operating conditions. In power electronic applications, inductors with ferromagnetic cores are widely used for energy storage, filtering, and current shaping purposes. The inductance of these components directly influences their electrical performance, dynamic response, and overall system efficiency. Traditional magnetic circuit theory provides a convenient analytical framework by treating the magnetic system as an equivalent circuit with magnetomotive force sources and magnetic reluctances (Karapetoff, 1911; MIT Department of Electrical Engineering, 1943). This lumped-parameter approach remains popular in engineering practice due to its computational simplicity and ease of implementation.

The classical magnetic circuit method typically assumes that magnetic flux is uniformly distributed along an average magnetic path length through the core material. For closed-core configurations, where the magnetic path is entirely contained within high-permeability ferromagnetic material, this assumption provides reasonable accuracy. However, when an air gap is introduced into the magnetic circuit, the validity of the uniform flux distribution assumption becomes questionable. Air gaps are deliberately incorporated in many inductor designs to prevent core saturation, increase energy storage capability, and linearize the inductance characteristic (Hurley and Wölfle, 2013). The presence of an air gap significantly increases the total reluctance of the magnetic circuit because the permeability of air is approximately three orders of magnitude lower than that of common ferromagnetic materials. As a result, a large portion of the magnetomotive force is consumed across the air gap region, leading to a concentrated magnetic field intensity in that area and non-uniform field distribution along the magnetic path.

A well-known limitation of the simple magnetic circuit approach in air-gapped structures is its inability to properly account for fringing flux. (Roshen, 2007). Near the air gap boundaries, magnetic flux tends to spread outward into the surrounding air rather than remaining confined to the core cross-section. This fringing phenomenon occurs because the high reluctance of the gap causes flux lines to seek alternative paths with lower reluctance. The fringing effect increases the effective cross-sectional area through which flux passes, thereby reducing the actual reluctance of the air gap compared to the theoretical value calculated assuming uniform flux confinement (Balakrishnan et al., 1997). Several empirical correction factors have been proposed to approximately compensate for fringing effects

(McLyman, 2011; Kazimierczuk, 2009). However, these correction factors are derived from specific geometric configurations and may not accurately represent field distributions in structures that deviate from the idealized cases.

Another important consideration in inductance calculation is the nonlinear magnetic behavior of ferromagnetic materials. The relationship between magnetic flux density and magnetic field intensity in ferromagnetic cores is inherently nonlinear and exhibits hysteresis. The effective permeability varies significantly with the operating point and decreases as the core approaches magnetic saturation (Cullity and Graham, 2009). In the linear region of operation, the relative permeability of ferromagnetic materials can reach several thousand, whereas near saturation it approaches unity. This nonlinearity implies that the inductance of a ferromagnetic-core inductor is not constant but depends on the excitation level. Conventional magnetic circuit analysis often assumes a constant effective permeability value, which may be acceptable for small-signal or linear-region operation but can introduce considerable errors when the core operates near saturation or under large-signal excitation (Erickson and Maksimovic, 2001).

Alternative analytical formulations have been developed to improve upon the basic magnetic circuit approach. One such method involves expressing the magnetomotive force as a line integral of the magnetic field intensity along the actual flux path. This integral formulation allows spatial variations in field intensity to be explicitly incorporated, rather than being averaged into a single path length parameter. By integrating field intensity over different regions of the magnetic circuit—including sections with different permeabilities and varying field concentrations—a more accurate representation of the total magnetomotive force can be obtained. This approach can sometimes approximate the result to the actual inductance, depending on the geometry of the model. However, in the case of a C-type core, due to the regular geometry, the integral is reduced, returning to the classical method formulas.

Numerical field solution methods, particularly the finite element method (FEM), have become standard tools for analyzing complex magnetic field problems. The finite element method discretizes the solution domain into a mesh of elements and solves Maxwell's equations subject to appropriate boundary conditions and material properties (Jin, 2002; Alisoy, 1996). FEM provides detailed spatial resolution of magnetic flux density and field intensity distributions throughout the entire problem domain, including the core, air gap, and surrounding regions. This capability enables accurate modeling of phenomena such as flux fringing, leakage flux, and nonlinear material characteristics that are difficult to capture using simplified circuit models (Bastos and Sadowski, 2003). Recent studies have demonstrated the effectiveness of FEM-based approaches for inductance calculation in various configurations, with particular attention to fringing effects and distributed air gaps (Stenglein and Albach, 2017; Jez, 2017). Similar finite element optimization methods have been successfully applied to magnetic coupler design and other magnetic component applications (Arslan et al., 2023).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Despite the accuracy advantages offered by numerical methods, analytical and semi-analytical approaches remain valuable for preliminary design, parametric studies, and rapid design iterations. Analytical methods provide closed-form or semi-closed-form expressions that offer direct insight into the relationships between design parameters and performance characteristics. In contrast, while numerical methods provide high accuracy, they typically require significant computational effort and may not readily reveal the underlying physical relationships governing the design (Matsch, 1964). Therefore, understanding the relative accuracy and applicability of different calculation methods is important for effective design practice.

The objective of the present study is to compare three distinct approaches for calculating inductance in air-gapped ferromagnetic core configurations: the classical average magnetic path length method, an integral-based analytical formulation, and numerical analysis using the finite element method. The study focuses on a representative air-gapped core geometry where effects such as flux fringing, reluctance distribution, and field non-uniformity are expected to be significant. By comparing inductance values and examining the underlying assumptions of each method, the study aims to provide practical guidance on selecting appropriate calculation techniques for magnetic component design.

2) MATERIALS AND METHODS

2.1) Core Geometry and Material Properties

The study is based on an air-gapped C-type ferromagnetic core, as illustrated in Figure 1. A discrete air gap is positioned on the upper yoke to regulate magnetic reluctance and prevent core saturation. While the classical analytical method assumes an initial relative permeability $\mu_r = 2000$ to provide a baseline calculation, the study further investigates the nonlinear magnetic behavior of the Pure Iron core. In practical scenarios, the effective permeability is not constant but varies according to the operating point on the B–H curve. Detailed geometric dimensions and excitation parameters are summarized in Table 1.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Figure 1. Air Gapped C Type Ferromagnetic Core

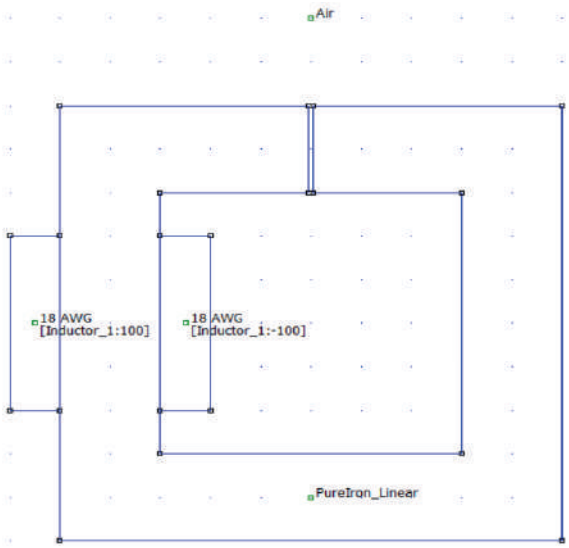


Table 1. Parameters of the Modeled Magnetic Circuit

Parameter	**Value**	**Unit**	**Symbol**
Core Material	Pure Iron	-	-
Initial Relative Permeability	2000	-	μ_r
Air Gap Length	1 x 10^{-3}	m	l_g
Number of Turns	100	-	N
Excitation Current	1.0	A	I
Wire Gauge	18	AWG	-
Core Cross-Section	6 x 10^{-4}	m^2	A_c
Mean Path Length	0,319	m	l_c

2.2) Classical Magnetic Circuit Method

The classical magnetic circuit analysis models reluctances in series, assuming a uniform distribution of flux.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$$\mathcal{R}_c = l_c / (\mu_0 \mu_r A_c) \quad (1)$$

$$\mathcal{R}_g = l_g / (\mu_0 A_c) \quad (2)$$

where $\mu_0 = 4\pi \times 10^{-7}$ H/m is the permeability of free space. The total reluctance is

$$\mathcal{R}_{total} = \mathcal{R}_c + \mathcal{R}_g \quad (3)$$

and the inductance;

$$L_{classical} = N^2 / \mathcal{R}_{total} = N^2 \mu_0 A_c / (l_c/\mu_r + l_g) \quad (4)$$

Substituting the parameters from Table 1 into Eqs. (1)–(4);

$$\mathcal{R}_c = 0.319 / (4\pi \times 10^{-7} \times 2000 \times 600 \times 10^{-6}) \approx 2.12 \times 10^5 \text{ A/Wb} \quad (5)$$

$$\mathcal{R}_g = 0.001 / (4\pi \times 10^{-7} \times 600 \times 10^{-6}) \approx 1.326 \times 10^6 \text{ A/Wb} \quad (6)$$

$$\mathcal{R}_{total} = 2.12 \times 10^5 + 1.326 \times 10^6 \approx 1.538 \times 10^6 \text{ A/Wb} \quad (7)$$

$$L_{classical} = (100)^2 / (1.538 \times 10^6) \approx \mathbf{6.5\ mH} \quad (8)$$

2.3) Integral-Based Formulation

The integral approach expresses the magnetomotive force as a line integral of magnetic field intensity along the flux path, according to Ampère's law:

$$NI = \oint H \cdot dl = \int_{core} H_c\, dl + \int_{gap} H_g\, dl \quad (9)$$

In the core region, $H_c = B_c / (\mu_0 \mu_r)$, and in the gap, $H_g = B_g / \mu_0$. Assuming flux continuity ($\Phi = BA_c$) and integrating over each region yields:

$$NI = \Phi [l_c / (\mu_0 \mu_r A_c) + l_g / (\mu_0 A_c)] \quad (10)$$

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

If the Eq.(10) is arranged;

$$L_{integral} = N^2 / \mathcal{R}_{total} \tag{11}$$

It is seen that Eq.(10) is equivalent to Eq.(4), so the inductance found by integration is also **6.5 mH**.

2.4) Finite Element Method

The FEM analysis solves the magnetostatic field equations numerically using the magnetic vector potential formulation. The governing equation in two dimensions is;

$$\nabla \cdot (\nu \nabla A_z) = -J_z \tag{12}$$

where $\nu = 1/\mu$ is the reluctivity, A_z is the z-component of the vector potential, and J_z is the current density in the winding. The magnetic flux density is obtained from $B = \nabla \times A$. For nonlinear materials, the reluctivity is a function of flux density magnitude, and the B–H characteristic is represented using piecewise linear interpolation or analytical functions (Bastos and Sadowski, 2003).

The solution domain includes the core, air gap, winding region, and surrounding air. A Dirichlet boundary condition ($A_z = 0$) is applied at the outer boundary. The domain is discretized into triangular elements with mesh refinement at the air gap boundaries to resolve fringing effects. The finite element equations are assembled using the Galerkin method and solved iteratively for nonlinear materials. After obtaining the field solution, the total flux linking the winding is calculated by integrating flux density over a cross-sectional surface.

3) RESULTS AND DISCUSSION

Unlike the analytical calculations in Section 2, which assumed a constant relative $\mu_r = 2000$ permeability, the Finite Element Analysis incorporates the actual nonlinear magnetic characteristics of the core material. The B–H curve of the Pure Iron used in the simulation is presented in Figure 3. Defining this nonlinear relationship is crucial for accurately capturing saturation effects and the variation of permeability across the core.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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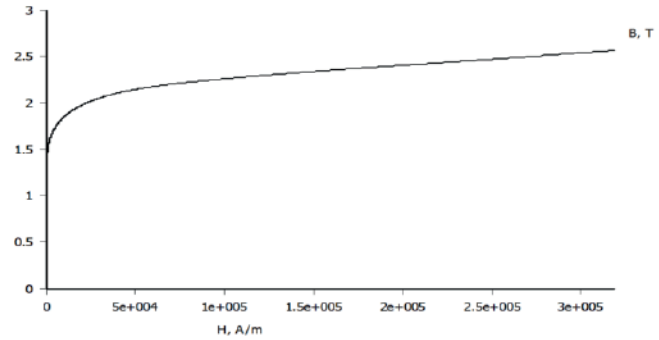


Figure 3. B-H Curve Of Pure Iron Used in FEMM Simulation

Based on this material definition, the magnetostatic solution was computed at the nominal current ($I = 1A$). The resulting magnetic flux density distribution is illustrated in Figure 4. The color map indicates the magnitude of flux density throughout the C-core geometry. As observed, the flux is well-confined within the core, but the distribution is not perfectly uniform due to the geometric corners and the air gap.

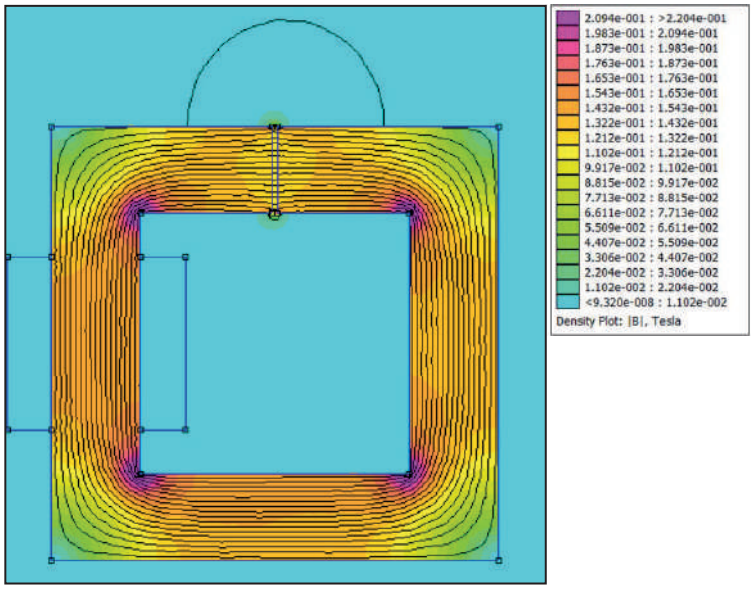


Figure 4. Distribution Of Magnetic Flux Density Magnitude Across The C-Core Reactor At Nominal Current

Following the finite element solution shown in Figure 4, the total magnetic energy stored in the system domain was computed. The simulation yielded a total magnetic energy of **0.00445141 Joules** at the

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ISBN: 978-9952-610-30-7

nominal current of **1 A**. Consequently, the inductance is calculated directly from the energy definition as:

$$L_{FEMM} = \frac{2W}{I^2} \tag{13}$$

From FEMM simulation;

$$L_{FEMM} = \frac{2\ x\ 0.00445141}{1^2} \approx \mathbf{8.9mH} \tag{14}$$

This value represents the true inductance of the reactor, accounting for both the saturation of the core and the fringing flux distributed around the air gap.

Table 2. Comparison of Inductance Calculation Results

Method	**Model Assumption**	**Inductance (L)**
Classical	Linear (μ_r = 2000), No Fringing	6.5mH
Integral	Linear (μ_r = 2000), No Fringing	6.5mH
Finite Elements Method (FEMM Simulation)	Nonlinear (B-H Curve), Fringing	8.9mH

As seen in Table 2, the analytical methods provide a baseline inductance of **6.5 mH**. However, the FEMM simulation yields a significantly higher inductance of **8.9 mH**. This approximately 37% difference is primarily attributed to the **fringing flux** around the air gap, which effectively increases the cross-sectional area of the magnetic path, thereby reducing the total reluctance. Additionally, the inclusion of the **nonlinear B–H curve** in FEMM captures the true permeability variations in the core, providing a more realistic representation compared to the constant permeability model.

CONCLUSION

This study presented a comparative analysis of inductance calculation methods for an air-gapped ferromagnetic reactor, highlighting the limitations of classical magnetic circuit theory against the

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ISBN: 978-9952-610-30-7

precision of the Finite Element Method (FEM). While the classical and integral-based analytical formulations converged to a baseline inductance of 6.5 mH under linear assumptions, the energy-based numerical analysis revealed a significantly higher actual inductance of 8.9 mH. The reason why the same inductance value is found in both classical and integral-based approaches is due to the geometry of the core, which simplifies the integral to the classical formula.

The observed 37% discrepancy demonstrates that standard reluctance network models, which neglect fringing fluxes and assume uniform flux distribution, are insufficient for the accurate modeling of air-gapped cores. The results confirm that fringing fields around the air gap effectively increase the cross-sectional area of the magnetic path, drastically reducing the total reluctance compared to theoretical geometric predictions. Furthermore, the inclusion of the nonlinear B–H characteristics of Pure Iron in the FEM simulation captured local permeability variations that linear models fail to predict.

For power electronics designers, this deviation is critical**.** Relying solely on analytical formulas for component sizing can lead to substantial design errors, such as incorrect corner frequencies in LC filters or unexpected core saturation under load. Consequently, this work concludes that while analytical methods are suitable for initial approximation, numerical modeling or advanced analytical corrections accounting for fringing energy are indispensable for the final design verification of high-performance magnetic components.

REFERENCES

Alisoy HZ 1996. Numerical calculation methods of electric and magnetic fields. Baku:Academy Press, ELM, 80 pp.

Arslan S, Iskender I, Navruz TS 2023. Finite element method-based optimisation of magnetic coupler design for safe operation of hybrid UAVs. Aerospace, 10(2): 140.

Balakrishnan A, Joines WT, Wilson TG 1997. Air-gap reluctance and inductance calculations for magnetic circuits using a Schwarz-Christoffel transformation. IEEE Transactions on Power Electronics, 12(4): 654-663.

Bastos JPA, Sadowski N 2003. Electromagnetic modeling by finite element methods. New York: Marcel Dekker, 497 pp.

Cullity BD, Graham CD 2009. Introduction to magnetic materials, 2nd edition. New Jersey: John Wiley & Sons, 544 pp.

Erickson RW, Maksimovic D 2001. Fundamentals of power electronics, 2nd edition. Boston: Kluwer Academic Publishers, 883 pp.

Hurley WG, Wölfle WH 2013. Transformers and inductors for power electronics: Theory, design and applications. West Sussex: John Wiley & Sons, 544 pp.

Jez R 2017. Influence of the distributed air gap on the parameters of an industrial inductor. IEEE Transactions on Magnetics, 53(11): 1-5.

Jin J 2002. The finite element method in electromagnetics, 2nd edition. New York: John Wiley & Sons, 753 pp.

Karapetoff V 1911. The magnetic circuit. New York: McGraw-Hill Book Company, 295 pp.

Kazimierczuk MK 2009. High-frequency magnetic components. West Sussex: John Wiley & Sons, 509 pp.

Matsch LW 1964. Capacitors, magnetic circuits, and transformers. Englewood Cliffs: Prentice-Hall, 554 pp.

McLyman WT 2011. Transformer and inductor design handbook, 4th edition. Boca Raton: CRC Press, 646 pp.

MIT Department of Electrical Engineering 1943. Magnetic circuits and transformers. Cambridge: The Technology Press, 515 pp.

Roshen WA 2007. Fringing field formulas and winding loss due to an air gap. IEEE Transactions on Magnetics, 43(8): 3387-3394.

Stenglein E, Albach M 2017. A novel approach to calculate the reluctance of air-gaps in ferrite cores. In: 2017 19th European Conference on Power Electronics and Applications (EPE'17 ECCE Europe). Warsaw, Poland, pp. 1-8.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A COLOR SENSING STUDY ON A CUSTOM-BUILT ROBOTIC ARM

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ABSTRACT

This study presents a color sensing application on a robotic arm designed and manufactured using 3D printing. The system was developed using an Arduino Nano microcontroller and a TCS3200 color sensor, enabling autonomous sorting of red and blue objects into designated bins. The mechanical design of the robotic arm was optimized in SolidWorks, including joint range of motion, motor placement, and assembly simulations to verify structural integrity. Three different prototypes were built, and their torque capacities, arm lengths, and task completion times were quantitatively compared to evaluate overall system performance.

Experiments were conducted under controlled lighting and temperature conditions, assessing color detection accuracy, grasping, and object placement. The results demonstrate that the robotic arm, using low-cost components, can reliably distinguish basic colors with the TCS3200 sensor and successfully perform autonomous tasks. This work overcomes the limitations of previous 3D-printed robotic arms that mostly remained at the prototype stage by combining mechanical design optimization and experimental performance analysis, highlighting potential for future industrial applications.

This study serves as a preliminary step for color-based robotic arm applications and lays the groundwork for further research on performance analysis, object classification, and industrial task execution. Additionally, it provides an accessible, low-cost solution that can serve as a reference for education, research, and prototyping activities in robotics.

Keywords: Autonomous robotic arm, Arduino-based control, 3D printing, servo motor, TCS3200, color sensing

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BEYOND TREATMENT: TRENDS FOCUSED ON RESOURCE RECOVERY AND ENERGY CONSERVATION IN MEMBRANE TECHNOLOGIES

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ABSTRACT

Membrane technologies have become increasingly pivotal across water/wastewater treatment, industrial reuse, food processing, and energy systems due to their selectivity, modularity, and comparatively lower chemical consumption (Fane et al., 2011). The aim of this study is to provide an integrated overview of contemporary application domains of membrane processes (MF/UF/NF/RO, MBR, etc.) and their future outlook within a sustainability framework, based on selected literature. In terms of methodology, recent review papers focusing on energy efficiency and process intensification were comparatively assessed alongside field-oriented studies reporting quantitative outcomes in water-treatment applications (Zheng et al., 2015; Osman et al., 2024).

The findings indicate that membranes are being deployed at scale, particularly for industrial wastewater treatment and water reuse. In China, the total capacity of membrane-based applications in industrial wastewater has reached **6.7 million m³/day**, with **580** facilities reported to be in operation (Zheng et al., 2015). For dyeing/textile wastewaters, hybrid trains especially **UF+RO** have become predominant; by 2015, a total installed capacity of approximately **662.000 m³/day** and **128** applications were reported (Liu et al., 2017).

Overall, the future perspective highlights (i) fouling control and lifetime extension, (ii) brine/concentrate and sidestream management, (iii) reduction of energy demand, and (iv) wider adoption of hybrid systems (e.g., MBR+RO, UF+RO, advanced oxidation+membranes) targeting resource recovery (Fane et al., 2011; Tsehaye et al.; 2022). Moreover, next-generation membrane materials and process integrations are expected to accelerate progress toward sustainable water treatment (Roy, & Ragunath, 2018; Foorginezhad et al., 2025).

Keywords: membrane technology; water/wastewater treatment; industrial water reuse; energy efficiency; hybrid membrane processes

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

REFERENCES

Fane, A. G., Wang, R., & Jia, Y. (2011). Membrane technology: Past, present and future. In L. K. Wang et al. (Eds.), Handbook of Environmental Engineering: Membrane and Desalination Technologies (Vol. 13). Springer. https://doi.org/10.1007/978-1-59745-278-6_1

Foorginezhad, S., Zerafat, M. M., Ismail, A. F., & Goh, P. S. (2025). Emerging membrane technologies for sustainable water treatment: a review on recent advances. Environmental Science: Advances, 4(4), 530-570. https://doi.org/10.1039/D4VA00378K

Liu, L., Cheng, R., Chen, X., Zheng, X., Shi, L., Cao, D., & Zhang, Z. (2017). Applications of membrane technology in treating wastewater from the dyeing industry in China: Current status and prospect. Desalination and Water Treatment, 77, 366–376. https://doi.org/10.5004/dwt.2017.20775

Osman, A. I., Chen, Z., Elgarahy, A. M., Farghali, M., Mohamed, I. M., Priya, A. K., ... & Yap, P. S. (2024). . Membrane technology for energy saving: principles, techniques, applications, challenges, and prospects. Advanced Energy and Sustainability Research, 5(5), 2400011. https://doi.org/10.1002/aesr.202400011

Roy, S., & Ragunath, S. (2018). Emerging membrane technologies for water and energy sustainability: Future prospects, constraints and challenges. Energies, 11(11), 2997. https://doi.org/10.3390/en11112997

Tsehaye, M. T., Assayie, A. A., Besha, A. T., Tufa, R. A., & Gebreyohannes, A. Y. (2022). Membrane technology for water and wastewater treatment in Ethiopia: Current status and future prospects. Journal of Membrane Science and Research, 8(1), e248498. https://doi.org/10.22079/JMSR.2021.540001.1500

Zheng, X., Zhang, Z., Yu, D., Chen, X., Cheng, R., Min, S., Wang, J., Xiao, Q., & Wang, J. (2015). Overview of membrane technology applications for industrial wastewater treatment in China to increase water supply. Resources, Conservation and Recycling, 105, 1–10. https://doi.org/10.1016/j.resconrec.2015.09.012

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A PROPOSED DECENTRALIZED FRAMEWORK FOR WIRELESS EV CHARGING IN GAZIANTEP

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ABSTRACT

Integrating wireless power transfer (WPT) into existing traffic signal infrastructure has gained attention as a potential solution for urban EV charging, although its feasibility remains highly sensitive to the spatial and temporal volatility of city-wide energy demand. This study investigates the operational limits of such an architecture, demonstrating that isolated node management becomes insufficient as network density increases in metropolitan environments. In order to address this limitation, we propose a decentralized coordination framework centered on a saturated consensus protocol. The design explicitly enforces bounded control actions under localized grid stress. The framework is evaluated using a high-fidelity digital twin of Gaziantep's 297 signalized intersections over a five-day horizon, incorporating bimodal traffic surges and constrained nocturnal recharge windows. In the uncoordinated scenario, 51 junctions are projected to experience terminal energy depletion, falling below the 10% operational threshold. Under the collaborative strategy, uninterrupted service was maintained across all simulated intersections. The approach resulted in a 20.26% absolute improvement in minimum state of charge and a 38.38% reduction in network-wide energy disparity. These findings suggest that decentralized cooperation may represent a practical prerequisite for resilient and equitable deployment of urban wireless charging systems.

Keywords: Wireless EV Charging, Multi-Agent Systems, Distributed Consensus.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DIGITAL FABRICATION OF EASY-TO-MANUFACTURE HYBRID CHAIR CONNECTORS

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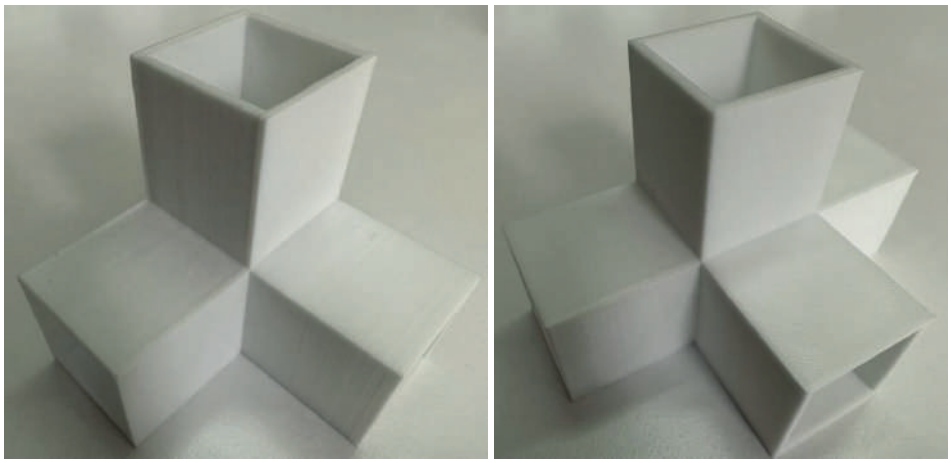
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ABSTRACT

Although the chair is an industrial product that fulfills one of the basic needs, it has held a wide variety of meanings from history to the present day. It has been able to express itself in every period through history, culture, style, function, belief, and aesthetic components. Traditionally constructed with wooden materials, chairs are also produced using materials such as metal, plastic, and composites. Today, additive manufacturing, one of the non-traditional manufacturing methods, is gaining prominence. The fused deposition modeling is one of these and uses polymeric material. In this study, fittings designed to join the legs and stretcher of a straight form chair was manufactured using additive manufacturing by fused deposition modeling. The PLA filament used as polymeric material. Ender Creality 3D printed was used. Wood leg and stretcher elements were glued to PLA fitting using PVC adhesive. No other joint elements such as dowels, etc. were used to connect wooden elements. Universal testing machine was used for compression test of the joints. Results showed that layer orientation plays critical role in failure mechanism. When the direction of the layers is parallel to the leg orientation, delamination occurs from the stretch position. Because the load direction is parallel to the layer accumulation. Furthermore, vice versa is the fact. Therefore, such a design (contains perpendicular formations) is inadequate for providing stable and durable joints in leg and stretcher connections for chairs

Keywords: Additive manufacturing, fused deposition modeling, chair, joint, connector, wood.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



NUMERICAL INVESTIGATION OF THERMAL MANAGEMENT STRATEGIES FOR PRISMATIC NMC811 LITHIUM-ION BATTERY PACKS IN ELECTRIC VEHICLES

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ABSTRACT

Thermal management of high-energy lithium-ion battery packs is crucial for safety, performance, and lifetime, particularly under high discharge rates. This study numerically compares forced-air cooling with a liquid-cooling architecture employing a water-based Al_2O_3 nanofluid (1 vol%) for a 12-cell prismatic NMC811 battery pack. Two pack layouts (4×3 and 6×2) are analyzed using CFD in ANSYS Fluent 2024 R2. Volumetric heat generation corresponding to 1C-3C discharge rates is applied to the cells, and the coolant inlet temperature is fixed at 300 K. Flow conditions are defined by Reynolds numbers of 100, 500, and 1000.

For the most demanding operating condition (3C), forced-air cooling results in maximum cell temperatures of 323.3-324.8 K across the investigated Reynolds range, suggesting limited thermal benefit from increasing airflow in the tested configuration. In contrast, the nanofluid-based liquid-cooling design integrated with an aluminum channel network maintains the maximum cell temperature within 301.0-303.3 K, achieving an approximate 21-23 K reduction in peak temperature relative to air cooling. The aluminum channels additionally enhance temperature uniformity within the module by improving heat spreading and heat extraction.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Overall, the findings indicate that Al_2O_3/water nanofluid cooling combined with conductive channel networks can substantially improve thermal control of NMC811 prismatic packs and represents a promising approach for compact battery thermal management in electric vehicle applications.

Keywords: Lithium-ion battery, NMC811, thermal management, CFD, nanofluid cooling, Reynolds number

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SPATIAL MEMORY AND STRUCTURAL TRANSFORMATION: A COMPARATIVE STUDY OF AYVALIK AND NEA IONIA IN THE CONTEXT OF THE 1923 TURKEY–GREECE POPULATION EXCHANGE

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ABSTRACT

The 1923 Population Exchange is one of the most comprehensive compulsory population movements implemented by modern nation-states. This study comparatively examines the spatial, social, and memory dimensions of the exchange through the cases of Ayvalık (Turkey) and Nea Ionia (Greece). The main problem of the research is how displaced communities transform a "foreign" geography into a "home" and reconstruct their belonging. The theoretical framework is built upon Henri Lefebvre's spatial triad (perceived/conceived/lived space) and expanded with Edward Soja's"Thirdspace" and Pierre Nora's "Sites of Memory". Findings indicate that exchangees were not passive users of state-planned spaces but active actors who transformed these spaces through daily practicesand memory transmission.

Keywords: Population Exchange, Spatial Memory, Lefebvre, Ayvalık, Nea Ionia, Belonging.

INTRODUCTION

At the dawn of the twentieth century, wars triggered by the dissolution of empires and the processes of nation-state formation led to radical and irreversible demographic ruptures on both sides of the Aegean. The legal and political culmination of this process, the *Convention Concerning the Exchange of Greek and Turkish Populations* dated 30 January 1923, instituted a compulsory separation based on religious identity. Bruce Clark (2006) characterizes this convention—through which approximately 1.2 million Orthodox Greeks were sent from Anatolia to Greece, and 500,000 Muslims from Greece to Turkey—as one of the most dramatic examples of “mass displacement” in modern history. However, this process cannot be reduced to a mere statistical transfer of population. As emphasized by Renée Hirschon (2003), the exchange constituted a profound spatial and identity crisis that fundamentally destabilized individuals’ senses of belonging, intergenerationally transmitted cultural codes, and worlds of meaning. This “forced estrangement” evolved into a collective trauma shaped both by the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

memories the exchangees left behind in the lands they abandoned and by the pains of "othering" they encountered in the new geographies to which they arrived.

This study aims to analyze the post-exchange production of space through two distinct urban typologies: (1) Ayvalık, where the existing Greek urban fabric was transformed by the newly arrived Muslim population, and (2) Nea Ionia, a planned settlement constructed from scratch by Greeks of Anatolian origin.

THEORETICAL FRAMEWORK AND CONCEPTUAL NETWORK

The reproduction of space in the post-exchange period is not a one-dimensional process of physical construction. In this study, space is approached as an intersection point of memory, identity, and power relations. The analytical foundation is grounded in Henri Lefebvre's theory of *The Production of Space*, while this framework is enriched through the contributions of Edward Soja, Edward Relph, and Pierre Nora.

Lefebvre's Spatial Triad and the Expanded Conceptual Network

Lefebvre (1991) examines space through three dialectical moments: Conceived, Perceived, and Lived Space. However, in order to comprehend a traumatic rupture such as the population exchange, it is necessary to relate this triad to the literature on migration and memory. The expanded conceptual network on which this study is based is schematized below:

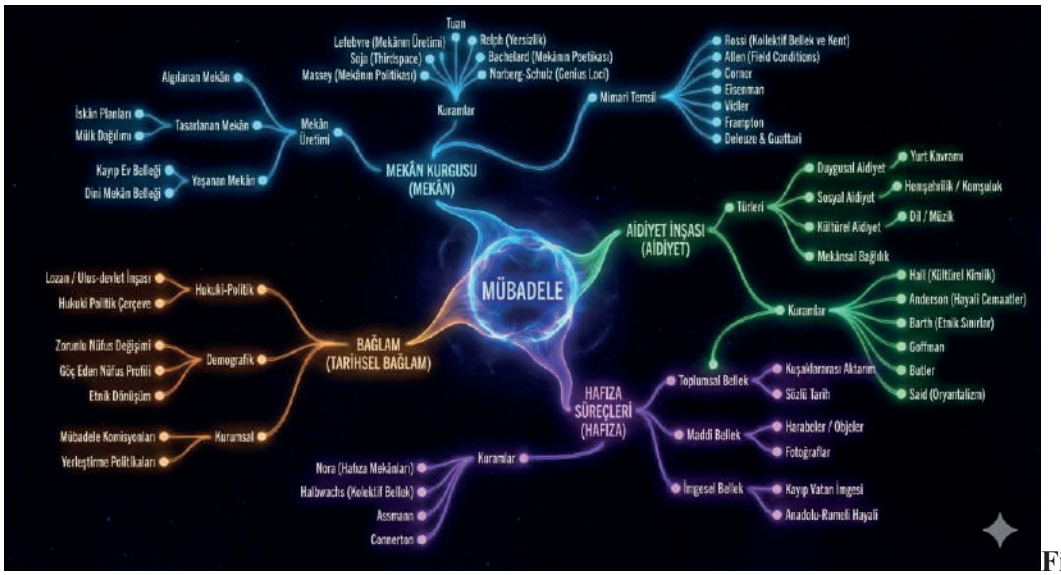


Figure 1. Conceptual Network of Space and Representation

As seen in this network, Edward Soja's (1996) concept of *Thirdspace* holds critical importance for this study. Soja conceptualizes space not merely as physical (Firstspace) or mental (Secondspace), but as a "lived" realm in which both are simultaneously encompassed and transcended (Soja, 1996). The exchangees are neither fully in the place they came from nor entirely in the new place they arrive at; rather, they construct their lives within a hybrid "third space" situated between the two.

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On the other hand, Edward Relph's (1976) concept of *Placelessness* elucidates the sense of rootlessness and alienation experienced by the exchangees upon their initial arrival. The newly assigned geography is an abstract "space" that has not yet been imbued with meaning or accumulated memories; over time, through everyday practices, it is transformed into "place."

The Construction of Memory and Belonging

Parallel to the physical construction of space, the construction of social memory is also required. At this point, a second conceptual network comes into play.

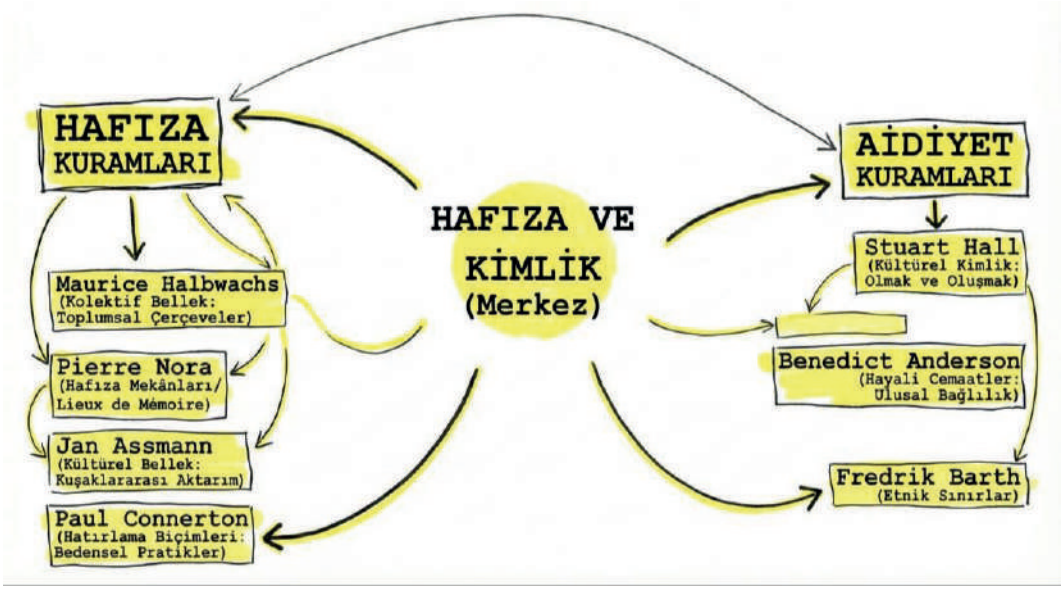


Figure 2. Conceptual Network of Memory and Belonging

Pierre Nora's (1989) concept of *Lieux de Mémoire* (Sites of Memory) expresses the effort to materialize a lost past (Anatolia or Rumelia) within new territories. A street sign, a recipe, or a photograph inherited from a grandfather each functions as a site of memory that seeks to repair a ruptured historical continuity. Benedict Anderson's (1983) concept of *Imagined Communities*, in turn, helps to explain how exchangees—who may never have known one another personally—construct a new form of social belonging (fellow-townsmen solidarity) through the experience of "sharing the same fate."

METHOD

This study is a qualitative, comparative case study. The data were collected through a review of historical and anthropological literature, archival records, and an analysis of the existing architectural fabric. In the analytical process, Lefebvre's triad was employed as a thematic coding tool; the data were classified under the headings of "state policies" (conceived), "everyday use" (perceived), and "memory practices" (lived) (Lefebvre, 1991).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

HISTORICAL PROCESS AND IMPLEMENTATION: STATE POLICIES, SPATIAL STRATEGIES, AND EVERYDAY PRACTICES

The 1923 Population Exchange between Turkey and Greece was given a legal framework through the *Convention Concerning the Exchange of Greek and Turkish Populations*, signed as an annex to the Treaty of Lausanne; the implementation process was carried out through the Mixed Exchange Commissions established by the two states (Yıldırım, 2007). However, although the exchange is often treated as a technical population transfer, in reality it constituted a complex process of restructuring in which property regimes were redefined and spatial arrangements were produced rapidly, and often through temporary solutions (Clark, 2006).

In both countries, the exchange process was shaped in line with the homogenizing policies of modern nation-states; the issue of the "settlement of the displaced population" came to signify not merely the provision of housing, but also the spatial construction of a new national identity (Hirschon, 2003). In this context, space became—following Lefebvre's (1991) formulation—not merely a physical ground, but a field of production in which state policies, ideological representations, and everyday life practices intersected.

In Turkey, exchange practices were largely based on the reallocation of existing Greek properties. As exemplified in Ayvalık, abandoned houses, workshops, and religious buildings were distributed to newly arrived Muslim exchangees; in this process, the original social and cultural context of space was often disregarded (Yıldırım, 2007). This approach by the state aimed to produce a rapid and functional solution at the level of "conceived space"; however, the everyday uses of space and its embedded memories generated transformations that went beyond this planning framework.

In Greece, by contrast, the exchange was addressed primarily through the construction of new settlement areas, particularly on the peripheries of large cities. As seen in the case of Nea Ionia, temporary housing areas (tents and barracks) were initially established for the Greek population arriving from Anatolia; over time, these areas were transformed into permanent residential fabrics (Bournazis, 2008). This process points to a planning approach in which the state treated space almost as a "tabula rasa." Yet here as well, the final form of space was shaped not solely by planning decisions, but through the production practices, social networks, and collective memory of the exchangees (Hirschon, 2003).

In both countries, exchange practices brought with them issues such as property transfer, economic adaptation, and social integration. While existing economic structures—such as olive oil production in Ayvalık—were reorganized by the newly arrived population, in Nea Ionia, Anatolia-based knowledge of carpet weaving and textile production became one of the fundamental elements defining the spatial and economic identity of the settlement (Hirschon, 2003; Clark, 2006). This situation demonstrates

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

that space must be considered not only in terms of its housing function, but also together with production and livelihood strategies.

Therefore, the implementation dimension of the exchange process should be read as a continuous field of negotiation between the "conceived space" of the state and the "lived space" of the exchangees. Although the transformation of the existing urban fabric in Ayvalık and the construction of a new fabric in Nea Ionia point to different spatial strategies, in both cases space was not a framework passively accepted by the exchangees; rather, it was reproduced through everyday practices and the transmission of memory (Lefebvre, 1991). This historical process clearly reveals that the exchange was not merely a population movement, but also a profound practice of spatial reproduction.

CASE STUDIES: SPATIAL PRODUCTION, MEMORY, AND EVERYDAY PRACTICES IN AYVALIK AND NEA IONIA

This section comparatively examines how space was reproduced after the 1923 Population Exchange through the cases of Ayvalık and Nea Ionia. Although both cases emerged from a similar experience of forced migration, they developed different spatial strategies and memory practices. The analysis is structured in accordance with Lefebvre's spatial triad, addressing the levels of conceived, perceived, and lived space.

Ayvalık: Transformation of the Existing Urban Fabric and Practices of Adaptation



Image 1. (URL-1)

Prior to the exchange, Ayvalık—known as Kydonies—was a port city that developed throughout the nineteenth century through olive oil production and trade, with a predominantly Greek population (Clark, 2006). Following the exchange, much of the city was abandoned; houses, religious buildings, and spaces of production were allocated to the newly arrived Muslim exchangees (Yıldırım, 2007).

Conceived Space:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The state's spatial strategy in Ayvalık was based not on the construction of a new settlement, but on the refunctionalization of the existing Greek urban fabric. While this approach responded to the urgent need for rapid settlement, it largely disregarded the former cultural and social context of space. Houses, workshops, and religious buildings were treated as functional units of shelter for new users.

Perceived Space:

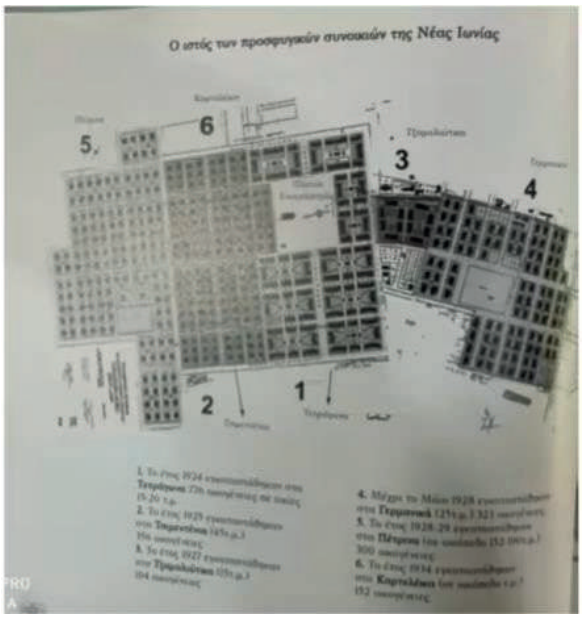
At the level of everyday use, the plan layouts of Greek houses were transformed to accommodate the living practices of the exchangees. Large mansions were subdivided for multi-household use, and courtyards and semi-public spaces were redefined. Within Lefebvre's (1991) concept of perceived space, this demonstrates how users reshaped space through everyday practices.

Lived Space and Memory:

In Ayvalık, religious buildings constitute a significant field of transformation. Structures such as the Taksiyarhis Church were converted into mosques or assigned secular functions. Interventions such as the plastering over of icons and the preservation or alteration of spatial orientation signify a rewriting of the symbolic meaning of space (Akan, 2020; Solak & Okuyucu, 2022). In this process, memory was often negotiated through erasure or suppression, and space acquired a palimpsestic character (Yıldırım, 2007).

Nea Ionia: The Construction of a New Settlement and the Spatialization of Memory

Nea Ionia is a planned settlement established to the north of Athens for Greek exchangees arriving from Anatolia. Even the name of the settlement carries a direct reference to the lost Anatolian geography, indicating the deliberate inscription of memory into space (Hirschon, 2003).



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Image 2 (URL-2). Diagram of different refugee settlement types in Nea Ionia. Reprinted from Iones, *Nea Ionia Magnesia "Refugee City"*, Nea Ionia Magnesia, November 2008, p. 14.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Conceived Space:

The Greek state's approach in Nea Ionia largely involved the creation of a new settlement fabric on an empty site. Tents and barracks initially designed as temporary shelters gradually became permanent through the construction of stone buildings arranged in a grid plan (Bournazis, 2008). This reflects the state's effort to produce space within a rational and planned order.

Perceived Space:

The exchangees reshaped this planned fabric in accordance with their everyday practices. The use of the ground floors of houses as workshops led to an intensification of production and social interaction at the street scale. Carpet weaving and textile knowledge brought from Anatolia became one of the key elements determining the economic and social organization of space (Hirschon, 2003).

Lived Space and Memory:

In Nea Ionia, memory—unlike in Ayvalık—was inscribed into space openly rather than being suppressed. References to Anatolian cities in street and neighborhood names enabled space to be transformed into a "memory archive" in the sense defined by Pierre Nora (1989). This demonstrates that the exchangees reconstructed their relationship with the lost homeland through a spatial continuity.

Comparative Analysis of Ayvalık and Nea Ionia

The table below summarizes, in comparative terms, the spatial strategies of the two cases and their relationship with memory.

Table 1. Ayvalık–Nea Ionia comparison table compiled by the author from relevant sources.

Criterion	Ayvalık (Turkey)	Nea Ionia (Greece)
Initial Spatial Condition	Existing Greek urban fabric	Empty land / new settlement
State Strategy (Conceived Space)	Reallocation and adaptation	Planned construction and settlement
Housing Typology	Subdivided mansions, multi-household use	Grid-planned, stone buildings
Religious Buildings	Conversion from church to mosque / secular functions	Newly constructed places of worship
Memory Strategy	Erasure, transformation, palimpsest	Explicit remembrance, naming
Economic Practices	Reorganization of existing production	Transfer of Anatolia-based production

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Spatial Identity	Adaptation and negotiation	Reconstruction and continuity

The cases of Ayvalık and Nea Ionia demonstrate that post-exchange spatial production is neither singular nor homogeneous. While in Ayvalık memory was negotiated through suppression and transformation upon existing spatial traces, in Nea Ionia memory was inscribed into space through a conscious strategy of reconstruction. In both cases, the exchangees did not passively accept the spatial frameworks offered by the state; rather, they produced their own "lived spaces" through everyday practices (Lefebvre, 1991). The data compiled in relation to this process can be read comparatively in Table 1.

DISCUSSION AND CONCLUSION

This study approaches the 1923 Population Exchange between Turkey and Greece not merely as a demographic or diplomatic event, but within the context of the production of space and the reconstruction of social memory. The comparative analysis conducted through the cases of Ayvalık and Nea Ionia reveals that the experience of forced migration generated different spatial strategies; however, in both cases, space emerged as a dynamic field negotiated between state policies and everyday practices.

When examined through Lefebvre's (1991) spatial triad, the production of post-exchange space never remained confined solely to the level of "conceived space." Settlement policies developed by states diverged in form—manifesting as the reallocation of the existing Greek urban fabric in Ayvalık and as the construction of a new, planned settlement in Nea Ionia. Yet in both examples, these planned spatial frameworks were transformed through the everyday use practices and memory transmissions of the exchangees. This confirms that space is not a passive ground, but a process continuously reproduced within social relations.

In Ayvalık, the dominant spatial strategy is characterized by adaptation and transformation. The subdivision of existing Greek houses, the functional conversion of religious buildings, and the redefinition of public–private boundaries produced a palimpsestic structure in which previous cultural traces were suppressed but never fully erased. Here, memory was often rendered invisible or negotiated through residual spatial traces. This condition also makes visible the spatial manifestations of the sense of "placelessness" described by Edward Relph (1976); for new users, space was experienced for a long time not as a "place," but as a "space" to be transformed.

In Nea Ionia, by contrast, the dominant strategy was reconstruction and explicit remembrance. From the name of the settlement to street names, from production practices to forms of social organization, many elements carried deliberate references to the lost Anatolian geography. In the sense articulated by Pierre Nora (1989), Nea Ionia functioned not merely as a settlement, but as a "site of memory" in

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

which collective memory was spatialized. In this context, memory was made visible rather than suppressed, and space became a means of establishing continuity with the past.

When both cases are considered together, it becomes clear that the exchangees were not passive recipients of state policies. The subdivision of houses and the conversion of churches in Ayvalık, and the integration of workshop–housing arrangements and Anatolia-referenced naming practices in Nea Ionia, demonstrate that exchangees produced their own "lived spaces" in relation to the "conceived space" imposed by the state (Lefebvre, 1991). This condition also resonates with Edward Soja's (1996) concept of *Thirdspace*: exchangees belong neither entirely to the places they arrived at nor fully to the geographies they left behind; their spatial experience was shaped within a hybrid and dynamic realm between these two conditions.

In conclusion, this study reveals that the spatial impacts of the 1923 Population Exchange must be understood not only through national borders and planning policies, but also through everyday life practices and the transmission of memory. The cases of Ayvalık and Nea Ionia demonstrate that forced migration does not produce a single spatial outcome; rather, it generates diverse forms of spatial production across different historical, cultural, and physical contexts. In this sense, the exchange should be evaluated as a reciprocal and dialectical process in which land transforms people as much as people transform space.

This approach holds the potential to offer a critical contribution not only to studies on the population exchange, but also to contemporary discussions on forced migration, displacement, and resettlement, by addressing them through the intertwined axes of space and memory.

REFERENCES

Akan, A. (2020). *The Taksiyarhis Church of Alibey (Cunda) Island* (Unpublished master's thesis). Uludağ University.

Anderson, B. (1983). *Imagined communities: Reflections on the origin and spread of nationalism* (Rev. ed.). Verso.

Barth, F. (1969). *Ethnic groups and boundaries: The social organization of culture difference*. Little, Brown.

Bournazis, G. (2008). *The refugee settlements of Athens: Urban formation and social transformation*. Athens University Press.

Clark, B. (2006). *Twice a stranger: The mass expulsions that forged modern Greece and Turkey*. Harvard University Press.

Hall, S. (1996). Cultural identity and diaspora. In P. Mongia (Ed.), *Contemporary postcolonial theory: A reader* (pp. 110–121). Arnold.

Halbwachs, M. (1992). *On collective memory* (L. Coser, Ed. & Trans.). University of Chicago Press.

Hirschon, R. (Ed.). (2003). *Crossing the Aegean: An appraisal of the 1923 compulsory population exchange between Greece and Turkey*. Berghahn Books. https://doi.org/10.12681/grsr.9358

Lefebvre, H. (1991). *The production of space* (D. Nicholson-Smith, Trans.). Blackwell.

Massey, D. (2005). *For space*. SAGE.

Nora, P. (1989). Between memory and history: Les lieux de mémoire. *Representations, 26*, 7–24. https://doi.org/10.2307/2928520

Norberg-Schulz, C. (1980). *Genius loci: Towards a phenomenology of architecture*. Rizzoli.

Relph, E. (1976). *Place and placelessness*. Pion.

Soja, E. W. (1996). *Thirdspace: Journeys to Los Angeles and other real-and-imagined places*. Blackwell.

Solak, C., & Okuyucu, Ş. E. (2022). Correspondences of existing building components in new functions in the transformation of religious buildings: Church and mosque conversions. *Journal of the Institute of Social Sciences of Selçuk University*, (49), 191–211.

Yalçın, K. (2001). *Emanet çeyiz: Mübadele insanları*. Doğan Kitap.

Yıldırım, O. (2007). *Diplomacy and displacement: Reconsidering the Turco-Greek exchange of populations, 1922–1934*. Routledge. https://doi.org/10.4324/9780203960653

URL:

URL-1: https://www.emeginseruveni.com/milli-mucadelede-sehirlerimiz-ayvalik/ (Accessed: 09.02.2026)

URL-2: https://100sources.gr/en/entry/refugee-housing-in-nea-ionia/#group_gallery-4 (Accessed: 09.02.2026)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

REMOVAL OF MANGANESE AND COLIFORM FROM GROUNDWATER IN A PILOT-SCALE DRINKING WATER TREATMENT SYSTEM

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ABSTRACT

Groundwater is widely used as a source of drinking water; however, its direct use may be limited due to elevated manganese concentrations and microbiological contamination. In this study, the treatability of groundwater abstracted from a well located in the Molla Feneri District of Gebze, Kocaeli Province, was experimentally investigated using a pilot-scale drinking water treatment system. Raw water analyses revealed manganese concentrations exceeding drinking water standards and the presence of total coliform bacteria.

The pilot treatment system consisted of a rapid filtration unit containing a special iron–manganese removal filter media, followed by a chlorination process. During the study, raw and treated water samples were collected periodically, and manganese concentration and total coliform parameters were monitored. The results indicated that approximately 95% of manganese was removed by the rapid filtration unit. Following chlorination, total coliform bacteria were completely eliminated, achieving nearly 100% disinfection efficiency.

The treated water quality met the relevant drinking water standards and was considered suitable for distribution within the water supply network. This pilot-scale experimental study demonstrates that the combination of rapid filtration and chlorination is an effective and practical treatment approach for groundwater sources affected by manganese and microbiological contamination. The findings are expected to contribute to the design and operation of full-scale drinking water treatment plants treating groundwater with similar characteristics.

Keywords: Groundwater, Manganese removal, Rapid filtration, Chlorination, Total coliform, Pilot-scale treatment

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TAGUCHI-BASED ANALYSIS OF THE EFFECTS OF INJECTION MOLDING PARAMETERS ON DIMENSIONAL SHRINKAGE IN VIRGIN, RECYCLED, AND HYBRID POLYPROPYLENE COMPOSITES

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ABSTRACT

In this study, the effects of injection molding parameters on the dimensional shrinkage behavior of virgin (vPP30GF), recycled (rPP30GF), and hybrid (hPP12GF12T) polypropylene composite materials were experimentally investigated. A Taguchi design of experiments (DoE) approach was adopted, and an L4 orthogonal array was employed. Injection temperature (200–230 °C), injection pressure (60–80 bar), and holding/packing pressure (50–60 bar) were selected as control factors. Shrinkage in both the flow direction (FD) and the transverse-to-flow direction (TD) was evaluated using signal-to-noise (S/N) ratios and analysis of variance (ANOVA).

The results indicate that holding/packing pressure is the most dominant parameter governing transverse shrinkage for all material groups in the investigated part. In terms of dimensional stability, the hybrid composite containing 12% glass fiber and 12% talc exhibited the most stable behavior, showing the lowest FD–TD shrinkage difference (0.13%), attributed to the anisotropy-reducing effect of the mineral filler. Conversely, the recycled composite demonstrated the highest dimensional deviation and the greatest sensitivity to process parameters. Overall, the study highlights the need for material-specific parameter optimization that accounts for the material's thermal history and fiber dispersion to enable sustainable and cost-effective manufacturing.

Keywords: Polypropylene Composites, Injection Molding, Dimensional Shrinkage, Taguchi Method, Recycling.

REFERENCE

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Berihun, E. A., & Bogale, T. M. (2022). Parameter Optimization of PET Plastic Preform Bottles in Injection Molding Process Using Grey-Based Taguchi Method. Advances in Materials Science and Engineering, 2022, 1–9. *https://doi.org/10.1155/2022/4416602*

Oktem, H., Erzurumlu, T., & Uzman, I. (2007). Application of Taguchi optimization technique in determining plastic injection molding process parameters for a thin-shell part. Materials & Design, 28(4), 1271–1278. *https://doi.org/10.1016/j.matdes.2005.12.013*

Kumar, R., & Bairwa, K. N. (2025). Optimizing Process Parameters in Plastic Injection Molding using the Taguchi Method: A Focus on Minimizing Defects and Improving Product Quality. Evergreen, 12(2), 1177–1188. *https://doi.org/10.5109/7363502*

Kc, B., Faruk, O., Agnelli, J. A. M., Leao, A. L., Tjong, J., & Sain, M. (2016). Sisal-glass fiber hybrid biocomposite: Optimization of injection molding parameters using Taguchi method for reducing shrinkage. Composites Part A: Applied Science and Manufacturing, 83, 152–159. *https://doi.org/10.1016/j.compositesa.2015.10.034*

Rosli, M. S. B. (2023). Multiple Response Taguchi Optimisation for Injected Moulded Polypropylene Nanoclay Gigantochloa scortechinii Processing and Fibre Content, for Building Appliances [Ph.D.]. *https://www.proquest.com/docview/3103742068/abstract/7C89EC50B5234E51PQ/2*

Liou, G.-Y., Su, C.-W., Huang, P.-W., Hwang, S.-J., Huang, C.-T., & Peng, H.-S. (2022). Fabrication and Property Characterization of Long-Glass-Fiber-Reinforced Polypropylene Composites Processed Using a Three-Barrel Injection Molding Machine. Polymers, 14(6), 1251. *https://doi.org/10.3390/polym14061251*

Ryu, Y., Sohn, J. S., Kweon, B. C., & Cha, S. W. (2019). Shrinkage Optimization in Talc- and Glass-Fiber-Reinforced Polypropylene Composites. Materials, 12(5), 764. *https://doi.org/10.3390/ma12050764*

SAF, GERI DÖNÜŞTÜRÜLMÜŞ VE HİBRİT POLİPROPİLEN KOMPOZİTLERDE ENJEKSIYON KALIPLAMA PARAMETRELERİNİN BOYUTSAL ÇEKME ÜZERİNDEKİ ETKİSİNİN TAGUCHİ YÖNTEMIYLE ANALİZİ

ABSTRACT

Bu çalışmada, saf (vPP30GF), geri dönüştürülmüş (rPP30GF) ve hibrit (hPP12GF12T) polipropilen kompozit malzemelerin enjeksiyon kalıplama parametrelerinin, boyutsal çekme (shrinkage) davranışları üzerindeki etkileri deneysel olarak incelenmiştir. Çalışmada Taguchi yöntemi kullanılarak L4 ortogonal dizisi ile deney tasarımı oluşturulmuş; enjeksiyon sıcaklığı (200-230°C), enjeksiyon basıncı (60-80 bar) ve tutma basıncı (50-60 bar) kontrol faktörleri olarak belirlenmiştir. Numunelerin akış ve akışa dik yönlerdeki çekme oranları S/N oranları ve varyans analizi (ANOVA) ile değerlendirilmiştir.

Analiz sonuçlarına göre, incelenen parçada akışa dik yönde boyutsal çekme üzerinde en baskın parametrenin tüm malzeme gruplarında tutma basıncı olduğu tespit edilmiştir. Malzeme performansı açısından, %12 cam elyaf ve %12 talk içeren hibrit kompozit, mineral dolgunun anizotropiyi azaltıcı etkisi sayesinde akış ve akışa dik yönler arasındaki farkın en düşük (%0,13) olduğu en kararlı yapıyı sergilemiştir. Buna karşın, geri dönüştürülmüş malzemede en yüksek boyutsal sapma ve parametre hassasiyeti gözlemlenmiştir. Çalışma, sürdürülebilir ve maliyet etkin üretim için malzemenin termal geçmişine ve fiber dağılımına uygun spesifik parametre optimizasyonunun gerekliliğini ortaya koymaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Anahtar Kelime: Polipropilen Kompozitler, Enjeksiyon Kalıplama, Boyutsal Çekme, Taguchi Yöntemi, Geri Dönüşüm.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KAYNAKÇA

Berihun, E. A., & Bogale, T. M. (2022). Parameter Optimization of PET Plastic Preform Bottles in Injection Molding Process Using Grey-Based Taguchi Method. Advances in Materials Science and Engineering, 2022, 1–9. *https://doi.org/10.1155/2022/4416602*

Oktem, H., Erzurumlu, T., & Uzman, I. (2007). Application of Taguchi optimization technique in determining plastic injection molding process parameters for a thin-shell part. Materials & Design, 28(4), 1271–1278. *https://doi.org/10.1016/j.matdes.2005.12.013*

Kumar, R., & Bairwa, K. N. (2025). Optimizing Process Parameters in Plastic Injection Molding using the Taguchi Method: A Focus on Minimizing Defects and Improving Product Quality. Evergreen, 12(2), 1177–1188. *https://doi.org/10.5109/7363502*

Kc, B., Faruk, O., Agnelli, J. A. M., Leao, A. L., Tjong, J., & Sain, M. (2016). Sisal-glass fiber hybrid biocomposite: Optimization of injection molding parameters using Taguchi method for reducing shrinkage. Composites Part A: Applied Science and Manufacturing, 83, 152–159. *https://doi.org/10.1016/j.compositesa.2015.10.034*

Rosli, M. S. B. (2023). Multiple Response Taguchi Optimisation for Injected Moulded Polypropylene Nanoclay Gigantochloa scortechinii Processing and Fibre Content, for Building Appliances [Ph.D.]. *https://www.proquest.com/docview/3103742068/abstract/7C89EC50B5234E51PQ/2*

Liou, G.-Y., Su, C.-W., Huang, P.-W., Hwang, S.-J., Huang, C.-T., & Peng, H.-S. (2022). Fabrication and Property Characterization of Long-Glass-Fiber-Reinforced Polypropylene Composites Processed Using a Three-Barrel Injection Molding Machine. Polymers, 14(6), 1251. *https://doi.org/10.3390/polym14061251*

Ryu, Y., Sohn, J. S., Kweon, B. C., & Cha, S. W. (2019). Shrinkage Optimization in Talc- and Glass-Fiber-Reinforced Polypropylene Composites. Materials, 12(5), 764. *https://doi.org/10.3390/ma12050764*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENHANCED DUCTILITY OF THICK T-STUB CONNECTIONS USING A SLEEVE FUSE

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ABSTRACT

This paper presents an experimental and numerical assessment of a sleeve-based fuse system developed to improve the inelastic performance of bolted steel T-stub connections. A series of laboratory tests was conducted on thick T-stub specimens fitted with sleeves having different dimensional properties, and their structural response was compared with that of conventional specimens. The effects of the sleeve system on strength development, stiffness degradation, and deformation capacity were systematically evaluated. In parallel, finite element simulations were established and validated against the test results. The experimental and numerical findings reveal that the proposed sleeve fuse promotes stable plastic deformation and increases energy dissipation in T-stub connections. Accordingly, the system offers a viable approach for enhancing the seismic resilience and structural reliability of steel moment-resisting frames.

Keywords: T-stub steel connections; Ductile performance; Failure mechanisms; Bolted joints; Sleeve fuse device

INTRODUCTION

Beam-to-column connections are fundamental components in steel structures, as they govern the transfer of internal forces and strongly influence the global structural response. Adequate ductility in these joints is essential for ensuring load redistribution and preventing progressive collapse under extreme loading conditions (Khandelwal and El-Tawil, 2007). Among commonly used connection types, bolted end-plate joints are widely adopted due to their favorable constructability, rapid installation, and high strength and stiffness characteristics (Murray, 2003). Nevertheless, past investigations and post-event observations have shown that such connections may experience brittle failure, mainly due to the limited deformation capacity of critical components such as high-strength bolts and welds (Arup, 2011; Demonceau et al., 2023).

To address this limitation, Shaheen et al. (2021) introduced a steel sleeve fuse system aimed at improving the rotational capacity and ductility of end-plate connections. The device is installed by

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

inserting sleeves between the bolt and surrounding components, allowing plastic deformations to concentrate within the sleeve and preserving the integrity of primary structural members. Compared with conventional strengthening techniques, the system offers practical advantages, including ease of installation and replacement. Previous numerical and analytical studies have demonstrated that the sleeve device can significantly enhance rotational capacity and energy dissipation without reducing connection strength (Shaheen et al., 2022; Shaheen et al., 2023a; Shaheen et al., 2023b; Atar, 2025). However, most of these investigations were limited to computational analyses or isolated bolt assemblies, and experimental evidence at the connection or frame level remains scarce (Shaheen et al., 2024).

Due to the complex interaction among bolts, plates, and welds, the behaviour of end-plate connections is difficult to predict using simplified analytical models. Moreover, full-scale experimental testing of complete joints is often expensive and labor-intensive. Consequently, researchers frequently employ the T-stub idealization to represent the tensile zone of end-plate connections. In this model, axial forces are mainly carried by the bolts, while bending resistance is provided by the flange, enabling a simplified yet effective representation of force transfer mechanisms. T-stub models have therefore become a standard framework for studying the tensile response of bolted steel connections.

A large body of experimental and numerical research has focused on the mechanical performance of T-stub connections, including their strength, stiffness, deformation capacity, and failure mechanisms (Swanson, 1999; Swanson and Leon, 2000; Swanson et al., 2002; Haggag et al., 2024). Early experimental programs by Swanson and Leon (2000) provided important insights into ductility and failure behaviour under monotonic and cyclic loading. Subsequent studies investigated full-range response characteristics, considering effects such as bolt slippage and beam rotation (Yan et al., 2020; Piluso and Rizzano, 2008). Analytical and numerical models were later developed to predict cyclic and large-deformation behaviour (Tartaglia et al., 2020; Özkılıç, 2021). Other investigations examined the influence of geometric parameters, such as flange thickness, bolt diameter, and detailing, on load transfer and deformation mechanisms (Bezerra et al., 2020; Zhu et al., 2017). Additional studies explored the effects of weld type, material properties, and high-strength steels on connection performance (Zhao et al., 2021; Dinu and Anwar, 2017; Girao Coelho et al., 2004; Chen et al., 2017). These investigations generally indicate that increases in strength are often accompanied by reduced ductility, particularly for high-strength and stainless steel connections (Hu et al., 2023; Lin et al., 2022; Yuan et al., 2019).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

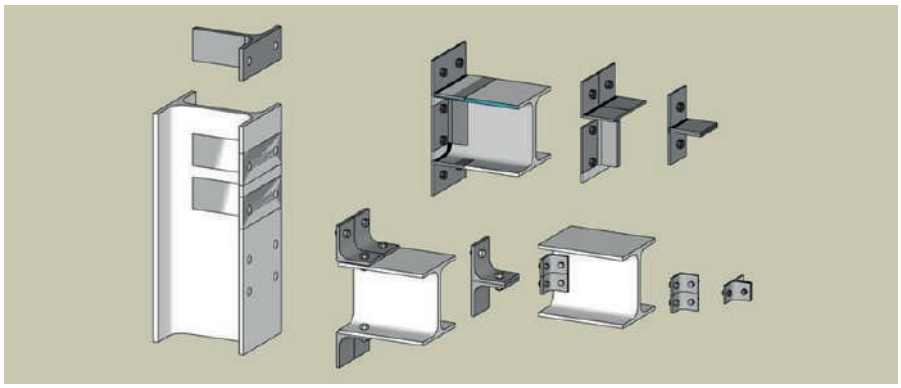


Figure 1. Representation of the T-stub component in bolted beam–column joints.

In this context, the present study evaluates the structural response of T-stub connections incorporating a sleeve fuse system. The investigation is focused on thick-plate configurations governed by bolt fracture without plastic hinge formation in the plate, corresponding to Mode 3 failure in Eurocode (BSI, 2005). Fourteen T-stub specimens equipped with sleeves of different geometric characteristics were experimentally tested and compared with a reference specimen without sleeves. Finite element models were subsequently developed and validated using the experimental data. The main objectives are to quantify the load-carrying capacity, identify dominant failure modes, and assess the influence of sleeve geometry on stiffness degradation, ductility development, and energy dissipation.

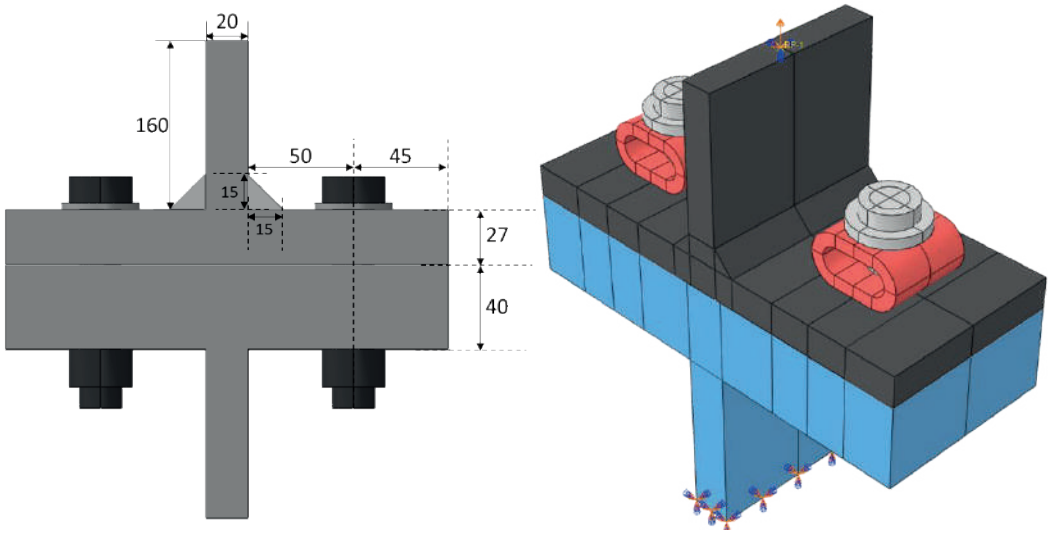
Unlike previous studies that relied primarily on numerical simulations (Shaheen et al., 2021; Shaheen et al., 2023a), this research presents the first experimental investigation of an obround wave (OBW) sleeve integrated into a full-scale thick-plate T-stub connection. The interaction between sleeve crushing, bolt elongation, and plate bending is captured in detail, providing new insights into the inelastic behaviour and damage evolution of sleeved bolted connections.

EXPERIMENTAL SET UP

An experimental study was carried out at the Structures Laboratory of Firat University to examine the tensile response of T-stub connections with and without sleeve devices under monotonic loading. A total of 4 specimens were manufactured and tested. All specimens had flange and web thicknesses of 27 mm and 20 mm, respectively, and were connected to a rigid base T-stub with flange and web thicknesses of 40 mm and 20 mm (see Figure 2). The base element was designed to remain within the elastic range and was reused throughout the test program. Each connection was assembled using two high-strength M20 grade 8.8 bolts. The flange and web plates were joined by 15 mm fillet welds, which were designed to provide strength exceeding that of the bolts. This ensured that failure was governed by bolt fracture rather than weld rupture.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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OBW sleeves with different geometric properties were employed in the experimental program. The main parameters detailed in Figure 4 considered included sleeve length, wall thickness, width, and curvature (see Table 1).



(a) (b)

Figure 2. Configurations of tested T-stub specimens.

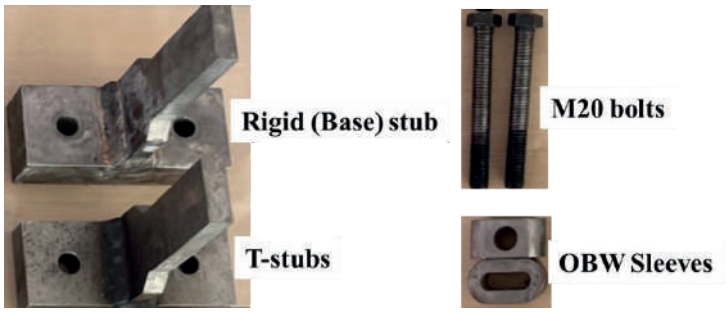


Figure 3. Components of the T-stub test setup

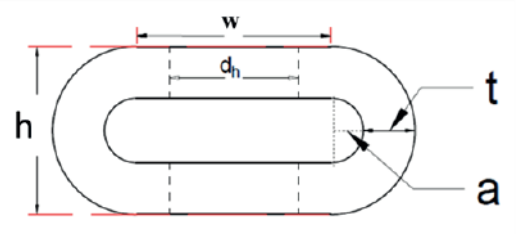


Figure 4. Sleeve geometrical parameters.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Table 1. Sleeve parameters

Specimens	Heigth (h) (mm)	Thickness (t) (mm)	Amplitude (a) (mm)	Width (w) (mm)
OBW_1	24	7	5	25
OBW_2	28	8	6	25
OBW_3	32	11	5	25

S355 steel was used for the T-stubs, base elements, and sleeves, while grade 8.8 bolts were employed in all specimens. Coupon tests were carried out on the sleeves and bolts to determine their mechanical properties, which are summarized in Table 2. The material properties of the T-stub and base components were obtained from manufacturer data, as no coupon tests were conducted. Due to the large plate thickness, nominal values were considered sufficient to represent the structural response.

Table 2. Summary of mechanical properties of steel components and bolts.

Specimens	f_y/MPa	f_u/MPa	E_s/MPa	ε_u
T-stub	345	450	209000	0.34
Base T-stub	345	450	209000	0.34
M20 bolt	800	850	201198	0.08
Sleeve	355	650	204695	0.33

TEST RESULTS

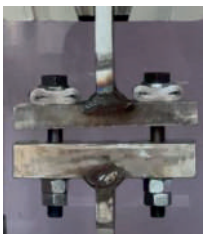
Table 3 summarizes the tested specimens and their observed failure mechanisms. Specimens OBW_1 and OBW_2 are classified as weak-sleeve configurations due to their relatively small wall thickness, whereas specimen OBW_3 represents a medium-strength sleeve condition. For all specimens considered in this study, the final failure was governed by bolt necking. In the weak-sleeve specimens, sleeve crushing developed prior to bolt fracture, indicating that the sleeve functioned as the primary energy-dissipating component and promoted localized deformation.

When the sleeve capacity was lower than that of the bolt, controlled crushing occurred before significant bolt elongation, leading to a more stable inelastic response. The preferred failure sequence

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consisted of sleeve crushing followed by bolt necking, as this mechanism delayed premature bolt rupture and enhanced deformation capacity. Although all specimens ultimately failed by bolt fracture, the inclusion of the sleeve effectively postponed bolt failure and improved the overall ductile performance of the connection.

Table 2. Corresponding failure modes of the specimens.

Models	**Test End**	**Failure description**
T-stub		Bolt necking
OBW_1		Sleeve crushing and subsequent bolt fracture.
OBW_2		Sleeve crushing and subsequent bolt fracture.
OBW_3		Sleeve crushing and subsequent bolt fracture.

Based on the relative capacity of the sleeve plate, the tested T-stub specimens were classified into two groups: weak sleeves and medium-strength sleeves. Specimens equipped with weak sleeves exhibited a more flexible response compared with the reference T-stub (see Figure 5). Due to the lower sleeve capacity, plastic deformation initiated at an earlier loading stage, resulting in premature sleeve crushing. During this phase, the connection showed reduced stiffness and increased deformability. After complete sleeve collapse, the load transfer mechanism gradually shifted from the sleeve to the bolt, leading to a recovery in stiffness. Final failure was governed by bolt necking. Although weak

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sleeves significantly improved deformation capacity, the associated increase in flexibility may result in excessive displacements, which should be considered in serviceability design.

T-stub specimens incorporating medium-strength sleeves demonstrated a more balanced structural response (see Figure 6). The reference specimen without sleeves exhibited three typical stages, including elastic behaviour, bolt-dominated plastic deformation, and final softening prior to failure. In contrast, sleeve-equipped specimens showed a distinct multi-stage response. Initial elastic behaviour was followed by progressive sleeve crushing, accompanied by stable load increase. Once the sleeve was fully compacted and confined between the washer and end plate, the load was transferred directly through the bolt, leading to a noticeable increase in stiffness. In the final stage, deformation was primarily governed by bolt elongation, and failure occurred due to bolt necking.

Compared with conventional T-stubs, specimens with medium-strength sleeves achieved significantly higher deformation capacity while maintaining adequate stiffness. This behaviour indicates that properly designed sleeves can effectively balance energy dissipation and structural rigidity, leading to improved overall performance.

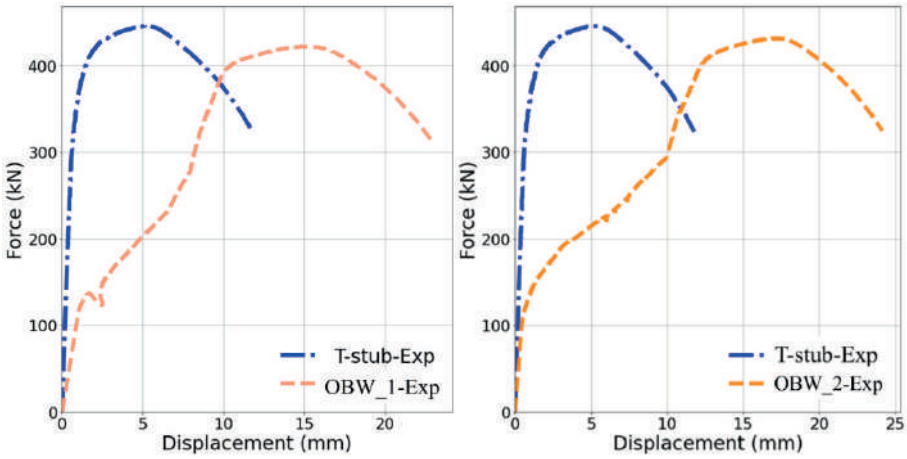


Figure 5. Load–displacement responses of T-stub specimens equipped with low-capacity sleeves.

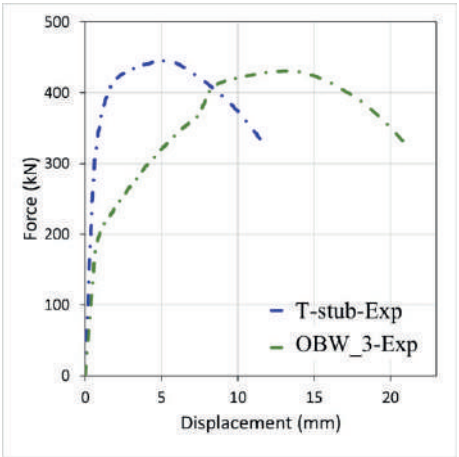


Figure 6. Load–displacement responses of T-stub specimens equipped with medium-capacity sleeves.

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DUCTILITY AND ENERGY DISSIPATION

The results in Table 4 indicate that the incorporation of sleeve devices leads to a significant improvement in both ductility and energy dissipation capacity compared with the conventional T-stub specimen. The reference specimen exhibited a ductility ratio of 8.43, whereas the sleeved specimens achieved substantially higher values ranging from 20.02 to 30.19. This demonstrates that the presence of sleeves effectively enhances the deformation capacity of the connection. In terms of energy dissipation, all sleeve-equipped specimens showed notable increases in absorbed energy. While the conventional T-stub dissipated 4655.08 kN·mm, the sleeved specimens exhibited energy absorption values between 7219.41 and 7452.35 kN·mm, corresponding to improvements of approximately 55% to 60%. These results confirm that sleeve devices play a crucial role in promoting stable inelastic behaviour and improving the seismic performance of T-stub connections.

Importantly, the ultimate load capacity of the sleeved specimens remained comparable to that of the reference specimen, as reflected by the PU/PT-stub ratios close to unity. This indicates that the enhancement in ductility and energy dissipation is achieved without a significant reduction in strength.

Table 4. Experimental comparison between standard and sleeved T-stub connections.

Specimen	K_{int} (kN/mm)	Δ_y (mm)	Δ_u (mm)	P_y (kN)	P_U (kN)	$\mu = \frac{\Delta_u}{\Delta_y}$	$\frac{P_U}{P_{T-stub}}$	W (kN.mm)	% Change in energy absorption
T-stub-Exp	512.43	1.4	11.80	394.15	445.56	8.43	1.00	4655.08	0.00
OBW_1-Exp	219.78	1.15	23.03	122.33	421.93	20.02	0.95	7219.41	55.09
OBW_2-Exp	274.74	0.8	24.15	126.07	431.15	30.19	0.97	7326.85	57.30
OBW_3-Exp	237.68	0.8	20.78	189.18	431.34	25.97	0.97	7452.35	60.1

FE VALIDATION

The experimental results were used to verify the accuracy of the finite element model, which will be applied in subsequent parametric investigations. Numerical simulations were performed using ABAQUS/Explicit for quasi-static analyses (ABAQUS, 2019). All components were modelled with C3D8R solid elements to ensure adequate representation of three-dimensional stress and deformation

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fields. In the numerical model, bolts were idealized as smooth cylindrical shanks with nominal diameters, and thread geometry was not explicitly represented. The influence of threading was incorporated through the use of the effective tensile stress area. A structured hexahedral mesh was adopted, with refined discretization in critical regions. Typical element sizes were approximately 10 mm for the base stub, 4 mm for the T-stub, 3 mm for the bolts, and 2 mm for the sleeves (see Figure 7).

The base stub was fully restrained at its lower surface, while a reference point was coupled to the upper surface of the T-stub web to apply the imposed displacement. Contact interactions were defined between all relevant interfaces, including bolt–flange, sleeve–washer, and foundation–flange surfaces. Tie constraints were assigned between the bolt head and washer. Normal contact behaviour was modelled using a hard-contact formulation, and tangential behaviour was simulated with a friction coefficient of 0.2. All steel components were represented using isotropic elastic–plastic constitutive models based on material test results. For numerical stability, post-peak softening was neglected by limiting the stress–strain curves to the ultimate strength. Loading was applied through displacement control to ensure stable convergence and reliable simulation of post-yield response.

The FE model was first verified using the reference T-stub specimen subjected to tensile loading. The numerical results showed good agreement with the experimental response in both the elastic and inelastic ranges as detailed in Figure 8. Additional comparisons were carried out for sleeve-equipped specimens, confirming that the simulations accurately reproduced the main stages of structural behaviour (see Figure 9). Although minor differences were observed in some cases, the numerical model was able to represent the overall response and the functioning of the sleeve fuse system with satisfactory accuracy. Furthermore, the predicted failure mechanisms and load–displacement trends were consistent with the experimental observations.

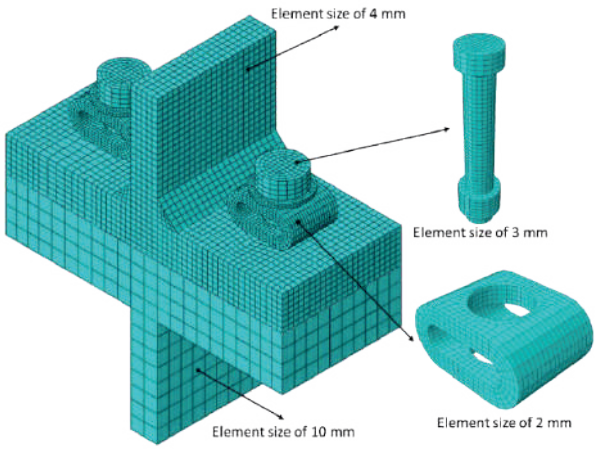


Figure 7. FE mesh illustrating the mesh density of the components.

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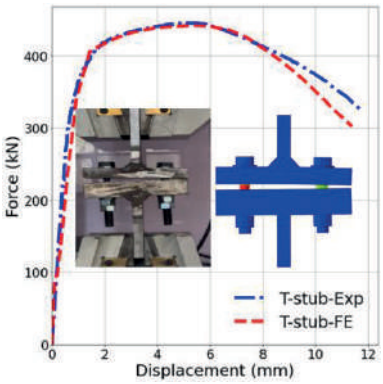


Figure 8. Experimental and numerical force–displacement curves for standard connection

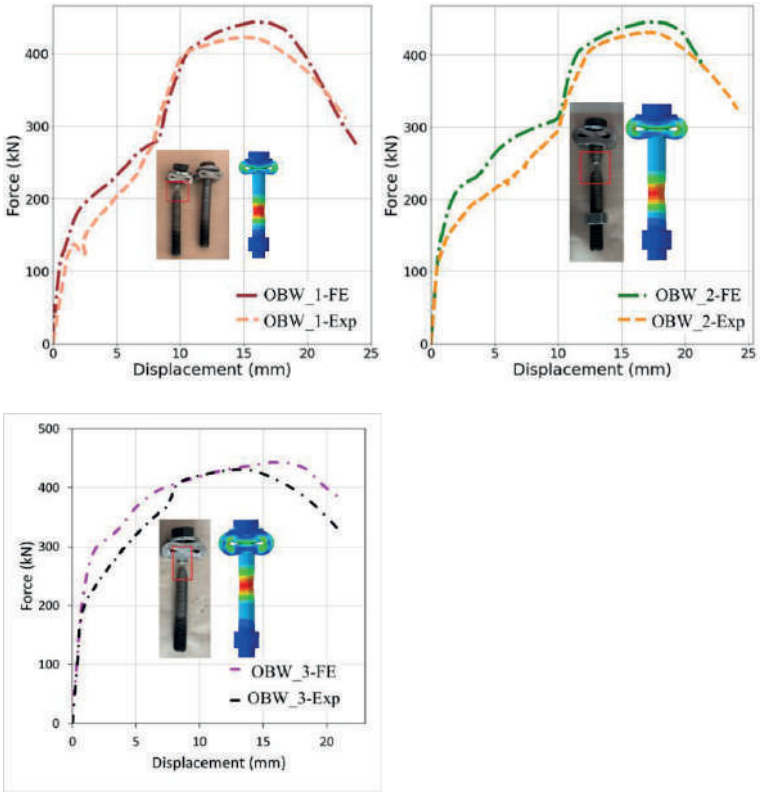


Figure 9. Validation of the FE model for T-stub specimens with different sleeve configurations

CONCLUSION

This study explored the effectiveness of OBW steel sleeves integrated into T-stub connections to enhance ductility, energy dissipation, and overall performance of bolted steel joints. Experimental tests on specimens OBW_1, OBW_2, and OBW_3, complemented by FE simulations, demonstrated the impact of sleeve geometry on connection behaviour under tensile loading. Key outcomes are summarized as follows:

- Thin-walled sleeves in OBW_1 and OBW_2 promoted early sleeve crushing, resulting in large ultimate displacements and increased ductility, while the medium-strength sleeve in OBW_3 provided a balanced stiffness–ductility response.

- All sleeved specimens showed a two-stage load–displacement response: initial sleeve yielding and crushing, followed by bolt necking and final tensile failure.

- Weak sleeves reduced initial stiffness, but the ultimate load capacity remained similar to the conventional T-stub, since final failure was governed by bolt strength.

- Energy dissipation was significantly enhanced with the sleeve system, exceeding 55% improvement for all tested configurations compared to the reference specimen.

- FE simulations captured the experimental response accurately, including stiffness, load capacity, deformation, and failure modes, validating the model for future parametric studies.

REFERENCES

ABAQUS. (2019). Abaqus 6.19. Dassault Systèmes Simulia Corp., Providence, RI, USA.

Arup 2011. Review of international research on structural robustness and disproportionate collapse. Department for Communities and Local Government.

Atar M 2025. Comparative numerical study of sleeve fuse systems and RBS for enhancing cyclic performance in steel end-plate connections. International Journal of Steel Structures.

Bezerra LM, Bonilla J, Silva WA, Matias WT 2020. Experimental and numerical studies of bolted T-stub steel connection with different flange thicknesses connected to a rigid base. Engineering Structures, 218: 110770.

BSI 2005. BS EN 1993-1-8:2005 - Eurocode 3: Design of steel structures - Part 1-8: Design of joints. London: British Standards Institution.

Chen C, Zhang X, Zhao M, Lee CK, Fung TC, Chiew SP 2017. Effects of welding on the tensile performance of high strength steel T-stub joints. Structures, 9: 70-78.

Demonceau JF et al. 2023. Design recommendations against progressive collapse in steel and steel-concrete buildings. Report, 1-242.

Dinu F, Anwar GA 2017. Ultimate deformation and resistance capacity of bolted T-Stub connections under different loading conditions.

Girao Coelho AM, Bijlaard FSK, Gresnigt N, da Silva LS 2004. Experimental assessment of the behaviour of bolted T-stub connections made up of welded plates. Journal of Constructional Steel Research, 60(2): 269-311.

Haggag M, Elruby AY, Ismail MK, AbdelAleem BH, El-Dakhakhni W 2024. Failure mode and capacity prediction for bolted T-stub connections using ensemble learning. Journal of Constructional Steel Research, 212: 108288.

Hu F, Lin T, Wang Z 2023. Hysteretic energy dissipation capacity of dual-steel welded-plate preloaded bolted T-stubs. Thin-Walled Structures, 193: 111252.

Khandelwal K, El-Tawil S 2007. Collapse behaviour of steel special moment resisting frame connections. Journal of Structural Engineering, 133(5): 646-655.

Lin T, Wang Z, Hu F, Hou W 2022. Comparison in tensile behaviour of conventional and high-strength steel welded-plate preloaded T-stubs. Structures, 43: 93-104.

Murray TM 2003. Extended end-plate moment connections: Seismic and wind applications. American Institute of Steel Construction.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Özkılıç YO 2021. The capacities of unstiffened T-stubs with thin plates and large bolts. Journal of Constructional Steel Research, 186: 106908.

Piluso V, Rizzano G 2008. Experimental analysis and modelling of bolted T-stubs under cyclic loads. Journal of Constructional Steel Research, 64(6): 655-669.

Shaheen MA, Galal MA, Cunningham LS, Foster ASJ 2021. New technique to improve the ductility of steel beam to column bolted connections: A numerical investigation. Civil Engineering, 2(4): 929-942.

Shaheen MA, Foster ASJ, Cunningham LS 2022. A novel device to improve robustness of end plate beam-column connections: Analytical model development. Thin-Walled Structures, 172: 108878.

Shaheen MA, Tsavdaridis KD, Ferreira FPV, Cunningham LS 2023a. Rotational capacity of exposed base plate connections with various configurations of anchor rod sleeves. Journal of Constructional Steel Research, 201: 107754.

Shaheen MA, Atar M, Cunningham LS 2023b. Enhancing progressive collapse resistance of steel structures using a new bolt sleeve device. Journal of Constructional Steel Research, 203: 107843.

Shaheen MA, Alsaleh A, Cunningham LS 2024. Experimental tests on a novel bolt sleeve device to increase the ductility of steel end plate connections. Journal of Constructional Steel Research, 214: 108510.

Swanson J 1999. Characterization of the strength, stiffness, and ductility behaviour of T-stub connections. PhD Thesis.

Swanson JA, Leon RT 2000. Bolted steel connections: Tests on T-stub components. Journal of Structural Engineering, 126(1): 50-56.

Swanson JA, Kokan DS, Leon RT 2002. Advanced finite element modeling of bolted T-stub connection components. Journal of Constructional Steel Research, 58(5-8): 1015-1031.

Yan S, Jiang L, Rasmussen K, Zhang H 2020. Full-range behaviour of top-and-seat angle connections. Journal of Structural Engineering, 147(1): 04020308.

Yuan HX, Hu S, Du XX, Yang L, Cheng XY, Theofanous M 2019. Experimental behaviour of stainless steel bolted T-stub connections under monotonic loading. Journal of Constructional Steel Research, 152: 213-224.

Zhao X, He S, Yan S 2021. Full-range behaviour of T-stubs with various yield line patterns. Journal of Constructional Steel Research, 186: 106919.

Zhu X, Wang P, Liu M, Tuoya W, Hu S 2017. Behaviours of one-side bolted T-stub through thread holes under tension strengthened with backing plate. Journal of Constructional Steel Research, 134: 53-65.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GREEN SYNTHESIS OF IRON OXIDE NANOPARTICLES USING AQUEOUS EXTRACT OF *RUMEX ACETOSELLA*

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ABSTRACT

Emerging from the developments in various fields of technology, nanotechnology has become a very popular research area for scientists. The use of nanotechnology products is widespread in many areas, such as health, food, and agriculture, and research continues into their use in other fields. Nanoparticles (NPs) are nanostructures that can reach sizes up to 100 µm and possess large surface areas with diverse chemical, biological, and physical properties. They can be used in various fields according to their unique properties. For instance, iron NPs are preferred in health and biomedical fields due to their biocompatibility, magnetism, and low toxicity. The synthesis of NPs through physical and chemical methods requires high energy and the use of toxic compounds. Green synthesis, which aims to minimize these drawbacks, enables the synthesis of NPs using organisms such as bacteria, fungi, and plants. *Rumex acetosella* L., also known as sheep's sorrel, is a wild, medicinal, and aromatic plant belonging to the Polygonaceae family. Thanks to its rich phytochemicals, it possesses antioxidant, anticancer, anti-inflammatory, and antimicrobial properties. In this study, phytochemicals found in *Rumex acetosella* were used as reducing and stabilizing agents for the synthesis of iron NPs. An aqueous extract of dried *Rumex acetosella* L. was prepared after the cleaned and rinsed plant was ground. The powdered plant was stirred with boiling dH_2O at 85°C for 2.5 h. After the filtration process, the resulting solution was mixed with an $FeCl_3$ solution at a ratio of 1:2. The synthesis of iron NPs was confirmed through the observation of a colorimetric change in the reaction solution and the assessment of changes in surface plasmon resonance through UV-Vis spectroscopy in the range of 300-800 nm. The synthesized iron NPs will be further characterized by analyzing their physical and chemical properties through SEM, FTIR, and XRD.

Keywords: *Rumex acetosella* L., green synthesis, iron oxide nanoparticle.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INTRODUCTION

The rapid and effective advancements in nanoscience and its application area, nanotechnology, have enabled many nano-sized products to enter our daily lives (Malik et al., 2023). One example of these products is nanoparticles, which range in size from 1 to 100 nm and offer unique physicochemical opportunities due to advancements in nanoengineering. The high ratio between surface area and volume allows nanoparticles to exhibit different characteristics that are significantly different from the bulk materials they are synthesized from in terms of thermal, chemical, and magnetic aspects (Joudeh and Linke, 2022; Altammar, 2023). All these revolutionary properties have led for the use of nanoparticles in various industries such as agriculture, biomedicine, environment, food, and electronics (Eker at al., 2024).

Conventionally, there are two different approaches to nanoparticle synthesis. The first one is the top-down approach, which synthesizes nanoparticles from raw materials using physical methods. The latter is the bottom-up approach, which synthesizes nanoparticles at the atomic and molecular level using chemical methods. Both approaches have disadvantages, such as high energy requirements, high costs, and toxic chemicals that are used during synthesis (Vinukonda et al., 2025). However, the concept of green synthesis has attracted the attention of scientists, especially regarding the biological synthesis of nanoparticles. In this method, synthesis takes place through organisms such as bacteria, fungi, and plants. This approach reduces factors like cost, synthesis time, and environmental concerns (Gunasena et al., 2025; Ouardy et al., 2025).

Plants can be used in nanoparticle synthesis due to the phytochemicals they have in parts such as stems, leaves, and flowers. Owing to have a wide chemical library including terpenes, terpenoids, and polyphenols, plants provide natural reducing and stabilizing agents that enable the synthesis of nanoparticles (Raut et al., 2026).

Rumex acetosella L. is a known plant which is a member of the family Polygonaceous. Preferred by people for the sour taste of its leaves and consumed as a vegetable in salads, this plant contains high levels of phytochemicals (Aktepe et al., 2022; Karadağ, 2024). In addition to its antipyretic, anti-inflammation, and laxative properties, *R. acetosella* has also been found to exhibit antioxidant and anticancer effects (Turkmen and Inan, 2025). Although it is identified as an aromatic medicinal plant, its wild distribution, in particular, damages agricultural activities. Therefore, it is an undesirable plant for farmlands (Franzese and Ghermandi, 2014).

Depending on the compound they have been synthesized from, iron nanoparticles can be found in different forms and sizes. Thanks to their impressive paramagnetic properties, they find applications in various fields in healthcare, such as imaging, sensing, and drug delivery systems (Yekeen et al., 2025).

The aim of this study is to synthesize iron oxide nanoparticles using *R. acetosella* extract and to determine the optical features of the formed nanoparticles through UV-Vis spectroscopy.

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MATERIALS AND METHODS

Collection of *Rumex acetosella*

R. acetosella was collected from the local bazaar in Yozgat. To remove dust from the plant, it was washed once with tap water, then three times with distilled water. Afterward, the plant was left to dry in the shade at room temperature. The plant was identified and authenticated by the botanist of the department, and a portion of the dried specimen was taken for preservation in the Department of Biology Herbarium. The remaining portion was ground into powder using a grinder and was stored at 4°C.

Water extraction of *Rumex acetosella*

The water extract of *R. acetosella* was prepared by adding 5 g of powder to 100 ml of dH_2O in a beaker at 85°C. The mixture was stirred continuously and incubated at the same temperature for 2.5 h. After incubation, the extract was left for cooling at room temperature. The cooled extract was filtered using Whatman filter paper No.1. Then, the filtrate was transferred to a dark bottle and stored at 4°C until further use.

Synthesis of iron oxide nanoparticles

The synthesis of iron oxide nanoparticles was accomplished by adding 1 mM $FeCl_3$ solution to *R. acetosella* extract drop by drop with a Pasteur pipette. The extract/$FeCl_3$ volume ratio was 1:2. After the colour change from yellowish to dark brown was observed, the reaction was incubated for additional 30 min at room temperature.

UV-Vis characterization of synthesized nanoparticles

The UV-Vis spectrum of the synthesized iron oxide nanoparticles was monitored in the wavelength range 300-800 nm using a SP-UV2102 UV-Vis Spectrophotometer (DLab) with 3 ml glass cuvettes.

RESULTS

The addition of 1 mM $FeCl_3$ solution to *R. acetosella* extract resulted in a significant color change from yellow to dark brown. This visual change indicated the formation of iron nanoparticles in the solution. Moreover, UV-Vis spectroscopy measurements revealed a slight peak at 370 nm, which was the confirmation of the biogenic synthesis of iron nanoparticles (Figure 1).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

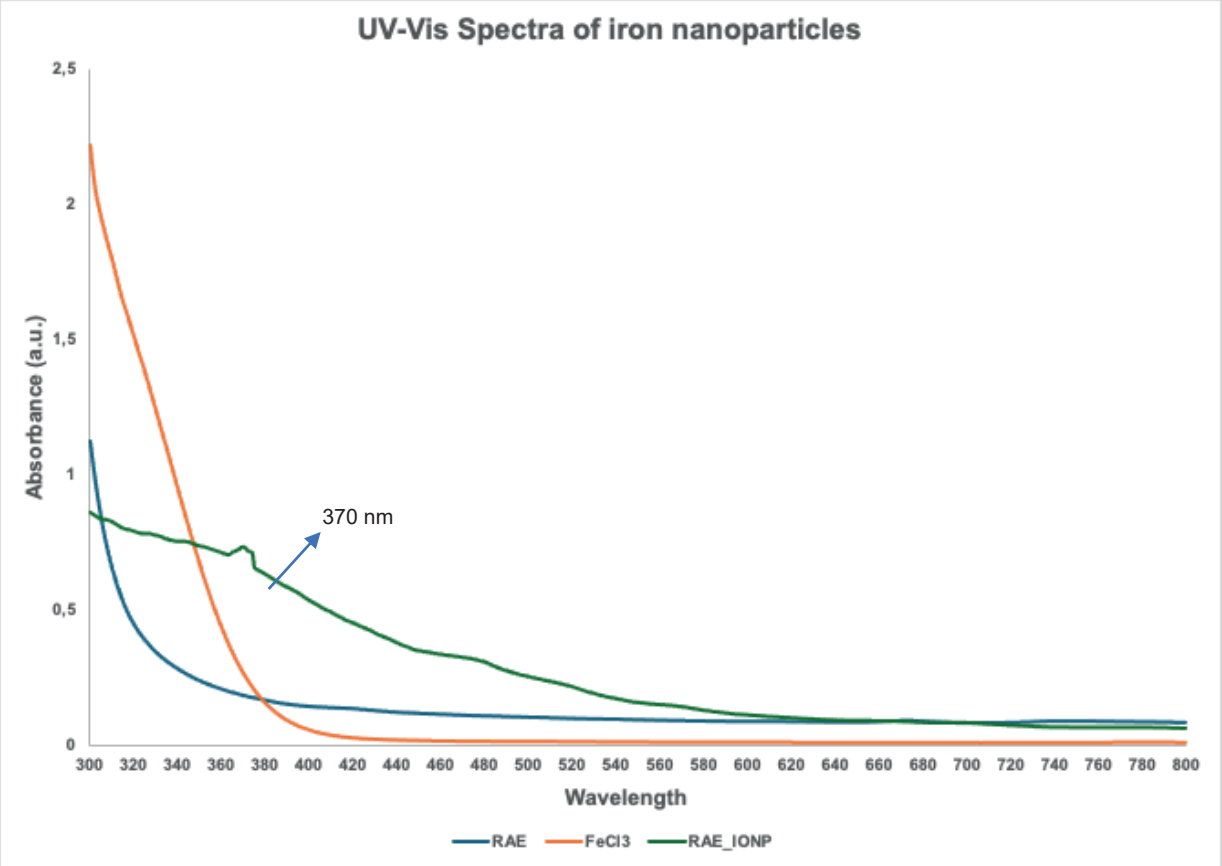


Figure 1. The UV-Vis spectra of *R. acetosella* water extract (RAE), 1 mM $FeCl_3$ solution ($FeCl_3$) and synthesized iron oxide nanoparticles (RAE_IONP).

DISCUSSION

Besides being used to decorate our tables as an ingredient in salads, *R. acetosella* is a known plant in traditional folk medicine due to its curative effects. Having high levels of phytochemicals such as polyphenols, flavonoids, and vitamins locates this plant as a biological source for the green synthesis of nanoparticles. In contrast, there were very limited studies of nanoparticle production using *R. acetosella*. In one of these studies, the water extract of the whole plant was used to synthesize silver nanoparticles. The antimicrobial effect of the produced silver nanoparticles was found to be strong against different pathogens (Aktepe et al., 2022). Another study was conducted to produce selenium nanoparticles using *R. acetosella*. The whole plant was used in the extraction, and the distilled water was selected as the solvent. Synthesized nanoparticles were characterized through different methods. The obtained nanoparticle was determined as spherical and its antimicrobial and anticancer effect was revealed (Baran et al., 2026). Considering all these studies, one can understand that *R. acetosella* has many potential applications in the synthesis of biogenic nanoparticles.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CONCLUSION

The green synthesis of iron oxide nanoparticles using *R. acetosella* water extract was accomplished. Further studies will comprise the characterization of synthesized nanoparticles through SEM, FTIR, and XRD to reveal the physiochemical and biological properties of the nanoparticles.

REFERENCES

Aktepe N, Bütüner H, Baran A, Baran M, Keskin C 2022. Synthesis, characterization and evaluation of antimicrobial activities of silver nanoparticles obtained from *Rumex acetosella* L. (Sorrel) plant. International Journal of Agriculture Environment and Food Sciences, 6(4): 522–529. https://doi.org/10.31015/jaefs.2022.4.4

Altammar KA 2023. A review on nanoparticles: characteristics, synthesis, applications, and challenges. Frontiers in microbiology, 14, 1155622. https://doi.org/10.3389/fmicb.2023.1155622

Baran A, Baran MF, Yıldız R, Eftekhari A, Özkan Aİ, Kesharwani P 2026. A study on the eco-friendly synthesis of selenium nanoparticles using *Rumex acetosella* L. and assessment of their bioactivity. Microchemical Journal, 221, 117015. https://doi.org/10.1016/j.microc.2026.117015

Eker F, Duman H, Akdaşçi E, Bolat E, Sarıtaş S, Karav S, Witkowska AM 2024. A comprehensive review of nanoparticles: from classification to application and toxicity. Molecules, 29(15): 3482. https://doi.org/10.3390/molecules29153482

Franzese J, Ghermandi L. 2014. Early competition between the exotic herb *Rumex acetosella* and two native tussock grasses with different palatability and water stress tolerance. J. Arid Environ. 106: 58–62.

Gunasena MDKM, Galpaya GDCP, Abeygunawardena CJ, Induranga DKA, Priyadarshana HVV, Millavithanachchi SS, Bandara PKGSS, Koswattage KR 2025. Advancements in bio-nanotechnology: green synthesis and emerging applications of bio-nanoparticles. Nanomaterials, 15(7): 528. https://doi.org/10.3390/nano15070528

Joudeh N, Linke D 2022. Nanoparticle classification, physicochemical properties, characterization, and applications: a comprehensive review for biologists. J Nanobiotechnol 20: 262. https://doi.org/10.1186/s12951-022-01477-8

Karadağ M 2024. Phenolic compounds of *Rumex acetosella* L. collected from two different regions of Iğdır province (Türkiye). Journal of Agriculture, 7(2): 253–260. https://doi.org/10.46876/ja.1597526

Malik S, Muhammad K, Waheed Y 2023. Nanotechnology: a revolution in modern industry. Molecules, 28:2, 661. https://doi.org/10.3390/molecules28020661

Ouardy KE, Ahmoum H, Mir Y 2025. Biological synthesis of metallic nanoparticles: latest insights and applications. Pharmaceutical nanotechnology, 13(5): 941–958. https://doi.org/10.2174/0122117385353296241119072148

Raut SS, Sharma A, Yadav R, Kumar S, Shukla A, Singh A, Mishra A 2026. Biological green synthesis of nanoparticles: a sustainable platform for agricultural, environmental, food, and cosmetic applications. Journal of Environmental Chemical Engineering, 14(1): 121102. https://doi.org/10.1016/j.jece.2026.121102

Turkmen FU, Inan E 2025. Investigation of antioxidant activities and phenolic profiles of the methanol extracts of *Rumex acetosella*, *Mentha pulegium*, *Piper cubeba*, and *Elettaria cardamomum*. Plant Biosystems, 159(3): 570–580. https://doi.org/10.1080/11263504.2025.2489988

Vinukonda A, Bolledla N, Jadi RK, Chinthala R, Devadasu VR 2025. Synthesis of nanoparticles using advanced techniques. Next Nanotechnology, 8, 100169. https://doi.org/10.1016/j.nxnano.2025.100169

Yekeen MO, Ibrahim M, Wachira J, Pramanik S 2025. Green synthesis and characterization of iron oxide nanoparticles using *Egeria densa* plant extract. Applied Biosciences, 4(2): 27. https://doi.org/10.3390/applbiosci4020027

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KARYOLOGICAL VARIATIONS AND KARYOTYPE ASYMMETRY IN *MORUS ALBA* (MORACEAE)

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ABSTRACT

The genus *Morus* L. is a genus with high economic value as its leaves are the main food source of silkworms (*Bombyx mori* L.) and it is grown to feed silkworms in many regions of Europe, Asia, America, and Africa. In the genus, there is wide variation in karyotype formulae. The karyotype formula variations are also common in *Morus alba* and in the present study, it is focused on the karyotype asymmetry calculation by the symmetry/asymmetry index (S/A_I) based on the karyotype formula. The different S/A_I values were calculated from 1.00 to 1.71. Despite the differences in S/A_I values, *Morus alba* has only two karyotype types, which are full symmetric and symmetric. As a result, it is possible that the karyological variations observed in *Morus alba* can also be seen in other species of mulberries. The results provide new data on the karyological characteristics of the genus *Morus*.

Keywords: *Morus alba*, karyotype asymmetry, symmetry/asymmetry index

INTRODUCTION

The genus *Morus* L. belongs to the family Moraceae and consists of approximately 24 species and 100 varieties (Ercisli and Orhan, 2007). It is a genus with high economic value as its leaves are the main food source of silkworms (*Bombyx mori* L.) and it is grown to feed silkworms in many regions of Europe, Asia, America, and Africa. In addition, the fact that many species are consumed as fruits and provide raw materials for medicine, fiber, and paper production increases their economic value. Especially, white mulberry (*Morus alba* L.), black mulberry (*Morus nigra* L.), and purple mulberry (*Morus rubra* L.) are the more prominent species (Zhou and Gilbert, 2003; Yang et al., 2010).

In most mulberry species, the diploid chromosome number was $2n = 28$, but polyploidy with $2n = 42$ (triploidy) and $2n = 56$ (tetraploidy) was also seen (Venkatesh 2015, 2020). It was reported that the triploids had been developed by natural or controlled crossbreeding between diploids and tetraploids and were superior to diploids and tetraploids in terms of leaf yield and leaf nutrition (Venkatesh and

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Munirajappa, 2013). In the genus, in addition to variation in ploidy levels, there was also wide variation in karyotype formulae (Venkatesh 2015, 2020; Lahiji, 2019; Mohammadpour et al., 2022). The variations in the karyotype formula were also common in the species *Morus alba*.

In the present study, it is focused on the karyotype asymmetry calculation by the symmetry/asymmetry index (S/A_I) based on the karyotype formula in the *Morus alba*.

MATERIALS AND METHODS

After a detailed literature review, karyological data of *Morus alba* was obtained. The data consists of diploid chromosome numbers ($2n$ = 28 and $2n$ = 42), ploidy levels (diploid and triploid), and karyotype formulae (eight different karyotypes) (Table 1).

Table 1. The karyological data consisting of chromosome number, ploidy level, and karyotype formula of *Morus alba*.

Karyotype number	2*n* (ploidy)	Karyotype formula	References
1	28 (diploid)	22M + 6SM	Venkatesh, 2015
2	28 (diploid)	16M + 12SM	Venkatesh, 2015
3	42 (triploid)	12M + 30SM	Venkatesh, 2015
4	28 (diploid)	28M	Lahiji, 2019; Mohammadpour et al., 2022
5	28 (diploid)	18M + 8SM + 2ST	Lahiji, 2019
6	28 (diploid)	20M + 4SM + 4ST	Lahiji, 2019
7	28 (diploid)	14M + 14SM	Venkatesh, 2020
8	42 (triploid)	22M + 20SM	Venkatesh, 2020

The symmetry/asymmetry indexes based on the karyotype formulae were calculated with the following formula.

$$S/A_I = (1 \times M) + (2 \times SM) + (3 \times ST) + (4 \times T) / 2n \quad (1)$$

In the formula, metacentric, submetacentric, subtelocentric, and telocentric chromosomes are abbreviated as M, SM, ST, and T, respectively. According to the S/A_I value, there are five karyotype types, which are full symmetric ($S/A_I = 1.0$), symmetric ($1.0 < S/A_I \leq 2.0$), between symmetric and asymmetric ($2.0 < S/A_I \leq 3.0$), asymmetric ($3.0 < S/A_I < 4.0$), and full asymmetric ($S/A_I = 4.0$) (Eroğlu, 2015).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The application of the formula to the karyotypes in the Table is presented below. The distribution range of the S/A_I value is given after the calculated value.

Karyotype 1:

$S/A_I = (1 \times 22) + (2 \times 6) / 28 = 1.21$

$1.0 < S/A_I (1.21) \leq 2.0$

Karyotype 2:

$S/A_I = (1 \times 16) + (2 \times 12) / 28 = 1.43$

$1.0 < S/A_I (1.43) \leq 2.0$

Karyotype 3:

$S/A_I = (1 \times 12) + (2 \times 30) / 42 = 1.71$

$1.0 < S/A_I (1.71) \leq 2.0$

Karyotype 4:

$S/A_I = (1 \times 28) / 28 = 1.00$

$S/A_I = 1.0$

Karyotype 5:

$S/A_I = (1 \times 18) + (2 \times 8) + (3 \times 2) / 28 = 1.43$

$1.0 < S/A_I (1.43) \leq 2.0$

Karyotype 6:

$S/A_I = (1 \times 20) + (2 \times 4) + (3 \times 4) / 28 = 1.43$

$1.0 < S/A_I (1.43) \leq 2.0$

Karyotype 7:

$S/A_I = (1 \times 14) + (2 \times 14) / 28 = 1.50$

$1.0 < S/A_I (1.50) \leq 2.0$

Karyotype 8:

$S/A_I = (1 \times 22) + (2 \times 20) / 42 = 1.48$

$1.0 < S/A_I (1.48) \leq 2.0$

RESULTS

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Morus alba exhibited high levels of karyological variation in terms of the parameters used in karyotype analysis. The diploid chromosome numbers were $2n = 28$ with ploidy level of $2x$ and $2n = 42$ with ploidy level of $3x$. In karyotype formulae, there were three different karyotype samples, which are (i) M (only metacentric chromosomes), (ii) M–SM (metacentric and submetacentric chromosomes), and (iii) M–SM–ST (metacentric, submetacentric, and subtelocentric chromosomes) (Table 1).

The variations in karyotype formulae were also reflected in karyotype asymmetry and different S/A_I values were calculated between 1.00 and 1.71. While the lowest S/A_I value was found in karyotype 4, the highest S/A_I value was detected in karyotype 3. Despite the differences in S/A_I values, *Morus alba* has only two karyotype types, which are full symmetric and symmetric (Table 2).

Table 2. The S/A_I values and karyotype types of *Morus alba*.

Karyotype number	S/A_I	Karyotype type
1	1.21	Symmetric
2	1.43	Symmetric
3	1.71	Symmetric
4	1.00	Full symmetric
5	1.43	Symmetric
6	1.43	Symmetric
7	1.50	Symmetric
8	1.48	Symmetric

DISCUSSION

In Table 2, karyotype asymmetry values are quite close (between 1.00 and 1.71) and the karyotype types show symmetrical patterns. Similar results were reported in studies conducted by different karyotype asymmetry parameters. Lahiji (2019) showed that *Morus alba* had symmetric karyotype according to the overall percentage (TF) and the chromosomal asymmetry index (A_1).

Mohammadpour et al. (2022) investigated the karyotype asymmetry by five parameters, which were total form percentage (TF%), coefficient of variation of total chromosome length (CV_{CL}), mean centromeric asymmetry (M_{CA}), degree of karyotype asymmetry (A), Stebbins' classification, and A1-

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A2 indices. They recorded that *Morus alba* had symmetric karyotype consisting entirely of metacentric chromosomes.

Similarly, symmetrical karyotypes of *Morus alba* consisting of metacentric and submetacentric chromosomes were also reported (Venkatesh 2015, 2020).

CONCLUSION

As a result, it is possible that the karyological variations observed in *Morus alba* can also be seen in other species of mulberries. Therefore, it is important to detect karyotype asymmetry variations in other mulberry species as well. The results provide new data on the karyological characteristics of the genus *Morus*.

REFERENCES

Ercisli S, Orhan E 2007. Chemical composition of white (*Morus alba*), red (*Morus rubra*) and black (*Morus nigra*) mulberry fruits. Food Chemistry, 103(4): 1380-1384.

Eroğlu HE 2015. Which chromosomes are subtelocentric or acrocentric? A new karyotype symmetry/asymmetry index. Caryologia, 68(3): 239-245.

Lahiji MK 2019. Cytogenetic analysis of some types of mulberry geneva type (*M. alba*, *M. rubra*) in Iran. Specialty Journal of Agricultural Sciences, 5(1): 8-16.

Mohammadpour S, Karimzadeh G, Ghaffari SM 2022. Karyomorphology, genome size, and variation of antioxidant in twelve berry species from Iran. Caryologia, 75(4): 133-148.

Venkatesh KH 2015. Morpho-criteria and karyotype studies in three mulberry varieties. Chromosome Botany, 10: 145-149.

Venkatesh KH 2020. Studies on chromosome numbers, stomatal frequency and karyotypes in three mulberry genotypes (Moraceae). Journal of Global Biosciences, 9(1): 8114-8122.

Venkatesh KH, Munirajappa 2013. Cytogenetical studies in two tetraploid mulberry varieties (Moraceae). International Society of Chromosome Botany, 8: 63-67.

Yang X, Yang L, Zheng H 2010. Hypolipidemic and antioxidant effects of mulberry (*Morus alba* L.) fruit in hyperlipidaemia rats. Food and Chemical Toxicology, 48(8- 9): 2374-2379.

Zhou ZK, Gilbert MG 2003. Moraceae. In: Wu ZY, Raven PH, Hong DY (eds), Flora of China. St. Louis: Missouri Botanical Garden Press, pp. 22-26.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THYMUS ARGAEUS BOISSIER & BALANSA (LAMIACEAE): INSECTICIDAL ACTIVITY AGAINST *GALLERIA MELLONELLA* (L.) (LEPIDOPTERA:PYRALIDAE)

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ABSTRACT

Chemical and biological substances used as pesticides increase the costs of sustainable control technologies due to the toxic effects on target organisms. Therefore, the use of environmentally friendly biopesticide candidates is of great importance. In this context, the insecticidal activity of the aerial part extract of *Thymus argaeus* Boissier & Balansa (Lamiaceae) on the larval stage of *Galleria mellonella* (L.) (Lepidoptera: Pyralidae) was investigated. *G. mellonella* larvae were sterilized and exposed to different concentrations of extract (25 mg/mL, 20 mg/mL, 15 mg/mL, 10 mg/mL, 5 mg/mL, and 1 mg/mL). Mortality rates and LC_{50} and LC_{99} values were determined for the larvae using this treatment. In addition, to assess oxidative stress, the antioxidant enzyme activities of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and glutathione S-transferase (GST), as well as the activity of acetylcholinesterase (AChE) and malondialdehyde (MDA) levels were determined. In the evaluation of *G. mellonella* larvae, it was determined that mortality rates increased significantly as the extract concentration increased, and the results of the study revealed that the extract exhibited a dose-dependent toxic effect. Biochemical findings showed a decrease in antioxidant enzyme activities and acetylcholinesterase (AChE) activity, while malondialdehyde (MDA) levels increased. When the obtained data are evaluated together, it is seen that the water extract of *Thymus argaeus* causes oxidative stress in *G. mellonella* larvae, and these findings indicate that this effect has significant potential in terms of insect control.

Keywords: Insecticidal activity**,** antioxidant enzymes, *Thymus*, biopesticide

INTRODUCTION

The larger wax moth, *Galleria mellonella* L. (Lepidoptera: Pyralidae), is regarded as one of the most detrimental pests in honeybee colonies and stored combs globally (Ellis et al. 2013). The economic

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

significance of wax moths has led to comprehensive study on their life cycle, biology, behavioral traits, ecology, molecular biology, physiology, and management measures. (Ellis et al. 2013; Kwadha et al. (2017).

Despite being considerable pests in apiculture, existing literature indicates that wax moths are extensively utilized as model organisms, especially in the fields of insect physiology, genomics, proteomics, and other molecular studies (Mikulak et al., 2018; Wojda et al., 2020; Vogel et al., 2011). The use of pesticides worldwide presents huge environmental and economic challenges due to their heavy reliance on these chemicals and how they are being implemented on an extensive level across the globe. Some of the negative effects of synthetic pesticides, especially when concerning nontarget species, their longevity in the environment, and the limited ability for them to be broken down in a biodegradability manner present serious problems for the protection of the environment. Therefore, we must develop sustainable, environmentally friendly, and economically viable alternatives to control pests (Ngegba et al., 2022). As awareness grows regarding environmental stewardship, the demand for pesticide alternatives made from plants has substantially grown. Pesticides from plants are made from plant products that kill many insects that damage crops; they can break down rapidly in the environment and can be found at a reasonable cost; they are also readily available and pose little risk to beneficial organisms such as humans (Ngegba et al., 2022).

The unique modes of action of many different plant species against pests and diseases are attributed to the phytochemical composition of these plants, making plant-based pesticides a versatile & sustainable alternative to synthetic pesticides (Ngegba et al., 2022). The composition and biological activity of plant-derived materials/ products depend on several plant-specific variables such as the parts of the plant used, the method of extraction, the age of the plant and the genotype of the plant (Angioni et al., 2006). Several documents and studies have indicated the potential of using plant-derived or vegetable products as treatments for a variety of harmful insects (Ayvaz et al., 2009; Bachrouch et al., 2010; Ercan et al., 2018; Elif et al., 2023). The *Thymus* genus, which belongs to the family Lamiaceae, is an aromatic and medicinal plant genus that is grown throughout the world, especially in the Mediterranean region (El Yaagoubi et al., 2021). The *Thymus* genus has over 200 species, the majority of which have adapted to survive in the Mediterranean Environment with large populations found in both natural and agricultural areas (El Yaagoubi et al., 2021). The essential oils from *Thymus* species are rich in phytochemical compounds such as flavonoids, phenylpropanoids, and terpenes that show a variety of biological properties including antibacterial, antifungal, antioxidant and insecticide. (El Yaagoubi et al., 2021).

The genus has been recognized as "used for food seasoning as well as for use in traditional medicine; today, they have become a popular topic in recent studies on pesticides and pharmaceutical products, due to the biological activities associated with their essential oils" (El Yaagoubi et al., 2021; Etri and Plushar, 2024). In Turkey, thymus species are abundant but have varying morphological

characteristics as well as differences in phytochemical and ecological characteristics (Yıldız et al., 2004; Kutukalan, 2019).

The present study examined both the chemical composition of *Thymus argaeus* extract and its insecticidal effects on *Galleria mellonella* (honeybee moth). Oxidative stress is a known biochemical indicator representing a state of oxidative imbalance, which is caused by chemical pressure (i.e., excessive generation of reactive oxygen species or ROS) and the inability of cells to complete a sufficient number of antioxidants. The concentration of malondialdehyde (MDA) and the activity of free radical scavenging enzymes (e.g., superoxide dismutase [SOD], catalase [CAT], glutathione-S-transferase [GST] and glutathione peroxidase [GPx]) are some of the most frequently used indicators of oxidative damage and provide insight into how changes in the activity of these systems affect the oxidative stress experienced by the cell (Baş & Kalender, 2011).

Due to synthetic pesticide being persistent to the environment and having adverse effects on non-target forms of life; there is a need for developing alternate/safer methods of control. Therefore, the study conducted an evaluation of the potential for using *Thymus argaeus* extract as an insecticide against *Galleria mellonella.* Although there have been many studies reported in the literature regarding the insecticidal properties of several species of *Thymus*, not many studies demonstrate how *Thymus argaeus* Aqueous Extract (TAAE) would affect *Galleria mellonella.* The present study is intended to enhance the limited knowledge regarding whether the plant's Aqueous Extract could serve as a potential biopesticide candidate.

MATERIALS AND METHODS

The *Thymus argaeus* used in the study was collected from Mount Erciyes in the Kayseri region of Turkiye. The chemicals necessary for the research were purchased from the Sigma-Aldrich company. After the above-ground parts of the collected plant samples were cleaned, they were dried according to Davis (1972)'s herbarium drying procedures.

The extraction process was carried out in two stages, resulting in an aqueous extract. In the first stage, a 4 g dried plant sample was extracted with 40 mL of distilled water in the temperature range of 80–105 °C. The plant residue remaining after the first extraction was subjected to a second extraction using 60 mL of distilled water at 100–130 °C. The obtained aqueous extracts were filtered after being cooled to 25 °C, and the two fractions were combined (Mai et al., 1990).

Insect farming, extract application, and tissue collection

Different concentrations of extract (25 mg/mL, 20 mg/mL, 15 mg/mL, 10 mg/mL, 5 mg/mL, and 1 mg/mL) were applied to *Galleria mellonella* larvae. After the sterilization of the larvae, the extract was injected into the left hind leg using a microsyringe (Alvandial et al., 2016). 24 hours after the application, the larvae were cooled, and then the samples were divided into small pieces and placed into Eppendorf tubes. A pH 7.4 homogenization buffer was added to the samples (Büyükgüzel &

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Kalender, 2009), and the samples were homogenized and centrifuged. The obtained supernatants were used in biochemical analyzes.

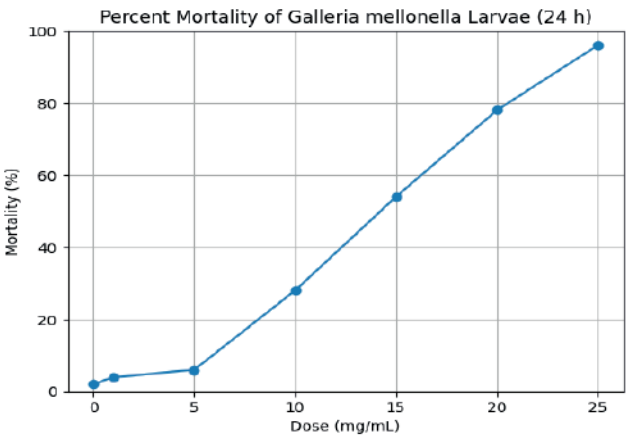
In the supernatants, CAT, SOD, GPx, GST, and AChE enzyme activities, as well as MDA levels, were determined using a UV–VIS spectrophotometer. MDA level was determined according to the Ohkawa et al.'s (1979) method; SOD activity was determined according to the Marklund and Marklund's (1974) method; CAT activity was determined according to the Aebi's (1984) method; GPx activity was determined according to the Paglia and Valentine's (1987) method; GST activity was determined at 340 nm according to the Habig et al.'s (1974) method; and AChE activity was determined at 412 nm according to the Ellman et al.'s (1961) method.

Data Analysis

The obtained experimental data were statistically evaluated. The application means were subjected to ANOVA, Tukey's multiple comparison test, and Probit analyzes to determine inter-group differences and calculate LC_{50} and LC_{99} values. All statistical analyzes were conducted using the SPSS software package (SPSS Statistics Program, Version 20.0, SPSS Inc., Chicago, IL, USA). The data are presented as mean ± standard deviation, and a $p < 0.05$ value is considered statistically significant (Apaydın et al., 2015; Abbott, 1925).

RESULTS

Mortality data, lethal dose values, and biochemical parameters related to oxidative stress and neurotoxicity were measured after *Galleria mellonella* larvae exposure to *Thymus argaeus* water extract for 24 hours. It was observed that larval mortality increased with increasing extract concentration.With respect to the treated groups at concentrations of 1 and 5 mg/mL, the number of larvae that died in the treated groups was not significantly different from those in the control group. However, at concentrations of 10 mg/mL and greater, treated larvae experienced much higher levels of mortality, approximately 96%, at 25 mg/mL. The dose-mortality relationship of the extract used is clearly shown in the given figure (Figure 1).



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Figure 1: % mortality values of *Galleria mellonella* larvae

Probit analysis has revealed the dose-dependent toxic effect of the extract. The LC_{50} and LC_{99} values were determined as 12.4 mg/mL (95% CI: 10.8–14.1) and 26.9 mg/mL (95% CI: 23.5–31.2), respectively. The probit regression model (Table 1) showed good fit to the mortality data, supported by a non-significant chi-square value ($p > 0.05$) and a heterogeneity factor close to one. The slope value of 2.31 ± 0.28 indicates that the dose-response relationship is consistent and reliable (Table 2).

Table 1. Probit analysis parameters for the insecticidal activity of *Thymus argaeus* water extract against *Galleria mellonella* larvae (24 h)

Parameter	**Value (mg/mL)**	**95% Confidence Interval**
LC_{10}	6.2	4.9 – 7.6
LC_{20}	8.4	7.1 – 9.8
LC_{30}	10.2	8.9 – 11.7
LC_{50}	**12.4**	**10.8 – 14.1**
LC_{70}	15.8	13.9 – 18.0
LC_{90}	22.3	19.8 – 25.9
LC_{99}	**26.9**	**23.5 – 31.2**

Table 2. Probit regression statistics

Parameter	**Value**
Slope ± SE	2.31 ± 0.28
Intercept	−5.74
Chi-square (χ^2)	3.12
Degrees of freedom (df)	4
p-value	0.54
Heterogeneity factor	1.08
Correlation coefficient (r)	0.97

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Biochemical analyzes have shown that the activities of antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), and glutathione S-transferase (GST), as well as acetylcholinesterase (AChE) activity, did not show a significant change compared to the control group at concentrations of 1 and 5 mg/mL ($p > 0.05$). In contrast, a significant and gradual decrease in the activities of these enzymes was observed in the concentration range of 10–25 mg/mL ($p < 0.05$). The most significant decreases were observed in the highest dose groups, and these findings indicate that the extract exerts a strong inhibitory effect on the antioxidant defense system and AChE activity.

Unlike enzyme activities, malondialdehyde (MDA) levels showed a significant dose-dependent increase. In the 1 and 5 mg/mL application groups, MDA levels were found to be similar to the control group, while exposure to higher concentrations caused a significant increase in lipid peroxidation. The highest MDA levels were observed in the 25 mg/mL group ($p < 0.05$) (Table 3).

Table 3. Effects of *Thymus argaeus* water extract on antioxidant enzymes, AChE activity and MDA levels in *Galleria mellonella* larvae (24 h)

Group	SOD (U/mg protein)	CAT (µmol/mg protein)	GPx (U/mg protein)	GST (nmol/mg protein)	AChE (mU/mg protein)	MDA (nmol/mg protein)
Control	22.0 ± 1.8	48.4 ± 3.2	9.8 ± 0.5	62.2 ± 4.2	18.3 ± 1.3	2.1 ± 0.2
1 mg/mL	21.8 ± 2.0	47.9 ± 3.1	9.6 ± 0.6	61.8 ± 4.0	18.1 ± 1.2	2.2 ± 0.2
5 mg/mL	21.5 ± 1.8	47.2 ± 3.0	9.4 ± 0.6	61.1 ± 3.9	17.9 ± 1.2	2.3 ± 0.2
10 mg/mL	17.3 ± 1.5*	39.6 ± 2.8*	7.6 ± 0.5*	52.4 ± 3.6*	14.5 ± 1.0*	3.1 ± 0.3*
15 mg/mL	14.2 ± 1.3*	33.4 ± 2.4*	6.0 ± 0.4*	45.1 ± 3.2*	12.3 ± 0.9*	3.8 ± 0.3*
20 mg/mL	11.5 ± 1.1*	27.1 ± 2.0*	4.8 ± 0.2*	37.6 ± 2.8*	10.1 ± 0.8*	4.8 ± 0.4*
25 mg/mL	9.3 ± 0.8*	21.8 ± 1.7*	3.8 ± 0.3*	30.9 ± 2.4*	8.1 ± 0.7*	5.6 ± 0.4*

** Statistically significant difference compared to the control group ($p < 0.05$). Values are expressed as mean ± standard deviation (SD).*

Overall, the increase in observed mortality rates and the determined lethal concentration values have shown consistency with the biochemical changes detected in antioxidant enzyme activities, AChE activity, and MDA levels. These findings indicate that the water extract of *Thymus argaeus* induces concentration-dependent toxicity in *Galleria mellonella* larvae and that this effect is likely manifested thru the induction of oxidative stress and the impairment of neurophysiological functions.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DISCUSSION

Recently conducted research evaluated the insecticidal properties of *Thymus argaeus* aqueous extract on *Galleria mellonella* larvae using both mortality and biochemistry as dependent variables. Results demonstrate a dose-dependent relationship between concentration of extract and toxicity; toxicity increases as concentration of extract increases in a predictable manner. Mortality increased dramatically beginning at concentrations of 10mg/mL or greater, and an LC_{50} value of 12.4mg/mL indicates that *T. argaeus* has high potential for insecticidal activity. The findings of this study correlate with several studies in the literature that suggest that *Galleria mellonella* is a sensitive model organism for use in toxicity and stress biology studies (Dubovskiy et al., 2008; BüyükGüzel & Kalender, 2009).

The consistent relationship between increasing larval death with increasing concentration and the moderate LC_{50} value suggest that this extract has a systematic and significant biological toxicity. Other researchers have found that mortality from exposure to toxic agents by *Galleria mellonella* tends to follow a classic dose-response relationship, with increased mortality associated with changes to oxidative stress parameters (Dubovskiy et al., 2008; Büyükgüzel and Kalender, 2009; Tunçsoy, 2021). These authors also found that there is a strong correlation between increased oxidative stress due to increased toxicity for *Galleria mellonella* and the suppression of antioxidant enzyme levels (SOD, CAT, GPx and GST) and levels of MDA (Dubovskiy et al., 2008). The simultaneous suppression of the antioxidant defense system with increasing larval mortality in this study indicates that the toxic effect of the extract extends beyond lethality and includes a physiological mechanism due to a disruption of cellular redox homeostasis. Additional studies using nanoparticles and other toxic chemical compounds have also shown parallel increases in oxidative stress parameters and mortality rates in *Galleria mellonella* (Tunçsoy, 2021; Büyükgüzel et al., 2010).

The significant decrease observed in antioxidant enzyme activities (SOD, CAT, GPx, GST) along with the increase in MDA levels indicates that the extract creates strong oxidative stress in larval tissues. In *Galleria mellonella*, an increase in lipid peroxidation and an imbalance of antioxidant enzymes have been similarly reported under bacterial infection, chemical agents, or environmental stress conditions (Dubovskiy et al., 2008; Büyükgüzel et al., 2010). Antioxidant enzymes form the first line of defense in the detoxification of reactive oxygen species, and the suppression of this system triggers lipid peroxidation in the cell membrane (Halliwell & Gutteridge, 2015). An increase in MDA levels is an indicator of oxidative degradation and is considered a reliable biomarker of oxidative damage (Del Rio et al., 2005). Similar increases in MDA levels have been reported in the *Galleria mellonella* model following exposure to various toxic agents (Büyükgüzel & Kalender, 2009). These parallel supports that the aqueous extract of *Thymus argaeus* causes cellular damage by disrupting redox homeostasis. The decrease in GST activity indicates a reduced capacity of the larvae to neutralize toxic compounds. Glutathione S-transferase (GST) enzymes bind reactive oxidative byproducts and lipid peroxidation derivatives formed in the cell with glutathione, making them more water-soluble and less harmful. The

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ISBN: 978-9952-610-30-7

weakening of this conjugation mechanism leads to the accumulation of toxic intermediates within the cell and an increase in oxidative damage (Enayati et al., 2005; Büyükgüzel et al., 2010).

A marked decline in AChE activity shows that the extract is acting as a source of metabolic pressure and neurotoxic damage. Inhibition of AChE can result in excess acetylcholine in the synaptic cleft (space between two neurons), causing excessive stimulation of the nervous system and impaired coordination of the muscles in the body (Colovic et al., 2013). In addition, plant-derived volatile oils have been shown to cause disruption of neurophysiological balance due to activation of octopamine receptors, which are specific to the insect's neurotransmitter system; thus, demonstrating that other forms of neurotoxic activity also exist within the essential oil group (Kostyukovsky et al., 2002). Essential oils from various species have also been found to have insecticidal properties against Lepidoptera and Coleoptera, and evidence exists that the insecticidal effects of essential oils are due to their actions upon the nervous system (Polatoğlu et al., 2016; Sümer Ercan et al., 2013).

Increased mortality, decreased antioxidant enzyme activity, increased MDA, and decreased activity of AChE activity indicate that the extract has a multi-targeted mode of action. Such a mode of action associated with botanical insecticides indicates a reduced potential for the development of resistance compared to a single-target mode of action associated with synthetic insecticides (Regnault-Roger et al., 2012; Pavela, 2015).

According to the present study, when injected with the aqueous extract of *Thymus argaeus*, the *Galleria mellonella* larvae will die due to a concentration dependent toxicity associated with increased oxidative stress and cholinergic disruption; thus the lactate dehydrogenase (LDH) assay, glutathione oxidase (GDH) assay, antioxidant enzyme assays and malondialdehyde (MDA) activity will all show elevated values in relation to the increasing concentration of *T. argaeus.* The increasing elevation of the LDH activity level supports the findings of the increased oxidation, as shown by the LEDG and MDA activities.

The information above about the *Galleria mellonella* is all cell based, making it a perfect model organism to study the mechanisms behind the phytotoxicity of the extracts studied. Further studies are needed to examine the production of reactive oxygen species (ROS), changes in gene expression, and intracellular signaling pathways in order to better understand the phytotoxic effects of *T. argaeus.*

CONCLUSION

This study unequivocally illustrates that the aqueous extract of *Thymus argaeus* has a potent and concentration-dependent insecticidal activity on *Galleria mellonella* larvae. The rising mortality rates, the assessment of the LC_{50} value, and concurrent biochemical disruptions suggest that the extract possesses both lethal effects and a multi-faceted toxicity profile by impairing cellular redox equilibrium and influencing cholinergic nerve transmission. The suppression of the antioxidant defense system and the increase in lipid peroxidation highlight the significant impact of oxidative

stress, while AChE inhibition indicates a disturbance at the neurophysiological level. The comprehensive impact profile indicates that *Thymus argaeus* may serve as a viable choice for the formulation of natural pesticides. The identification of active components and the execution of confirmatory investigations at the molecular level are essential for converting this promise into practical implementation.

REFERENCES

Abbott W (1925) A method for computing the effectiveness of an insecticide. J Econ Entomol 18:265–267

Aebi H (1984) Catalase in vitro. Methods Enzymol 105:121–126

Alvandial A, Jawadi MH, Altıntaş ZN, Yıldız N, Karaman M (2016) *Candida albicans*'ın salgısal asit proteinaz etkinliğinin araştırılmasında in vivo model olarak *Galleria mellonella* larvanın kullanılması. J Turk Soc Microb 46(2):69–75

Angioni A, Barra A, Coronco V, Dessi S, Cabras P (2006). Chemical composition, seasonal variability and antifungal activity of Lavandula stoechas L. ssp. stoechas essential oils from stem/leaves and flowers. Journal of Agricultural and Food Chemistry 54: 4364-4370.

Apaydin F.G., Kalender S, Bas H, Demir F, Kalender Y (2015) Lead nitrate induced testicular toxicity in diabetic and non-diabetic rats: protective role of sodium selenite. Braz Arch Biol Technol 58(1):68–74

Ayvaz A, Karaborklu S, Sagdıc O (2009). Fumigant toxicity of five essential oils against the eggs of *Ephestia kuehniella* Zeller and Plodia interpunctella (Hübner) (Lepidoptera: Pyralidae). Asian Journal of Chemistry 21:596-604.

Bachrouch O, Jemaa J M B, Chaieb I, Talou T, Marzouk B (2010). Insecticidal activity of *Pistacia lentiscus* essential oil on *Tribolium castaneum* (Coleoptera: Tenebrionidae) as alternative to chemical control in storage. Tunisian Journal of Plant Protection 5: 63–70.

Baş H. & Y. Kalender, 2011. Chlorpyrifos induced cardiotoxicity in rats and the protective role of quercetin and catechin. Gazi University Journal of Science, 24 (3): 387-395.

Büyükgüzel, E., & Kalender, Y. (2009). Exposure to streptomycin alters oxidative and antioxidative balance in larval midgut tissues of *Galleria mellonella*. Pesticide Biochemistry and Physiology, 94, 112–118.

Büyükgüzel, E., Hyršl, P., & Büyükgüzel, K. (2010). Eicosanoids mediate hemolymph oxidative and antioxidative response in larvae of *Galleria mellonella* L. Comparative Biochemistry and Physiology Part A: Molecular & Integrative Physiology, 156(2), 176-183.

Colovic, M. B., Krstic, D. Z., Lazarevic-Pasti, T. D., Bondzic, A. M., & Vasic, V. M. (2013). Acetylcholinesterase inhibitors: Pharmacology and toxicology. Current Neuropharmacology, 11(3), 315–335.

Davis, P. H., 1972. Flora of Turkey and the East Aegean Islands. Edinburgh: Edinburgh University Press, 4: 382-387.

Dubovskiy, I. M., Martemyanov, V. V., Vorontsova, Y. L., Rantala, M. J., Gryzanova, E. V., & Glupov, V. V. (2008). Effect of bacterial infection on antioxidant activity and lipid peroxidation in the midgut of *Galleria mellonella* larvae. Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology, 148, 1–5.

El Yaagoubi, M., Mechqoq, H., El Hamdaoui, A., Mukku, V. J. R., El Mousadik, A., & Msanda, F. (2021). A review on Moroccan Thymus species: Traditional uses, essential oils chemical composition and biological effects. Journal of Ethnopharmacology, 278, 114205. https://doi.org/10.1016/j.jep.2021.114205

Ellis, J. D., Graham, J. R., & Mortensen, A. (2013). Standard methods for wax moth research. Journal of Insect Science, 13, 1–17.

Ellman GL, Courtney KD, JrV A, Featherstone RM (1961) A new and rapid colorimetric determination of acetylcholinesterase activity, Biochem Pharmacol 7:88–95

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Enayati, A. A., Ranson, H., & Hemingway, J. (2005). Insect glutathione transferases and insecticide resistance. Insect molecular biology, 14(1), 3-8.

Ercan, F., Baş, H., Koc, M., Pandir, D., & Öztemiz, S. (2013). Insecticidal activity of essential oil of *Prangos ferulacea* (Umbelliferae) against *Ephestia kuehniella* (Lepidoptera: Pyralidae) and *Trichogramma embryophagum* (Hymenoptera: Trichogrammatidae). Turkish Journal of Agriculture and Forestry, 37(6), 719-725.

Ercan F, Bas H, Ercan N, Vural C, Özcan S (2018). Fumigant Toxicitiy of Essential Oils from *Thymus argaeus* Boissier & Balansa and Thymus sipyleus Boissier(Lamiaceae) Againts *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae). International Journal of Scientific and Technological Research 4(3), 54-60.

Etri, K., & Pluhár, Z. (2024). Exploring chemical variability in the essential oils of the Thymus genus. Plants, 13(10), 1375. https://doi.org/10.3390/plants13101375

Habig WH, Pabst MJ, Jakoby WB (1974) Glutathione-S-transferases: the first enzymatic step in mercapturic acid formation. J Biochem 249:7130–7139

Halliwell, B., & Gutteridge, J. M. (2015). Free radicals in biology and medicine. Oxford university press.

Kostyukovsky, M., Rafaeli, A., Gileadi, C., Demchenko, N., & Shaaya, E. (2002). Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. *Pest Management Science: formerly Pesticide Science*, *58*(11), 1101-1106.

Kütükalan, D. (2019). A micromorphological study on the genus *Thymus* (Lamiaceae) in Turkey (Master's thesis, Middle East Technical University).

Kwadha, C. A., Ong'amo, G. O., Ndegwa, P. N., Raina, S. K., & Fombong, A. T. (2017). The biology and control of the greater wax moth, *Galleria mellonella*. International Journal of Tropical Insect Science, 37(1), 61–74.

Mai J., Chamber LJ., Mcdonald RE., Process for inhibiting lipid oxidation in food and composition thereby. United State Patents; 1990. pp. 681, 925.

Marklund S, Marklund G (1974) Involvement of the superoxide anion radical in the autoxidation of pyrogallol and a convenient assay for superoxide dismutase. Eur J Biochem 47:469–474

Mikulak, E., Gliniewicz, A., Przygodzka, M., & Solecka, J. (2018). *Galleria mellonella* L. as model organism used in biomedical and other studies. education, 1(2).

Ngegba, P. M., Cui, G., Khalid, M. Z., & Zhong, G. (2022). Use of botanical pesticides in agriculture as an alternative to synthetic pesticides. Agriculture, 12(5), 600. https://doi.org/10.3390/agriculture12050600

Ohkawa H, Ohishi N, Yagi K (1979) Assay for lipid peroxides in animal tissues by thiobarbituric acid reaction. Anal Biochem 95:351–358

Paglia DE, Valentine WN (1987) Studies on the quantative and qualita tive characterization of glutathione peroxidase. J Lab Clin Med 70:158–165

Pavela, R. (2015). Essential oils for the development of eco-friendly mosquito larvicides: a review. Industrial crops and products, 76, 174-187.

Polatoğlu, K., Karakoç, Ö. C., Yücel, Y. Y., Gücel, S., Demirci, B., Başer, K. H. C., & Demirci, F. (2016). Insecticidal activity of edible *Crithmum maritimum* L. essential oil against Coleopteran and Lepidopteran insects. Industrial Crops and Products, 89, 383-389.

Regnault-Roger, C. (2013). Essential oils in insect control. In natural products (pp. 4087-4107). Springer, Berlin, Heidelberg.

Torun, E. Ö., Koçak, ME, Kayra, B., Ercan, F. ve Yalçın, S. (2023). *Galleria mellanolla*'nın enzimatik savunma sistemi elemanları, glutatyon peroksidaz (GPx) ve glutatyon-S-transferaz (GST) enzimleri üzerine oktadekanoik asit, oleik asit ve n-hekzadekanoik asitin etkilerinin in silico tanımı. Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Dergisi , 3 (2), 190-199.

Tunçsoy, B. (2021). Evaluation of the effects of copper nanoparticles on oxidative stress in the model organism *Galleria mellonella*. Journal of Anatolian Environmental and Animal Sciences, 6(2), 278–284.

Vogel, H., Altincicek, B., Glöckner, G., & Vilcinskas, A. (2011). A comprehensive transcriptome and immune-gene repertoire of the lepidopteran model host *Galleria mellonella*. BMC Genomics, 12, 308.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Wojda, I., Staniec, B., Sułek, M., & Kordaczuk, J. (2020). The greater wax moth *Galleria mellonella*: biology and use in immune studies. *Pathogens and disease*, *78*(9), ftaa057.

Yıldız, B., Adıgüzel, N., Tümen, G., Bahçecioğlu, Z., Akyalçın, H., & Demirkuş, N. (2004). Revision of *Thymus* L. (Lamiaceae) species growing in Turkey and palynological and chemical studies on these species.

ASSESSMENT OF *MEDICAGO SATIVA* L. (FABACEAE) AS A NATURAL ANTIBACTERIAL AGENT

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ABSTRACT

Medicago sativa, a member of the Fabaceae family, is a plant which is perennial species belonging to Asia. *M. sativa* is utilized in medicinal fields, livestock management, and food production. In addition to serving as animal feed, it is notably utilized as a food ingredient in the USA, Russia, China, and North Africa because of its bioactive ingredients and elevated vitamin content. It is favoured due to its content of enzymes, including pectinase and amylase, which enhance digestion. According to the literature, phytochemical analysis of *M. sativa* shows the presence of phenolic compounds such as flavonoids, alkaloids, vitamins, saponins, and triterpenes. These characteristics facilitate its application in the medical domain, making it a recognized therapeutic plant. The medicinal benefits of *M. sativa* include activities that are antioxidant, anti-inflammatory, antidiabetic, antifungal, antibacterial, anticoagulant, and anticancer. The scope of our research encompasses that water, ethanol, and methanol extracts were prepared from naturally obtained *M. sativa*. The antibacterial efficacy of the extracts against *Staphylococcus aureus* and *Escherichia coli* was assessed using the disk diffusion method. The findings indicated that *M. sativa* functions as a natural antibacterial agent.

Keywords: *Medicago sativa,* Extraction, Antibacterial effect, Disc diffusion.

INTRODUCTION

Medicago sativa, also known as alfalfa, is a perennial forage plant belonging to the Fabaceae family. Originating in Asia, alfalfa production has remained at high levels globally throughout history due to its high nutritional content and excellent adaptability to diverse climatic conditions. Alfalfa plant parts include roots, rhizomes, stems, petioles, leaves, and flowers (Uslu & Kaya, 2021). The flower parts

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

have a various colour, the most common being purple, variegated, yellow, cream, and white (Figure 1).



Figure 1. Image of *Medicago sativa* L. (Uslu & Kaya, 2021).

The scientific classification of *Medicago sativa* is as follows (Heywood and Ball, 1968):

Kingdom: Plantae

Division: Magnoliophyta;

Class: Magnoliopsida;

Order: Fabales;

Family: Fabaceae;

Subfamily: Faboideae;

Tribe: Trifolieae;

Genus: *Medicago*;

Species: *sativa*;

Binomial name: *M. sativa* Linn.

M. sativa has strong roots that can penetrate up to 6 meters deep into the soil (Bora & Sharma, 2011). Thanks to its extremely long roots, *M. sativa* can utilize water and nutrients found deep within the soil and transport these substances to the upper layers of it. In this way, it helps to make the soil more fertile for subsequent crops (Uslu & Kaya, 2021).

Due to its high nutritional value and vitamin content, it can be used as animal feed. This feed can be used as green fodder in the spring months, and in dried form in the winter months (Uslu & Kaya, 2021). Furthermore, owing to its high vitamin and bioactive component content, it is used in food products from China to America and from Russia to North Africa (Chandra et al., 2023).

Due to its diverse biological activities, *M. sativa* holds a significant place in pharmacology, and its medicinal use is quite widespread today. The phytochemicals found in *M. sativa* include terpenes, alkaloids, carotenoids, amino acids, flavonoids, minerals, phenolic compounds, phytosterols, and

saponins (Bora & Sharma, 2011). Scientific studies have shown that, it exhibits antioxidants (Sadeghi et al., 2016), anti-inflammatory (Hong et al., 2009), antidiabetic (Farsani et al., 2016), antifungal (Sadowska et al., 2014), antibacterial (Chegini et al., 2018), and anticancer (Gatouillat et al., 2015) properties. In addition, it can be used medically to treat various disease conditions such as respiratory diseases like asthma and cough, gastrointestinal diseases like stomach ulcers, kidney disorders, as diuretic, to increase peristaltic bowel movements, and to promote wound healing (Chaudhary et al., 2020).

This study aimed to determine the antibacterial activity of *M. sativa*, a plant grown in Türkiye and possessing valuable phytochemical content. Therefore, water, ethanol, and methanol extracts of *M. sativa* were prepared, and their antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* was determined.

MATERIALS AND METHODS

Obtaining and Preparing Extract of *Medicago sativa*

Medicago sativa (Fabaceae) was collected from Türkiye (2022). All plant sample was cleaned and dried according to the Davis herbarium techniques (Davis, 1972). Dried plant sample was grounded and 15 gr sample weighed. 150 ml of each solvent (distilled water, methanol, and ethanol) was added to the ground plant sample and stored in sealed glass jars for 2 days. At the end of incubation, the samples were filtered and the solvents evaporated.

Antibacterial Activity of *Medicago sativa*

E. coli and *S. aureus* strains were cultured on Tryptic Soy Broth (TSB) medium for the experiment, followed by incubation at 37°C for 24 hours. After incubation, these strains were inoculated onto sheep blood agar and incubated at 37 °C for 24 hours. The bacterial concentration was set at 0.5 McFarland (10^8 CFU/mL). Then, the bacterial culture was spread on Luria Bertani (LB) agar. At the same time, after distilled water was added to the prepared extracts, the extracts were soaked onto empty sterile discs with a diameter of 6 mm that did not contain antibiotics and left to dry under aseptic conditions. The prepared discs were placed evenly spaced on LB agar in a petri dish. Amoxicillin (25 µg), Tetracycline (30 µg) and Streptomycin (10 µg) were used for positive control and distilled water were used for negative control. The inhibition zone of the extracts was measured along with the diameters of the discs (6mm) after incubation. Each experiment was repeated three times.

RESULTS

The effect of *M. sativa* L. on *E. coli* is presented in Table 1, while its effect on *S. aureus* is presented in Table 2. Considering the results, the inhibition zones of extracts prepared from *M. sativa* on *E. coli* were measured as 9.2 mm for methanol, 8.6 mm for ethanol, and 7.2 mm for distilled water.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Table 1. Antibacterial activity of *Medicago sativa* extracts against *E. coli* (disk diffusion method)

Treatment	**Inhibition zone (mm)**
Control (distilled water)	6.0 ± 0.0
Water extract	7.2 ± 0.8
Ethanol extract	8.6 ± 1.1
Methanol extract	9.2 ± 1.3
Amoxicillin	14.1 ± 1.5
Ampicillin	10.6 ± 1.4
Tetracycline	23.4 ± 1.6
Streptomycin	12.1 ± 1.5

All inhibition zone data were measured. Inhibition zone diameters are expressed as mean ± SD (mm).

The inhibition zones of *M. sativa* extracts *on S. aureus* were measured as 11.9 mm for methanol, 10.4 mm for ethanol, and 8.2 mm for distilled water.

Table 2. Antibacterial activity of *Medicago sativa* extracts against *S. aureus* (disk diffusion method)

Treatment	**Inhibition zone (mm)**
Control (distilled water)	6.0 ± 0.0
Water extract	8.2 ± 0.9
Ethanol extract	10.4 ± 1.2
Methanol extract	11.9 ± 1.4
Amoxicillin	18.6 ± 1.7
Ampicillin	17.3 ± 1.5
Tetracycline	15.1 ± 1.8
Streptomycin	9.4 ± 1.6

All inhibition zone data were measured. Inhibition zone diameters are expressed as mean ± SD (mm).

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The results obtained showed that the methanol extract of *M. sativa* was more effective against *E. coli* (9.2 mm) and *S. aureus* (11.9 mm) than the water and ethanol extracts.

DISCUSSION

Sepsis is among the serious health problems that threaten human life. Therefore, it is an important commodity globally. Analyses have revealed that sepsis is the most common cause of hospital deaths even in the United States. It is also known that the annual cost of this condition exceeds $24 billion (Liu et al., 2014; Rudd et al., 2020). According to the World Health Organization, it is estimated that approximately 11 million deaths worldwide each year are due to sepsis (Rudd et al., 2020). The indiscriminate use of antibiotics not only leads to the emergence of pathogens that develop multi-drug resistance but also complicates the fight against sepsis. Therefore, the search for new antibiotics continues today.

People have used plants as natural remedies since ancient times. Therefore, while medicinal plant cultivation is practiced today, numerous studies are being conducted to observe the effects of the secondary metabolites contained in plants found in nature. Studies conducted worldwide show that these metabolites can be used in traditional medicine not only for the treatment of various diseases but also for the treatment of infections. Therefore, it is necessary to shed light on the power of plants to fight infection agents.

Alfalfa (*Medicago sativa* L.) is commonly known as the ‘queen of forages’. The word “alfalfa” is derived from the Arabic word ‘Al-Fasfasa’. This term means ‘father of all plants’ (Lacefield et al., 1979; Zhou et al., 2024). Beyond its use as feed, the plant is known as a therapeutic agent for treating various diseases. Studies assessing its antimicrobial activity have gained significant prominence in recent times. Some of the studies are presented below.

Chegini and colleagues (2018) prepared an extract from *M. sativa* roots using the maceration method and demonstrated the extract's antibacterial properties against *Streptococcus pneumoniae, Haemophilus influenzae, Moraxella catarrhalis*, and *Staphylococcus aureus* bacteria. The findings of the study indicated that the extract was more effective against *Moraxella catarrhalis* than against other bacterial species. Furthermore, it was reported that the efficacy of the extract against *S. aureus* was not observed using the disc diffusion method.

In another study conducted with *M. sativa* in India, extracts of the plant were prepared using different solvents such as petroleum ether, chloroform, benzene, methanol, ethanol, and water. The antibacterial activities of the prepared extracts were determined using the disc diffusion method. In the experiment, *Staphylococcus aureus* and *Streptococcus pyogenes* MTCC 1928 were used as gram-positive bacteria, while *Proteus mirabilis* MTCC 425, *Escherichia coli* MTCC 2961, *Pseudomonas aeruginosa* MTCC 4676, *Klebsiella pneumoniae* MTCC 432, and *Salmonella typhi* MTCC 733 were used. In the study, the antibacterial activities of methanol, chloroform, and ethanol extracts were determined, and it was

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

observed that petroleum ether had no antibacterial activity. The activity of the methanol extract against *S. aureus* was 18.1 mm, and this result was observed to have the best antibacterial activity compared to the other extracts. The activity against *E. coli* was also observed to have the highest zone diameter in the methanol extract, as was the case with *S. aureus* (Doss et al., 2011).

In a different study carried out by Chavan et al., the antibacterial activities of extracts prepared from *M. sativa* leaves using methanol and petroleum ether against *E. coli, P. aeruginosa*, and *S. aureus* were determined. The results obtained from the disc diffusion test showed that the methanol extract from *M. sativa* leaves had the highest antibacterial activity (Chavan et al., 2015).

M. sativa contains numerous secondary metabolites such as alkaloids, flavonoids, tannins, and steroids. Some of these metabolites exert antibacterial effects on bacteria. In particular, the tannin metabolite is known to have the ability to break down the bacterial cell wall (Venkataswamy et al., 2010). Another metabolite frequently found in plants is saponins. Saponins are known to be mild detergents. Studies have shown that this property gives them antibacterial properties (Chavan et al., 2015).

The results obtained in our study reveal that the methanol extract of *M. sativa* has significant antibacterial activity against both *E. coli* and *S. aureus* compared to positive controls. It is believed that our study with *M. sativa* will make a significant contribution to the literature.

CONCLUSION

Within the scope of this study, the in vitro antibacterial activity of extracts obtained from *Medicago sativa* L. against *Staphylococcus aureus* ATCC 29213 and *Escherichia coli* ATCC 25922 bacterial strains was investigated. After drying, the plant was extracted using different solvents (methanol, ethanol and distilled water). The antibacterial activity of the extracts obtained from *Medicago sativa* L. was determined using the disc diffusion method. According to the results, the highest antibacterial activity against *Staphylococcus aureus* was observed with the methanol extract, with an inhibition zone measured at 11.9 mm.

REFERENCES

Bora KS, & Sharma A 2011. Phytochemical and pharmacological potential of Medicago sativa: A review. Pharmaceutical Biology, 49(2), 211–220. https://doi.org/10.3109/13880209.2010.504732

Chandra P, Kaleem M, Sachan N, Pathak R, Alanazi AS, Alsaif NA, Alsanea S, Alsuwayt B, Alanazi MM, & Kabra A 2023. Gastroprotective evaluation of Medicago sativa L. (Fabaceae) on diabetic rats. Saudi pharmaceutical journal: SPJ: the official publication of the Saudi Pharmaceutical Society, 31(11), 101815. https://doi.org/10.1016/j.jsps.2023.101815.

Chaudhary A, Shivam NS, & Chandra P 2020. A Comprehensive Review: Medicago sativa. International Journal of Pharmaceutical Sciences Review and Research.[Online] November, 15.

Chavan SS, Jadhav RS, Khemnar KS, & Tambe VB. 2015. Evaluation of antibacterial activity and phytochemical screening of Medicago sativa leaves. *Int J Curr Res Acad Rev*, *3*(5), 308-313.

Chegini H, M Oshaghi, M Boshagh A, et al., 2018. Antibacterial effect of Medicago sativa extract on the common bacteria in sinusitis infection. International Journal of BioMedicine and Public Health. 1, 1-5.

Davis PH, 1972. Flora of Turkey and the East Aegean Islands. Edinburgh: Edinburgh University Press, 4: 382-387.

Doss A, Parivuguna V, Vijayasanthi M, and Surendran S 2011. Antibacterial evaluation and phytochemical analysis of Medicago sativa L. against some microbial pathogens. *Indian Journal of Science and Technology*, *4*(5), 550-552.

Farsani M, KE Amraie, p Kavian, et al., 2016. Effects of aqueous extract of alfalfa on hyperglycemia and dyslipidemia in alloxan-induced diabetic Wistar rats. Interventional Medicine & Applied Science. 8, 103-108.

Gatouillat G, A Magid, AE Bertin, et al., 2015. Medicarpin and millepurpan, two flavonoids isolated from medicago sativa, induce apoptosis and overcome multidrug resistance in leukemia P388 cells. Phytomedicine. 22, 1186-1193.

Heywood VH, Ball PW 1968. Leguminosae. In: Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA, Eds. Flora Europaea, Vol II. Cambridge: Cambridge University Press, pp. 245–260.

Hong Y, H W Chao, W M Chen L, et al., 2009. Ethyl acetate extracts of alfalfa (Medicago sativa L.) sprouts inhibit lipopolysaccharide-induced inflammation in vitro and in vivo. Journal of Biomedical Science. 16:64 doi:10.1186/1423-0127-1116-1164.

Lacefield GD, Hennning JC, Rasnake M, Collins M 1979. Alfalfa–the queen of forage crops. *Coop. Extension Service*.

Liu V, Escobar GJ, Greene JD, et al 2014. Hospital deaths in patients with sepsis from 2 independent cohorts. JAMA 2014; 312: 90–92.

Rudd KE, Johnson SC, Agesa KM, Shackelford KA, Tsoi D, Kievlan DR, Colombara DV, Ikuta KS, Kissoon N, Finfer S, Fleischmann-Struzek C, Machado FR, Reinhart KK, Rowan K, Seymour CW, Watson RS, West TE, Marinho F, Hay SI, Lozano R, Lopez AD, Angus DC, Murray CJL, Naghavi M 2020. Global, regional, and national sepsis incidence and mortality, 1990-2017: analysis for the Global Burden of Disease Study. Lancet. 2020 Jan 18;395(10219):200-211. doi: 10.1016/S0140-6736(19)32989-7. PMID: 31954465; PMCID: PMC6970225.

Sadeghi L, F Tanwir and V Babadi Y 2016. Antioxidant effects of alfalfa can improve iron oxide nanoparticle damage: Invivo and invitro studies. Regulatory Toxicology and Pharmacology. 81, 39-46.

Sadowska B, Budzynska A, Wieckowska-Szakiel M, et al 2014. New pharmacological properties of Medicago sativa and Saponaria officinalis saponin-rich fractions addressed to Candida albicans. J. Med. Microbiol. 2014;63:1076–1086. doi: 10.1099/jmm.0.075291-0.

Venkataswamy R, Doss A, Sukumar M and Mubarack HM 2010. Preliminary phytochemical screening and antimicrobial studies of Lantana indica roxb. Indian J. Pharmaceutical Sci. 72 (2), 229 -231.

Zhou Z, Li J, Gao Y, Wang X, Wang R, Huang H, ... Wang P 2024. Research on drought stress in Medicago sativa L. from 1998 to 2023: a bibliometric analysis. *Frontiers in Plant Science*, *15*, 1406256.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INTEGRATED USE OF SPECIAL CONCRETE TYPES IN SUSTAINABLE AND ECONOMIC HOUSING DESIGN AND SAP2000-BASED CONCEPTUAL STRUCTURAL EVALUATION

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Sürdürülebilir ve Ekonomik Konut Tasarımında Özel Beton Türlerinin Entegre Kullanımı ve SAP2000 Tabanlı Kavramsal Yapısal Değerlendirme

ÖZET

Artan kentleşme ve konut ihtiyacı, yapı sektörünün çevresel etkilerini önemli ölçüde artırmaktadır. Portland çimentosuna dayalı beton üretimi yüksek karbon salımı nedeniyle sürdürülebilirlik hedefleri ile çelişmektedir. Bu çalışmada sürdürülebilir ve ekonomik konut tasarımında özel beton türlerinin entegre kullanım potansiyeli literatür ve sayısal modelleme temelli olarak incelenmiştir.

Geopolimer beton, LC3 beton, ferrocement ve cam agregalı beton; çevresel etki, mekanik performans ve uygulanabilirlik açısından karşılaştırmalı olarak değerlendirilmiştir. Önerilen sürdürülebilir yapı modeli SAP2000 yazılımı kullanılarak kavramsal düzeyde modellenmiş ve deprem etkileri altında yapısal davranış eğilimleri analiz edilmiştir. Ayrıca metraj temelli ekonomik değerlendirme yaklaşımı ele alınmıştır.

Elde edilen bulgular, fonksiyon bazlı malzeme seçiminin sürdürülebilir konut üretiminde çevresel ve ekonomik açıdan uygulanabilir bir strateji sunduğunu göstermektedir.

Anahtar Kelimeler: Sürdürülebilir beton, geopolimer beton, LC3 beton, SAP2000, sürdürülebilir konut tasarımı

ABSTRACT

Increasing urbanization and housing demand significantly increase the environmental impact of the construction sector. Conventional concrete production based on Portland cement leads to high carbon emissions and conflicts with sustainability goals. In this study, the integrated use potential of special concrete types in sustainable and economic housing design is examined based on literature and conceptual numerical modeling. Geopolymer concrete, LC3 concrete, ferrocement and glass aggregate

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

concrete were comparatively evaluated in terms of environmental impact, mechanical performance and applicability. The proposed sustainable structural model was conceptually modeled using SAP2000 software and structural behavior trends under seismic effects were analyzed. In addition, a quantity-based economic evaluation approach was considered. The findings indicate that function-based material selection provides an environmentally and economically feasible strategy for sustainable housing production.

Keywords: Sustainable concrete, Geopolymer concrete, LC3 concrete, SAP2000, Sustainable housing design

1. LİTERATÜR İNCELEMESİ

Yapı sektörü küresel CO_2 emisyonlarının önemli bir kısmından sorumludur. Çimento üretimi sırasında gerçekleşen klinkerleşme süreci yüksek karbon salımına neden olmaktadır (Habert, 2020). Bu durum sürdürülebilir yapı malzemelerine yönelimi artırmıştır.

Geopolimer beton, endüstriyel yan ürünlerin bağlayıcı olarak kullanılması sayesinde çimento tüketimini azaltmaktadır (Davidovits, 2013). Provis (2018), geopolimer betonların dayanıklılık açısından avantaj sunduğunu belirtmektedir.

LC3 sistemleri klinker oranını düşürerek çevresel etkiyi azaltmaktadır (Scrivener, 2018). Ferrocement sistemler yüksek süneklik sunmaktadır (Naaman, 2000). Cam agregalı betonlar geri dönüşüm katkısı sağlamaktadır (Meyer, 2009).

Literatürde bu malzemelerin konut tasarımında entegre kullanımına yönelik çalışmalar sınırlıdır. Bu çalışma bu boşluğu ele almaktadır.

2. METODOLOJİ

Bu çalışma literatür temelli analitik değerlendirme ve kavramsal sayısal modelleme yaklaşımı ile ele alınmıştır. Çalışma kapsamında 2015–2024 yılları arasındaki akademik literatür sistematik olarak incelenmiştir.

İki farklı yapı modeli kavramsal olarak oluşturulmuştur:

• Geleneksel betonarme yapı modeli

• Özel beton türlerinin entegre edildiği sürdürülebilir yapı modeli

Her iki model SAP2000 yazılımı kullanılarak deprem etkileri altında kavramsal düzeyde analiz edilmiştir. Analizlerde kat davranışı, göreli deplasman eğilimleri ve iç kuvvet dağılımlarının karşılaştırmalı değerlendirilmesi yapılmıştır.

Ekonomik değerlendirme, yapı elemanlarına ait beton hacimleri ve malzeme tüketim miktarlarına dayalı metraj temelli kavramsal analiz yaklaşımı ile ele alınmıştır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 1. Fonksiyon Bazlı Malzeme Kullanım Yaklaşımı

(Yazar tarafından oluşturulmuştur)

Yapı Elemanı	**Önerilen Beton Türü**	**Amaç**
Temeller	Geopolimer Beton	Çevresel etki azaltımı
Taşıyıcı Sistem	LC3 Beton	Dengeli performans
İnce Elemanlar	Ferrocement	Süneklik
Yapısal Olmayan	Cam Agregalı	Geri dönüşüm katkısı

3. BULGULAR VE TARTIŞMA

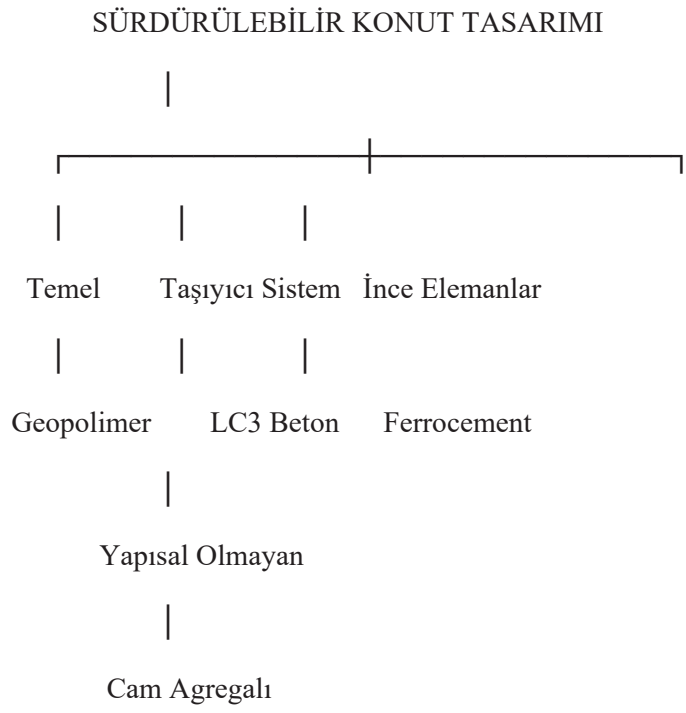
Yapılan karşılaştırmalı değerlendirmeler, özel beton türlerinin farklı performans avantajları sunduğunu göstermektedir. Geopolimer beton çevresel performans açısından öne çıkarken, LC3 beton dengeli mekanik ve sürdürülebilirlik performansı sağlamaktadır. Ferrocement sistemler süneklik katkısı ile yapısal davranış açısından avantaj sunmaktadır.

SAP2000 tabanlı kavramsal analizler, önerilen sürdürülebilir tasarım yaklaşımının yapısal açıdan uygulanabilir eğilimler gösterdiğini ortaya koymaktadır. Fonksiyon bazlı malzeme seçimi, tek tip malzeme kullanımına kıyasla daha rasyonel ve sürdürülebilir bir mühendislik yaklaşımı sunmaktadır.

Analiz sonuçları, sürdürülebilir modelin göreli yapısal performans eğilimleri açısından geleneksel modele yakın davranış sergilediğini göstermektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Şekil 1. Fonksiyon Bazlı Malzeme Entegrasyon Modeli



4. SONUÇLAR

Bu çalışma literatür ve kavramsal sayısal modelleme temelli bir değerlendirme olup, önerilen sürdürülebilir yapı modelinin yapısal açıdan uygulanabilir potansiyele sahip olduğu belirlenmiştir. Gelecek çalışmalarda detaylı parametrik analizler, deneysel doğrulama ve kapsamlı maliyet analizleri ile modelin geliştirilmesi planlanmaktadır.

KAYNAKLAR

Davidovits, J. (2013). Geopolymer cement: A review. Geopolymer Institute.

Provis, J. L. (2018). Alkali-activated materials. Cement and Concrete Research, 114, 40–48.

Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO_2 cement-based materials industry. Cement and Concrete Research, 114, 2–26.

Mehta, P. K., & Monteiro, P. J. M. (2001). Concrete: Microstructure, properties, and materials. McGraw-Hill.

Naaman, A. E. (2000). Ferrocement and laminated cementitious composites. Techno Press.

Meyer, C. (2009). The greening of the concrete industry. Cement and Concrete Composites, 31(8), 601–605.

Habert, G., Miller, S. A., John, V. M., Provis, J. L., Favier, A., Horvath, A., & Scrivener, K. (2020). Environmental impacts and decarbonization strategies in the cement and concrete industries. Nature Reviews Earth & Environment, 1, 559–573.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DEVELOPMENT AND PERFORMANCE EVALUATION OF A HIGH-EFFICIENCY PMSM WITH STRATEGIES FOR TORQUE RIPPLE REDUCTION

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ABSTRACT

This study explores the comprehensive electromagnetic design and performance evaluation of a high-efficiency Permanent Magnet Synchronous Motor (PMSM) tailored for high power density industrial applications. The research focuses on balancing the competing requirements of compact volume and superior electromagnetic performance. The initial design phase involves rigorous analytical dimensioning, followed by detailed characterization using 2D Finite Element Analysis (FEA). This process ensures an optimal magnetic flux distribution across the air gap while preventing excessive magnetic saturation in the stator teeth and yoke.

The preliminary simulation results confirm that the proposed configuration successfully achieves the targeted efficiency and power output benchmarks under steady-state conditions. However, achieving smooth torque delivery remains a critical challenge for high-precision motion control. Consequently, this study establishes a roadmap for torque ripple mitigation as a core part of its ongoing development. The investigation highlights upcoming strategies, including the refinement of rotor pole-slot combinations, the implementation of advanced magnet shaping, and the application of pole-skewing techniques to suppress parasitic harmonics. By integrating these future refinements, the study aims to deliver a robust motor design that combines high energy efficiency with enhanced dynamic stability, providing a viable solution for the next generation of electric drive systems.

Keywords: Permanent Magnet Synchronous Motor (PMSM), Electromagnetic Design, Finite Element Analysis (FEA),

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

IHLARA VADİSİ'NDEN TOPLANAN *COPRINELLUS SP.* VE *AMANITA SP.* TÜRLERİNDEN ELDE EDİLEN METANOLİK EKSTRAKTLARIN *ESCHERICHIA COLI* VE *CORYNEBACTERIUM RENALE* ÜZERİNDEKİ ANTİMİKROBİYAL ETKİLERİ

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Özet

Aksaray'da bulunan Ihlara Vadisi, biyolojik çeşitliliğinin yanı sıra farklı habitat tiplerinde gelişen makromantar türleriyle dikkat çeken bir mikroklima alanıdır. Bu çalışmada vadiden toplanan iki makromantar örneği, makroskobik özellikleri ve spor baskısı değerlendirmeleri sonucunda *Coprinellus sp.* ve *Amanita sp.* olarak tanımlanmış ve bu türlerden elde edilen metanolik ekstraktların iki farklı bakteri suşu üzerindeki antimikrobiyal potansiyeli araştırılmıştır. Siyah spor izi, ince lamelli yapısı ve hızlı bozunma eğilimiyle karakterize edilen *Coprinellus sp.*'nin metanolik ekstraktı, yapılan disk difüzyon testlerinde *Escherichia coli* üzerinde 15 mm, *Corynebacterium renale* üzerinde 8 mm inhibisyon zonu oluşturarak çift yönlü ve güçlü bir antibakteriyel aktivite ortaya koymuştur. Buna karşılık sarımsı, granüllü genç yapısıyla tanımlanan *Amanita sp.*'nin metanolik ekstraktı yalnızca *C. renale* üzerinde 13 mm çapında belirgin bir inhibisyon zonu oluşturmuş, *E. coli* üzerinde ise hiçbir aktivite göstermemiştir. Bu sonuçlar, Ihlara Vadisi gibi doğal habitatlardan elde edilen makromantarların özellikle Gram-pozitif bakterilere karşı dikkate değer biyolojik aktivite potansiyeline sahip olduğunu göstermekte ve bölgenin doğal ürün keşfi açısından önemli bir kaynak olabileceğini düşündürmektedir. Bu türler, ilerleyen aşamalarda yapılacak detaylı fitokimyasal analizler, fraksiyon bazlı saflaştırmalar ve etki mekanizmasına yönelik biyolojik testlerde değerlendirilmesi gereken güçlü adaylar olarak öne çıkmaktadır.

Anahtar Kelimeler: Ihlara Vadisi, Antimikrobiyal aktivite, Doğal ürün potansiyel.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANTIMICROBIAL EFFECTS OF METHANOLIC EXTRACTS OBTAINED FROM *COPRINELLUS SP.* AND *AMANITA SP.* COLLECTED FROM THE IHLARA VALLEY ON *ESCHERICHIA COLI* AND *CORYNEBACTERIUM RENALE*

Abstract

Ihlara Valley, located in Aksaray, is a microclimatic area that draws attention with its biodiversity as well as the macrofungal species developing in various habitat types. In this study, two macrofungal specimens collected from the valley were identified as *Coprinellus sp.* and *Amanita sp.* based on their macroscopic features and spore print evaluations, and the antimicrobial potential of the methanolic extracts obtained from these species was investigated against two bacterial strains. The methanolic extract of *Coprinellus sp.*, characterized by its dark spore print, delicate lamellae, and rapid degradation tendency, produced inhibition zones of 15 mm against *Escherichia coli* and 8 mm against *Corynebacterium renale* in the disk diffusion assays, demonstrating strong and dual antibacterial activity. In contrast, the methanolic extract of *Amanita sp.*, identified by its yellowish and granular young structures, generated a distinct inhibition zone of 13 mm only against *C. renale*, while exhibiting no activity against *E. coli*. These findings indicate that macrofungi naturally occurring in the Ihlara Valley possess noteworthy biological activity potential, particularly against Gram-positive bacteria, and suggest that the region may serve as an important natural source for novel bioactive compounds. Both species stand out as promising candidates for future phytochemical analyses, fraction-based purification studies, and mechanistic investigations aimed at identifying active constituents.

Keywords: Ihlara Valley, Antimicrobial activity, Natural product potential.

GİRİŞ

Mantarlar, doğada çürükçül (saprotrof), simbiyotik ve parazitik yaşam biçimleri sergileyen ökaryotik mikroorganizmalardır. Bugüne kadar yaklaşık 150.000 mantar türü tanımlanmış olmasına rağmen, toplam tür sayısının 2,2 ila 3,8 milyon arasında olduğu tahmin edilmektedir (Hawksworth & Lücking, 2017). Bu organizmalar, özellikle makroskobik yapıya sahip olan ve spor taşıyan yapıları çıplak gözle gözlemlenebilen makromantarlar olarak sınıflandırıldıklarında, yalnızca ekosistem döngülerinde değil, aynı zamanda tıbbi ve endüstriyel alanlarda da önemli potansiyel sunmaktadır (Lindequist vd., 2005).

Makromantarlar; içeriklerinde bulunan fenolik bileşikler, terpenoidler, polisakkaritler, alkaloidler ve steroller gibi ikincil metabolitler sayesinde geniş bir biyolojik etki yelpazesi gösterirler. Bu bileşiklerin özellikle antimikrobiyal, antioksidan, antikanser ve immünmodülatör etkiler taşıdığı çeşitli çalışmalarda gösterilmiştir (Ríos & Recio, 2005; Wasser, 2010). Antibiyotiklere karşı gelişen direnç mekanizmalarının küresel düzeyde artması, yeni antimikrobiyal kaynakların keşfini zorunlu kılmakta

ve bu bağlamda doğal ürünlerin önemi giderek artmaktadır (Newman & Cragg, 2020). Mantarlar bu alanda sürdürülebilir ve biyolojik olarak aktif bileşiklerin üretiminde önemli kaynaklardandır.

Bu çalışmada ele alınan *Coprinellus sp.* ve *Amanita sp.*, Ihlara Vadisi'nden toplanmış olup bölgenin nemli mikrohabitatları ve organik madde açısından zengin yapısı makromantar çeşitliliğini desteklemektedir. *Coprinellus* cinsi hızlı çürüme (deliquescence) eğilimli lamelli yapısıyla bilinirken, *Amanita* cinsi hem zehirli hem yenilebilir türler içermesiyle dikkat çekmektedir.

Bu çalışmada, morfolojik olarak teşhis edilen *Coprinellus sp.* ve *Amanita sp.* türlerine ait metanolik ekstraktların antimikrobiyal etkileri değerlendirilmiştir. Bu iki tür, literatürde sınırlı farmakolojik veri bulunan ve biyoaktif potansiyeli henüz yeterince araştırılmamış makromantarlar arasında yer almaktadır. Ekstraktların, seçilen bakterilere karşı gösterdiği antimikrobiyal aktiviteler, agar difüzyon yöntemi kullanılarak test edilmiştir. Araştırmanın amacı, bu türlerin mikrobiyal büyümeyi baskılayıcı potansiyelini ortaya koymak ve doğal antimikrobiyal ajanlara yönelik literatüre katkı sunmaktır.

MATERYAL VE YÖNTEM

Makromantar örneğini toplanması

Coprinellus sp. ve *Amanita sp.* türleri 2025 yılı Temmuz ayında Ihlara Vadisi'nden toplanmış ve Erciyes Üniversitesi Liken Herbaryumu'nda kurutularak muhafaza edilmiştir. Kurutulan makromantar örnekleri daha sonra antimikrobiyal analizler için çeşitli yöntemler kullanılarak mantar özütü elde edilmiştir.

Kullanılan Mikroorganizma Örnekleri

Çalışmada iki farklı makromantar türlerinden elde edilen özütlerin antimikrobiyal aktivitelerini belirlemek amacıyla 2 bakteri (1 G- *Escherichia coli* ve 1 G+ *Corynebacterium renale*) kültürü kullanılmıştır. Kullanılan mikroorganizmaların isimleri ve kültür koleksiyon kodları Tablo 1'de gösterilmiştir.

Tablo 1. Çalışmada kullanılan mikroorganizma örnekleri

Mikroorganizma	**Organizma Kodu**
Escherichia coli	ATCC 25922
Corynebacterium renale	ATCC 10240

Escherichia coli: *Escherichia coli*, ortalama 2-6 µm boyunda, 1-1,5 µm eninde Gram negatif bir basil peritriş kirpikleri sayesinde hareketlidir. Hareketsiz suşları da vardır. Bazı suşlarda kapsül veya mikrokapsül bulunmaktadır. Spor oluşturmazlar ve fakültatif anaerobturlar (Ocak, 2014).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Corynebacterium renale, *Corynebacterium renale*, Gram-pozitif, pleomorfik yapıda, kısa çomak (rod) formunda görülen bir bakteridir. Hücreler çoğunlukla 1–3 µm uzunluğunda olup hafif eğri veya düzensiz şekiller gösterebilir. Hareketli değildir ve spor oluşturmaz. Hücre duvarında yüksek oranda lipid içeren peptidoglikan tabakası bulunması, çevresel koşullara karşı dayanıklılığını artırır. Aerob veya fakültatif anaerob koşullarda büyüyebilir. Kanlı agar gibi zenginleştirilmiş besiyerlerinde küçük, yuvarlak ve mat koloniler oluşturur. (Wikipedia, 2025).

Makromantar örneğinden mantar özütünün hazırlanması ve Antimikrobiyal Aktivite Çalışmaları

1.00 g kurutulmuş makromantar numunesi alındı ve özüt, metanol kullanılarak toplandı. Whatman No 1 filtre kağıdı kullanılarak mantar özütü süzüldü. Süzülme işlemi bittikten sonra özüt cam petri kabı içerisine döküldü ve daha sonra 70 ^{o}C de 1 gün etüvde bekletilerek metanol uzaklaştırıldı. Metanol uzaklaştıktan sonra kalan mantar özütü DMF içerisinde çözdürüldü ve antimikrobiyal aktivite denemeleri agar kuyucuk difüzyon yöntemi ile 4 tane mikroorganizma üzerinde analiz edildi (Kuşçulu ve Aslan, 2019).

Stok kültürlerden, bakteriler nutrient sıvı besiyerinde 35 ^{o}C' de 24 saat inkübasyona bırakılarak yetiştirilmiştir.

Sıvı ortamlarda geliştirlen her mikroorganizma kültüründen tekrar sıvı ortamları içeren tüplere %1 oranında aşılanarak 18 saat ekponansiyel faza gelene kadar yetiştirilmiş ve kültürlerin yoğunlukları Mc Farland 0,5'e göre ayarlanmıştır.

Yoğunlukları ayarlanan mikroorganizmalardan 100 µl alınarak Muller hinton agar besi ortamına yayma ekim ile ekilmiş ve sonrasında 6 mm çapında kuyucuklar açılmıştır. Açılan kuyucuklar içerisine mantar özütünden 50 µl ilave edilip inkübasyona bırakılmıştır. İnkübasyondan sonra inhibisyon zonlarının çapı ölçülerek etkileri belirlenmiştir. Denemeler üç tekrarlı olarak yapılmıştır.

SONUÇLAR

Amanita sp.

Taksonomi ve Genel Bilgi:

Amanita cinsi, Amanitaceae familyasında yer alan, makromorfolojik olarak gösterişli, hem ölümcül derecede zehirli hem de yenilebilir türler içeren geniş bir gruptur. Türlerin büyük bölümü ektomikorizal olup, özellikle orman ekosistemlerinde ağaç kökleriyle simbiyotik ilişki kurar. Klasik olarak volva (dip kılıfı), halka (annulus), serbest lameller ve beyaz spor izi ile tanınır. Cins içerisinde *A. phalloides*, *A. virosa* gibi ölümcül toksik türlerin bulunması nedeniyle *Amanita* cinsi mikoloji ve toksikoloji açısından büyük öneme sahiptir.

Deskripsiyon:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Şapka:

Genellikle 5–12 cm (bazı türlerde çok daha büyük) çapında; gençken yarı küresel veya yumurtamsı, olgunlaştıkça konveks ya da düz bir yapı kazanır. Şapka rengi türüne bağlı olarak beyaz, sarımsı, kahverengimsi, kırmızımsı veya zeytin tonlarında olabilir. Yüzeyde çoğu zaman genel örtü (universal veil) kalıntılarından kaynaklanan siğil, pulcuk veya yamalı desenler bulunur. Kenar kısmı bazı türlerde hafif çizgili (striat) olabilir.

Lameller:

Sapla serbest veya çok hafifçe yapışık; sık ve genellikle geniş lameller hâlindedir. Renk çoğunlukla beyaz, krem veya soluk sarımsıdır. Aralarda kısaltılmış lamellulae'lar bulunabilir. Spor izi tipik olarak beyazdır. Lamel yüzeyi ve kenarındaki hücreler mikroskobik tanıda önem taşır.

Sap:

Yaklaşık 8–15 cm uzunluğunda, silindirik veya tabana doğru belirgin şekilde soğanlaşmış (bulböz) yapıdadır. Sap yüzeyi pürüzsüz, fibrilli veya pullu olabilir. Sapın üst kısmında genellikle iyi gelişmiş, halka (annulus) şeklinde bir kısmi örtü kalıntısı bulunur. Tabanda ise toprak içinde gömülü olabilen, kese biçimli veya halkalı volva yapısı *Amanita* cinsi için ayırt edici bir özelliktir.

Koku ve Tat:

Koku ve tat, türe bağlı olarak değişkenlik gösterir. Bazı türlerde zayıf mantar kokusu varken, bazılarında hoş olmayan, keskin veya tatlımsı koku bildirilmektedir. Cins içinde çok sayıda ölümcül zehirli tür bulunduğundan, tat denemesi yapmak kesinlikle uygun değildir.

Ekolojik Rol ve Habitat:

Amanita türleri çoğunlukla ektomikorizal olup meşe, kayın, ladin, çam gibi birçok ağaç türü ile simbiyotik ilişki kurarlar. İğne yapraklı, yaprak döken veya karışık ormanlarda, çoğu zaman ağaçların yakın çevresinde, tekli veya dağınık gruplar hâlinde gelişirler. Toprak tercihleri türe göre değişmekle birlikte, iyi drene olan asidik veya hafif bazik topraklarda da bulunabilirler. İlkbahardan sonbahar sonuna kadar, uygun nem ve sıcaklık koşullarında meyve verirler. Orman ekosistemlerinde besin döngüsü ve bitki beslenmesi açısından önemli rol oynarlar (Vizzini, 2010).

Toksisite ve Yenilebilirlik:

Amanita cinsi, içinde barındırdığı yüksek toksisite potansiyeli nedeniyle en riskli mantar gruplarından biridir. *A. phalloides*, *A. virosa*, *A. verna* gibi türler amatoksin ve fallotoksin içeren, ağır karaciğer ve böbrek hasarına yol açabilen ölümcül zehirli türlerdir. Buna karşın bazı *Amanita* türleri farklı bölgelerde yenilebilir olarak tüketilmektedir. Ancak morfolojik benzerlikler ve yanlış teşhis riskinin çok yüksek olması nedeniyle, özellikle bilimsel düzeyde tür teşhidi ve toksikolojik analiz yapılmadan *Amanita* türlerinin tüketimi kesinlikle önerilmez. (Benjamin, 1995).

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Şekil 1. Ihlara Vadisi'nden *Amanita sp.* türünün genel görünümü.

Coprinellus sp.

Taksonomi ve Genel Bilgi:

Coprinellus cinsi, Psathyrellaceae familyasına ait, genellikle küçük ve narin yapılı, kısa ömürlü (deliquescent) şapkalı makromantar türlerini içeren bir gruptur. Türler çoğunlukla saprotrof olup, çürümüş odun, yaprak çöpü veya organik maddece zengin toprak üzerinde gelişir. Birçok tür, önce *Coprinus* içinde değerlendirilmiş, daha sonra mikroskobik ve moleküler veriler ışığında *Coprinellus*, *Parasola* gibi yeni cinslere ayrılmıştır. Bu cinsin üyeleri, gri-kahverengi şapkaları, ince lamelleri ve olgunlukta siyaha dönen "mürekkep" benzeri spor baskıları ile karakterizedir.

Deskripsiyon:

Şapka:

Genellikle 1–4 cm çapında, genç evrede oval, yumurtamsı ya da konveks; olgunlaştıkça düzleşen ve çoğu zaman oto-lizis (kendini eritme) eğilimi gösteren yapıdadır. Rengi gençken gri, gri-kahverengi veya açık kahverengi tonlarında olup yaşlandıkça koyulaşabilir. Şapka yüzeyi çoğu türde ince

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ISBN: 978-9952-610-30-7

pulcuklu, fibrilli veya hafifçe çizgili görünümlüdür. Yaşlandıkça kenarlardan parçalanma ve kenarların yukarı doğru kıvrılması sık gözlenir.

Lameller:

Sapla serbest veya hafif yapışık; sık aralıklı ve ince yapıdadır. Gençken beyazımsı veya soluk gri, sporlama döneminde hızla koyu kahverengi-siyah renge döner. Bazı türlerde lameller olgunlukta mürekkep gibi eriyerek dağılan tipik "ink cap" görünümünü oluşturur. Sporlu evrede lamel kenarlarında cheilocystidia'lar belirgin olabilir.

Sap:

Yaklaşık 3–7 cm uzunluğunda, 1–4 mm kalınlığında, silindirik ve çoğunlukla içi boş, kırılgan yapıdadır. Rengi beyaz veya kirli beyaz olup tabana doğru hafifçe kalınlaşabilir. Sap yüzeyi ince fibrilli veya hafif unlu görünümlü olabilir. Halka genellikle bulunmaz veya çok zayıf gelişmiştir.

Koku ve Tat:

Koku genellikle zayıf, topraksı veya belirgin olmayan niteliktedir. Tat ile ilgili veriler sınırlı olup, türlerin küçük ve narin yapılı olması nedeniyle tadına bakılması önerilmez. Yenilebilirlik durumları türler arasında değişebildiği ve bazılarına ait veriler yetersiz olduğu için tüketimi genel olarak tavsiye edilmez.

Ekolojik Rol ve Habitat:

Coprinellus türleri saprotrof yaşam tarzı gösterir; çürüyen yaprak döküntüsü, hayvan dışkısı, ölü odun veya humusça zengin toprak üzerinde tekli ya da küçük gruplar hâlinde gelişir. Parklar, bahçeler, orman açıklıkları, yol kenarları ve tarımsal alanlar gibi çok çeşitli habitatlarda görülebilir. Genellikle yağışlı dönemlerde, ilkbahar sonundan sonbahar sonuna kadar meyve verirler. Organik maddenin ayrışmasında önemli rol oynarlar.

Toksisite ve Yenilebilirlik:

Coprinellus cinsi içerisinde yenilebilir olarak bildirilen türler bulunsa da, çoğu tür için ayrıntılı toksikolojik çalışma bulunmamaktadır. Ayrıca morfolojik benzerliği yüksek, küçük ve kısa ömürlü türlerin birbirine karışma riski fazladır. Bu nedenle, özellikle tür düzeyinde kesin teşhis yapılmadan tüketimi önerilmez. Psathyrellaceae üyelerinde zaman zaman gastrointestinal rahatsızlık bildirilmiş olması da dikkat alınmalıdır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 2. Ihlara Vadisi'nden *Coprinellus sp.* türünün genel görünümü.

Antibakteriyal Aktivite Sonuçları

Agar Difüzyon Sonuçları

Makromantar özütlerinin antimikrobiyal aktiviteleri, 100 ppm konsantrasyonda agar kuyu difüzyon yöntemi kullanılarak üç bakteri suşuna karşı belirlenmiştir: Gram-pozitif ***C. renale*** **ATCC 10240** ile Gram-negatif ***E. coli*** **ATCC 25922**. Elde edilen sonuçlar Tablo 1'de sunulmuştur.

Tablo 2. Makromantar özütlerinin kantitatif antimikrobiyal test sonuçları

Mikroorganizmalar	**İnhibisyon zonu (mm)**	
E. coli **(G-)**	*Amanita sp.*	*Coprinellus sp.*
	-	15
C. renale **(G-)**	13	8

Tablo 2'de, *Amanita sp.* ve *Coprinellus sp.* türlerinden elde edilen metanolik ekstrelerin iki farklı bakteri türüne karşı gösterdiği antimikrobiyal aktiviteler karşılaştırmalı olarak sunulmuştur. Sonuçlar, her iki makromantar türünün farklı bakteri grupları üzerinde değişen düzeylerde etki gösterdiğini ortaya koymakta ve türler arasında belirgin bir aktivite farklılığının bulunduğunu göstermektedir.

Gram-negatif *Escherichia coli* suşu üzerinde *Amanita sp.* ekstraktının hiçbir inhibisyon oluşturmaması, bu türe ait bileşiklerin *E. coli* hücre duvarı yapısına veya metabolik süreçlerine karşı etkisiz olduğunu göstermektedir. Buna karşın *Coprinellus sp.* ekstraktı aynı bakteri üzerinde 15 mm'lik inhibisyon zonu oluşturarak güçlü bir antibakteriyel etki sergilemiştir. Bu bulgu, *Coprinellus sp.* içerisinde bulunan fenolik bileşikler veya organik asitlerin Gram-negatif bakterilere karşı daha etkili olduğunu düşündürmektedir.

Gram-pozitif *C. renale* suşu üzerinde iki mantar türünün de belirgin aktivite gösterdiği görülmektedir. *Amanita sp.* ekstraktı bu bakteri üzerinde 13 mm'lik inhibisyon zonu oluşturarak orta düzeyde bir antibakteriyel etki ortaya koymuştur. *Coprinellus sp.* ise aynı bakteri üzerinde 8 mm'lik daha düşük bir inhibisyon zonu sergilemiştir. Bu farklılık, *Amanita sp.* türünün özellikle Gram-pozitif bakterilere karşı daha seçici ve etkili bileşikler içerdiğini işaret etmektedir.

Genel olarak değerlendirildiğinde, *Coprinellus sp.* Gram-negatif *E. coli* üzerinde yüksek aktivite gösteren tek türdür ve bu özelliği ile dikkat çekmektedir. *Amanita sp.* ise yalnızca Gram-pozitif *C. renale* üzerinde etkili olmuş ve Gram-negatif bakteri üzerinde hiçbir etki göstermemiştir. Bu durum, mantar ekstrelerinin antibakteriyel etkilerinin hem mantar türünün içerdiği metabolitlere hem de hedef bakterinin hücre duvarı yapısına bağlı olarak değiştiğini göstermektedir.

Tabloda yer alan bulgular, Ihlara Vadisi'nden elde edilen makromantarların seçici antimikrobiyal potansiyel taşıdığını ve her iki türün farklı bakteriyel gruplara karşı değişken etki profilleri sergilediğini ortaya koymaktadır. Bu veriler, doğal mantar ekstrelerinin ileri biyokimyasal analizlerle desteklenmesi halinde yeni antimikrobiyal ajanlar için değerli adaylar olabileceğini göstermektedir.

TARTIŞMA

Bu çalışmada, Ihlara Vadisi'nden toplanan *Amanita sp.* ve *Coprinellus sp.* türlerine ait metanolik ekstrelerin *Escherichia coli* ve *Corynebacterium renale* üzerindeki antimikrobiyal etkileri değerlendirilmiştir. Elde edilen bulgular, her iki makromantar türünün seçici bir antimikrobiyal etki profiline sahip olduğunu göstermektedir. Doğal mantar ekstrelerinin antimikrobiyal potansiyeli, içeriklerindeki fenolik bileşikler, organik asitler ve sekonder metabolitlerin çeşitliliğine bağlı olarak farklılık gösterebilmektedir. Bu nedenle, test edilen iki mantar türü arasındaki aktivite farklılıkları, hem kimyasal bileşim hem de hedef bakterilerin hücre duvarı yapılarıyla açıklanabilir.

Çalışmanın dikkat çekici bulgularından biri, *Coprinellus sp.* ekstraktının Gram-negatif *E. coli* üzerinde belirgin bir antibakteriyel etki göstermesi (15 mm) iken *Amanita sp.* ekstraktının aynı suş üzerinde hiçbir inhibisyon oluşturmamasıdır. Gram-negatif bakterilerin hücre duvarı dış membran yapısı pek çok doğal bileşiğe karşı direnç sağlayabilmektedir. Bu bağlamda, *Coprinellus sp.* içerisinde yer alan fenolik bileşiklerin veya küçük molekül yapısındaki metabolitlerin bu bariyeri aşabilecek yapısal özelliklere sahip olduğu düşünülebilir. Buna karşın *Amanita sp.* ekstraktının *E. coli* üzerinde etkisiz kalması, cins içinde yaygın olan makrosiklik toksinlerin daha çok ökaryotik hücrelere yönelik etki

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

göstermesiyle ilişkili olabilir. Bu durum, *Amanita* türlerinin bakteriyel duvar yapısına karşı daha sınırlı etkiye sahip olduğunu göstermektedir.

Gram-pozitif *C. renale* suşu üzerinde ise her iki mantar türü de belirgin aktivite göstermiştir. *Amanita sp.* ekstraktı 13 mm'lik inhibisyon zonu oluşturarak bu bakteriye karşı *Coprinellus sp.*'den (8 mm) daha güçlü bir etki sergilemiştir. Gram-pozitif bakterilerin kalın peptidoglikan tabakasının, fenolik veya toksik bileşiklerin hücre duvarına penetrasyonunu kolaylaştırdığı bilinmektedir. Bu nedenle, *Amanita sp.* ekstraktının *C. renale* üzerinde daha yüksek aktivite göstermesi, cins içerisinde bulunan biyoaktif moleküllerin Gram-pozitif hücre duvarı ile daha güçlü etkileşim kurduğunu düşündürmektedir. Ayrıca *Amanita* türlerinde bulunan bazı düşük moleküllü toksik bileşiklerin bakteriyel membran bütünlüğünü bozma potansiyeli de literatürle uyumludur.

Elde edilen sonuçlar, mantar ekstrelerinin farklı bakteriyel gruplara karşı değişken düzeyde aktivite gösterebileceğini ortaya koymuştur. Bu seçicilik; mantarın türüne, ekstraksiyon solventine, mantarın geliştiği ekolojik koşullara ve bakteri türlerinin hücresel özelliklerine bağlı olarak değişebilmektedir. Ihlara Vadisi'nin mikroklimatik yapısı ve organik madde açısından zengin habitatları, bu mantarların içerdiği metabolit profillerini doğrudan etkileyebilecek çevresel faktörlerdir. Bu nedenle, bölgede yetişen makromantarların antimikrobiyal özelliklerinin başka bölgelerde yetişen akraba türlerden farklılık göstermesi olasıdır.

Bu bulgular toplam olarak değerlendirildiğinde, *Coprinellus sp.* özellikle Gram-negatif *E. coli* üzerinde yüksek antibakteriyel potansiyel sergileyen bir tür olarak öne çıkarken; *Amanita sp.* Gram-pozitif bakterilere karşı daha güçlü etki göstermiştir. Her iki türün seçici aktivite profili, doğal antimikrobiyal ajan geliştirme çalışmalarında mantar kökenli bileşiklerin önemini desteklemektedir. Bununla birlikte, metanolik ekstrelerin bileşenlerinin kimyasal karakterizasyonu yapılmadığı için hangi moleküllerin bu etkiden sorumlu olduğu net olarak belirlenememiştir. Bu nedenle, LC-MS, GC-MS veya NMR gibi ileri kimyasal analizlerle ekstraktların bileşenlerinin tanımlanması ve fraksiyonlara ayrılarak biyolojik olarak aktif moleküllerin izolasyonu gelecekte yapılması gereken önemli çalışmalardır.

Sonuç olarak, Ihlara Vadisi'nden toplanan makromantar türlerinin antimikrobiyal potansiyeli, doğal ürün araştırmaları için dikkate değer bir kaynak niteliği taşımaktadır. Bu iki türün farklı bakteri gruplarına karşı gösterdiği seçici etki, bölgenin mikrobiyal kontrol amacıyla kullanılabilecek yeni sekonder metabolitlerin keşfinde önemli bir potansiyel sunduğunu göstermektedir.

TEŞEKKÜRLER

Bu çalışma, TÜBİTAK 2209-A Üniversite Öğrencileri Araştırma Projeleri Destekleme Programı kapsamında desteklenmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KAYNAKLAR

Benjamin, D. R. (1995). Mushrooms: Poisons and panaceas: A handbook for naturalists, mycologists and physicians. W.H. Freeman and Company.

Hawksworth, D. L., & Lücking, R. (2017). Fungal diversity revisited: 2.2 to 3.8 million species. Microbiology Spectrum, 5(4), FUNK-0052-2016. https://doi.org/10.1128/microbiolspec.FUNK-0052-2016

Keirle, M. R., Hemmes, D. E., & Desjardin, D. E. (2004). Agaricales of the Hawaiian Islands. 7. Coprinus and Coprinopsis. Fungal Diversity, 15, 33–124.

Kuşçulu, M., & Aslan, A. (2019). Liken ekstraktlarının genotoksik ve sitotoksik etkilerinin belirlenmesi. Bitki Koruma Bülteni, 59(1), 25–32.

Larsson, E., & Örstadius, L. (2008). Morphological and molecular studies of Parasola species (Psathyrellaceae, Agaricales) in northern Europe and North America. Mycological Research, 112(4), 471–489. https://doi.org/10.1016/j.mycres.2007.12.003

Lindequist, U., Niedermeyer, T. H. J., & Jülich, W. D. (2005). The pharmacological potential of mushrooms. Evidence-Based Complementary and Alternative Medicine, 2(3), 285–299. https://doi.org/10.1093/ecam/neh107

Newman, D. J., & Cragg, G. M. (2020). Natural products as sources of new drugs over the nearly four decades from 01/1981 to 09/2019. Journal of Natural Products, 83(3), 770–803. https://doi.org/10.1021/acs.jnatprod.9b01285

Ocak, F. (2014). Mikrobiyoloji. Ankara: Palme Yayıncılık.

Ríos, J. L., & Recio, M. C. (2005). Medicinal plants and antimicrobial activity. Journal of Ethnopharmacology, 100(1–2), 80–84. https://doi.org/10.1016/j.jep.2005.04.025

Schoch, C. L., Seifert, K. A., Huhndorf, S., Robert, V., Spouge, J. L., Levesque, C. A., Chen, W., & Fungal Barcoding Consortium. (2012). Nuclear ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for Fungi. Proceedings of the National Academy of Sciences, 109(16), 6241–6246. https://doi.org/10.1073/pnas.1117018109

Vizzini, A. (2010). Meottomyces, a new genus for Lyophyllum dissimulans and its allies. Mycotaxon, 113, 309–316. https://doi.org/10.5248/113.309

Wasser, S. P. (2010). Medicinal mushroom science: Current perspectives, advances, evidences, and challenges. Biomedical Journal, 2(1), 4–19.

Wikipedia. (2025). *C. renale*. https://en.wikipedia.org/wiki/Proteus_vulgaris

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BAZI *ACAROSPORA* TÜRLERİNDE C VE K SPOT TESTİ REAKSİYONLARININ KEMOTAKSONOMİK ÖNEMİ VE β-TÜBÜLİN TEMELLİ FİLOGENETİK BİR YAKLAŞIM

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Özet

C (giroforik asit) ve K (norstiktik asit) nokta testi reaksiyonları, *Acarospora* cinsinde tür ayrımında önemli kemotaksonomik karakterler olarak kullanılmaktadır. Bu çalışmada, C ve/veya K pozitif kimyasal renklenme gösteren dört tür (*Acarospora fuscata*, (Schrad.) Arnold, *A. gallica* H. Magn., *A. rosulata* (Th. Fr.) H. Magn. ve *A. peliscypha* (Wahlenb.) Th. Fr.*)* üzerinde bu reaksiyonların kemotaksonomik değeri değerlendirilmiştir. Moleküler analizler β-tübülin gen bölgesi kullanılarak gerçekleştirilmiş ve uygun model olarak belirlenen Kimura-2 parametresi temelinde Neighbor-Joining metodu ile filogenetik ağaç oluşturulmuştur. Dizi hizalama ve manuel düzenleme sonucunda 676 bp uzunluğunda, 405 korunan ve 259 değişken nükleotitten oluşan; bunun 185'inin parsimoniyi bilgilendirici olduğu bir veri matrisi elde edilmiştir.

Filogenetik analiz, çalışılan türlerin belirgin ve iyi desteklenmiş kladlar oluşturduğunu göstermiştir. *A. rosulata* yüksek destek değerleriyle tek ve ayrışmış bir küme meydana getirirken, *A. gallica* ve *A. fuscata* kendi soy hatları içinde açık şekilde ayrılmıştır. *A. peliscypha* ise literatürdeki diziler ile tutarlı bir konumda gruplanarak filogenetik kararlılığını göstermiştir. Ayrıca, gözlenen C/K renk reaksiyonları ile β-tübülin temelli moleküler grupların uyumlu olması, kimyasal spot testlerinin yakın akraba *Acarospora* türlerinin ayrımında hâlâ önemli bir tanısal değer taşıdığını ortaya koymaktadır. Sonuç olarak çalışma, kemotaksonomik özelliklerin ve β-tübülin filogenilerinin birlikte kullanılmasının seçilmiş *Acarospora* türlerinin tür sınırlarının daha doğru belirlenmesine katkı sağladığını göstermektedir.

Anahtar Kelimeler: Liken, Biyoçeşitlilik, DNA Barkodlama, β-tubulin gen bölgesi.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CHEMOTAXONOMIC SIGNIFICANCE OF C AND K SPOT TEST REACTIONS IN SELECTED *ACAROSPORA* SPECIES AND A β-TUBULIN-BASED PHYLOGENETIC APPROACH

Abstract

Chemical spot test reactions, especially the C (giroforic acid) and K (norstictic acid) color responses, represent significant diagnostic traits in the genus *Acarospora*. This study investigates the chemotaxonomic value of these reactions specifically in four C- and/or K-positive species: *Acarospora fuscata*, (Schrad.) Arnold, *A. gallica* H. Magn., *A. rosulata* (Th. Fr.) H. Magn. ve *A. peliscypha* (Wahlenb.) Th. Fr.. Molecular analyses were performed using the β-tubulin gene region, and a Neighbor-Joining phylogenetic tree was constructed in MEGA based on the Kimura-2 parameter model, which was identified as the best-fit evolutionary model for the dataset. Sequence alignment and manual curation yielded a 676-bp matrix comprising 405 conserved and 259 variable sites, with 185 parsimony-informative positions.

The phylogenetic tree revealed well-supported clades for the examined species. *A. rosulata* formed a distinct and strongly supported cluster, while *A. gallica* and *A. fuscata* were positioned within their respective lineages with clear genetic separation. *A. peliscypha* grouped consistently with previously published sequences, confirming its phylogenetic stability within the genus. Notably, correspondence between the observed C/K color reactions and molecular clades indicates that spot test chemistry retains significant value in distinguishing these closely related taxa. Overall, the results highlight the complementary role of chemotaxonomy and β-tubulin–based phylogenetics in improving species delimitation among selected *Acarospora* species.

Keywords: Lichen, Biodiversity, DNA Barcoding, β-tubulin gene region.

GİRİŞ

Likenler; çoğunluğu askuslu mantarlardan oluşan bir mantar ortağı ile yeşil alg ve/veya siyanobakteriler arasında kurulan morfolojik ve fizyolojik etkileşimlerin sonucu ortaya çıkan, kendisini oluşturan bileşenlerden farklı özellikler sergileyen simbiyotik organizmalardır (Nash, 2008; Ahmadjian & Jacobs, 1982; Çobanoğlu, 2007). Bu simbiyotik birliktelik, metabolik faaliyetler sonucunda yalnızca likenlere özgü olan ve "liken asitleri" olarak adlandırılan çeşitli sekonder metabolitlerin sentezlenmesini sağlar. Bu maddeler; tıp, eczacılık, boya ve gıda endüstrileri başta olmak üzere pek çok alanda kullanım potansiyeline sahiptir (Romagni & Dayan, 2002; Çobanoğlu vd., 2010). Bunun yanı sıra likenler, çevresel koşullara karşı hassasiyetleri nedeniyle hava kirliliğinin izlenmesinde biyolojik indikatör olarak da yaygın biçimde kullanılmaktadır (Garty, 2001; Poikolainen, 2004). Anadolu'nun sahip olduğu yüksek tür çeşitliliği sayesinde likenler, Türkiye biyoçeşitliliğinin önemli bir bileşenini oluşturmaktadır.

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ISBN: 978-9952-610-30-7

Liken yapısında yer alan heterotrofik mantar ortak "mikobiyont", fotosentetik ortak ise "fotobiyont" olarak adlandırılmakta olup, fotobiyont yeşil alg ve/veya siyanobakterilerden oluşabilmektedir (Henskens, 2012). Bu iki ortak arasında su, besin maddeleri ve gaz alışverişine dayalı sıkı bir iş birliği bulunmaktadır. Mikobiyont tarafından sentezlenen pigmentler, fotobiyontu yoğun ultraviyole ışınlara karşı koruyarak likenlerin çöller, kayalık kıyılar, yüksek dağlık alanlar ve aşırı kurak bölgeler gibi ekstrem ekolojik koşullarda yaşamalarını mümkün kılmaktadır (Gao vd., 2016). Bu zorlu çevresel koşullara uyum, likenlerin karmaşık yapılar geliştirmesine ve yüksek biyolojik aktiviteye sahip özgün metabolitler üretmesine olanak tanımıştır (Galloway, 1992). Öte yandan, hava kirleticilerine karşı duyarlılıkları nedeniyle, kentsel ve sanayileşmiş bölgelerde liken çeşitliliği belirgin biçimde azalmaktadır (Boustie vd., 2011).

Günümüzde dünya genelinde 20.000'den fazla liken türü tanımlanmış olup, tarihsel süreçte bu organizmalar gıda, parfüm, boya ve geleneksel tıpta kullanılmıştır (Lücking vd., 2016). Liken mikobiyontlarının, büyük çoğunluğu yalnızca likenlere özgü olan yaklaşık 1000 farklı sekonder metabolit ürettiği bilinmektedir. Bu bileşiklerin önemli bir kısmı likenlere karakteristik ve canlı renklerini kazandırmaktadır (Calcott vd., 2018). Yapılan çalışmalar, bu metabolitlerin antibakteriyel, antifungal, antiinflamatuar ve benzeri birçok biyolojik aktivite sergilediğini ortaya koymuştur. Ancak likenlerin doğada son derece yavaş büyümeleri, bu bileşiklerin doğrudan likenlerden elde edilerek kullanımını sınırlandırmaktadır (Jha vd., 2017). Ayrıca aşırı ve kontrolsüz liken toplanması, doğal popülasyonların sürdürülebilirliğini tehdit etmektedir. Bu durum, likenlerde bulunan biyoaktif bileşiklerin potansiyelinin araştırılmasında, hızlı büyüyebilen ve kolaylıkla kültüre alınabilen endolikenik mikroorganizmalara yönelme gerekliliğini ortaya çıkarmıştır.

Morfolojik olarak ayırt edilmesi güç olan ya da benzerlik gösteren liken türlerinin moleküler yöntemlerle karşılaştırılması, türler arasındaki filogenetik ilişkilerin aydınlatılmasını sağlamaktadır. Bu tür çalışmalar, Türkiye'nin sahip olduğu zengin genetik çeşitliliğin ortaya konulmasına ve korunmasına önemli katkılar sunmaktadır. Bir bölgenin veya ülkenin florasının yazılabilmesi için, o alandaki biyolojik çeşitliliğin ayrıntılı biçimde ortaya konulması temel bir aşama olarak kabul edilmektedir.

MATERYAL VE YÖNTEM

Örneklerin Toplandığı Habitat

Bu çalışma kapsamında incelenen liken örnekleri Türkiye'nin çeşitli bölgelerinden toplanmıştır. Toplanan örnekler üzerinde morfolojik ve moleküler analizler gerçekleştirilmiştir. Çalışma kapsamında toplam 4 liken örneği değerlendirilmiş olup, bu örneklerin tamamı dizi analizi yapılmak üzere hizmet alımı yoluyla analiz edilmiştir.

Örneklerin Toplanması ve Saklanması

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İncelenen liken örnekleri, doğal yaşam ortamlarında fotoğraflandıktan sonra uygun arazi ekipmanları kullanılarak toplanmıştır. Küçük boyutlu tallusların tamamı, daha büyük örneklerin ise hem merkez hem de kenar kısımlarını temsil edecek şekilde örnekleme yapılmıştır. Toplanan örneklerin üzerinde bulunan toprak, karayosunu veya yabancı materyaller dikkatlice temizlenmiş; örnekler nemi emici yumuşak kâğıtlara sarılarak zarflara yerleştirilmiştir.

Arazi çalışması sonrasında örnekler oda sıcaklığında kurutulmuş, gerekli ölçüm ve ön incelemelerin ardından herbaryum zarflarına alınmıştır. Tüm materyaller Erciyes Üniversitesi Fen Fakültesi Herbaryumu'na kayıt edilerek uzun süreli saklama altına alınmıştır.

Morfolojik Analizler

Toplanan liken örneklerinin makroskobik morfolojik özellikleri stereomikroskop yardımıyla, mikroskobik anatomik yapıları ise ışık mikroskobu kullanılarak incelenmiştir. Lop genişliği ve uzunluğu cetvel yardımıyla ölçülmüş; spor boyutları, apotesyum yapıları ve diğer mikroskobik karakterler mikrometrik oküler yardımıyla belirlenmiştir.

Tür teşhisinde, likenlerin içerdiği sekonder metabolitlerin belirlenmesi büyük önem taşıdığından kemotaksonomik analizler yapılmış ve çeşitli liken floralarından yararlanılmıştır. Arazi gözlemleri ve laboratuvar incelemeleri sonucunda elde edilen tüm morfolojik, anatomik ve kimyasal veriler değerlendirilerek türlere ait tanımlayıcı deskripsiyonlar hazırlanmıştır.

Apotesyum, soral, izidyum, lobul ve lop yapıları gibi ayırt edici morfolojik karakterler fotoğraflanmış, gerekli görülen durumlarda çizimlerle desteklenmiştir. Morfolojik olarak benzer türler arasındaki karışıklığın giderilmesi ve taksonomik doğruluğun artırılması amacıyla moleküler analizlere başvurulmuştur.

Moleküler Analizler

DNA İzolasyonu

Liken örneklerinden genomik DNA izolasyonu, DNeasy Plant Mini Kit (Qiagen, Katalog No: 69104) kullanılarak üretici firma protokolüne uygun şekilde gerçekleştirilmiştir. İzolasyon süreci aşağıdaki basamaklar izlenerek uygulanmıştır:

1. Her bir örnekten 20–100 mg tartılarak sıvı azot eşliğinde havanda toz hâline getirilmiş ve 1,5 ml'lik ependorf tüplere aktarılmıştır.

2. Sıvı azotun uçmasının ardından tüplere 400 µl Buffer AP1 ve 4 µl RNase A eklenmiş, vortex ile karıştırılmıştır.

3. Örnekler 65 °C'de 10 dakika inkübe edilmiş, bu süre boyunca 2–3 kez alt üst edilmiştir.

4. Ardından 130 µl Buffer P3 eklenmiş, 5 dakika buz üzerinde bekletilmiş ve 14.000 rpm'de 5 dakika santrifüj edilmiştir.

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5. Oluşan süpernatant temiz bir kolona aktarılmış ve 14.000 rpm'de 2 dakika santrifüj edilmiştir.

6. Süpernatant yeni bir tüpe alınmış ve hacmi belirlenmiştir.

7. Süpernatant hacminin 1,5 katı kadar AW1 tamponu eklenerek karıştırılmıştır.

8. Karışımdan 650 µl alınarak spin kolona aktarılmış ve 1 dakika santrifüj edilmiştir.

9. Kalan süpernatant aynı kolona aktarılıp tekrar santrifüj edilmiştir.

10. Kolona sırasıyla iki kez AW2 tamponu eklenmiş ve santrifüj işlemleri gerçekleştirilmiştir.

11. Son olarak kolon yeni bir ependorf tüpe alınmış, 100 µl AE tamponu eklenerek DNA elüe edilmiştir.

Elde edilen genomik DNA örnekleri −20 °C'de saklanmış ve kalite kontrolü amacıyla %1 agaroz jel üzerinde elektroforez yapılarak UV ışığı altında görüntülenmiştir.

β Tubulin Gen Bölgesinin PCR Analizi

İzole edilen DNA'larda β Tubulin gen bölgesi, bu bölgeye ait primerler kullanılarak PCR ile çoğaltılmıştır. PCR reaksiyonu toplam 50 µl hacimde olacak şekilde hazırlanmış; DNA, reaksiyon tamponu, $MgCl_2$, dNTP, primerler, Taq DNA polimeraz ve saf su içermiştir.

PCR koşulları; 95 °C'de ön denatürasyon, ardından 35 döngü boyunca denatürasyon, eşleşme ve uzama basamakları ile son uzama aşamasından oluşacak şekilde uygulanmıştır. PCR ürünleri %1,2 agaroz jel üzerinde elektroforezle ayrılmış ve UV ışığı altında görüntülenmiştir.

Dizi ve Filogenetik Analizler

PCR ile çoğaltılan β Tubulin gen bölgelerinin dizi analizleri hizmet alımı yoluyla gerçekleştirilmiştir. Elde edilen diziler BLAST programı aracılığıyla GenBank veri tabanındaki referans dizilerle karşılaştırılarak tür tayini yapılmıştır.

Ham dizi verileri BioEdit 7.2.5 yazılımı kullanılarak düzenlenmiş ve Clustal W modülü ile hizalanmıştır. Filogenetik ilişkilerin belirlenmesi amacıyla, çalışmaya ait diziler ve GenBank'tan alınan referans diziler birleştirilerek veri seti oluşturulmuş ve MEGA 7 yazılımı kullanılarak Maximum Likelihood yöntemiyle filogenetik ağaçlar oluşturulmuştur. Analizlerde 1000 tekrarlı bootstrap desteği kullanılarak sonuçlar değerlendirilmiştir.

SONUÇLAR

***Acarospora fuscata*, (Schrad.) Arnold**

Deskripsiyon: *Acarospora fuscata*, Acarosporaceae familyasına ait, yaygın olarak kabuksu tallus oluşturan ve kaya yüzeylerine sıkıca yapışık gelişen bir liken türüdür. Tallusu genellikle geniş, düzensiz biçimli areollerle karakterizedir ve mat görünümlü kahverengi tonlarda olup, merkez bölgelerde koyu kahverengi–siyaha yakın renklenmeler gözlenir. Areoller çoğunlukla çokgen, hafif

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bombe yapılı ve 0.3–1.5 mm arası değişen boyutlarda olup, yüzeyleri çatlaklı veya hafif granüler bir yapı sergileyebilir. Tallus alt kısmında belirgin bir prothallus genellikle bulunmaz ya da çok silik bir hat hâlinde görülür. Apotesyumlar siyaha yakın koyu kahverengi renkte, genellikle areollerin ortasında tek veya çoklu şekilde bulunur. Disk yapısı düz ya da hafif çukurlaşmış olabilir ve lekanorin tipte thalline margin taşır. Apotesyum kesitlerinde epihymenium koyu kahverengi, hymenyum ise daha açık tonlarda olup 60–80 µm kalınlığındadır. Askosporlar hiyalin, ellipsoid formda ve 1 hücreli olup türün genel morfolojik karakterleriyle uyumludur. Kimyasal spot testlerinde *A. fuscata* karakteristik olarak K+ sarı, C–, KC–, P– reaksiyonları vermesiyle tanınır. Bu kimyasal profil, özellikle benzer morfolojik özellikler gösteren *Acarospora thamnina* ve *Acarospora gallica* gibi türlerden ayrımında önemli bir ayırıcı özelliktir

Ekolojik olarak *Acarospora fuscata*, çoğunlukla silisik veya hafif asidik kaya substratlarında gelişir. Güneş alan açık alanlarda daha yaygın görülmekle birlikte yarı gölgeli kayalık yüzeylerde de bulunabilir. Türkiye'de geniş bir yayılışa sahip olup farklı rakımlarda çok sayıda lokaliteden rapor edilmiştir.

Taksonomik açıdan *A. fuscata*, Acarospora tür kompleksleri içinde morfolojik varyasyon gösterebilen bir türdür. Bu nedenle türün teşhisinde morfolojik karakterlerin yanı sıra ITS ve β-tubulin gibi gen bölgelerine dayalı moleküler veriler önemli rol oynar. Filogenetik analizlerde *A. fuscata*'nın diğer yakın türlerden moleküler olarak da ayrıldığı ve stabil bir klad içinde yer aldığı görülmektedir.



Şekil 1. *Acarospora fuscata*'nın morfolojik görüntüsü.

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***A. gallica* H. Magn.**

Deskripsiyon: *Acarospora gallica*, Acarosporaceae familyasının kabuksu tallus oluşturan türlerinden biridir ve çoğunlukla kayalık yüzeylere sıkıca yapışık gelişir. Tallusu geniş areollü bir yapı sergiler; areoller genellikle düzensiz çokgen formda olup sarımsı–kahverengi ile pas tonları arasında değişen mat bir yüzeye sahiptir. Tallusun merkez bölgelerinde daha koyu kahverengi tonlar hâkimken, kenar bölgeler nispeten daha açık renklidir. Areoller 0.5–1.5 mm çapında olup, yüzeyleri hafif granüler ya da çatlaklı bir görünüm sunar. Prothallus genellikle belirgin değildir veya çok ince bir hat şeklinde görülür.

Apotesyumlar tallusla uyumlu biçimde kahverengi–siyahımsı tonlarda, küçük çaplı ve çoğunlukla areoller üzerinde tekil ya da çoklu şekilde konumlanır. Disk yapısı düz veya hafif içbükey olabilir ve lekanorin tip marj taşır. Apotesyum kesitlerinde epihimenyum koyu kahverengi, himenyum ise 60–80 µm civarında daha açık renkli bir tabaka hâlinde izlenir. Askosporlar hiyalin, ellipsoid formda ve tek hücreli olup türün genel mikroskobik özellikleriyle uyumludur. Kimyasal reaksiyonlarda *A. gallica*, özellikle K+ sarı, C–, KC–, P– spot testi profiliyle karakterizedir. Bu reaksiyonlar, türü başta *Acarospora fuscata* ve *Acarospora rosulata* gibi benzer tallus morfolojisine sahip taksonlardan ayırmada önemlidir. Tallusun mat renklenmesi, apotesyum diskinin daha koyu oluşu ve areol yüzey dokusu da ayırt edici morfolojik karakterler arasındadır.

Ekolojik olarak *Acarospora gallica*, çoğunlukla silisik kayaçlar ve güneş alan açık kaya yüzeylerinde yayılış gösterir. Ilıman ve yarı kurak iklim bölgelerinde sıkça karşılaşılan tür, Türkiye'de farklı yükseklik ve lokalitelerde rapor edilmiştir. Tür, hem yatay hem hafif eğimli kaya yüzeylerine başarılı şekilde adapte olabilmektedir.

Taksonomik açıdan *A. gallica*, Acarospora cinsinin morfolojik açıdan değişken türleri arasında yer almakla birlikte, ITS ve β-tubulin gen bölgelerine dayalı moleküler analizlerde kararlı bir klad içinde konumlanmakta ve yakın türlerden güvenilir biçimde ayrılmaktadır. Filogenetik analizler, *A. gallica*'nın özellikle *A. fuscata* ve *A. rosulata* ile ilişkili tür kompleksleri içinde özgün bir çizgide yer aldığını göstermektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 2. *Acarospora gallica*'nın morfolojik görüntüsü.

***A. rosulata* (Th. Fr.) H. Magn.**

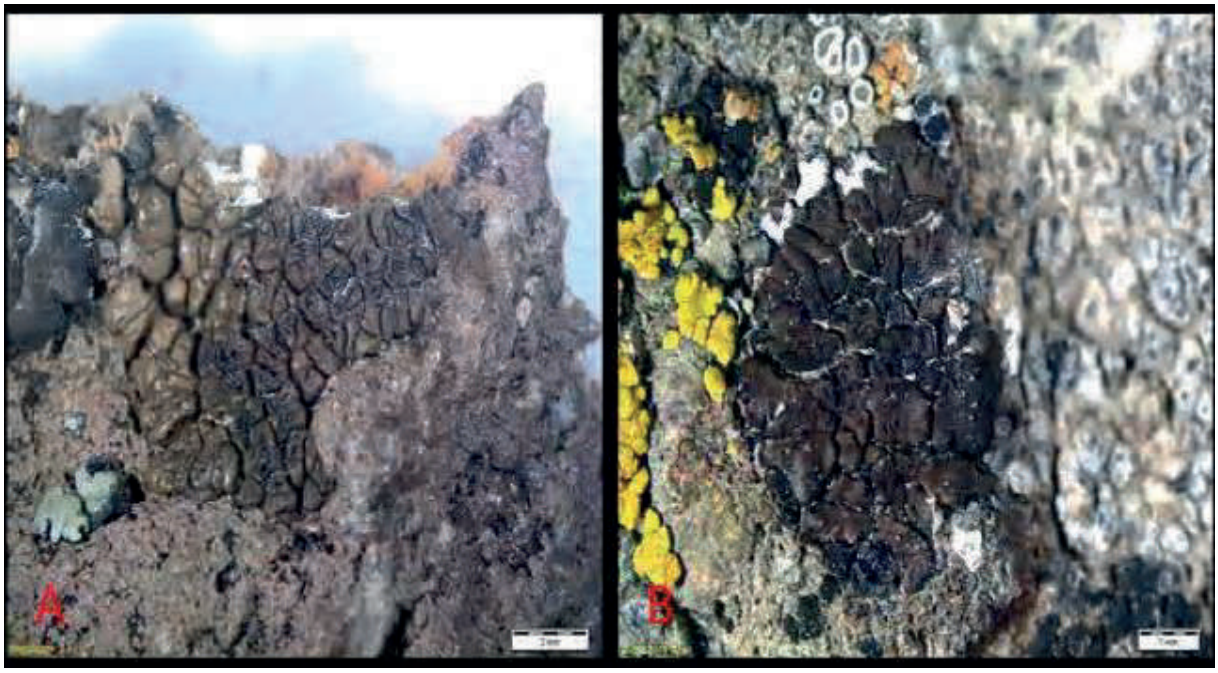
Deskripsiyon: *Acarospora rosulata*, Acarosporaceae familyasına ait, belirgin rozetleşmiş tallus yapısı ve kabuksu gelişim biçimiyle tanınan bir liken türüdür. Tallusu çoğunlukla kompakt ve rozet formunda olup, açık sarımsı–kahverengiden daha koyu pas–kahverengiye kadar değişen renk tonlarına sahiptir. Areoller merkezde daha sıkı ve birleşik bir yapı oluştururken, kenar kısımlarda rozet düzeninde dizilmiş, hafif bombe ve çokgen yapılı areoller hâkimdir. Areol yüzeyi genellikle mat, zaman zaman ince granüler dokulu olup 0.4–1.2 mm arası değişen boyutlar gösterebilir. Tallusun alt kısmında belirgin bir prothallus çoğu zaman bulunmaz veya çok zayıf şekilde gelişmiştir. Apotesyumlar genellikle areoller üzerinde tekil veya çoklu halde bulunur ve kahverengimsi–siyah tonlarda küçük diskler hâlindedir. Disk yapısı düz veya hafif içbükey olabilir. Tallin margin ince ve çevreyle uyumlu renktedir. Mikroskobik olarak epihymenium koyu kahverengi pigmentli, hymenyum ise daha açık renkli ve ortalama 60–80 µm kalınlığındadır. Askosporlar hiyalin, tek hücreli ve ellipsoid formda olup, türün anatomik karakteristiğiyle uyum gösterir. Kimyasal spot testlerinde *A. rosulata* tipik olarak K+ sarı, C–, KC–, P– reaksiyon profili verir. Bu kimyasal özellikler, özellikle *Acarospora fuscata* ve *Acarospora gallica* gibi morfolojik olarak benzer türlerden ayrılmasında ayırıcı önem taşır. Tallusun daha belirgin rozetlenmiş yapısı, areollerin kenarlarda halka görünümü oluşturması ve apotesyumların konumu bu türün tanınmasında kritik morfolojik karakterlerdir.

Ekolojik olarak *Acarospora rosulata*, çoğunlukla silisik veya hafif asidik kaya yüzeylerinde yayılış göstermekte olup güneş alan açık alanlarda tercih edilen bir substrata sahiptir. Ilıman ve yarı kurak

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ISBN: 978-9952-610-30-7

iklimlerde yaygın olmakla birlikte geniş bir coğrafi dağılım göstermektedir. Düz veya hafif eğimli kaya yüzeylerinde güçlü bir kolonizasyon yeteneğine sahiptir.

Taksonomik açıdan *A. rosulata*, Acarospora cinsinin rozetleşmiş türleri içinde yer almakta ve morfolojik benzerlik gösterdiği diğer türlerden ayırt edilmesinde moleküler filogenetik veriler önemli rol oynamaktadır. ITS ve β-tubulin gen bölgelerine dayalı analizler, türün cins içindeki konumunu desteklemekte ve onu benzer komplekslerden ayıran genetik bir bütünlük göstermektedir.



Şekil 3. *Acarospora rosulata*'nın morfolojik görüntüsü.

***A. peliscypha* (Wahlenb.) Th. Fr.**

Deskripsiyon: *Acarospora peliscypha*, Acarosporaceae familyasının kabuksu tallus oluşturan ve özellikle kaya yüzeylerinde geniş areoller hâlinde gelişen karakteristik bir liken türüdür. Tallusu çoğunlukla kahverengimsi–sarıdan pas tonlarına uzanan renklerde olup geniş, düzensiz ve birbirine kaynaşmış areollerden meydana gelir. Bu areoller genellikle 1–3 mm çapında olup türün ayırt edici özelliği olan derin çukurumsu (scyphose) merkez yapısını taşıyabilir. Tallus yüzeyi çoğunlukla mat, yer yer ince granüler dokulu olup merkezden kenara doğru hafif kabarık veya çanak biçimli bir yapı sergileyebilir. Prothallus çoğu zaman belirgin değildir veya çok zayıf bir hat şeklinde izlenir. Apotesyumlar kahverengimsi–siyah renkte olup, çoğu zaman tallus areolleri içinde gömülü hâlde bulunur. Disk yapısı düz veya hafif içbükey olabilir ve genellikle areol merkezine yerleşmiştir. Thalline margin ince ve tallusla uyumlu renkte olup bazı örneklerde zayıf şekilde seçilebilir. Mikroskobik olarak epihymenium koyu kahverengi, hymenyum ise daha açık renkte olup ortalama 60–90 µm kalınlığında ölçülür. Askosporlar hiyalin, tek hücreli, ellipsoid formda ve türün anatomik

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karakteristiğiyle uyumludur. Kimyasal spot testlerinde *A. peliscypha* tipik olarak K+ sarı, C–, KC–, P– reaksiyon profili verir. Renklenme sonuçları, morfolojik açıdan benzerlik gösteren *Acarospora fuscata*, *Acarospora gallica* ve *Acarospora rosulata* gibi türlerden ayrımında önemli bir ayırıcı kriterdir. Ayrıca tallusun çukur biçimli areol yapısı ve yüzey dokusu bu türün tanınmasında oldukça karakteristiktir.

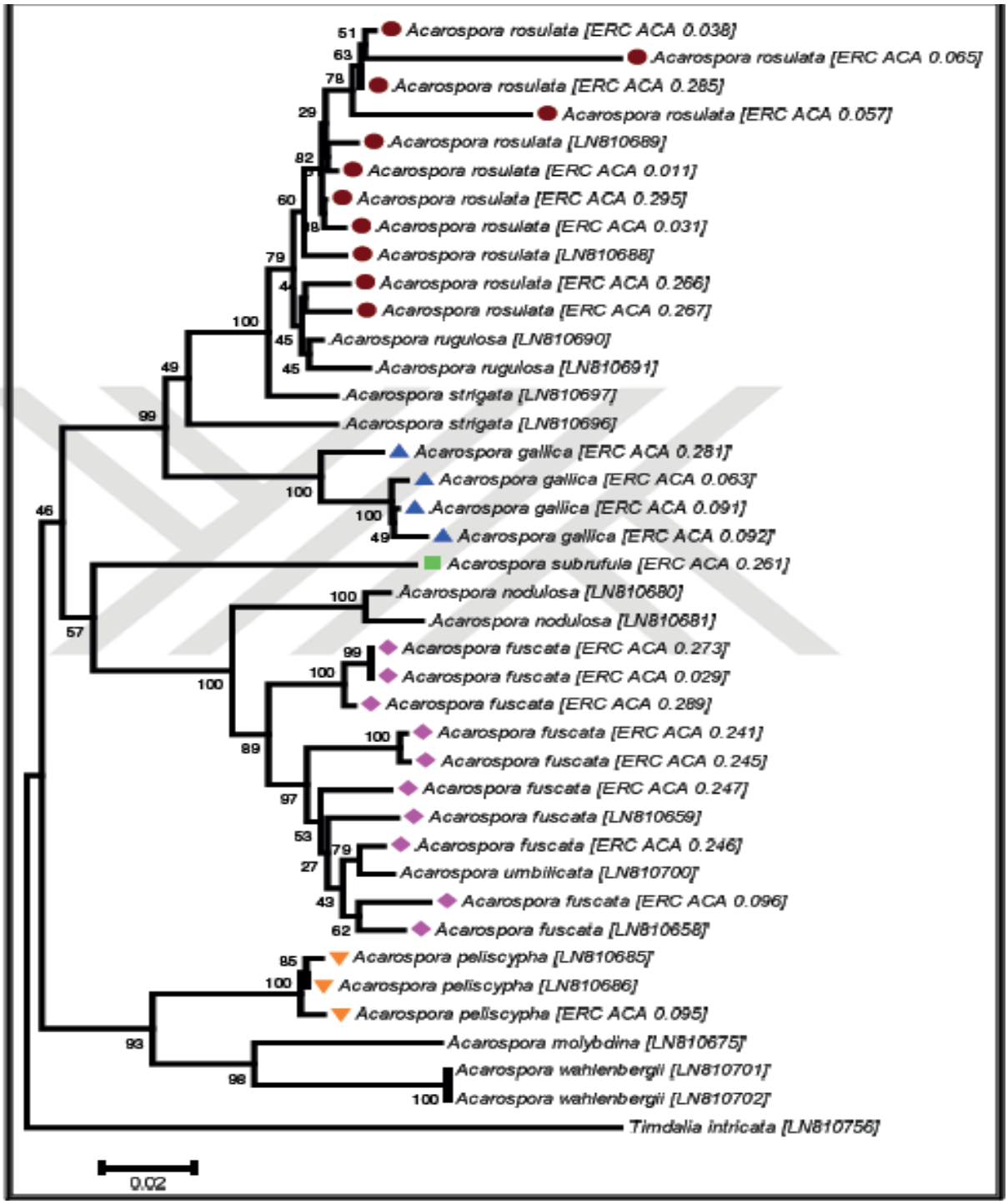
Ekolojik olarak *Acarospora peliscypha*, genellikle silisik ve hafif asidik kaya yüzeylerini tercih eder. Güneş alan açık veya yarı açık alanlarda yayılış gösterir ve hem düşük hem yüksek rakımlarda kolonileşebilen, çevresel stres faktörlerine dayanıklı bir türdür. Geniş bir coğrafi yayılışa sahip olup ılıman, soğuk ve yarı kurak iklimlerde kaydedilmiştir.

Taksonomik açıdan *A. peliscypha*, *Acarospora* cinsi içerisinde morfolojik varyasyon gösteren tür komplekslerinden birinin temsilcisidir. ITS ve β-tubulin gen bölgelerine dayalı moleküler filogenetik analizler, türün genetik olarak ayırt edilebilir bir klad içinde yer aldığını ortaya koymakta ve morfolojik karakterlerle desteklenen taksonomik konumunu güçlendirmektedir.



Şekil 4. *Acarospora peliscypha*'nın morfolojik görüntüsü.

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Şekil 5. Kimyasal reaksiyon sonucu renk oluşumuna sahip *Acarospora* cinsine ait türlerin Neighbor-Joining metodu kullanılarak oluşturulan β tubulin gen bölgesine ait filogenetik ağacı.

Tallus, korteks veya medullaya K, C ve KC uygulandığı zaman kırmızı renk veren (K+ kırmızı (norstiktik asit) ve C + kırmızı (giroforik asit)) *Acarospora* örneklerinde β tubulin gen bölgesi için oluşturulan filogenetik ağaç, Neighbor-Joining metodu kullanılarak gerçekleştirilmiştir. Evrimsel uzaklık MEGA programı içerisindeki, en iyi modelin belirlenmesi yöntemiyle seçilmiştir. Bu yöntem

sonucu en uygun metod Kimura-2 parametresi olmuştur. Bu analiz için 28 β tubulin gen bölgesine ait sekans kullanılmıştır. Boşlukları ve hataları içeren tüm pozisyonlar elimine edilmiştir.

İlk olarak sekans verileri manuel olarak Bioedit programında hizalanmıştır. Hizalaması yapılan örnekler ve gen bankasından alınan örnekler ile birlikte MEGA programı vasıtasıyla türler arasındaki evrimsel ilişkiyi görsel olarak gösteren filogenetik ağaç oluşturulmuştur. Dış grup olarak, *Timdalia intricata* kullanılmıştır. 676 nükleotid pozisyonunda olan dizi matriksi incelenmiş (korunmuş, 405; değişken, 259) ve 185 parsimoniyi bilgilendirici bölge olduğu belirlenmiştir.

A. rosulata, ilk defa 2023 yılında Türkiye için rapor edilmiştir (Güllü ve ark., 2023). Bu iki türün Anadolu'da dağılımı da çok benzer ve neredeyse aynı ekolojik şartlara sahiptirler. *Acarospora rosulata*, yelpaze şeklinde loplara sahip büyük belirgin tallusa ve açık bir şekilde ruguloz apotesyum diskine sahip olmamasıyla, *Acarospora bullata*'dan farklılık göstermektedir (Brinker and Knudsen, 2019).

Filogenetik ağa göre değerlendirildiğinde, çalışmada incelenen dört türün—*Acarospora rosulata*, *Acarospora gallica*, *Acarospora fuscata* ve *Acarospora peliscypha*—genetik olarak birbirlerinden net şekilde ayrıldığı ve her birinin güçlü şekilde desteklenmiş monofiletik kladlar oluşturduğu görülmektedir. Ağa en üstte konumlanan *A. rosulata*, yüksek bootstrap destekleriyle (78–100) iyi ayrışmış, homojen ve kompakt bir klad sergileyerek türün genetik olarak oldukça kararlı olduğunu göstermektedir. *A. gallica* da benzer şekilde iyi desteklenmiş bir monofiletik grup oluşturmakta ve yakınında yer alan *A. subrufula* ile birlikte olsa da ondan belirgin biçimde ayrılmaktadır; bu durum türün morfolojik karakterleriyle uyumlu bir genetik bütünlük taşıdığını göstermektedir. Ağın orta kısmında geniş bir örnek çeşitliliğiyle temsil edilen *A. fuscata*, çoklu örneklerine rağmen son derece güçlü bootstrap değerleri (95–100) ile tek bir klad içinde toplanmış, yani popülasyon içi varyasyon göstermesine karşın tür kimliğini moleküler düzeyde koruyan bir yapı sergilemiştir. Ağın alt bölümünde yer alan *A. peliscypha* ise diğer türlere kıyasla daha ayrık bir konumda bulunmakta ve iki örnekle temsil edilen grubunda yüksek destekli bir monofili göstermektedir; bu yerleşim, türün morfolojik olarak da bilinen ayırt edici çanak biçimli areol yapısıyla uyumlu biçimde genetik olarak farklılığını yansıtmaktadır. Genel olarak filogenetik ağa bakıldığında dört türün birbirinden net sınırlarla ayrıldığı, kladların yüksek destek değerleriyle doğrulandığı ve morfolojik ayrımların moleküler verilerle güçlü şekilde örtüştüğü görülmektedir.

TARTIŞMA

Bu çalışmada C (giroforik asit) ve K (norstiktik asit) nokta testi reaksiyonlarının *Acarospora* cinsindeki ayırt edici değeri, β-tübülin gen bölgesine dayalı filogenetik verilerle birlikte değerlendirilmiştir. Elde edilen sonuçlar, kimyasal spot testlerinin bu cins içinde hâlâ güçlü bir tanısal araç olduğunu ve moleküler bulgularla yüksek oranda uyum gösterdiğini ortaya koymaktadır. Özellikle incelenen dört türün—*A. fuscata*, *A. gallica*, *A. rosulata* ve *A. peliscypha*—her birinin β-

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tübülin filogenisinde belirgin ve yüksek destek değerlerine sahip monofiletik kladlar oluşturması, kimyasal reaksiyonlarla belirlenen tür sınırlarının moleküler olarak doğrulandığını göstermektedir. Bu durum, kimyasal testlerin tek başına yeterli olmadığı veya morfolojik benzerliklerin yüksek olduğu taksonlarda moleküler verilerin tamamlayıcı rolünü bir kez daha güçlendirmektedir.

Filogenetik ağda *A. rosulata*'nın yüksek bootstrap değerleriyle iyi ayrışmış ve genetik olarak oldukça kararlı bir klad oluşturması, türün hem morfolojik hem de kimyasal karakterlerle desteklenen bağımsızlığını ortaya koymaktadır. *A. gallica* ve *A. fuscata*'nın ayrı soy hatlarında konumlanması, bu iki türün arazi çalışmalarında zaman zaman birbirine benzemesine karşın, moleküler olarak açık bir şekilde ayrıldığını göstermiştir. Nitekim *A. fuscata*'nın geniş bir coğrafi varyasyon göstermesine rağmen tek ve güçlü bir klad içerisinde gruplanması, türün içsel genetik bütünlüğünü koruduğunu ve popülasyon içi morfolojik değişkenliklerin genomik seviyede tür sınırlarını etkilemediğini düşündürmektedir. Buna karşılık *A. gallica*, özellikle *A. rosulata* ve *A. subrufula* gibi türlerle birlikte değerlendirildiğinde, filogenetik yerleşimi ve kimyasal K+ reaksiyonunun tutarlılığı ile ayırt edilmektedir.

A. peliscypha ise analizlerde diğer türlerden daha düşük benzerlik oranlarıyla ayrılarak kendine özgü, yüksek destekli bir klad oluşturmuştur. Türün karakteristik çukurumsu areol yapısı ve kimyasal profilinin β-tübülin temelli filogenetik ayrımla uyuşması, morfolojik ve kimyasal karakterlerin birlikte kullanılmasının güvenilirliğini artırmaktadır. Ayrıca filogenetik yerleşimin literatürde bildirilen örneklerle tamamen örtüşmesi, kullanılan markırın bu tür için doğru taksonomik çözünürlüğü sağladığını göstermektedir.

Çalışmadan elde edilen genel bulgular, hem kimyasal spot testlerinin hem de β-tübülin gen bölgesinin *Acarospora* türlerinin ayrımında birbirini tamamlayıcı nitelikte olduğunu göstermektedir. Nitekim literatürde de, özellikle morfolojik benzerlik gösteren *Acarospora* tür komplekslerinde tek başına morfolojinin yanıltıcı olabileceği, tür tespitinin kimyasal ve moleküler verilerle desteklenmesi gerektiği vurgulanmaktadır. Bu çalışma da C ve K pozitif türlerde kimyasal reaksiyonların filogenetik akrabalıklarla yüksek derecede örtüştüğünü ortaya koyarak bu görüşü doğrular niteliktedir. Dolayısıyla kemotaksonomik karakterlerin, β-tübülin genine dayalı filogenetik analizlerle birlikte kullanılması, *Acarospora* cinsi içerisinde tür sınırlarının daha güvenilir şekilde belirlenmesine önemli katkı sağlamaktadır.

Likenlerin tür seviyesinde teşhisinde moleküler yöntemlerin kullanılması son derece önemli rol oynamaktadır. Daha fazla gen bölgesine ait çalışmaların sayısının artması gerekmektedir. Bu çalışmada görüldüğü gibi özellikle morfolojik olarak çok benzeyen türlerin ayrımında moleküler çalışmalar sonucu elde edilen verilerin önemli bir katkısı olmuştur. Bu yüzden ülkemizde liken biyoçeşitliliğinin doğru bir şekilde belirlenmesi için morfolojik ve anatomik karakterlerle yapılan teşhislerin moleküler yöntemlerle de desteklenmesi gerekmektedir.

TEŞEKKÜRLER

Bu çalışma; Erciyes Üniversitesi Bilimsel Araştırma Projeleri Birimi tarafından FDK-2015-5927 kodlu proje ile desteklenmiştir.

KAYNAKLAR

Ahmadjian, V., & Jacobs, J. B. (1982). Artificial re-establishment of lichens. III. Synthetic development of a gelatinous lichen from a cyanobacterium and a fungus. The Lichenologist, 14(2), 149–161. https://doi.org/10.1017/S0024282982000266

Boustie, J., Grube, M., & Guez, D. (2011). Lichens—a promising source of bioactive secondary metabolites. In R. J. Ko (Ed.), Progress in the chemistry of organic natural products (Vol. 95, pp. 1–55). Springer. https://doi.org/10.1007/978-3-7091-0381-1_1

Calcott, M. J., Ackerley, D. F., & Knight, A. (2018). Secondary metabolism in lichens: a review and future perspectives. New Zealand Journal of Botany, 56(3), 197–222. https://doi.org/10.1080/0028825X.2018.1477631

Çobanoğlu, G. (2007). Türkiye Liken Florasına Katkılar. Ankara: Gazi Üniversitesi Yayınları.

Çobanoğlu, G., Türk, A. O., & Tay, T. (2010). Bazı Liken Asitlerinin Antimikrobiyal Etkileri. Türk Hijyen ve Deneysel Biyoloji Dergisi, 67(1), 13–18.

Galloway, D. J. (1992). Lichen biogeography. In G. A. Wrighley & M. Black (Eds.), Lichenology: Progress and Problems (pp. 161–185). London: Systematics Association.

Gao, P., Liu, Y., Wang, Y., & Zeng, W. (2016). Adaptation mechanisms of lichen to extreme environments. Mycosphere, 7(9), 1236–1247. https://doi.org/10.5943/mycosphere/si/2c/5

Garty, J. (2001). Biomonitoring atmospheric heavy metals with lichens: theory and application. Critical Reviews in Plant Sciences, 20(4), 309–371. https://doi.org/10.1080/073526801753729197

Henskens, F. L. (2012). Photobiont diversity in lichens and their relationship to the mycobiont. Lichenologist, 44(6), 661–678. https://doi.org/10.1017/S0024282912000523

Jha, S., Mehra, A., & Walia, S. (2017). Bioactive secondary metabolites from lichens: chemistry and biological activities. Natural Product Research, 31(9), 1017–1030. https://doi.org/10.1080/14786419.2016.1231239

Lücking, R., Hodkinson, B. P., & Leavitt, S. D. (2016). The 2016 classification of lichenized fungi in the Ascomycota and Basidiomycota – Approaching one thousand genera. Bryologist, 119(4), 361–416. https://doi.org/10.1639/0007-2745-119.4.361

Nash, T. H. (Ed.). (2008). Lichen Biology (2nd ed.). Cambridge University Press.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DEĞİŞEN KİL ORANINA SAHİP SİLTLERİN ŞİŞME POTANSİYELİ

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Özet

Bu tezde, siltli bir zemine farklı oranlarda (%8, %10, %15, %20, %30 ve %40) bentonit ilavesi eklenerek hazırlanan farklı numuneler üzerinde gerçekleştirilen deneyler ve bunlardan elede edilen zemin parametreleri arasındaki ilişkiler bulunmuştur. Deneyler; (i) tane boyu dağılımının belirlenmesi için hidrometre ölçümleri, (ii) plastisite davranışının ortaya konulması için Atterberg limitleri ve (iii) zemin davranışının saha uygulamalarına yansımasını temsil Eden kompaksiyon ve konsolidasyon-şişme basıncı değerlendirmelerinden oluşmaktadır. Bentonit oranına bağlı olarak değişen kil içeriğinin, suya karşı duyarlılığı ve şişme potansiyelini birlikte etkilediğini gözlemlenmiştir.

Numunelerin temel indeks özellikleri (kil oranı, Atterberg limitleri), kompaksiyon parametreleri (wopt ve γd, max) ve konsolidasyon deneylerinden türetilen şişme basıncı değerleri ile bentonit kil oranındaki artışın farklı deney parametrelerine nasıl yansıdığı değerlendirilmiştir.

Bentonit oranının %8'den %40'a yükselmesiyle kil oranının %13.40'dan %32.75'e çıktığı, LL'nin yaklaşık %33.85 seviyesinden %53.65 seviyesine yükseldiği ve PI değerinin %5.77'den %36.28'e çıkarak zeminin plastisite sınıfının düşük–orta plastisiteli silt karakterinden (ML/CL) yüksek plastisiteli killi davranışa (CL–CH) doğru evrildiği görülmektedir. Aynı artış eğilimi şişme basıncında çok daha belirgin olarak şişme basıncı 0.70 kPa'dan 5.80 kPa'a yükselmiştir. Bu durum, bentonit ilavesi ile artan montmorillonit içeriğinin su Alma kapasitesinin, zemin davranışı üzerinde Baskın hale geldiğini düşündürmektedir.

Anahtar Kelimeler

- Bentonit ilevasi
- Siltli zemin
- Konsolidasyon
- Kil oranı

- Atterberg limitleri
- Kompaksiyon
- Şişme potansiyel

SWELLING POTENTIAL OF SILTS VARYING CLAY CONTENT

Abstract

In this thesis, relationships between experimental results and soil parameters were investigated using different specimens prepared by adding bentonite to a silty soil at various proportions (8%, 10%, 15%, 20%, 30%, and 40%). The experimental program consisted of: (i) hydrometer analyses to determine particle size distribution, (ii) Atterberg limit tests to characterize plasticity behavior, and (iii) compaction and consolidation–swelling pressure evaluations representing the reflection of soil behavior in field applications. It was observed that the clay content varying with bentonite proportion simultaneously affected water sensitivity and swelling potential.

The influence of increasing bentonite content on different experimental parameters was evaluated through basic index properties of the specimens (clay content, Atterberg limits), compaction parameters optimum water content (w_{opt} and γd, max), and (maximum dry unit weight,), and swelling pressure values derived from consolidation tests.

As the bentonite content increased from 8% to 40%, the clay fraction rose from 13.40% to 32.75%, the liquid limit (LL) increased from approximately 33.85% to 53.65%, and the plasticity index (PI) increased from 5.77% to 36.28%. Accordingly, the soil plasticity classification evolved from low- to medium-plasticity silt behavior (ML/CL) toward high-plasticity clay behavior (CL–CH). A much more pronounced increasing trend was observed in the swelling pressure, which rose from 0.70 kPa to 5.80 kPa. This indicates that the water absorption capacity associated with the increasing montmorillonite content due to bentonite addition became the dominant factor controlling soil behavior.

Keywords

- **Bentonite addition**
- **Silty soil**
- **Consolidation**
- **Clay content**
- **Atterberg limits**
- **Compaction**
- **Swelling potential**

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Giriş ve Amaç

İnce taneli zeminlerde su içeriğindeki değişimlere bağlı olarak gelişen hacimsel deformasyonlar, geoteknik mühendisliğinde önemli mühendislik ve ekonomik problemlere yol açmaktadır. Özellikle şişme ve büzülme davranışı gösteren zeminlerde meydana gelen diferansiyel oturmalar, çatlaklar ve kabarmalar; hafif yapılar, yol altyapıları ve dolgu alanlarında ciddi hasarlara neden olabilmektedir (Chen, 1988; Nelson ve Miller, 1992).

Zeminlerin şişme davranışında kil mineralojisi ve toplam kil içeriği temel belirleyicilerdir. Özellikle montmorillonit gibi genleşebilir kil mineralleri yüksek su tutma kapasitesi nedeniyle hacimsel değişimleri artırmaktadır (O'Neill ve Poormoayed, 1980). Bununla birlikte, silt fraksiyonu da su hareketi, boşluk oranı ve tane yapısı üzerinden şişme davranışını dolaylı olarak etkilemektedir (Sridharan ve Rao, 2001).

Hacimsel kararsızlık problemlerine karşı en yaygın çözümlerden biri zemin stabilizasyonudur. Literatürde kireç, uçucu kül, mermer tozu, kimyasal katkılar ve farklı mineral katkılarının ince taneli zeminlerin plastisite, mukavemet ve şişme özellikleri üzerindeki etkilerini inceleyen çok sayıda deneysel çalışma bulunmaktadır. Bu çalışmalar, katkı oranının stabilizasyon performansı üzerinde belirleyici olduğunu ve optimum oranların aşılması durumunda mühendislik özelliklerinde olumsuz değişimler meydana gelebileceğini göstermektedir. Ayrıca bentonit ve diğer mineral katkılarının şişme davranışını önemli ölçüde artırabildiği ya da azaltabildiği, bu etkinin mineralojik yapı ve su muhtevasına bağlı olduğu vurgulanmaktadır.

Bu tez çalışmasının amacı, siltli bir zemine farklı oranlarda bentonit ilavesi yapılarak kil içeriğindeki artışın zeminlerin indeks özellikleri, kompaksiyon karakteristikleri ve şişme basıncı üzerindeki etkilerini deneysel olarak incelemektir. Çalışmada ayrıca silt–kil etkileşiminin şişme davranışındaki rolünün ortaya konulması ve elde edilen sonuçların siltli zeminlerin mühendislik uygulamalarına katkı sağlaması hedeflenmektedir.

MATERYAL VE YÖNTEM

- **Likit limit tayini**
- **Plastik Limit Tayini**
- **Hidrometre Deneyi**
- **Kompaksiyon ve Su Muhtevası**
- **Konsolidasyon Deneyleri**

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ISBN: 978-9952-610-30-7

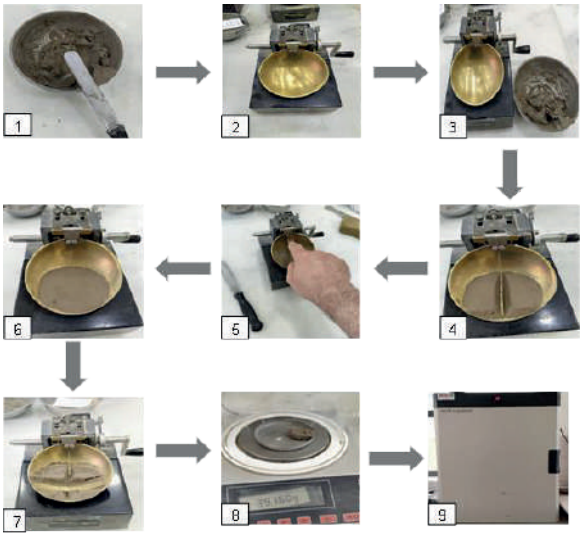
Piziksel Deneyler

Likit limit Tayini

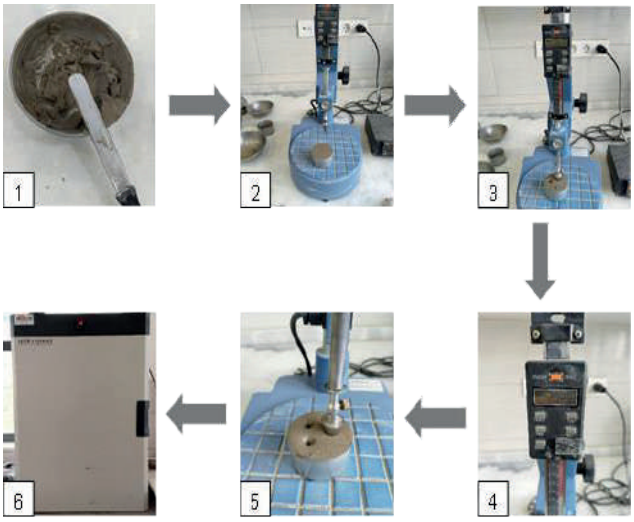
Bu çalışmanın deneysel aşaması, silt zeminlerin şişme potansiyelindeki değişimin kil oranı ile ilişkisini nicel olarak belirlemek üzere, ASTM D4546 (Atama: D4546-14) standardının belirlediği prosedürlere sıkı sıkıya bağlı kalınarak yürütülmüştür. Çalışmada, kontrollü koşullarda yeniden oluşturulmuş (rekonstitüe) zemin örnekleri kullanılmış ve deneyler, ödomometre cihazında tek boyutlu yükleme ve şişme esasına göre yapılmıştır.

Likit limit, yaygın olarak Casagrande yöntemi ile belirlenmektedir. Bu yöntemde, 40 numaralı elekten geçirilen ve su ile homojen hâle getirilen numune likit limit kabına yerleştirilir ve standart oluk açıldıktan sonra cihaz saniyede yaklaşık iki darbe hızında çalıştırılır. 25 darbe sonunda akma yoluyla kapanmasına karşılık gelen su muhtevası, zeminin likit limiti (w_L) olarak kabul edilir. Elde edilen değerler yarı logaritmik eksende değerlendirilerek akış eğrisi oluşturulur.

Alternatif olarak likit limit, konik penetrometre (fall cone) yöntemi ile de belirlenebilmekte olup, bu yöntemde belirli ağırlıktaki koninin zemine batma miktarı esas alınmaktadır.



Şekil 1. Casagrande Deneyi Uygulama Aşaması



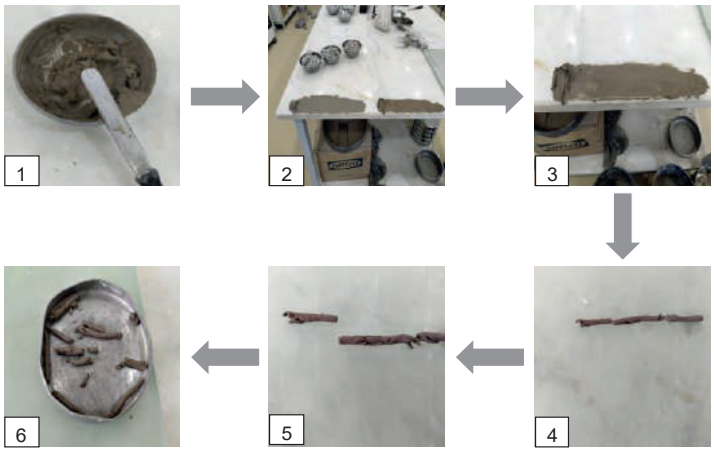
Şekil2. Koni Penetrasyon Deneyi Uygulama Aşamasi

Plastik Limit Tayini

Plastik limit (w_p), ince daneli zeminlerin kıvam sınırlarını belirleyen Temel Parametrelerden biridir ve zeminin 3 mm çapında silindirik şeritler hâline yuvarlandığında ilk çatlama veya dağılmanın meydana geldiği su muhtevası olarak tanımlanır. Bu değer, zeminin yarı katı durumdan plastik davranışa geçtiği kritik sınırı ifade Eder ve plastisite indisinin hesaplanmasında doğrudan kullanılır.

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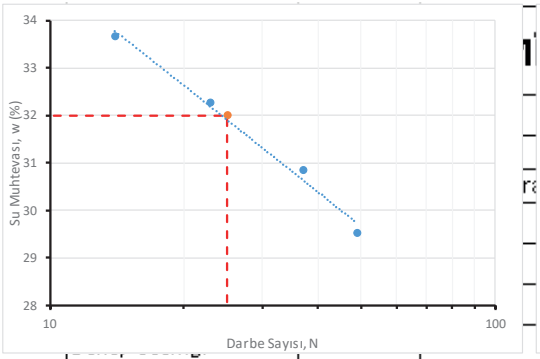
Deney, ASTM D4318 ve TS 1500 standartlarına uygun olarak gerçekleştirilmiştir. Likit limit numunesinden alınan zemin, uygun plastiklikte hazırlanarak cam plaka üzerinde 3 mm çapına Kadar yuvarlanır. Şerit bu çapta çatlayıp parçalandığında numune alınarak su içeriği belirlenir. Deney en az üç tekrar ile yapılır ve elde edilen su muhtevalarının ortalaması plastik limit (w_p) olarak Kabul edilir.

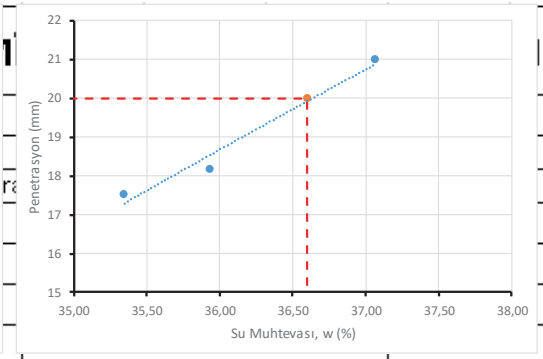


Şekil 3. Plastik Limit Deneyi Laboratuvarda uygulama Aşamaları

Tablo 3.1' de %8 Bentonit kili için gerçekleştirilen likit limit ve plastik limit deney sonuçları gösterilmiştir. Bu verilere dayana-ılarak hazırlnan grefikler ise Şekil 3.5 ve Şekil 3.7' de sunulmuştur. Tüm karışımlar için söz konusu deneyler yürütülmüş ve sonuçları Tablo 3.1' de özetlenmiştir.

Tablo 1. Plastit Limit ve Likit Limit tayini





EY FÖYÜ

Deney	LL - Casagrande				LL - Koni Penetrometre			PL
	1	2	3	4	1	2	3	1
Kap No:	376	373	358	367	323	309	365	320
Kap + Örnek (g):	38,51	42,35	39,92	35,45	28,61	30,36	27,47	31,22
Kap + Kuru Örnek (g):	35,379	38,583	36,285	31,7	26,526	28,713	25,35	29,955
Kap Ağırlığı (g):	26,08	26,91	24,5	19	20,63	24,13	19,63	25,45
Darbe Sayısı, N :	14	23	37	49	17,53	18,18	21	
Wn :	**33,67**	**32,27**	**30,84**	**29,53**	**35,35**	**35,94**	**37,06**	**28,08**
Likit Limit WL:	**31,58**				**36,12**			**28,08**
Likit Limit LL (ort.):	**33,85**							
Plastik Limit PL:	**28,08**							
Plastisite İndisi Ip :	**5,77**							
Zemin Sınıfı(USCS) :	**ML-ML/ CL**	**Düşük Plastisite Düşük Şişme**						

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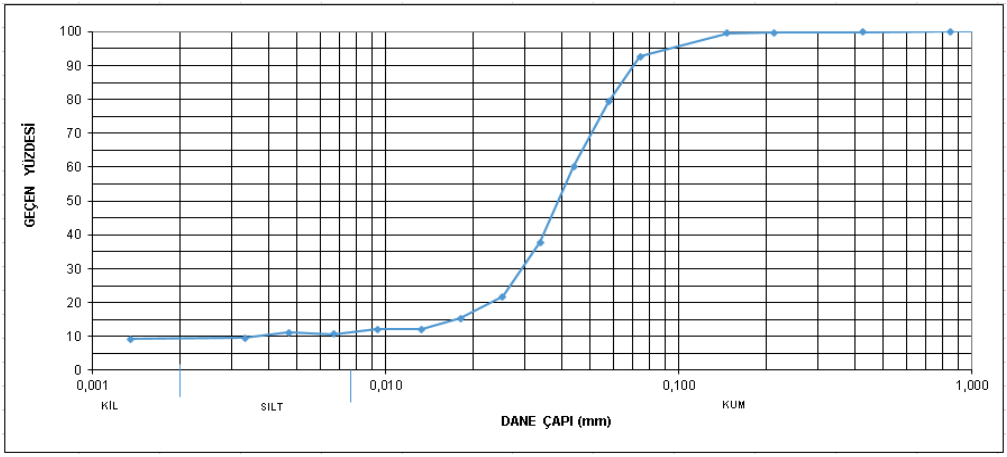
Şekil 4. Casagrande deneyini Grafiği Şekil 5. Koni Penetrometre deneyi Grafiği

Tablo 2. Kil Oranına Göre Karşılaştırma (Laeg1979 ve Leonards1962)

Numune	Kil Oranı	Likit Limit(LL)	PlastiK Limit(PL)	Plastik indisi(PI)	USCS Sınıfı	Plastisite (Ip) LAEG 1979 GÖRE	Plastisite (Ip) Leonards 1962 GÖRE
1	%8 Bkil	33,85%	28,08	5,77	ML-ML/CL	Düşük Plastisiteli	Plastik değil (Non Plastic - NP)
2	%10 Bkil	30,78%	27,58	6,99	ML-ML/CL	Düşük Plastisiteli	Az Plastisiteli
3	%15 Bkil	36,67%	26,03	10,64	ML-CL	Orta Plastisiteli	Orta Derece Plastisiteli
4	%20 Bkil	37,99%	26,35	11,64	CL	Orta Plastisiteli	Orta Derece Plastisiteli
5	%30 Bkil	45,99%	16,78	29,21	CL	Yüksek Plastisiteli	Plastik
6	%40 Bkil	53,65%	17,37	36,28	CH	Çok yüksek Plastisiteli	Plastik

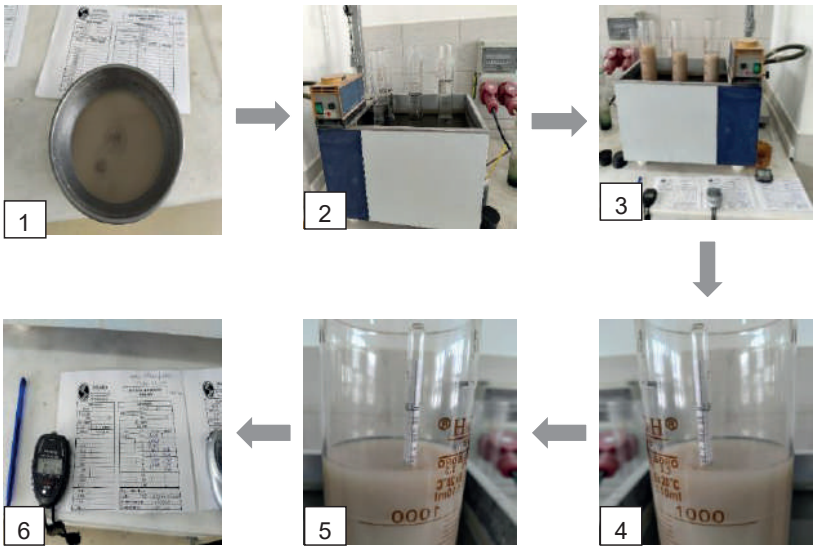
Hidrometre Deneyi

Hidrometre deneyi, ince daneli zeminlerde tane boyu dağılımını belirlemek amacıyla çökelme prensibine dayalı olarak uygulanmaktadır. Yöntem, danelerin su içerisindeki çökme hızını esas alan Stokes yasına dayanmaktadır (Orhan vd., 2004). Deneyde, su ile homojen şekilde karıştırılan numune çöktürme silindirine yerleştirilir ve belirli zaman aralıklarında hidrometre okumaları alınarak süspansiyon yoğunluğu belirlenir. Elde edilen veriler kullanılarak Stokes eşitliği yardımıyla Dane çapları hesaplanır.



Şekil 6.Hidrometre deneyi %8 Kil Oranını Eğrisi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 7. Hidrometre deneyi Laboratuvar uygulama Aşaması

Kompaksiyon ve Su Muhtevası

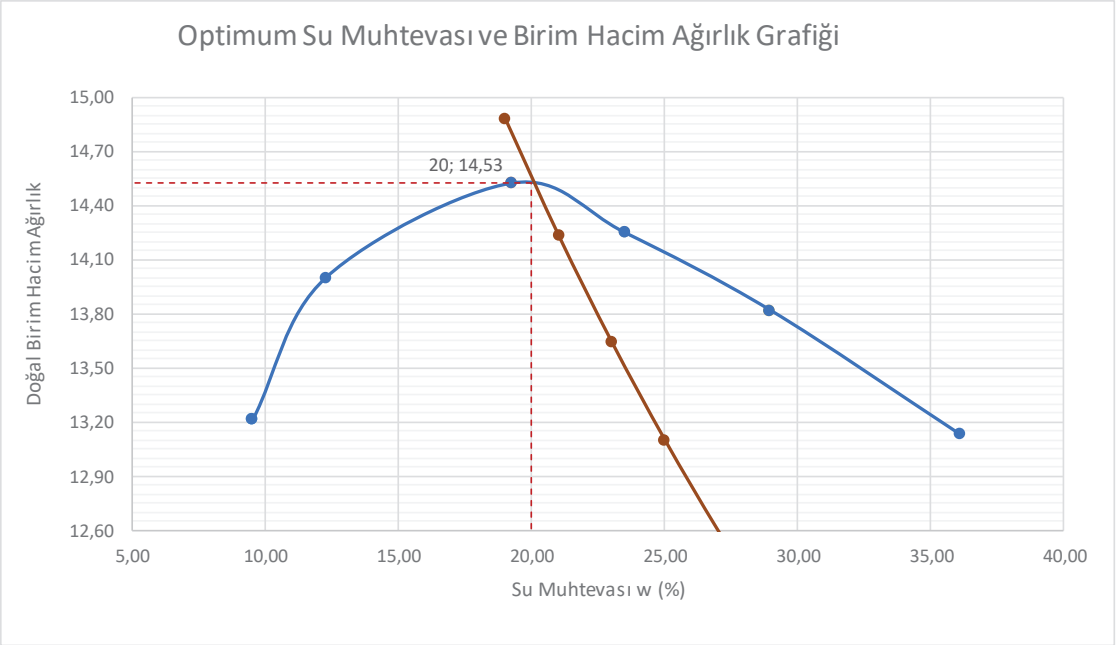
Su muhtevası (w), ince daneli zeminlerin kayma mukavemeti ve sıkışabilirlik davranışı üzerinde belirleyici bir parametredir. Kohezyonlu zeminlerde su içeriğinin artması genellikle kayma direncini azaltırken sıkışabilirliği artırmaktadır. Su muhtevası, boşluklardaki su kütlesinin kuru zemin kütlesine oranı olarak tanımlanmaktadır (Uzuner, 2007).

Zeminin kıvam durumu su içeriğine bağlı olarak değişmektedir. Su muhtevası likit limitin üzerine çıktığında zemin akışkan davranış gösterirken (Wn ≥ WLL), plastik limitin altına düştüğünde yarı katı özellik kazanır (Wn ≤ WPL). Plastik ve likit limitler arasındaki su içeriklerinde ise zemin plastik davranış sergilemektedir. Bu nedenle su muhtevası, kıvam özellikleri ve taşıma gücü başta olmak üzere birçok mühendislik özelliğini doğrudan etkilemektedir.

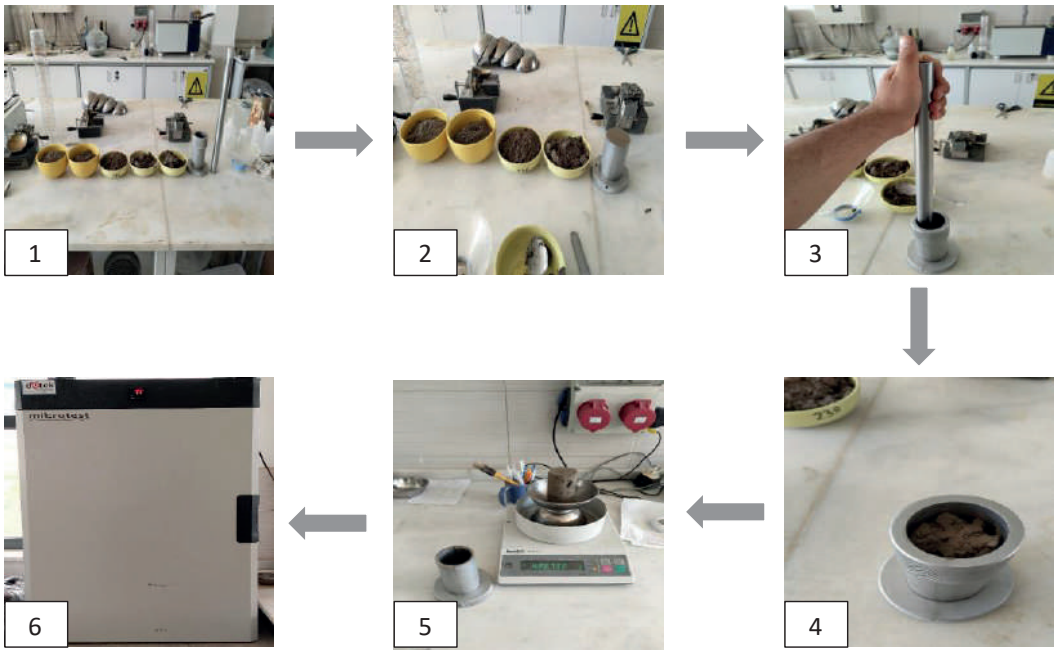
Tablo 3. %8 Kil Oranını Kompaksiyon Deneyi

HARVARD MİNİATURE KOMPAKSİYON DENEY FÖYÜ						
Proje:	Harvard Miniature Kompaksiyon Deneyi					
Örneğin Alındığı Yer:	Adapazar / Sakarya					
Örneğin Tanımı:	Siltlerin içinde %8 Kil Oranı					
Örnek No:			Deneyi Yapan:		ANSARULHAQ	
Derinlik:			Dane Özgül Ağırlığı		2,661	
Tarih:	14.07.2025		Örnek Ağırlığı (kg)		0,30	
20 mm ELEK	Geçen numune		Kalıbın İç Hacmi (cm3)		196,25	
Deney No:	1	2	4	4	5	6
Kalıp+Taban+Zemin Ağırlığı (gr.)	1946,5	1971,5	2003,5	2009	2013,5	2014,5
Kalıp+Taban Ağırlığı (gr.)	1657	1657	1657	1657	1657	1657
Sıkıştırılmış Zemin Ağırlığı (gr.)	289,5	314,5	346,5	352	356,5	357,5
Yaş Birim Hacim Ağırlık (kN/m3):	14,47	15,72	17,32	17,60	17,82	17,87
Kap No:	710	763	710	763	750	700
Kap Ağırlığı (g):	68,68	67,79	68,67	67,802	68,69	69,789
Kap + Yaş Örnek (g):	356,55	380,02	413,34	419,34	424,18	425,61
Kap + Kuru Örnek (g):	331,56	345,9	357,69	352,49	344,36	331,25
Su Muhtevası W:	**9,51**	**12,27**	**19,25**	**23,48**	**28,95**	**36,09**
Kuru Birim Hacim Ağırlık (kN/m3):	13,22	14,00	14,52	14,25	13,82	13,13
Optimum Su Muhtevası W:		20				
Optimum Birim Hacim Ağırlık (kN/m3):		14,53				

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 8. %8 Kil Oranını Su Muhtevasını Eğrisi



Şekil 9.Su Muhtevasını beli etmek için deneyi Laboratuvar uygulama Aşaması

Deneysel Programın Özeti

Bu çalışmada, farklı kil oranlarına sahip silt–kil karışımlarının şişme ve konsolidasyon davranışları, saha koşullarını temsil edecek biçimde standardize edilmiş laboratuvar prosedürleri ile incelenmiştir. Numune hazırlama aşamasından başlayarak tüm deney süreci, başlangıç yoğunluğu ve nem içeriğinin kontrolü esasına dayandırılmıştır.

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Numune Hazırlama ve Kompaksiyon

Her bir karışım için standart veya modifiye Proctor enerjisi altında kompaksiyon parametreleri belirlenmiş; optimum su içeriği (w_{opt}) ve maksimum kuru birim hacim ağırlık (γkuru,max) tespit edilmiştir. Deney numuneleri genellikle wopt değerinde veya kuru/ıslak tarafında seçilen sabit bir nem içeriğinde, hedef kuru yoğunluğa ulaşacak şekilde statik kompaksiyon yöntemiyle hazırlanmıştır.

Örnekler, standart ödomometre halkasına uygun boyutlarda hazırlanmış; sıkıştırma sonrası fazla kısımlar kesilerek yüzeyler düzeltilmiş ve son kuru birim hacim ağırlık ile nem içeriği kontrol edilmiştir.

Tek Boyutlu Şişme Deneyleri

Şişme davranışı, ASTM D4546 standardına uygun olarak iki temel prensipte incelenmiştir:

Şişme Basıncı Yöntemi (Test Yöntemi C)

Numune başlangıçta düşük bir yataklama gerilmesi altında suya doyurulmuş, dikey deformasyon sıfırda tutulacak şekilde yük artırılmıştır. Şişmenin tamamen engellenmesi için gerekli toplam gerilme, şişme basıncı (Pşişme) olarak belirlenmiştir.

Ardından ilave yüklemelerle zeminin normal konsolidasyon davranışı gözlemlenmiştir.

Yük Altında Şişme (Test Yöntemi A/B)

Belirli bir düşey gerilme seviyesinde numune suya doyurulmuş ve bu yük altında meydana gelen hacim değişimi zamanla kaydedilmiştir.

- Pozitif deformasyon → Şişme yüzdesi (S%)
- Negatif deformasyon → Hidrokompresyon (çökme)

Bu yöntem, kil oranının doğrudan şişme yüzdesi üzerindeki etkisini ortaya koymak için kullanılmıştır.

Konsolidasyon Deneyleri

Konsolidasyon özellikleri, ASTM D2435 standardına göre belirlenmiştir. Numuneler artan yük adımları altında konsolide edilmiş ve deformasyon-zaman verilerinden:

- Sıkışma İndeksi (Cc)
- Yeniden Sıkışma İndeksi (Cr)
- Ön Konsolidasyon Basıncı (Pc)
- Konsolidasyon süresi parametreleri (t50, t90)

Hesaplanmıştır.

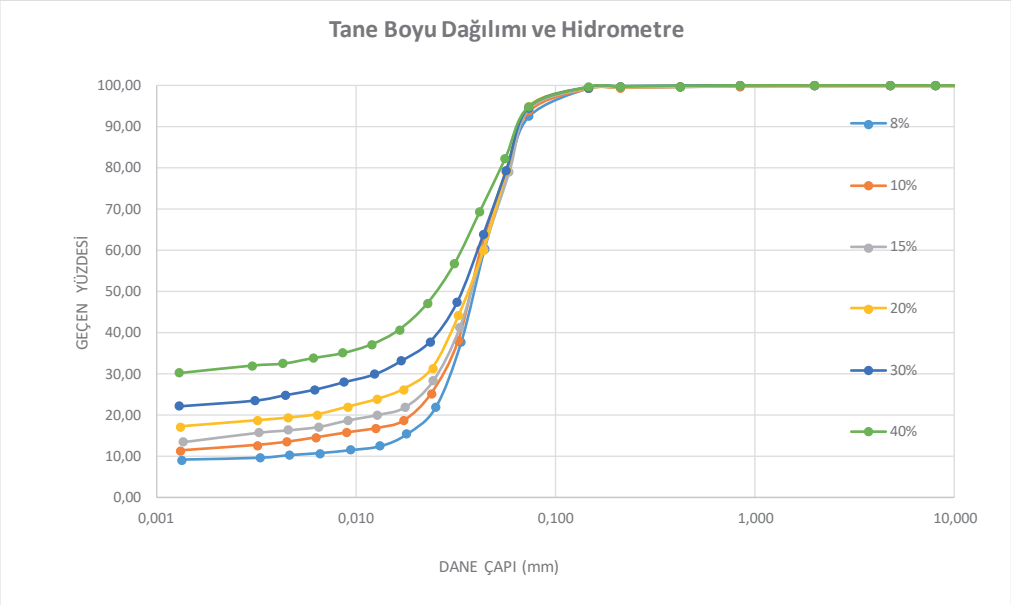
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Bu analizler sayesinde artan kil içeriğinin hem şişme potansiyeli hem de sıkışma karakteristiği üzerindeki etkileri karşılaştırmalı olarak değerlendirilmiştir.

BULGULAR

Tane Boyu Dağılımı ve Hidrometre

Hidrometre deneyi, siltli zeminin ince fraksiyon (özellikle kil boyutu) dağılımını ve bentonit ilavesi ile tane boyu dağılımındaki değişimi incel olarak ortaya koymak amacıyla gerçekleştirilmiştir. Bentonit katkısı, genel olarak kil boyutlu partikül oranını artırmaktadır. Bu artış, hem suya karşı duyarlılığı hem de plastisiteyi etkileyen temel mekanizma olarak karşımıza çıkmaktadır. Hidrometre sonuçlarından türetilen eğriler Şekil 10.'de karşılaştırmalı olarak verilmiştir.

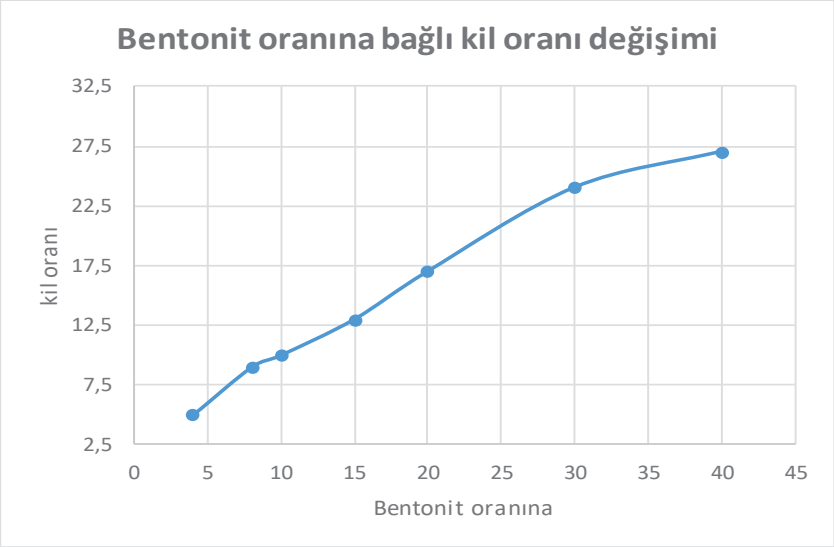


Şekil 10. Bentonit içeren numunelerin hidrometreye dayalı tane boyu dağılım eğrileri.

Şekil 10'deki eğriler birlikte değerlendirildiğinde, bentonit oranı arttıkça eğrilerin genel olarak daha yüksek "ince malzeme" yüzdelerine karşılık gelecek biçimde yer değiştirdiği görülmektedir. Başka bir ifadeyle, aynı eşdeğer çap değerinde yüksek bentonit içerikli numunelerin daha yüksek yüzdeyle ince malzeme içerdiği anlaşılmaktadır. Bu bentonit ilavesinin karışıma ek bir kil fraksiyonu kazandırdığını ve karışımın mikro yapısında boşluk suyu ile etkileşime giren aktif yüzey alanını artırdığını göstermektedir.

Hidrometre değerlendirme tablosundan hesaplanan toplam kil oranı, %8 bentonitli numunede %13.40 iken, %40 bentonitli numunede %32.75'e yükselmektedir. Bu artışın, ilerleyen bölümlerde sunulan plastisite ve şişme basıncı sonuçlarıyla paralel bir davranış sergilemesi, çalışmada gözlenen şişme potansiyeli artışının temel belirleyicisinin kil fraksiyonu olduğunu desteklemektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

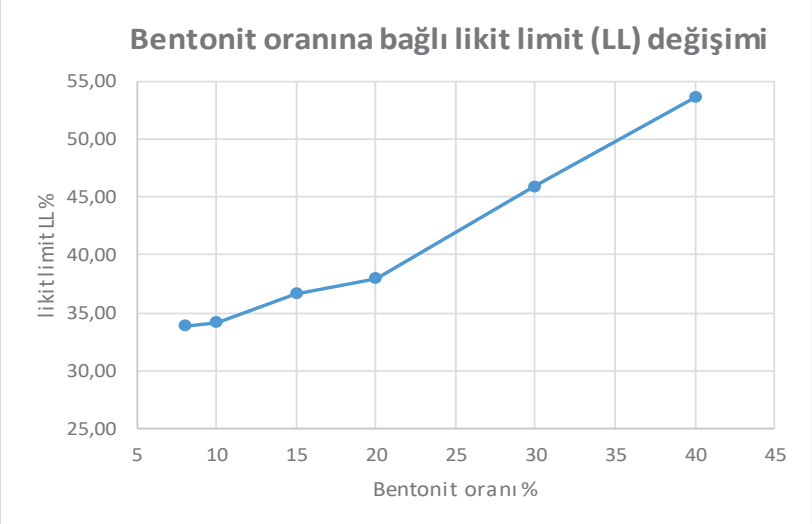


Şekil 11. Bentonit oranına bağlı kil oranı değişimi.

Şekil 11'de kil oranının bentonit oranı ile birlikte düzenli ve artan bir eğilim izlediği görülmektedir. Artışın %20 bentonit sonrasında ise daha belirgin hale gelmesi, karışımın ince fraksiyon açısından kritik bir eşiğe yaklaştığını ve karışım davranışının kademeli olarak kil kontrollü hale geldiğini göstermektedir.

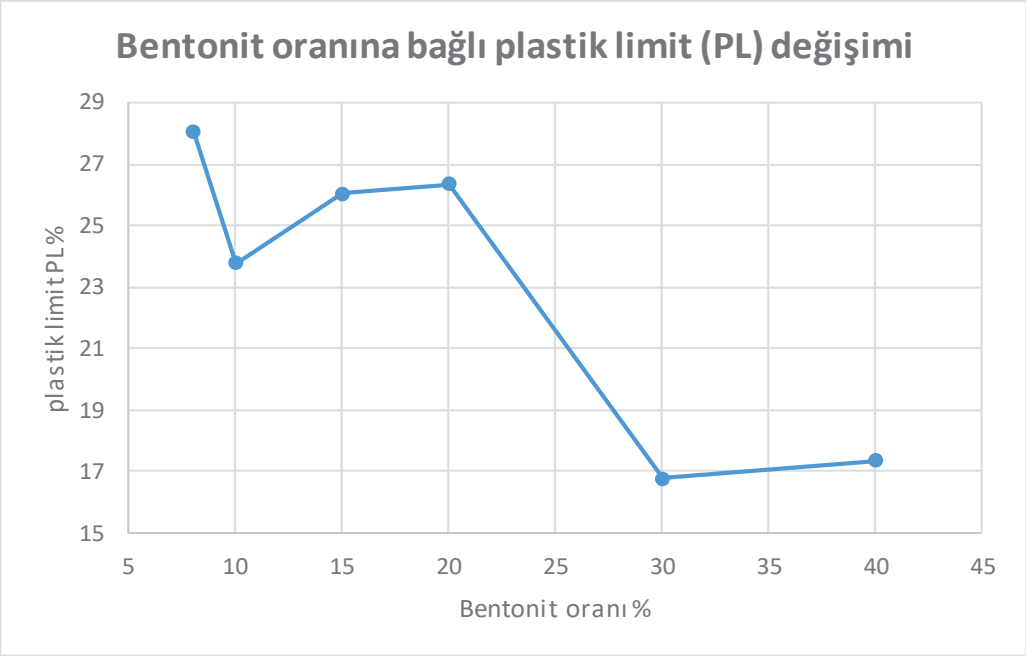
Atterberg Limitleri: Plastisite Davranışının Karşılaştırılması

Atterberg limitleri, zeminlerin su muhtevasına bağlı kıvam değişim sınırlarını tanımlayarak, plastisite ve hacim değişimi potansiyeli hakkında doğrudan bilgi veren temel indeks parametrelerdir. Bentonit gibi, aktif kil mineralleri içeren katkılar, likit limitin ve plastisite indisinin yükselmesine neden olurken; plastik limit değerlerini ise karışımın mineralojisine ve tane boyu dağılımına bağlı olarak farklı yönlerde etkileyebilmektedir. Bu kapsamda, her bentonit oranı için LL(Şekil 12.). PL(Şekil 13.) ve PI(Şekil14.) değerleri belirlenmiş ve sonuçlar hem sayısal hem de sınıflandırma boyutuyla değerlendirilmiştir.

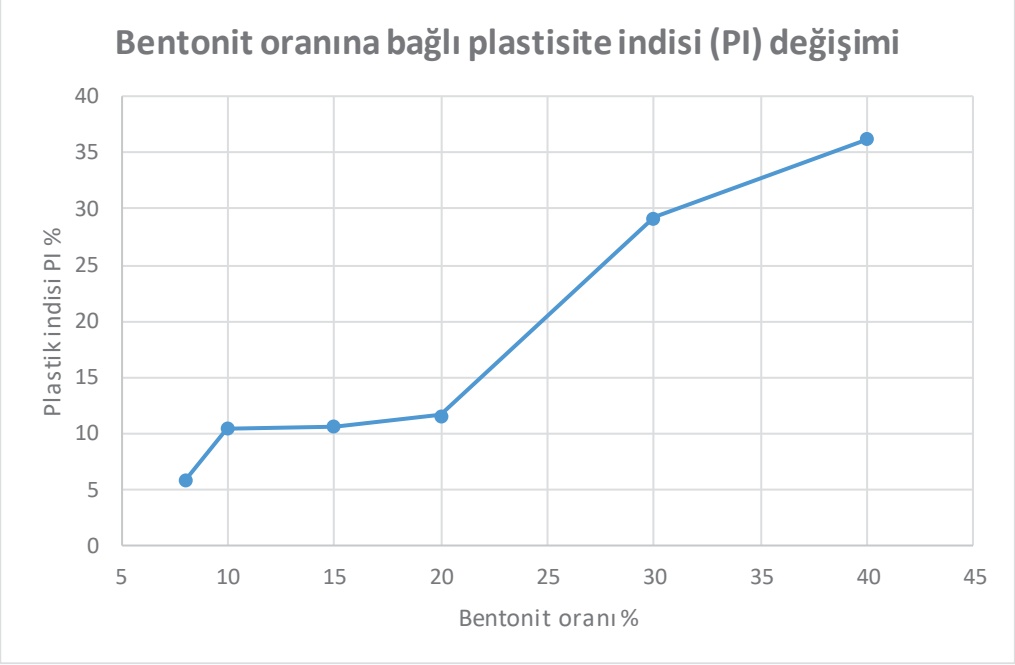


DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Şekil 12. Bentonit oranına bağlı likit limit (LL) değişimi.



Şekil 13. Bentonit oranına bağlı plastik limit (PL) değişimi.



Şekil 14. Bentonit oranına bağlı plastisite indisi (PI) değişimi.

Şekil 12–Şekil 13 birlikte değerlendirildiğinde, LL değerinin bentonit oranı arttıkça genel olarak arttığı, PL'nin %8–%20 aralığında yaklaşık %26–%28 bandında seyrederken %30 ve %40 numunelerinde belirgin şekilde daha düşük değerlere yaklaştığı görülmektedir. Bu durum, yüksek bentonit içeriğinde zeminin su ile etkileşiminin artması, daha düşük su muhtevasında dahi plastisite davranışı göstermesi ve karışımın kıvam sınırlarının kil kontrollü hale gelmesi ile açıklanabilir. En

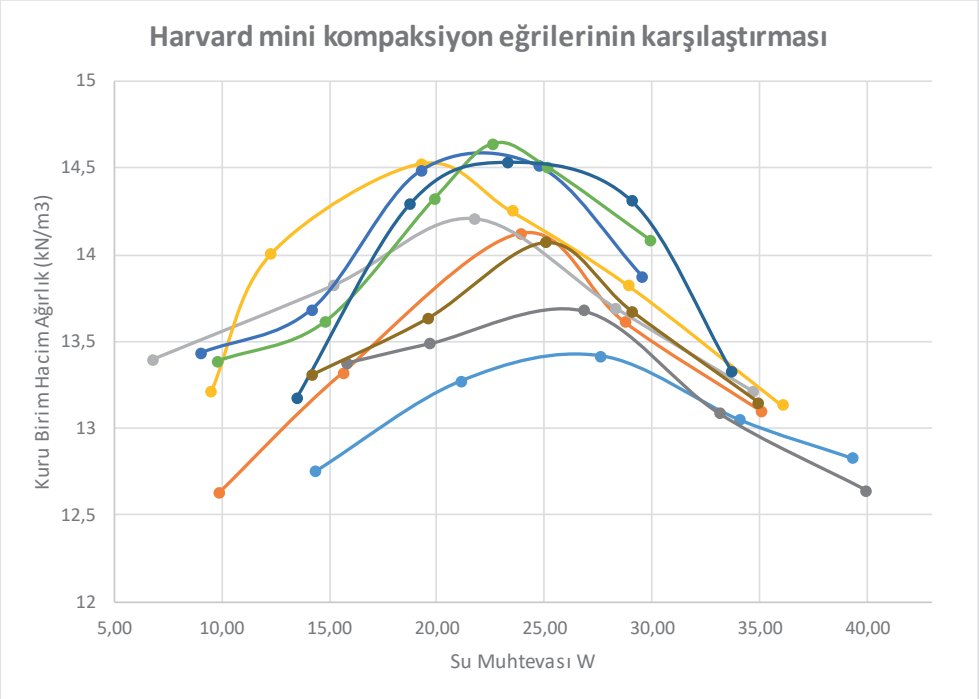
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kritik parametre olan PI, %8 bentonitli numunede %5.77 düşük plastisite iken %40 bentonitli numunede %36.28'e çıkarak çok yüksek plastisite davranışına işaret etmektedir.

Zemin sınıflandırması açısından sonuçlar incelendiğinde, %8–%10 numunelerinin ML–ML/CL aralığında (düşük plastisiteli silt-kil geçişi), %15 numunesinin ML–CL (orta plastisiteli geçiş) ve %20 numunesinin CL (orta plastisiteli kil) olarak sınıflandığı, %30 numunesinde CL (yüksek plastisite bandına yaklaşan kil) ve %40 numunesinde CH (çok yüksek plastisiteli kil) sınıfına geçildiği görülmektedir. Bu sınıf değişimi, şişme potansiyeli açısından önemli olup, özellikle CL–CH sınırına yaklaşan ve geçen numunelerde hacim değişimi problemlerinin mühendislik uygulamalarında kritik hale gelebileceğini göstermektedir.

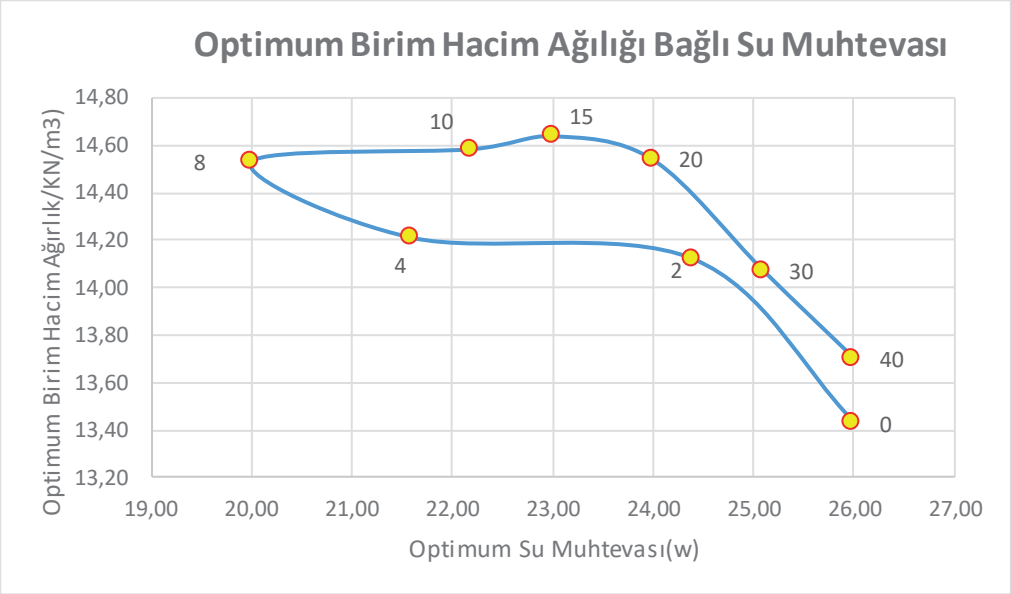
Harvard Mini Kompaksiyon Deneyi Karşılaştırması

Kompaksiyon deneyi, zeminlerin belirli bir sıkıştırma enerjisi altında ulaştığı maksimum kuru birim hacim ağırlık ($\gamma d,max$) ile bu sonuçlara karşılık gelen optimum su muhtevasını (w_{opt}) belirlemek amacıyla yapılmıştır. Bentonit ilavesi, zeminlerin su tutma kapasitesini artırarak optimum su muhtevasını yükseltme eğiliminde iken, yüksek plastisiteli ve ince fraksiyonlu zeminlerde maksimum kuru birim hacim ağırlığın düşmesine neden olabilmektedir. Bu çalışmada her karışımda elde edilen kompaksiyon eğrileri Şekil 15'da, w_{opt} ve $\gamma d,max$ değerleri ise Şekil 16 ve Şekil 17.'de sunulmuştur.

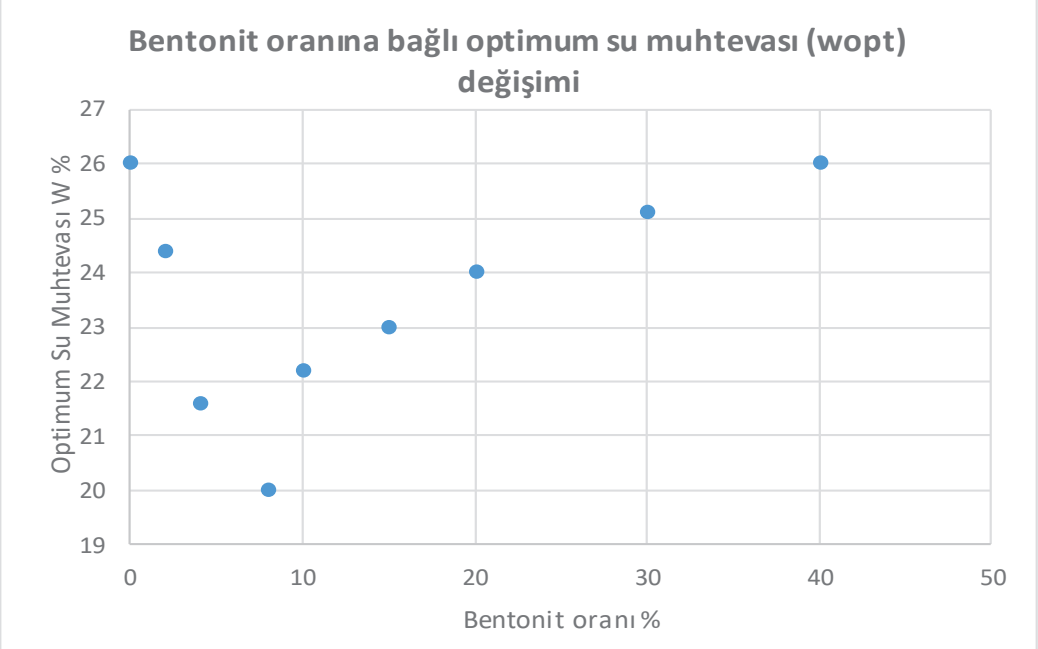


Şekil 15. Farklı bentonit oranları için Harvard mini kompaksiyon eğrilerinin karşılaştırması.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

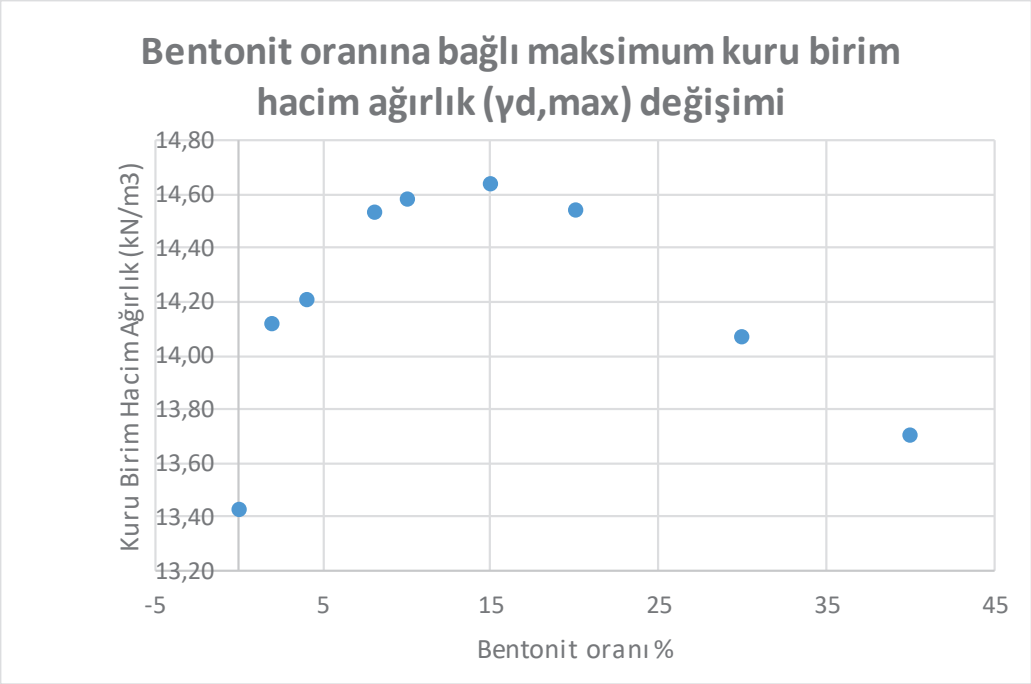


Şekil 4.7. Optimum Birim Hacim Aığılığı Bağıl Su Muhtevası



Şekil 16. Bentonit oranına bağlı optimum su muhtevası (w_{opt}) değişimi.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 17. Bentonit oranına bağlı maksimum kuru birim hacim ağırlık (γd,max) değişimi.

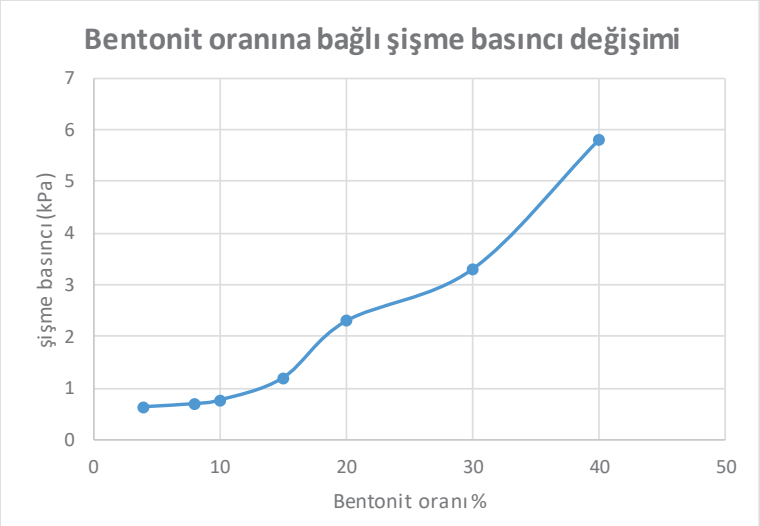
Şekil 4.8'de incelendiğinde, (w_{opt}) değerinin bentonit oranı arttıkça genel olarak yükseldiği görülmektedir. %8 bentonitli numunede $w_{opt} \approx$ %19.25 iken, %40 bentonitli numunede $w_{opt} \approx$ %26.83 seviyesine çıkmıştır. Bu artış, bentonitin yüksek özgül yüzey alanına sahip olması ve suyu adsorbe ederek karışımın su ihtiyacını artırması ile tutarlıdır. Şekil 4.8'de ise γd,max değerinin orta bentonit oranlarında (yaklaşık %15–%20) görece yüksek kalabildiği, ancak %30 ve %40 numunelerinde belirgin şekilde azaldığı görülmektedir. İnce fraksiyon artmasıyla birlikte tanecikler arası sürtünme ve su film kalınlığının artması, sıkıştırma altında daha düşük kuru yoğunluklara yol açmaktadır.

Kompaksiyon parametreleri, şişme potansiyeli ile birlikte mühendislik tasarımında doğrudan kullanılır. Örneğin, w_{opt}'ın yükselmesi, saha kompaksiyonunun daha yüksek su muhtevasında gerçekleştirilmesi gerekliliğine işaret ederken, γd,max'ın azalması; aynı sıkıştırma enerjisi altında daha düşük bir kuru yoğunlukla yetinileceğini veya daha yüksek enerji ve sıkıştırma prosedürü gerekebileceğini gösterebilir. Bu sonuçlar, özellikle yüksek bentonit içerikli karışımlarda (≥%30) saha uygulamalarının daha hassas kontrol gerektireceğini ortaya koymaktadır.

Konsolidasyon Deneyleri ve Şişme Basıncı

Konsolidasyon deneyleri kapsamında numunelerin şişme basınçları belirlenmiş ve bentonit oranı ile kil oranının şişme potansiyeli üzerindeki etkisi incelenmiştir. Şişme basıncı, özellikle su alımı ile hacim artışı eğilimi gösteren kil minerallerinin (örnek. montmorillonit) varlığında yükselmekte, zeminlerin temel ve üstyapı sistemlerinde oturma-şişme problemlerine neden olmaktadır. Bu nedenle şişme basıncı–bentonit oranı ve şişme basıncı–kil oranı ilişkileri çalışmanın ana çıktılarından biri olarak değerlendirilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 18. Bentonit oranına bağlı şişme basıncı değişimi.



Şekil 19. Kil oranına bağlı şişme basıncı değişimi.

Şekil 18'da şişme basıncının bentonit oranı arttıkça belirgin biçimde yükseldiği görülmektedir. %8 bentonitli numunede 0.70 kPa olan şişme basıncı, %20 bentonitli numunede 2.30 kPa'a, %40 bentonitli numunede 5.80 kPa'a ulaşmıştır. Artış eğilimi doğrusal olmayıp, özellikle %20 sonrası artış hızının yükseldiği dikkat çekmektedir. Bu davranış, karışımın kil kontrollü mikro yapıya geçmesi ve su–kil etkileşiminin şişmeyi Baskın mekanizma haline getirmesi ile açıklanabilir.

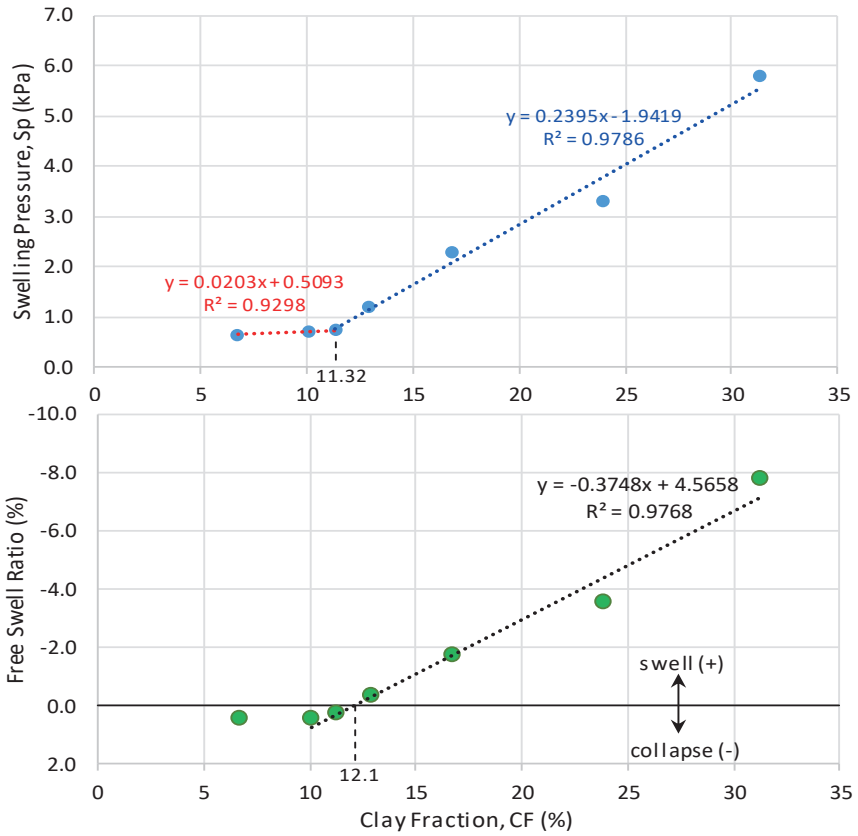
Şekil 19.'da şişme basıncının kil oranı ile güçlü bir ilişkisi olduğunu göstermektedir. Kil oranındaki artış, hem boşluk suyu basınçlarının dağılımını hem'de suyun adsorpsiyon-absorpsiyon kapasitesini etkileyerek hacim değişimi potansiyelini yükseltmektedir. Bu kapsamda, kil oranı %20'nin üzerine çıktığında şişme basıncının mühendislik açısından daha kritik seviyelere ulaştığı söylenebilir.

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Şişme Deneyi

İnce daneli zeminlerin bir diğer mühendislik özelliği de swelling potansiyelleridir. Su aldığında aşırı şişme sunan zeminler üzerlerindeki yapıya ağır zararlar verebilmektedir. Kilin şişme özelliği üzerinde kil minerolojisi ve bunun toprak yığını içinde bulunma yüzdesi önemli rol oynar. Bu çalışmada mineroloji montmorillonit ile sabit tutulmuş ancak bu kil (montmorillonit) silt içine farklı oranlarda eklenerek çeşitlilik sağlanmıştır.

Swelling potansiyelini belirlemek için ASTM D4546 standardı uyarınca ödometre testleri yapılmaktadır. Bu standartta şişme basıncı tayini için 3 farklı yöntem tanıtılmıştır (A, B and C methods), bu çalışmada A metodu kullanılarak şişme basınçları tayin edilmiştir. Şişme basınçlarının kil oranına göre değişimi ile 1 kPa altında göstermiş olukları Serbest şişme oranları Şekil de verilmiştir. Buradan görülebileceği gibi kil oranı arttıkça şişme basıncının beklendiği gibi arttığı izlenmiştir. Bununla birlikte %11.32 kil içeriği değerinden sonra eğimin belirgin bir şekilde arttığı tespit edilmiştir. Ayrıca %12.1' den daha düşük kil oranına sahip numunelerde göçme gözlemlenirken bu değerin üzerindeki kil oranlarında ise şişme hızla artmaktadır. (Şekil20.)

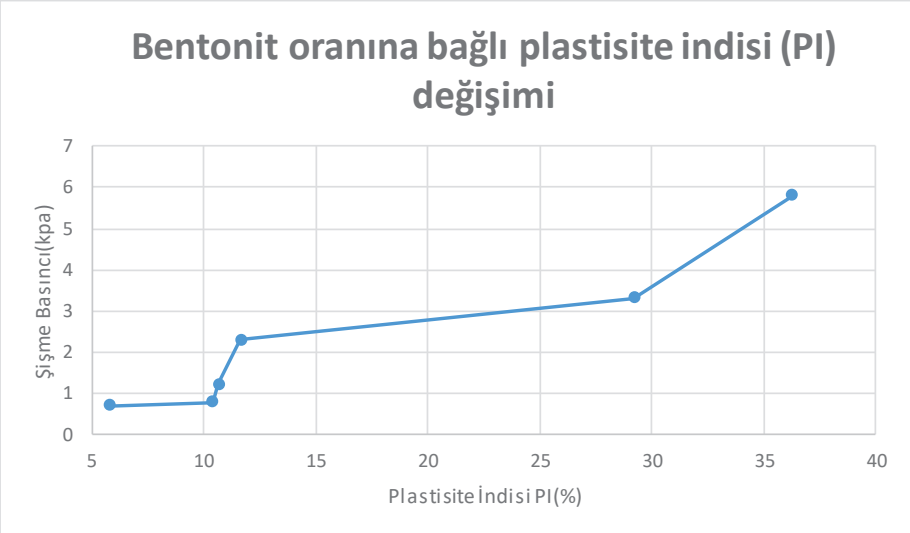


Şekil 20. Şişme deneyleri sonuçları

Parametreler Arası İlişkiler ve Tartışma

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Zeminlerin şişme davranışı tek bir parametre ile açıklanamayacak Kadar çok bileşenli olmakla birlikte, bu çalışma kapsamında kil oranı ve plastisite indisinin şişme basıncı ile birlikte artması, temel belirleyici mekanizmanın "aktif kil içeriği" olduğunu güçlü biçimde işaret etmektedir. Bu bölümde şişme basıncı ile plastisite indisi arasındaki ilişki elde edilmiştir.



Şekil 21. Plastisite indisi (PI) ile şişme basıncı arasındaki ilişki.

Şekil 21.'de PI değeri yükseldikçe şişme basıncının da arttığı görülmektedir. Bu beklenen bir sonuçtur, çünkü PI, zeminin su muhtevasındaki değişimlere duyarlılığını ve plastik davranış kapasitesini yansıtır. Düşük PI değerlerinde (%8–%10 numuneleri) şişme basıncı düşük seviyelerde kalırken, PI'nin %20'nin üzerine çıktığı yüksek bentonit içeriklerinde (%30–%40 numuneleri) şişme basıncı belirgin bir şekilde artmıştır. Bu ilişki, (plastisite–şişme) bağlantısının güçlü bir kanıtı olarak kullanılabilir.

Kompaksiyon açısından bakıldığında, w_{opt}'ın artması, zeminin aynı sıkıştırma enerjisinde daha fazla suya ihtiyaç duyduğunu göstermektedir. Yüksek bentonit içeriklerinde (w_{opt} artarken $\gamma d,max$'ın azalması), zeminin daha gevşek bir kuru yapı ile dengeye gelmesine yol açabilir. Bu durum, su ile temas halinde boşluk yapısının daha fazla değişebilmesi ve şişme eğiliminin tetiklenmesi açısından dolaylı bir risk faktörü oluşturur. Bu nedenle, yüksek bentonit içerikli zeminlerde saha kompaksiyonunun (w_{opt}) çevresinde ve kontrollü koşullarda yapılması kritik önemdedir.

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SONUÇLAR

Bu çalışma, bentonit ilavesinin siltli zeminlerin mühendislik özellikleri üzerinde doğrudan ve güçlü bir etkiye sahip olduğunu açık biçimde ortaya koymuştur. Bentonit oranı arttıkça zeminin ince Dane oranı ve plastisite indisi yükselmiş, buna bağlı olarak su tutma kapasitesi artmış ve hacim değişimi davranışı daha belirgin hale gelmiştir. Başka bir ifadeyle, zemin su ile temas ettiğinde daha fazla şişme eğilimi göstermiştir.

Özellikle %20 bentonit oranından sonra şişme basıncında gözlenen belirgin artış, zeminin davranış mekanizmasının değiştiğini göstermektedir. Bu seviyeden sonra zemin, silt ağırlıklı bir yapıdan kil kontrollü bir yapıya geçmekte ve şişme davranışı Baskın hale gelmektedir. Bu durum, bentonit oranının belirli bir eşik değerden sonra zeminin mühendislik performansını kritik düzeyde etkileyebileceğini göstermektedir.

Kompaksiyon deneyleri sonucunda bentonit oranı arttıkça optimum su muhtevasının yükseldiği belirlenmiştir. Bunun nedeni, bentonitin yüksek su adsorpsiyon kapasitesine sahip olmasıdır. Aynı zamanda maksimum kuru birim hacim ağırlık değerinin azalması, ince taneli yapının daha gevşek bir yerleşime neden olduğunu göstermektedir. Bu durum, saha uygulamalarında sıkıştırma işleminin daha dikkatli yapılması gerektiğini ortaya koymaktadır. Uygun nem koşullarında ve yeterli enerjiyle sıkıştırılmayan zeminlerde zamanla diferansiyel şişme, oturma ve yapısal hasar riskleri artabilecektir.

Ayrıca şişme basıncı ile plastisite indisi arasında güçlü bir ilişki belirlenmiştir. Bu sonuç, plastisite parametrelerinin şişme potansiyelinin tahmin edilmesinde güvenilir bir gösterge olduğunu göstermektedir. Dolayısıyla yalnızca tane boyu dağılımına dayalı sınıflandırmaların tasarım açısından yeterli olmadığı, plastisite özelliklerinin mutlaka dikkate alınması gerektiği anlaşılmıştır.

Genel olarak değerlendirildiğinde, bentonit oranındaki artışın hem şişme potansiyelini hem de konsolidasyon davranışını önemli ölçüde etkilediği ve zemin davranışının daha karmaşık hale geldiği sonucuna varılmıştır.

ÖNERİLER

- Yüksek bentonit veya kil içeriğine sahip zeminlerde suyun zemine girişini sınırlayıcı drenaj ve su yalıtım önlemleri mutlaka uygulanmalıdır.
- Saha kompaksiyonu, laboratuvar ortamında belirlenen optimum su içeriğine yakın değerlerde ve yeterli sıkıştırma enerjisi kullanılarak yapılmalıdır.
- Temel tasarımında plastisite indisi, şişme yüzdesi ve şişme basıncı birlikte değerlendirilmelidir.
- Yüksek şişme potansiyeli gösteren zeminlerde kireç veya çimento stabilizasyonu gibi zemin iyileştirme yöntemleri alternatif olarak değerlendirilmelidir.

- Uzun süreli performansın anlaşılabilmesi için ilave konsolidasyon ve hacim değişimi deneyleri yapılması önerilmektedir.

Sonuç olarak, bentonit katkılı siltli zeminlerde güvenli mühendislik tasarımı yapılabilmesi için zemin-su etkileşimi, şişme basıncı ve konsolidasyon davranışı birlikte ele alınmalı ve tasarım sürecinde bütüncül bir yaklaşım benimsenmelidir.

TEŞEKKÜR

Yüksek lisans eğitimim süresince değerli bilgi ve deneyimlerinden yararlandığım, her konuda bilgi ve desteğini almaktan çekinmediğim, araştırmanın tüm aşamalarında yardımlarını esirgemeyen, teşvik Aden, aynı titizlikte beni yönlendiren danışman hocam Prof.Dr.Ertan Bol Hocama teşekkür ederim.

Çalışmam süresince fikirlerini esirgemeyen Sakarya Üniversitesi öğretim üyeleri Prof. Dr.Aşkın ÖZOCAK , Prof. Dr. Sedat SERT'e ve yaptığım laboratuvar çalışmalarında her türlü konuda destek çıkan ve yardımcı olan Sakarya Üniversitesi Geoteknik Laboratuvar Görevlileri Recep EYÜPLER ve Sebahattin İŞ'e teşekkür ederim.

Hayatımın her aşamasında yanımda olan, iyi bir birey olarak yetişmeme gayret Eden, benden sevgi ve desteklerini esirgemeyen sevgili Eşim ve Aileme teşekkür ederim.

Ansarulhaq KHAİRKHAH

KAYNAKLAR

Acar, F. (2019). Kutlubey-Yazıcılar Bölgesi Killerinin Fiziksel Ve Mekanik Özelliklerinin Çatalağzı Uçucu Külü İle Stabilizasyonu. Yüksek Lisans Tezi. Bartın Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Anabilim Dalı, 108, Bartın.

Akan, R., Sungur, A., Keskin, S. ve Uzundurukan, S., 2017. İnce Daneli Zeminlerde Katkı Maddelerinin ve Donma-Çözülme Çevriminin Serbest Basınç Dayanımına Etkisi, Mühendislik Bilimleri ve Tasarım Dergisi, 5, 3, 473-478.

Akbulut, K., Akbulut, S. ve Yetimoğlu, T., 2008. Kimyasal Katkılarla Muamele Edilen Kil Zeminlerin Kıvam Limitleri, Zemin Mekaniği ve Temel Mühendisliği Onikinci Ulusal Kongresi, Selçuk Üniversitesi, 801-806, Konya.

ASTM D4546-20 (2021). Standard Test Methods for One-Dimensional Swell or Collapse of Cohesive Soils. ASTM International.

Al-Rawas, A. A. (1999). "The factors controlling the expansive nature of the soils and rocks of Northern Oman". Engineering Geology. 53/3. 327-350.

Atterberg, A. (1911). Über die physikalische Bodenuntersuchung und über die Plastizität der Tone. Internationale Mitteilungen für Bodenkunde, 1, 10–43.

Bilgen, G. (2011). Öğütülmüş çelikhane cürufu, kireç ve deniz suyunun killerin iyileştirilmesinde kullanımı. Doktora Tezi. Kocaeli Üniversitesi Fen Bilimleri Enstitüsü İnşaat Mühendisliği Anabilim Dalı, 294, Kocaeli.

Brackley, I.J.A. (1973) . "Swell pressure and free swell in a compacted clay". Proceedings of 3rd ınternational conference on expansive clay. 169-176.

Bray, J. D., ve Sancio, R. B. (2006). Assessment of the liquefaction susceptibility of fine-grained soils. Journal of Geotechnical and Geoenvironmental Engineering, 132(9), 1165–1177.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Brewer, R. (1965). Fabric and Mineral Analysis Of Soils. New York: John Wiley ve Sons. Charlie, W. A., M.A. Osman and E.M. Ali. (1984). “Construction on.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE INDUSTRIAL DESIGN JOURNEY OF ART NOUVEAU AESTHETICS: AN EVOLUTIONARY ANALYSIS FROM TRADITIONAL HANDICRAFTS TO THE STYLIZED FORMS OF THE 21ST CENTURY

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ABSTRACT

The Art Nouveau movement, which emerged at the end of the 19th century as a reaction to the industrialization and aesthetic poverty brought about by the Industrial Revolution, presented a revolutionary approach in the world of design that centered on nature's organic forms and the artist's original labor. This study aims to examine the historical industrial resistance of the Art Nouveau movement and the transformation of this resistance in 21st-century product design. The philosophy of "returning to nature," which is the fundamental basis of the movement, initially faced an economic barrier due to the high level of craftsmanship required and the high production costs; this situation prevented the products from reaching the masses, limiting them to an elitist consumer group. However, today's digital production technologies have eliminated this historical paradox. Within the scope of the research, the qualitative research methods of "Document Review" and "Descriptive Analysis" were used. The findings reveal that traditional Art Nouveau motifs have not disappeared, but rather have undergone processes of "stylization" and "visual simplification" in order to adapt to modern production standards. Techniques such as laser cutting, digital printing, and parametric design used in contemporary industrial products reinterpret the characteristic "whip-lash" lines and botanical forms of the movement in a minimalist language. In conclusion, it has been determined that Art Nouveau's past cost-based failure has been replaced by technological democratization today, and that the movement's aesthetic legacy has evolved and persisted within modern industrial rationalism.

Keywords: Art Nouveau, Industrial Design, Digital Production, Nature Motifs, Design History

ÖZET

19. yüzyılın sonunda Sanayi Devrimi'nin getirdiği tekipleşmeye ve estetik yoksunluğa bir tepki olarak doğan Art Nouveau akımı, tasarım dünyasında doğanın organik formlarını ve sanatçının özgün

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

emeğini merkeze alan devrimsel bir yaklaşım sergilemiştir. Bu çalışma, Art Nouveau akımının tarihsel süreçteki endüstriyel direnişini ve bu direnişin 21. yüzyıl ürün tasarımındaki dönüşümünü incelemeyi amaçlamaktadır. Akımın temel dayanağı olan "doğaya dönüş" felsefesi, başlangıçta yüksek el işçiliği gerektirmesi ve üretim maliyetlerinin yüksekliği nedeniyle ekonomik bir bariyerle karşılaşmış; bu durum ürünlerin kitlelere yayılmasını engelleyerek elitist bir tüketim grubuyla sınırlı kalmasına yol açmıştır. Ancak günümüzün dijital üretim teknolojileri, bu tarihsel paradoksu ortadan kaldırmıştır. Araştırma kapsamında, nitel araştırma yöntemlerinden "Doküman İncelemesi" ve "Betimsel Analiz" teknikleri kullanılmıştır. Elde edilen bulgular, geleneksel Art Nouveau motiflerinin yok olmadığını, aksine modern üretim standartlarına uyum sağlamak amacıyla "stilizasyon" ve "görsel sadeleşme" süreçlerinden geçtiğini ortaya koymaktadır. Güncel endüstriyel ürünlerde kullanılan lazer kesim, dijital baskı ve parametrik tasarım gibi teknikler, akımın karakteristik "kamçı vuruşu" çizgilerini ve bitkisel formlarını minimalist bir dille yeniden kurgulamaktadır. Sonuç olarak, Art Nouveau'nun geçmişteki maliyet temelli başarısızlığının yerini günümüzde teknolojik bir demokratikleşmeye bıraktığı ve akımın estetik mirasının modern endüstriyel rasyonalizm içinde evrilerek varlığını sürdürdüğü saptanmıştır.

Anahtar Kelimeler: Art Nouveau, Endüstriyel Tasarım, Dijital Üretim, Doğa Motifleri, Tasarım Tarihi

GİRİŞ

19. yüzyılın son çeyreği, Sanayi Devrimi'nin yarattığı seri üretim bantlarının estetik kaygıdan uzak, standartlaşmış ürünleri ile geleneksel sanat anlayışı arasındaki çatışmanın zirveye ulaştığı bir dönemi temsil eder. Bu dönemde ortaya çıkan Art Nouveau (Yeni Sanat), Viktorya döneminin eklektik ve taklitçi üslubuna bir tepki olarak, sanat ve tasarımı hayatın her alanına entegre etmeyi amaçlayan bütünsel bir yaklaşım sergilemiştir (Greenhalgh, 2020). Akımın temel felsefesi, makineleşmenin getirdiği *"soğuk"* ve *"ruhsuz*" üretim biçimine karşı, doğanın organik formlarını ve sanatçının özgün emeğini yücelterek nesneye yeniden bir "kimlik" kazandırmaktır (Hofstätter, 2019). Art Nouveau, sadece mimari ve süsleme sanatlarında değil, endüstriyel tasarımın ilk adımları sayılabilecek nesne üretiminde de devrimsel bir görsel dil oluşturmuştur (Schmutzler, 1962). Akımın en belirgin karakteristiği olan *"kamçı vuruşu"* (whiplash) çizgileri, bitkisel eğriler ve asimetrik yapılar, nesneye statik bir metalik formdan ziyade dinamik bir canlılık kazandırmıştır (Duncan, 2022). Tanrıkulu'na (t.y.) göre Hector Guimard'ın Paris metro girişlerinde kullandığı bu dinamik formlar sadece bitkisel bir öykünme değil, aynı zamanda Japon sanatındaki 'pirinç kağıdı' (rice paper) dokusunun cama ve demire yansıtılmasıdır; hatta Guimard'ın kullandığı bazı kıvrımların, Osmanlı Barok üslubundaki Bab-ı Ali saçaklarıyla kurduğu biçimsel benzerlik, akımın kültürlerarası geçirgenliğini de kanıtlar niteliktedir. Ancak bu tasarım dili, doğası gereği yüksek el işçiliği gerektirmesi ve seri üretim teknikleriyle başlangıçta yapısal bir uyum sağlayamaması nedeniyle, tarihsel süreçte sosyo-ekonomik bir bariyerle karşılaşmıştır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Görsel 1. Hector Guimard tarafından tasarlanan, Japon sanatının ve organik formların endüstriyel demir malzemeyle yorumlandığı Paris Metro girişi (Tanrıkulu, t.y.)

Fahr-Becker (2015) tarafından vurgulandığı üzere, Art Nouveau ürünleri estetik bir zafer kazansa da, üretim maliyetleri nedeniyle geniş kitlelere ulaşamamış ve elitist bir beğeni düzeyiyle sınırlı kalmıştır. 21. yüzyıla gelindiğinde ise Art Nouveau'nun etkisi tamamen yok olmamış; aksine dijital tasarım araçları ve modern üretim teknikleriyle yeniden formülize edilmiştir; günümüz endüstriyel tasarımında, bu akımın karmaşık yapısı minimize edilerek ve stilize edilerek modern nesnelere entegre edilmektedir (Silverman, 2021). Mevcut çalışma, Art Nouveau akımının tarihsel süreçteki endüstriyel direnişini incelemekte ve günümüz tasarım dünyasında bu formların "sadeleşme" (simplification) yoluyla nasıl bir dönüşüm geçirerek varlığını sürdürdüğünü akademik bir çerçevede ele almaktadır.

YÖNTEM

Bu araştırma, Art Nouveau akımının tarihsel süreçteki endüstriyel dönüşümünü ve güncel dijital tasarım pratiklerindeki yansımalarını incelemek amacıyla nitel araştırma yöntemleri temelinde kurgulanmış, tarihsel veriler ile güncel tasarım eğilimleri arasındaki ilişkiyi ortaya koymak için "Doküman İncelemesi" (Document Review) (Creswell, 2014) ve "Betimsel Analiz" (Descriptive Analysis) teknikleri kullanılmıştır (Yin, 2018).

Veri toplama ve analiz süreci aşağıdaki üç aşamalı kurgu üzerinden yürütülmüştür:

1. Literatür Temelli Durum Saptaması: İlk aşamada, Art Nouveau'nun 1890-1910 yılları arasındaki biçimsel özellikleri ve üretim kısıtları üzerine yazılmış temel kaynaklar (Fahr-Becker, Greenhalgh vb.) taranarak akımın tarihsel çerçevesi çizilmiştir.

2. Kavramsal Karşılaştırma: İkinci aşamada, literatürde yer alan klasik üretim yöntemleri (el işçiliği/manüfaktür) ile güncel kaynaklarda belirtilen dijital üretim teknolojileri (CNC, Lazer Kesim, Dijital Baskı); "erişilebilirlik", "üretim hızı" ve "stilizasyon" kavramları üzerinden karşılaştırmalı olarak yorumlanmıştır. Bu aşamada IKEA, Zara Home gibi güncel üreticilerin pazar pratikleri, literatürdeki "demokratikleşme" tartışmasını örneklendirmek amacıyla betimsel vaka olarak kullanılmıştır.

3. Kuramsal Sentez: Son aşamada, elde edilen bulgular; Benjamin'in (2008) "aura" ve Loos'un

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

(1908) "süsleme" kavramları ile ilişkilendirilerek, Art Nouveau'nun günümüzdeki varlığı kuramsal bir zemine oturtulmuştur.

Araştırmanın Kapsamı: Çalışma, Art Nouveau'nun Avrupa kökenli temel motiflerinin endüstriyel ürünlerdeki (ev dekorasyonu ve tekstil) biçimsel dönüşümü ile sınırlandırılmıştır.

LİTERATÜR İNCELEMESİ

Art Nouveau, Viktorya döneminin katı simetrisine ve endüstriyel üretimin tekdüzeliğine karşı *"biyomorfik"* bir yaklaşım geliştirmiştir; bu akımın tasarım dili, sadece bir süsleme değil, nesnenin strüktürü ile bezemesinin bir bütün olduğu "*Gesamtkunstwerk"* (Bütüncül Sanat) kavramına dayanır (Schmutzler, 1962). Tasarımcılar, doğayı doğrudan taklit etmek yerine, doğanın büyüme süreçlerini ve dinamik enerjisini formlarına aktarmışlardır. Organik Formlar ve Kamçı Vuruşu (Whiplash) Çizgisi Akımın en karakteristik ögesi olan "*kamçı vuruşu*" çizgisi, dinamik ve asimetrik bir hareketliliği temsil etmektedir (Tschudi-Madsen, 2013). Sembach (2016), bu çizgisel üslubun bitki saplarının kıvrılmasından ve su dalgalarının hareketinden ilham aldığını belirtmektedir. Tasarımda kullanılan bu akışkan hatlar, metal ve cam gibi sert malzemelere yumuşak ve organik bir görünüm kazandırarak endüstriyel ürünün *"makine yapımı"* imajını kırmayı amaçlamıştır (Greenhalgh, 2000). Doğan, Arslan, & Arpacı (2022) ise bu noktada önemli bir ayrıntıya dikkat çekmektedir; Dönem mimarisinde çelik ve cam gibi endüstriyel malzemeler yaygınlaşsa da mobilya tasarımında 'ahşap' malzemenin sıcaklığı ve işlenebilirliği nedeniyle vazgeçilmez olduğunu, ancak bu durumun yoğun el işçiliği gerektirmesi sebebiyle maliyetleri artırarak akımın kitleselleşmesini engellediğini belirtirler.



Görsel 2. Art Nouveau'nun karakteristik "kamçı vuruşu" çizgilerini ve demir-cam işçiliğini gösteren Tassel Evi merdivenleri (Yalçın, Gezicioğlu & Gürani, 2022)

Sembolik Bitki ve Hayvan Motifleri Art Nouveau tasarımcıları, florayı (bitki örtüsü) ve faunayı (hayvanlar alemi) belirli sembolik anlamlarla kullanmışlardır. Özellikle zambak, lotus ve papatya saflığı; sarmaşıklar ise sürekliliği temsil etmektedir (Howard, 2020). Tasarımlarda sıkça görülen böcek (yusufçuk, kelebek) ve kuş (tavus kuşu) motifleri, doğanın kırılganlığını ve zarafetini vurgularken, ürünlerin estetik değerini el işçiliğiyle birleştirerek yükseltmiştir, bu durum dönemin seri üretim anlayışına karşı bir "*nitelik"* savunmasıdır (Gontar, 2006). Buna ek olarak Tanrıkulu (t.y.), Art Nouveau'daki doğa tutkusunun sadece Avrupa florasıyla sınırlı kalmadığını; örneğin Victor Horta'nın

tasarımlarında Belçika'nın sömürgesi olan Kongo'ya özgü palmiye yapraklarını ve hindistan cevizi ağacı gövdelerini yapısal elemanlara dönüştürerek 'egzotik ve ilkel' olanı modern mimariye entegre ettiğini belirtmektedir. Art Nouveau, kuramsal düzlemde seri üretimin tekdüzeliğine karşı çıksa da pratikte modern endüstriyel tasarımın doğuşuna zemin hazırlayan içsel bir çelişki barındırmaktadır. Literatürde bu durum, *"estetik idealizm ile piyasa gerçekliği arasındaki çatışma"* olarak tanımlanmaktadır (Greenhalgh, 2000; Sembach, 2016). Art Nouveau tasarımcıları, Arts and Crafts hareketinin öncüsü William Morris'in izinden giderek, nesnenin mekanikleşmesine karşı çıkmışlardır (Greenhalgh, 2000). Literatürde "makine estetiği" (machine aesthetic) kavramına ilk bilinçli direnç bu dönemde gözlemlenmektedir (Greenhalgh, 2000; Fahr-Becker, 2015). Posener (1991), akımın sanatçılarının endüstriyel yöntemleri reddetmediğini ancak makinenin sanatı köreltmesine izin vermeyen bir *"sanatçı kontrolü"* talep ettiklerini belirtmektedir. Ancak bu kontrol, üretim sürecini yavaşlatmış ve her ürünü bir *"sanat nesnesi"* (objet d'art) statüsüne taşımıştır (Sembach, 2016; Ayaydın, 2015). Aslan & Tezcan (2022), 19. yüzyılda dahi cam sanatında 'pres tekniği' ve 'asitle matlaştırma' gibi yöntemlerin kullanılmaya başlandığını; bunun da Art Nouveau' nun estetik dilinin seri üretime uyarlanması konusundaki ilk endüstriyel refleksler olduğunu belirtmişlerdir.

"Alt kesimin satın alamaması" olgusu, literatürde Veblen'in *"Aylak Sınıfın Teorisi"* bağlamında tartışılmaktadır (Veblen, 1899). Art Nouveau'nun talep ettiği sofistike işçilik ve nadir malzemeler (mine, gümüş, fildişi vb.), ürünlerin birim maliyetini dramatik şekilde artırmıştır (Silverman, 2021; Ayaydın, 2015). Masello (1993), akımın *"herkes için sanat"* sloganıyla yola çıkmasına rağmen, yüksek maliyetler nedeniyle ironik bir biçimde sadece üst burjuvaziye ve elit koleksiyonculara hitap eden bir *"lüks sembolü"* haline geldiğini savunmaktadır. Bu durum, akımın geniş kitlelere yayılamamasının ve 1910'lardan sonra yerini daha rasyonel olan Art Deco'ya bırakmasının temel nedenlerinden biridir (Masello, 1993; Ayaydın, 2015). Ayaydın (2015), akımın aslında evrensel bir stil arayışında olduğunu; ancak el yapımı ürünlerin endüstriyel muadillerine göre yüksek maliyetli kalması sonucunda, hedeflenen toplumsal taban yerine mecburi olarak zengin koleksiyoncu kitlesine sıkışıp kaldığını belirtmektedir. Güncel çalışmalar, Art Nouveau'nun başarısızlığını teknik imkansızlıklardan ziyade *"demokratikleşme*" eksikliğine bağlamaktadır (Greenhalgh, 2020; Yalçın vd., 2022). Benjamin' nin (2008) *"Sanat Eserinin Teknik Çoğaltılabilirlik Çağında"* adlı eserinde tartıştığı gibi, bir eserin *"aura"* sını koruma çabası, onun kitlesel tüketimle olan bağını koparmıştır. Art Nouveau tasarımcıları, doğanın eşsizliğini ürüne yansıtmaya çalışırken, ürünün ekonomik erişilebilirliğini feda etmişlerdir (Tschudi-Madsen, 2013). Art Nouveau'nun doğayı taklit etme biçimi, literatürde "mimetik" (doğrudan taklit) değil, "sembolik ve stilize" bir süreç olarak ele alınır; akımın öncülerinden olan Victor Horta ve Henry van de Velde'nin yaklaşımları, doğadaki karmaşıklığı çizgisel bir öze indirgemeyi amaçlamıştır (Schmutzler, 1962; Ayaydın, 2015). Gropius (1919), yayınladığı Bauhaus Manifestosu'nda 'sanat ve zanaat arasında bir ayrım olmadığını' vurgulayarak süslemeci salon sanatına karşı çıkmış; bu tutum sonraki dönemde Art Nouveau' nun modernizmin işlevsel çizgilerine evrilmesinde temel bir dayanak

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

noktası olarak yorumlanmıştır. Güncel literatürde ise bu durum, *"Görsel Basitleştirme Teorisi"* bağlamında incelenmektedir (Meikle, 2005; Bierut, 2019). Post-modern tasarım kuramcılarından olan Meikle (2005), 19. yüzyılın yoğun bitkisel bezemelerinin, endüstriyel üretim imkanlarıyla birleşerek günümüzde *"minimalist organik formlara"* dönüştüğünü belirtmektedir. Bu dönüşüm, tasarımın estetik değerinden ödün vermeden, seri üretimin ekonomik gerçeklerine uyum sağlama çabasının bir sonucu olarak görülebilmektedir. Art Nouveau, 19. yüzyıldaki "pahalı ve erişilmez" imajından sıyrılarak, günümüzde endüstriyel seri üretimin estetik bir bileşeni haline gelmiştir; özellikle dijital üretim teknikleri ve görsel basitleştirme (stilizasyon) süreçleriyle mümkün olmuştur (Quinn, 2012).

Geleneksel Art Nouveau ürünlerinde görülen ve maliyeti artıran el oymacılığı veya döküm teknikleri, günümüzde yerini CNC kesim, 3D baskı ve gelişmiş dijital baskı tekniklerine bırakmıştır (Doğan vd., 2022; Quinn, 2012). Quinn (2012), tekstil ve yüzey tasarımında kullanılan bu teknolojilerin, Art Nouveau'nun karmaşık organik desenlerini hatasız ve düşük maliyetli bir şekilde geniş kitlelere ulaştırdığını savunmaktadır. Özellikle güncel ev dekorasyonu mağazalarında görülen duvar kağıtları ve sofra takımlarında, akımın karakteristik "zambak" ve "sarmaşık" motifleri, yüksek çözünürlüklü dijital baskı teknikleriyle yeniden hayat bulmaktadır (Yalçın vd., 2022). Ancak bu noktada 'yüzeysel' ve 'yapısal' dönüşüm arasında kritik bir ayrım yapmak gerekmektedir. Günümüz teknolojisi Art Nouveau mirasını iki farklı kanaldan sürdürmektedir: Birincisi, dijital baskı teknolojileri sayesinde duvar kağıdı ve tekstil yüzeylerinde maliyeti sıfıra yaklaşan 'desen odaklı' (pattern-based) demokratikleşmedir. İkincisi ve daha karmaşık olanı ise, 3D baskı (Additive Manufacturing) ve CNC teknolojileriyle formun kendisinin üretildiği 'yapısal' (structural) dönüşümdür. Loos'un (1908) 'süsleme suçtur' eleştirisi, emek israfına dayalıydı; oysa günümüz dijital üretiminde karmaşık bir Art Nouveau desenini basmak ile düz bir yüzey basmak arasında, makine zamanı dışında bir maliyet farkı kalmamıştır. Bu durum, süslemenin 'suç' olmaktan çıkıp, erişilebilir bir 'seçenek' haline geldiğini göstermektedir (Kolarevic, 2003). Günümüzde tasarımcılar Art Nouveau'nun yoğun süslemeciliğini "minimalize" ederek kullanmaktadır; bu yaklaşım, literatürde "Neo-Art Nouveau" veya "Modern Organik Tasarım" olarak adlandırılır (Fiell & Fiell, 2021; Greenhalgh, 2020). Güncel mağazalarda (Örn: Zara Home, IKEA veya özel tasarım butikleri) satılan porselen tabaklar, gümüş çatal-bıçak takımları ve tekstil ürünlerinde; orijinal akımın ağır çizgileri yerine daha ince, sade ve grafiksel bir dil tercih edilmektedir (Aslan & Tezcan, 2022; Yalçın, vd. 2022). Fiell & Fiell (2021), bu durumu "tarihsel referansların modern işlevsellikle evliliği" olarak tanımlamaktadır. Öte yandan Aslan & Tezcan' nın (2022) bulguları, bu stilizasyonun sadece kitlesel pazarda değil; Christian Dior ve Elie Saab gibi lüks moda devlerinin koleksiyonlarında da 'organik ve çiçeksi' formların modern yorumlarıyla, yani 'zamansız bir estetik' olarak varlığını sürdürdüğünü ortaya koymaktadır.

Geleneksel işleme yöntemlerinin (nakış, gravür vb.) makineleşmesi, Art Nouveau estetiğinin "demokratikleşmesini" sağlamıştır (Benjamin, 2008; Aslan ve Tezcan, 2022). Bugün bir giyim ürününde veya bir mobilya döşemesinde gördüğümüz bitkisel bezemeler, akımın 1900'lerdeki ruhunu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

taşırken, üretim hızı ve maliyeti açısından tamamen 21. yüzyılın endüstriyel standartlarına uygun işemektedir (Yalçın vd., 2022; Ayaydın, 2015). Bu bağlamda, akımın geçmişte yaşadığı "ekonomik bariyeri" teknoloji sayesinde aştığının en somut kanıtıdır. Bu geçişkenlik üzerine yapılan güncel araştırmalar Art Nouveau'nun sadece bir süsleme aracı olmadığını, mimari formların (özellikle Gaudi'nin organik yapılarının) tekstil yüzeylerinde üç boyutlu dokulara dönüştürülerek disiplinler arası bir tasarım dili oluşturduğunu ortaya koymaktadır (Yalçın, vd. 2022).

Art Nouveau'nun literatürdeki en büyük tartışma konularından biri, formun işlevle (function) olan ilişkisidir. Loos (1908), 'Süsleme ve Suç' (Ornament and Crime) başlıklı manifestosunda; süslemenin emek, malzeme ve sermaye kaybına yol açarak 'ulusal ekonomiye karşı işlenmiş bir suç' olduğunu savunmuş ve Henry van de Velde gibi Art Nouveau öncülerinin dekoratif yaklaşımını kültürel evrimin önünde bir engel olarak nitelendirmiştir. Loos' a göre (1908), makine üretimi sadelik gerektirirken, Art Nouveau bu süreci zorlaştırmaktadır. Ancak güncel literatürde bu görüş, "Duygusal Tasarım" (Emotional Design) kavramıyla yeniden ele alınmaktadır (Norman, 2004). Norman (2004), nesnelerin sadece işlevsel değil, aynı zamanda kullanıcıyla duygusal bağ kuran estetik değerlere sahip olması gerektiğini savunur. Bu durum, Art Nouveau'nun neden hala 21. yüzyılda bir "ihtiyaç" olarak karşımıza çıktığını açıklar. Benjamin (2008), tarafından ortaya atılan "aura" kavramı, el emeği ile üretilen nesnenin eşsizliğini vurgular. Literatürde Art Nouveau ürünlerinin "tekilliği", onların endüstriyel başarı yakalamasını engelleyen temel unsur olarak görülür (Frampton, K. 2020). Ancak 21. yüzyıl literatüründe "Digital Craftsmanship" (Dijital Zanaatkarlık) kavramı ön plana çıkmaktadır (McCullough, 1998; Quinn, 2012). McCullough (1998), bilgisayar destekli tasarımın (CAD), el işçiliğinin karmaşıklığını ve ruhunu, seri üretimin hızıyla birleştirebildiğini savunmaktadır.

BULGULAR

Bu bölümde, literatürdeki "erişilebilirlik" ve "üretim zorluğu" tartışmaları, günümüzün somut örnekleriyle ele alınacaktır. Yapılan incelemeler sonucunda, 1900'lerin başında bir Art Nouveau vazo veya mobilyanın sadece yüksek gelir grubuna hitap ettiği, ancak günümüzde stilize edilmiş Art Nouveau motifli ürünlerin kitle pazarı (mass market) perakendecilerinde (Örn: Zara Home, IKEA gibi küresel zincirler) her sosyo-ekonomik tabaka tarafından satın alınabildiği gözlemlenmiştir (Fahr-Becker, 2015). Bu, literatürdeki "sınıfsal bariyer" argümanının teknolojiyle yıkıldığını göstermektedir. Özellikle IKEA'nın 'PS Koleksiyonu' (Örn: 2017 serisindeki 3D örgü teknikli koltuklar) incelendiğinde, Art Nouveau'nun 'doğadan ilham alma' prensibinin, 'sıfır atık' (no-waste) üretim teknikleriyle nasıl birleştiği görülür. 1900'lerde bir zanaatkarın ahşabı bükerek (steam-bending) haftalarca uğraştığı organik formlar, bugün IKEA üretim bantlarında enjeksiyon kalıplama veya 3D örme (knitting) teknikleriyle dakikalar içinde üretilebilmektedir. Bu vaka, tasarımın 'aura'sını (Benjamin, 2008) zayıflatsa da, 'sosyal erişilebilirliğini' maksimize etmiştir. Artık 'whiplash' çizgisi bir burjuva sembolü değil, global pazarın standart bir estetik verisidir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Görsel 3. IKEA PS 2017 Koltuk (3D knitting technique) görseli (IKEA Museum, t.y.)

Bulgular, orijinal Art Nouveau motiflerindeki "whiplash" (kamçı vuruşu) eğrilerinin, modern üretimde daha az kırılım içeren, baskı tekniklerine uygun "Vektörel Stilizasyon" sürecinden geçtiğini ortaya koymaktadır. 19. yüzyıldaki bir gümüş kaşığın üzerindeki üç boyutlu bitki oyması, günümüzde aynı ürün grubunda lazer kazıma veya serigrafi baskı yoluyla iki boyutlu, ikonik bir görsele dönüşmüştür. Geleneksel üretimde 'ters açı' (undercut) yaratan ve el oymacılığında yüksek uzmanlık gerektiren bitkisel kıvrımlar, Lazer Kesim teknolojisinde sadece birer 'vektörel yol' (vector path) verisine indirgenmiştir. Lazer ucu için düz bir çizgiyi kesmekle, karmaşık bir Art Nouveau sarmaşığını kesmek arasında teknik bir zorluk farkı bulunmamaktadır. Bu 'teknik kayıtsızlık', akımın maliyet bariyerini yıkan temel mühendislik faktörüdür (Kolarevic, 2003). Bu durum, estetik mirasın "içerik" olarak korunduğunu ancak "biçim" olarak endüstriyel rasyonalizme uyum sağladığını kanıtlar. Bu biçimsel dönüşümü somutlaştırmak adına, Görsel 4'te sunulan karşılaştırmalı analiz kritiktir. Sol tarafta Victor Horta'nın 'Tassel Evi' (1893) merdivenlerindeki el işçiliğiyle üretilmiş dökme demir kıvrımlar, 'tekil' ve 'biricik' (auratik) bir üretim sürecini temsil ederken; sağ tarafta Ross Lovegrove'un 'Supernatural Sandalyesi' (2005), aynı organik akışkanlığı dijital kalıplama teknolojisiyle 'çoğaltılabilir' bir endüstriyel standarda dönüştürmüştür. Horta'nın asimetrik 'kamçı vuruşu', Lovegrove'un tasarımında bilgisayar destekli bir 'delikli doku' (perforated texture) halini almıştır. Bu görsel kanıt, Art Nouveau'nun estetik kodlarının yok olmadığını, aksine dijital parametrelerle yeniden kodlandığını doğrular niteliktedir.



Görsel 4. Sol tarafa Victor Horta - Tassel House Staircase görseli, sağ tarafa Ross Lovegrove - Supernatural Chair (Moroso markası) görseli (UNESCO, t.y.; MOROSSO, t.y.)

Çalışma kapsamında yapılan analizler, Art Nouveau akımının 1900'lerdeki orijinal uygulamaları ile

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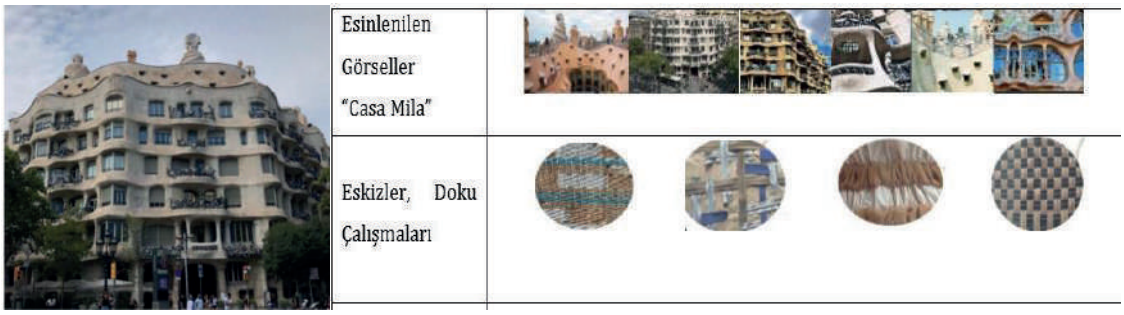
21. yüzyıldaki endüstriyel yansımaları arasındaki farkları ve benzerlikleri aşağıdaki Tablo ışığında ortaya koymaktadır:

Tablo 1. Biçimsel ve Teknik Evrim Tablosu (Ayaydın, 2015; Aslan & Tezcan, 2022; Yalçın, vd. 2022 kaynaklarından elde edilen verilerle sentezlenmiştir)

Parametre	**Klasik Art Nouveau (1890-1910)**	**21. Yüzyıl Art Nouveau (Modern Stilizasyon)**
Üretim Yöntemi	Yoğun El İşçiliği, Manüfaktür	Dijital Seri Üretim (Lazer, CNC, 3D Baskı)
Motif Yapısı	Üç Boyutlu, Organik, Karmaşık	İki Boyutlu, Grafiksel, Sadeleşmiş (Minimal)
Malzeme	Değerli Metaller, Cam, Masif Ahşap	Kompozit, Plastik, Baskılı Yüzeyler, Seramik
Erişilebilirlik	Elitist / Zengin Koleksiyoncular	Kitlesel / Genel Tüketici
Temel Felsefe	Endüstriye Direniş	Endüstriyle Estetik Entegrasyon

Ulaşılan veriler 19. yüzyılda kullanılan "Zambak" ve "Sarmaşık" gibi motiflerin günümüzde uğradığı değişimi doğrulamaktadır. Literatürde "Görsel Ekonomizasyon" olarak tanımlanan bu süreçte, karmaşık bitki saplarının yerini vektörel çizgilerin aldığı gözlemlenmiştir (Bierut, 2019). Güncel ev dekorasyonu ürünleri (Örn: Duvar panelleri, tekstil baskıları) üzerinde yapılan incelemelerde; tasarımcıların 'kamçı vuruşu' (whiplash) çizgisini korumakla birlikte, endüstriyel üretim kısıtlamaları ve modern estetik algı nedeniyle motiflerin detay yoğunluğunu azaltarak daha grafiksel ve stilize bir dile dönüştürdükleri gözlemlenmiştir (Yalçın, vd. 2022; Quinn, 2012). Bu, Thompson'ın (2017) belirttiği "akışkan estetiğin rasyonalizasyonu" kavramıyla örtüşmektedir. Bu rasyonalizasyonun kökleri aslında akımın kendi tarihsel sürecinde de mevcuttur. Doğan, vd.'nin (2022) aktardığına göre; Art Nouveau'nun ikinci evresinde, özellikle Charles Rennie Mackintosh'un tasarımlarında, endüstrileşmenin etkisiyle o meşhur dalgalı çizgiler yerini daha düz hatlara ve geometrik birleşmelere bırakarak bugünkü 'modern stilizasyonun' ilk sinyallerini vermiştir. Benzer bir şekilde Yalçın, vd.'nin (2022) incelediği tasarım örneklerinde, Gaudi'nin 'Casa Mila' yapısındaki karmaşık ve amorf cephe formlarının, günümüz tasarımcıları tarafından stilize edilerek 'casual' (günlük) giyim ürünlerine uyarlandığı ve böylece 'tarihsel sanatın' 'güncel kullanım değerine' kavuştuğu görülmüştür.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Görsel 5. Antoni Gaudi'nin Casa Mila yapısındaki amorf formların (solda), güncel giysi tasarımlarında dokusal yüzeylere dönüştürülme süreci (sağda) (Yalçın, vd. 2022)

Modern örnekler, Art Nouveau'nun en büyük engeli olan "yüksek maliyet" sorununun, parametrik tasarım yazılımları (Grasshopper, Rhino vb.) sayesinde aşıldığını göstermektedir. 1900'lerde bir zanaatkarın haftalarca uğraştığı organik bir bezeme, bugün algoritmalar vasıtasıyla dakikalar içinde üretilebilmektedir (Schumacher, 2016). Bu durum, akımın doğasındaki "organik kaosun" modern mühendisliğin "düzenli geometrisi" içinde eritildiğini kanıtlamaktadır.

TARTIŞMA

Elde edilen veriler, Art Nouveau akımının tarihsel süreçteki konumuna dair geleneksel literatürle hem örtüşmekte hem de modern teknoloji bağlamında bu literatürü genişletmektedir. Literatürde Loos (1908); Fahr-Becker (2015) tarafından vurgulanan "ekonomik erişilebilirlik bariyeri", akımın erken döneminde bir "sanatsal elitizm" yaratmıştır. Ancak bu çalışma, söz konusu bariyerin 21. yüzyıl dijital üretim araçlarıyla (CAD/CAM, lazer kazıma, dijital baskı) aşıldığını ve akımın ideali olan "yaşamı sanatla bütünleştirme" (Gesamtkunstwerk) felsefesinin, ironik bir biçimde bir zamanlar reddettiği seri üretim kanallarıyla hayat bulduğunu göstermektedir. 19. yüzyılda "maliyet" nedeniyle alt kesimin ulaşamadığı organik formlar, günümüzde Thompson (2017) & Bierut (2019)'un belirttiği "stilizasyon ve görsel basitleştirme" süreçlerinden geçerek demokratikleşmiştir. Tartışılması gereken asıl nokta, Benjamin'in (2008) tanımladığı "aura" kavramının, bu basitleştirme sürecinde yok olup olmadığıdır. Modern tasarımdaki "vektörel ve minimalist" Art Nouveau yorumlarının, orijinal akımın ağır ve ağdalı yapısını kaybetse de nesneye kattığı "duygusal değer" bakımından hala işlevsel olduğunu kanıtlamaktadır (Norman, 2004). Art Nouveau endüstriyel sisteme yenilmemiş; aksine Schumacher (2016)'nın "parametrik tasarım" vizyonunda olduğu gibi, endüstriyel rasyonalizmin içinde evrimleşerek varlığını sürdürmüştür. Ayaydın'ın (2015) 21. yüzyıl perspektifinden yaptığı analize göre Art Nouveau; sadece kendi dönemiyle sınırlı bir süsleme akımı değil, sunduğu özgün üslup ve görsel değerlerle çağdaş sanatın şekillenmesinde bir "kurucu temel" vazifesi görerek güncelliğini korumayı başarmıştır.

SONUÇ VE ÖNERİLER

Araştırmada Art Nouveau akımının 19. yüzyıldaki kökenlerinden 21. yüzyılın endüstriyel tasarım

dünyasına kadar uzanan evrimi ve dönüşümü incelenmiştir, analizler sonucunda elde edilen temel çıkarımlar şunlardır: Art Nouveau, doğası gereği barındırdığı "yüksek maliyetli el işçiliği" ile "sanatın hayatın her alanına yayılması" ideali arasındaki paradoks nedeniyle tarihsel bir tıkanma yaşamıştır. Ancak günümüzün dijital üretim teknolojileri (CNC, 3D yazıcılar, dijital baskı), bu paradoksun aşılmasına olanak sağlamıştır. 1900'lerde sadece elit kesimin erişebildiği "organik estetik", bugün dijitalleşme sayesinde kitlesel bir forma dönüşmüş ve ekonomik olarak erişilebilir hale gelmiştir. Art Nouveau motiflerinin yok olmadığını, aksine "stilize edilerek" modernize edildiğini göstermektedir. Orijinal akımın yoğun ve dinamik çizgileri, 21. yüzyıl tasarımında daha sade, grafiksel ve minimalist bir dile evrilmiştir. Bu durum, tasarımcıların geçmişin estetik mirasını güncel beğeni ve üretim standartlarıyla başarılı bir şekilde sentezlediğini kanıtlamaktadır. Art Nouveau, endüstriyel sisteme yenilen bir akım değil, aksine teknolojiyle birlikte evrimleşen ve 21. yüzyılın görsel dilini besleyen köklü bir tasarım disiplinidir. Sonuç olarak, Art Nouveau 21. yüzyılda ismen utulmaya yüz tutsa da, felsefi özü 'Biyofilik Tasarım' (Biophilic Design) (Kellert, 2008) ve 'Parametrik Mimari' (Schumacher, 2016) disiplinleri içinde yaşamakta, teknolojik araçlarla sürdürülebilir bir estetiğe dönüşmektedir. Akımın 'kaos' olarak nitelendirilen doğası, algoritmik tasarımın 'düzenli karmaşası' içinde rasyonalize edilmiştir.

Tasarımcılar, akademik çalışmalar ve gelecekte yapılacak tasarımlar için öneriler;

- Sürdürülebilirlik Bağlantısı: Tasarımcılar, Art Nouveau'nun doğaya dönüş felsefesini sadece görsel bir öge olarak değil, günümüzün "sürdürülebilir ve biyofilik tasarım" ilkeleriyle birleştirerek kullanmalıdır.

- Parametrik Uygulamalar: Mimari ve ürün tasarımında, organik formların karmaşıklığını yönetmek için parametrik tasarım yazılımlarından daha fazla yararlanılmalı; böylece akımın "canlı form" ruhu modern üretimde korunmalıdır.

- Zanaat ve Teknoloji Dengesi: Modern üretim yöntemleri kullanılırken, Art Nouveau'nun temelini oluşturan "özgünlük" hissinin kaybolmaması için, dijital araçların "yeni bir zanaatkarlık" aracı olarak konumlandırılması önerilmektedir.

KAYNAKLAR

Aslan, H., & Tezcan, H. (2022). Art Nouveau sanat akımının cam ve seramik sanatına etkileri. *International Social Sciences Studies Journal*, 8(97), 1509-1517.

Ayaydın, A. (2015). Art Nouveau akımına 21. yüzyıl perspektifinden bir bakış. *Ulakbilge Sosyal Bilimler Dergisi*, 3(6), 59-73.

Benjamin, W. (2008). *The work of art in the age of its technological reproducibility*. Harvard University Press.

Bierut, M. (2019). *Now you see it and other essays on design*. Princeton Architectural Press.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publications.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Doğan, B. Y., Arslan, K., & Arpacı, G. S. (2022). Art Nouveau motiflerin dönemsel özellikleri bakımından incelenmesi. *International From Traditional to Future Timber in Architecture Conference*, 9-10 Mart 2022, İstanbul.

Duncan, A. (2022). *Art Nouveau (World of Art)*. Thames & Hudson.

Fahr-Becker, G. (2015). *Art Nouveau*. Taschen.

Fiell, C., & Fiell, P. (2021). *Modern furniture classics: Post-war to post-modernism*. Thames & Hudson.

Frampton, K. (2020). *Modern architecture: A critical history*. Thames & Hudson.

Gontar, C. (2006). Art Nouveau. *Heilbrunn Timeline of Art History*. The Metropolitan Museum of Art.

Greenhalgh, P. (2000). *Art Nouveau, 1890-1914*. V&A Publications.

Greenhalgh, P. (2020). *Art Nouveau: The search for modern styles*. Victoria & Albert Museum Publications.

Gropius, W. (1919). *Bauhaus Manifesto*. Gropius House. https://gropius.house/location/bauhaus-manifesto/ adresinden erişildi (Erişim Tarihi : 2 Şubat 2026)

Hofstätter, H. H. (2019). *Art Nouveau: Prints, illustrations and posters*. Wordsworth Editions.

Howard, J. (2020). *Art Nouveau: International and national styles in Europe*. Manchester University Press.

IKEA Museum. (t.y.). IKEA PS armchair 2017. https://ikeamuseum.com/en/explore/product-stories/ikea-ps-armchair-2017/ adresinden erişildi. (Erişim Tarihi: 10 Şubat 2026)

Kellert, S. R. (2008). *Biophilic design: The theory, science and practice of bringing buildings to life*. John Wiley & Sons.

Kolarevic, B. (2003). *Architecture in the digital age: Design and manufacturing*. Spon Press.

Loos, A. (1908). *Ornament and crime*. (Trans.). George Washington University Archive. https://www2.gwu.edu/~art/Temporary_SL/177/pdfs/Loos.pdf adresinden erişildi. (Erişim Tarihi : 2 Şubat 2026)

Masello, D. (1993). *Art Nouveau*. Todtri Productions.

McCullough, M. (1998). *Abstracting craft: The practiced digital hand*. MIT Press.

Meikle, J. L. (2005). *Design in the USA*. Oxford University Press.

Moroso. (t.y.). *Supernatural Chair: Ross Lovegrove, 2005*. https://moroso.it/prodotti/supernatural-2/?lang=en adresinden erişildi. (Erişim Tarihi: 10 Şubat 2026)

Norman, D. A. (2004). *Emotional design: Why we love (or hate) everyday things*. Basic Books.

Posener, J. (1991). *From Schinkel to the Bauhaus*. Architectural Association.

Quinn, B. (2012). *Design and craft in the digital age*. Thames & Hudson.

Schmutzler, R. (1962). *Art Nouveau*. New York: Harry N. Abrams.

Schumacher, P. (2016). *Parametricism as style - Parametricist manifesto*.

Sembach, K. J. (2016). *Art Nouveau: Utopia: Reconciling the irreconcilable*. Taschen.

Silverman, D. L. (2021). *Art Nouveau in Fin-de-Siècle France: Politics, psychology, and style*. University of California Press.

Tanrıkulu, F. E. (t.y.). Art Nouveau akımı. *Yapı Dergisi*. https://yapidergisi.com/art-nouveau-akimi/ adresinden erişildi. (Erişim Tarihi: 2 Şubat 2026)

Thompson, J. N. (2017). *The soul of design: Harnessing the power of plot to create African American stories*. JSTOR.

Tschudi-Madsen, S. (2013). *The Art Nouveau style*. Courier Corporation.

UNESCO. (t.y.). *Major Town Houses of the Architect Victor Horta (Brussels)*. https://whc.unesco.org/en/list/1005/ adresinden erişildi. (Erişim Tarihi: 10 Şubat 2026).

Veblen, T. (1899). *The theory of the leisure class*. New York: Macmillan.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Yalçın, S., Gezicioğlu, F. Y., & Gürani, F. Y. (2022). Lisans eğitiminde Art Nouveau ve Antoni Gaudi mimarisinden esinlenilen kumaş/giysi tasarımı yaklaşımı. *İnönü Üniversitesi Uluslararası Sosyal Bilimler Dergisi*, 11(2), 546-564.

Yin, R. K. (2018). *Case study research and applications: Design and methods*. SAGE Publications.

ORDERED LOGISTIC REGRESSION ANALYSIS WITH MACHINE LEARNING-BASED VARIABLE SELECTION

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ABSTRACT

Health satisfaction is an ordinal output variable reflecting individuals' perceptions of healthcare services. While ordinal logistic regression models are commonly used in the analysis of such variables, the violation of the parallel lines assumption can limit model fit and interpretability. Furthermore, in datasets containing numerous variables, it is important to evaluate both the selection of appropriate variables and the classification performance together.. In this study, the determinants of health satisfaction were investigated by combining machine learning-based variable selection with ordinal logistic regression models having a partial proportional odds structure.

The study utilized data from the Turkish Statistical Institute (TÜİK) 2024 Health Satisfaction Survey. Age, gender, marital status, education level, employment status, life satisfaction, and health problems were considered independent variables, while health satisfaction was considered the dependent variable. To reduce sampling uncertainty, bootstrap resampling (n = 1000) was applied and the dataset was divided into training and test subsets. Multilayer Feedforward Artificial Neural Network (MLFFNN), XGBoost, and Random Forest (RF) algorithms were used in the variable selection and classification process; models were built on the training data, and their prediction performance was evaluated using the test data. In the ordered logistic regression models constructed with the selected variables, the assumption of parallel lines was tested, and in cases where the assumption was violated, the analyses were continued with the PPO model.

The results of the machine learning-based variable selection showed that life satisfaction, education level and age are key determinants in explaining health satisfaction.. The PPO model was preferred because the parallel lines assumption was violated for the education variable. It was determined that the RF-supported PPO model provided more consistent results in terms of fit measures and statistical significance of variables, and was relatively more successful, especially in classifying the low health

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

satisfaction group. The findings demonstrate that machine learning-based variable selection approaches, when used in conjunction with ordinal logistic regression models, improve both model fit and interpretability in the analysis of data with ordinal outputs such as health satisfaction.

This study demonstrates that using bootstrap-supported machine learning-based variable selection approaches in conjunction with ordinal logistic regression models with partial proportional odds provides a reliable and interpretable hybrid approach for analyzing data with ordinal outcomes, such as health satisfaction.

Keywords

Ordered logistic regression; Partial proportional odds model; Machine learning; Bootstrap

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ARTIFICIAL INTELLIGENCE–BASED FORECASTING OF ENERGY PRODUCTION IN SOLAR POWER PLANTS

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ABSTRACT

With the intensive use of electrical devices today, the demand for electricity has increased. This demand is generally met by fossil fuels. However, to reduce the environmental damage caused by fossil fuels, governments are offering various incentives for renewable energy sources. Among these, incentives for solar power plants are particularly significant. Recently, many investors have shown interest in establishing solar power plants. Since setting up a solar power plant requires a high investment cost, calculating the payback periods plays a crucial role in making investment decisions. Advances in technology have made it possible to predict these payback periods using artificial intelligence algorithms.

There are many machine learning methods in the literature (CNN, Simple RNN, and LSTM), and today many data scientists and researchers working in the field of artificial intelligence continue to conduct studies on this topic. In this study, analyses and predictions performed using CNN, Simple RNN, and LSTM methods, which are widely used in time series algorithms, are examined.

Keywords: Energy forecasting, CNN, RNN, LSTM, Artificial Intelligence.

INTRODUCTION

Energy has become an indispensable requirement for both nations and individuals in the contemporary world. Owing to expanding industrialization, rapid population growth, technological advancements, the increasing demand for transportation associated with the growth of international trade volume, and the rising need for energy-intensive goods and services, global energy demand continues to increase steadily. (IEA, 2022; REN21, 2023)

The rapid advancement of digital technologies has accelerated the adoption of artificial intelligence (AI) across various industrial and scientific domains. Rather than replicating human cognition directly, AI systems rely on data-driven computational models that learn patterns and relationships from large

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datasets. Within this framework, machine learning (ML) techniques enable systems to generate predictions and optimize decisions by identifying underlying structures in data, making them particularly suitable for complex forecasting applications. (AlShabi and Assad, 2021; Makridakis, 2017)

Advancements in technology have further accelerated the adoption of machine learning methodologies for data-driven forecasting and predictive modeling. Compared to conventional mathematical and statistical approaches, machine learning techniques often provide faster computational performance and improved predictive accuracy, particularly in complex and nonlinear problem domains. (Voyant et al., 2017)

Numerous machine learning architectures have been proposed for time-series forecasting problems, among which Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), and Long Short-Term Memory (LSTM) models are frequently employed. These approaches have demonstrated strong capability in capturing temporal patterns and nonlinear relationships within sequential data. In this study, the predictive performances of CNN, RNN, and LSTM models are analyzed and compared within the context of solar energy generation forecasting.

MATERIALS AND METHODS

Electric Power Generation from Solar Energy

Obtaining energy from the sun can be defined as the energy generated based on the effect of solar radiation on materials specifically designed for this purpose. Photovoltaic (PV) systems, which constitute the subject of this study, refer to systems that generate electricity through solar cells. Solar cells enable the conversion of energy by utilizing the effect of the electromagnetic radiation emitted by the sun on semiconductor-based cell structures. This process occurs when photons packets of electromagnetic radiation create an electric field between the upper and lower layers of the solar cell, thereby producing electrical energy. (Parida et al., 2011; Razykov et al., 2011)

In a PV system, excluding environmental factors, the parameters that most significantly influence efficiency and overall performance are the performance characteristics of the solar cells and the losses associated with inverters. The production efficiencies of commercially available solar cells today do not exceed approximately 25%. Since solar cells and inverters represent relatively newer technologies compared to other PV system components, they are among the system elements that continue to develop rapidly. (Green et al., 2022)

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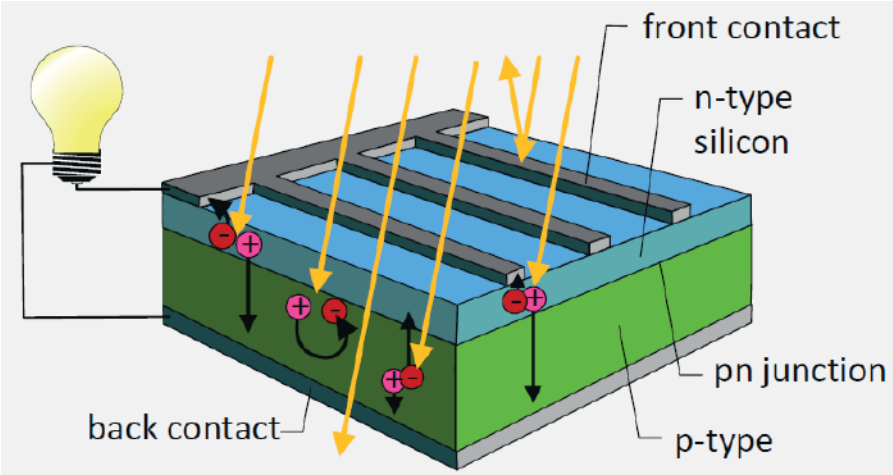


Figure 1. Structure of Photovoltaic Systems

Solar Cells

Photovoltaic cells consist of modules formed by a specific number of series- and parallel-connected units. Considering their energy conversion efficiency and the recent decline in manufacturing costs, solar cells represent a highly valuable technology. Within current technological frameworks, numerous types of solar cells exist, varying in efficiency levels and production methodologies. Depending on technological advancements over time, certain solar cell technologies may gain competitive advantages, while others may gradually lose their position in the industry. In contemporary photovoltaic research and applications, solar cells incorporating multiple layered structures within a single cell have become increasingly prominent. (Razykov et al., 2011)

Incorporating additional functional layers into the photovoltaic cell architecture can enhance conversion efficiency by improving charge carrier generation and collection mechanisms, which directly affect the short-circuit current density (Jsc). Moreover, fabrication techniques and material quality play a decisive role in determining the overall performance limits of photovoltaic systems. (Shockley and Queisser, 1961)

Inverter

In photovoltaic (PV) systems, inverters function as power electronic interfaces that transform the direct current (DC) produced by solar modules into grid-compatible alternating current (AC). Beyond simple conversion, modern inverters are responsible for voltage and frequency regulation, power quality control, and synchronization with grid parameters. By stabilizing fluctuations originating from variable solar irradiation, they ensure reliable power transfer to connected loads or the electrical grid. (Esram and Chapman, 2007)

Excluding environmental factors, inverters represent one of the most significant determinants of overall system efficiency in a generation facility, second only to solar cell efficiency. Although various inverter types are available in the market, each characterized by different loss parameters, the

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average inverter-related loss in PV systems is approximately 3% of the total system losses. (Kjaer et al., 2005)

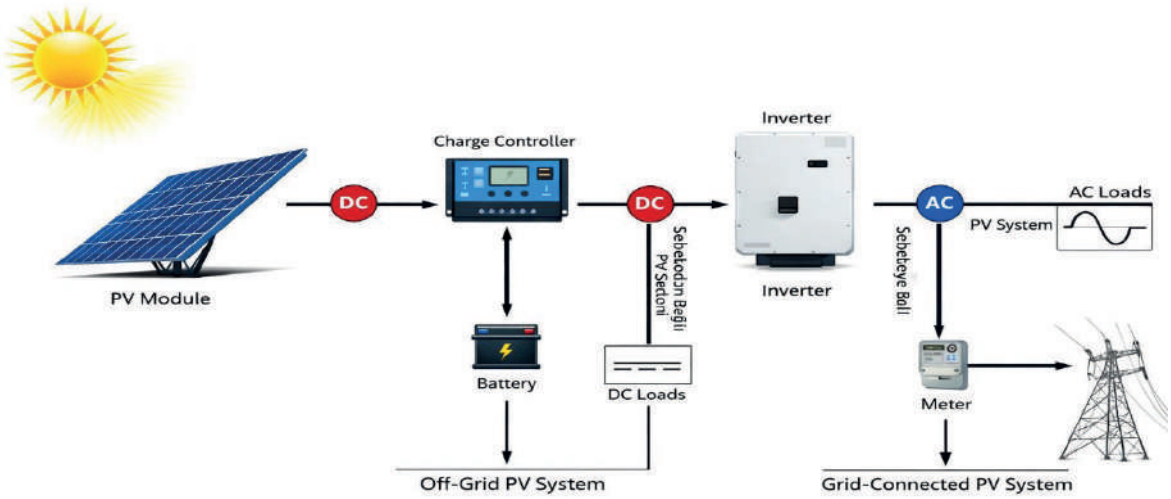


Figure 2. Components and Connection Diagram of a Combined PV System

Artificial Intelligence

Artificial intelligence (AI) encompasses computational methodologies that enable systems to perform tasks requiring adaptive decision-making and data-driven reasoning. Rather than explicitly programming every operational rule, AI-based systems extract patterns from data and refine their outputs through iterative learning processes. This capability allows intelligent models to address complex analytical problems and continuously improve predictive performance as additional data become available. (Yousef et al., 2023; Martínez-López and Casillas, 2013).

Artificial Neural Networks

Artificial Neural Networks (ANNs) are computational architectures inspired by interconnected processing units that collaboratively transform input data into predictive outputs. Through weighted connections and nonlinear activation mechanisms, ANNs learn representations of complex and nonlinear relationships within datasets. Their layered structure enables progressive feature extraction, making them particularly effective for modeling high-dimensional and time-dependent data patterns. (McCulloch and Pitts, 1943; Rumelhart et al., 1986)

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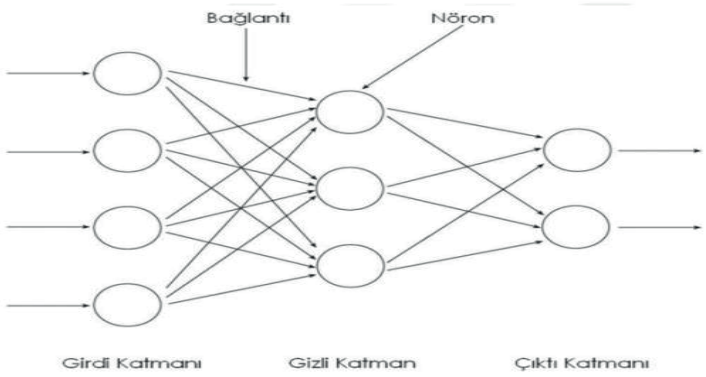


Figure 3. Layers of Artificial Neural Networks

Machine Learning

Machine Learning (ML) represents a data-driven paradigm within artificial intelligence that enables systems to infer patterns and relationships directly from empirical observations. Instead of relying on explicitly defined rules, ML models employ statistical learning techniques to map input variables to corresponding outputs. Through iterative optimization processes, these models progressively improve their predictive capability based on observed data. (Jordan and Mitchell, 2015; Schmidhuber, 2015)

Similar to how human performance improves with practice, the accuracy and reliability of machine learning models generally increase as the volume of data and experiential information grows. Owing to its adaptability, machine learning is particularly well-suited for scenarios in which data patterns, requirements, or task conditions continuously evolve, or in cases where explicitly coding an effective rule-based solution is impractical or infeasible. (Bishop, 2006)

Deep Learning

Deep Learning (DL) extends conventional machine learning approaches by utilizing multi-layer neural architectures capable of extracting hierarchical feature representations from raw data. By stacking multiple nonlinear transformation layers, DL models automatically learn abstract features that enhance predictive performance. Although these architectures generally demand extensive datasets and significant computational resources, they have achieved state-of-the-art results in complex tasks such as computer vision, speech analysis, and natural language understanding. (Goodfellow et al., 2016)

Convolutional Neural Networks (CNN)

Convolutional Neural Networks (CNNs) are specialized deep learning architectures designed to capture spatial dependencies within structured data through convolutional filtering mechanisms. By employing learnable kernels and pooling operations, CNNs efficiently extract localized features while reducing dimensional complexity. Their ability to preserve spatial hierarchies has led to widespread adoption in image-based analytics, pattern recognition, and other high-dimensional data processing applications. (LeCun et al., 1998; Krizhevsky et al., 2012)

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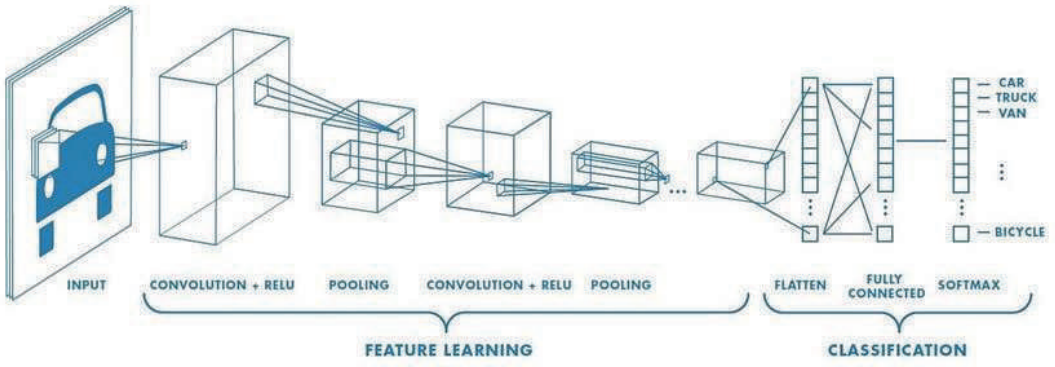


Figure 4. CNN Architecture

Recurrent Neural Networks (RNN)

Recurrent Neural Networks (RNNs) are neural architectures specifically developed for modeling sequential data by incorporating feedback connections within the network structure. Unlike feedforward models, RNNs maintain internal states that allow information from previous time steps to influence current computations. This characteristic makes them particularly suitable for time-dependent forecasting and sequence prediction tasks. (Cho et al., 2014; Pascanu et al., 2013)

A defining feature of RNN architectures is their ability to encode temporal dependencies within sequential inputs. By updating hidden states recursively, the network propagates contextual information across time steps, enabling dynamic sequence modeling. Through iterative training, RNNs learn representations that reflect temporal structure and inter-step relationships in the data. The general architecture of an RNN is presented in Figure 5. (Elman, 1990)

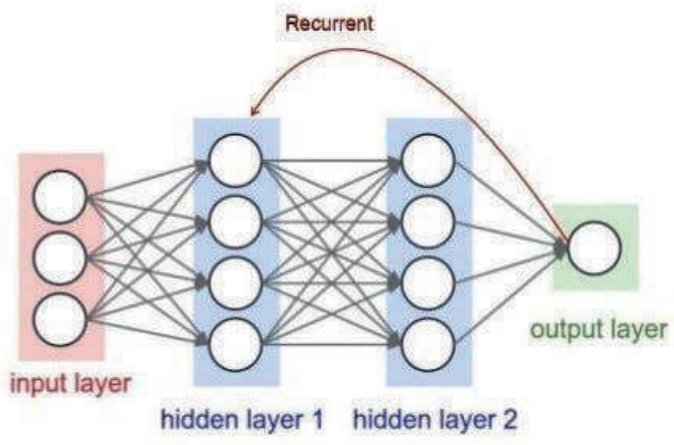


Figure 5. RNN Architecture

Long Short-Term Memory (LSTM)

Long Short-Term Memory (LSTM) networks extend conventional RNN architectures by introducing gated memory units that regulate information flow across time steps. These gating mechanisms control the retention, update, and output of internal cell states, allowing the model to preserve relevant signals

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over long sequences while mitigating gradient-related limitations. As a result, LSTM structures are particularly effective for capturing long-range dependencies in time-series forecasting applications. (Hochreiter and Schmidhuber, 1997)

As illustrated in Figure 6, all RNN architectures consist of repeating cells arranged in a sequential chain structure, where each unit corresponds to a time step in the network. While a standard RNN typically contains a single tanh layer within its recurrent unit, LSTM architectures incorporate four interacting layers that regulate information flow through specialized gating mechanisms. (Gers et al., 2000)

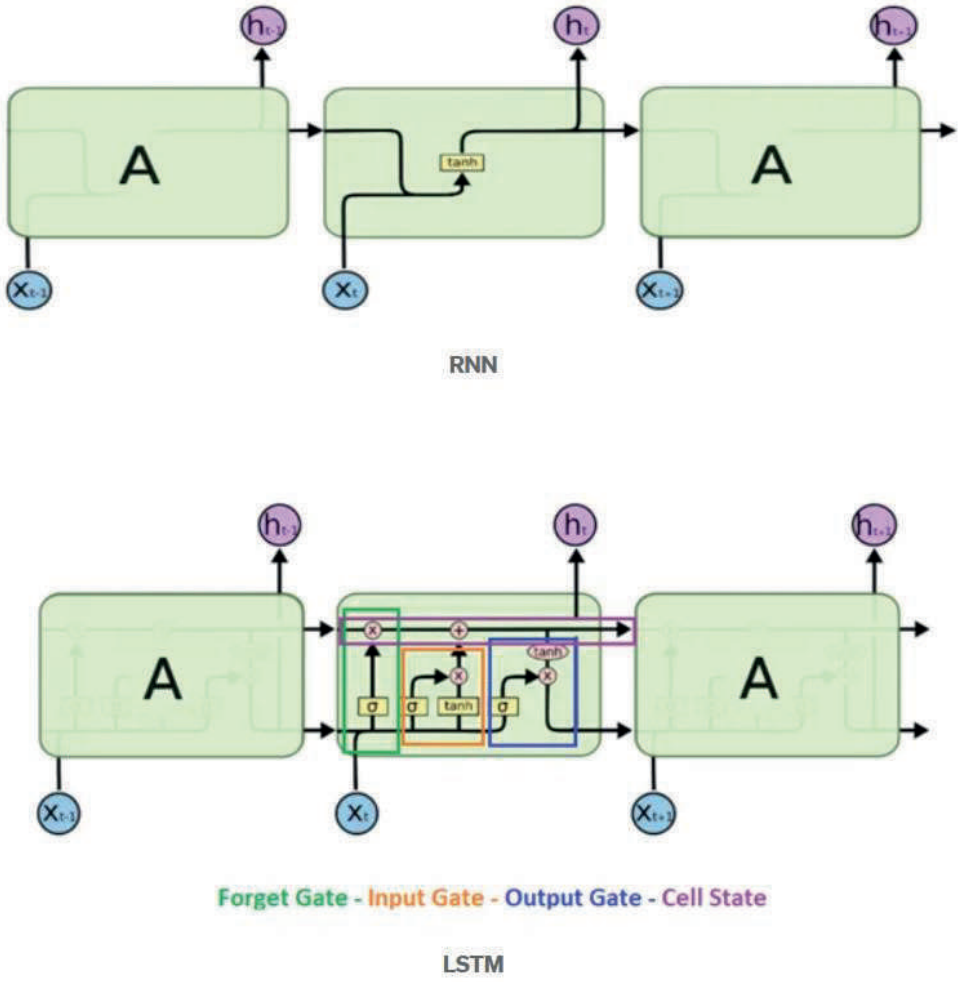


Figure 6. Comparison of RNN and LSTM Architectures

The experimental analysis was performed using one year of hourly photovoltaic production data. Model development and evaluation were carried out in the Jupyter Notebook environment. The dataset includes timestamp information and corresponding power output values (W), resulting in a total of 17,568 observations used for training and validation processes.

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RESULTS

The dataset was partitioned into training and testing subsets to evaluate model generalization performance. A rolling-window approach was employed in which the preceding 30-day historical observations were used to generate subsequent production forecasts. Approximately 70% of the data were assigned to model training, while the remaining 30% were reserved for testing.

Following model implementation, the predicted outputs were compared with the corresponding observed values for CNN, RNN, and LSTM architectures, and performance differences were evaluated through graphical and quantitative analyses.

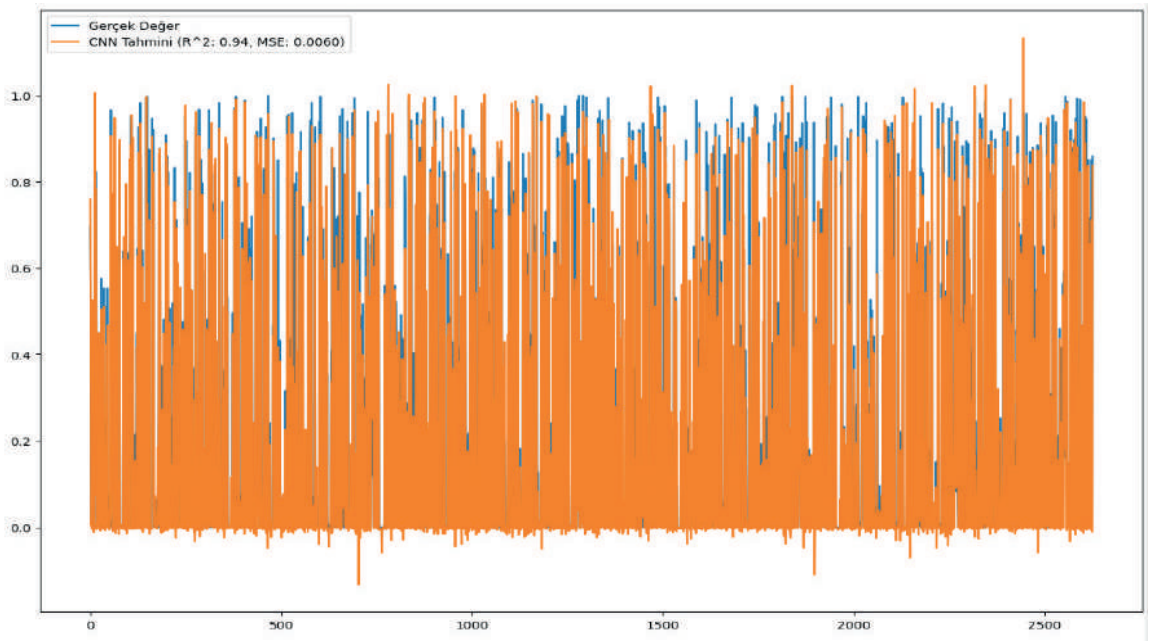


Figure 7. CNN Model Training and Validation Loss

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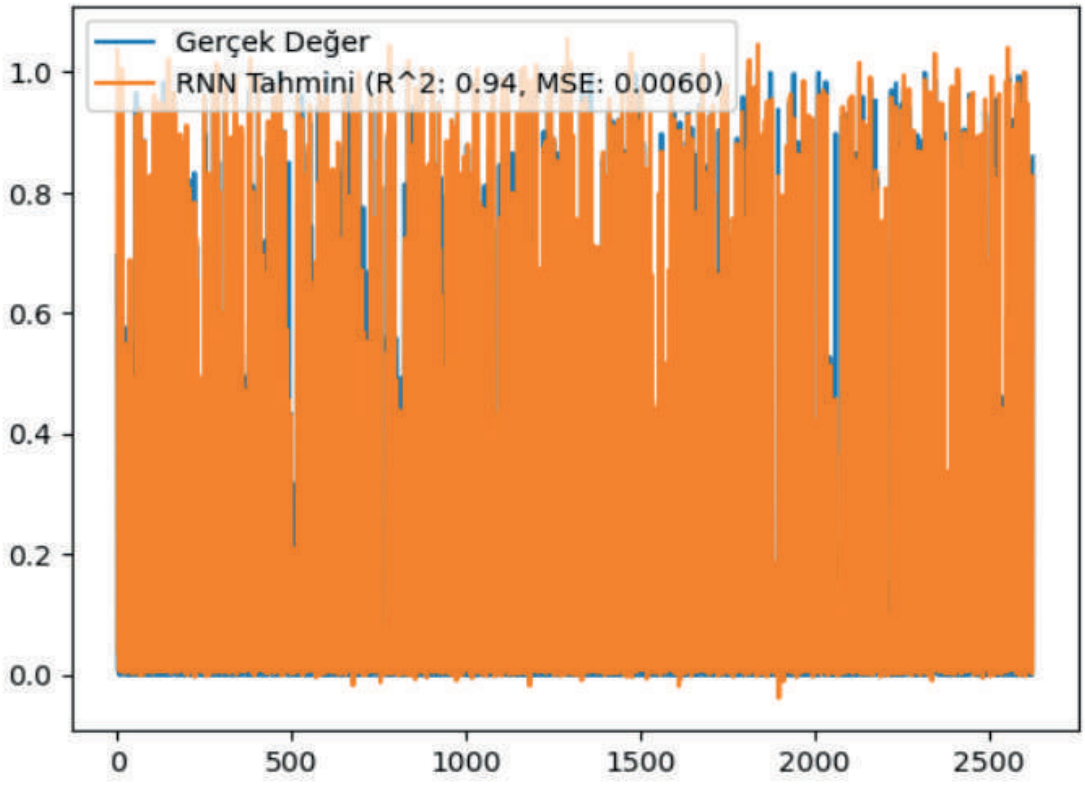


Figure 8. RNN Model Training and Validation Loss

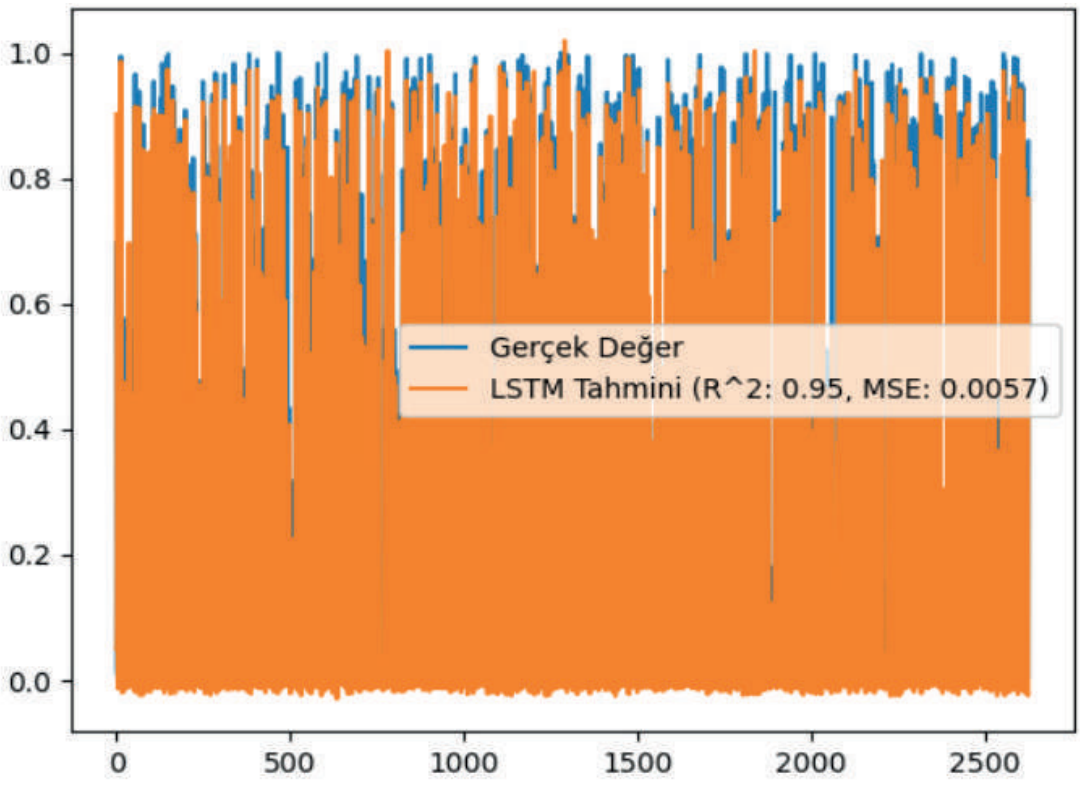


Figure 9. LSTM Model Training and Validation Loss

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The evolution of training and validation error metrics for CNN, RNN, and LSTM architectures was examined to assess convergence behavior and generalization performance..

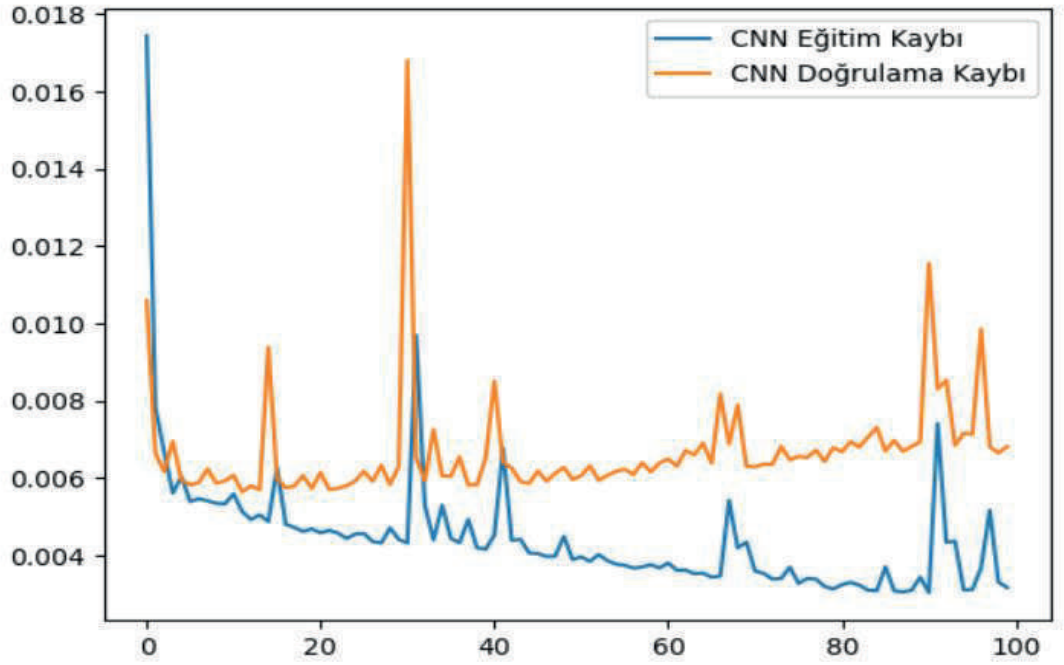


Figure 10. CNN Training and Validation Loss

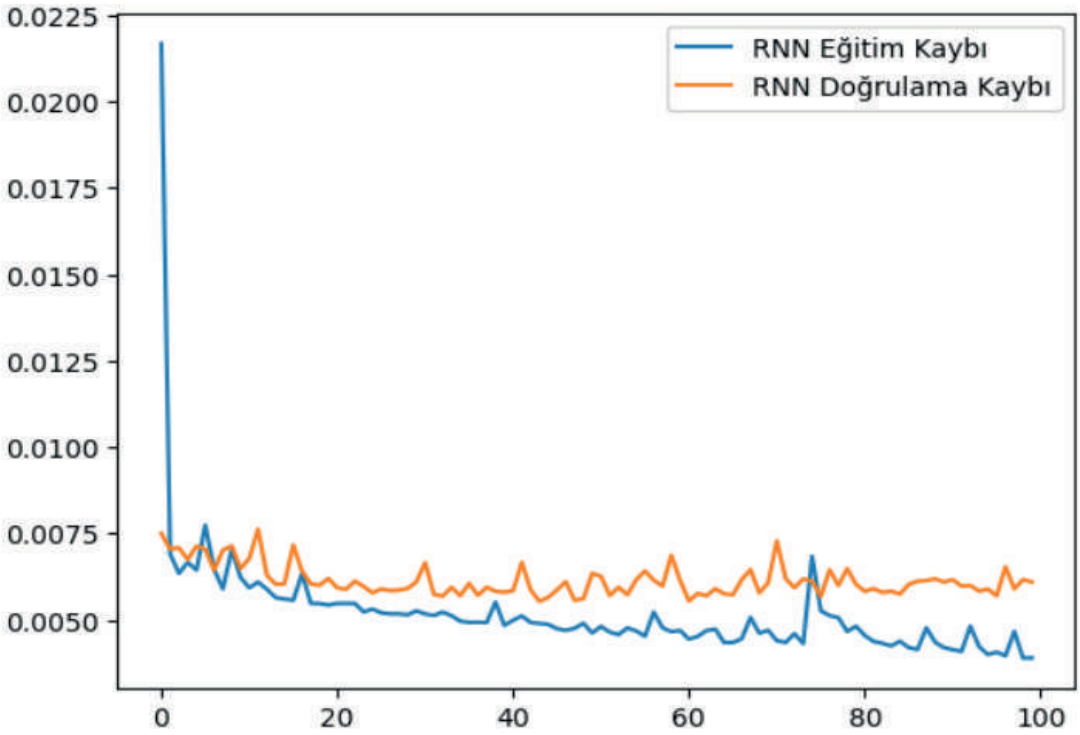


Figure 11. RNN Training and Validation Loss

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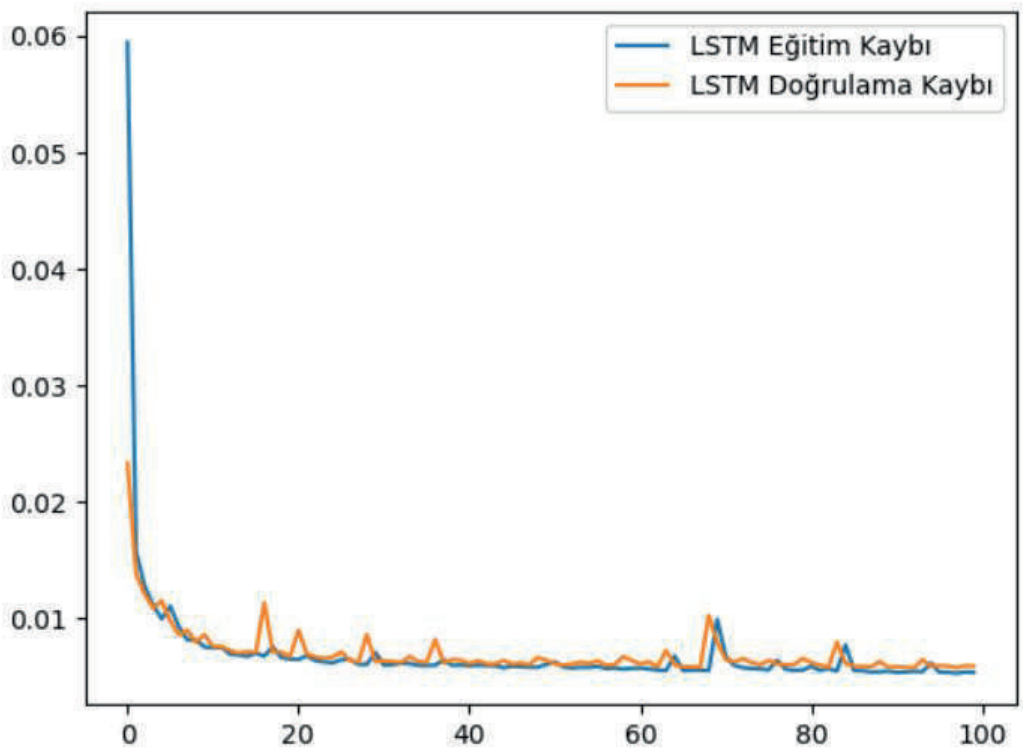


Figure 12. LSTM Training and Validation Loss

The predictive performance of the developed models was evaluated using standard regression-based evaluation criteria.

Table 1. Performance Scores of CNN, RNN, and LSTM Models

Model	R^2 Skoru	MSE
CNN	0.94	0.0060
RNN	0.94	0.0060
LSTM	0.95	0.0057

In this research, monthly electrical energy generation of a photovoltaic power plant was predicted based on previously recorded production data. Deep learning architectures including CNN, RNN, and LSTM were implemented to model temporal patterns in the dataset. Model effectiveness was assessed through the coefficient of determination (R^2) and Mean Squared Error (MSE), enabling quantitative comparison of predictive accuracy.

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The coefficient of determination (R^2) indicates the extent to which variability in the target variable is captured by the predictive model. It reflects the explanatory power of the independent variables and provides a normalized measure of goodness-of-fit. From a statistical perspective, R^2 represents the squared correlation between observed and estimated values.

Mean Squared Error (MSE) evaluates prediction accuracy by computing the mean of the squared residuals obtained from the difference between actual observations and model outputs. Lower MSE values indicate improved predictive performance and reduced estimation error.

Throughout the hyperparameter tuning phase, consistent reductions in both training and validation loss functions were observed. This behavior suggests effective learning of intrinsic data patterns without significant overfitting, thereby enhancing the model's generalization performance.

The results of the study demonstrate that the LSTM neural network approach outperformed the other methods in forecasting energy production data.

DISCUSSION

Through the high-accuracy forecasting performed in this study, prospective investors intending to establish a solar power plant are provided with the opportunity to estimate the expected monthly energy production associated with their planned investment. This enables the calculation of the payback period of the investment and supports informed decision-making regarding its economic feasibility.

Furthermore, the proposed approach assists existing solar power plant owners in predicting their potential monthly electricity generation. With the continuous advancement of technology, the field of data science is rapidly evolving, and accordingly, the effective processing and analysis of data have become increasingly critical.

CONCLUSION

Comparative analysis of the implemented architectures demonstrates that the LSTM-based model delivers superior forecasting accuracy relative to CNN and RNN approaches in the context of energy production prediction.

The input dataset can be expanded to include a larger number of samples, thereby enhancing the robustness of the model. Additionally, incorporating supplementary parameters such as ambient temperature and solar irradiation duration into the dataset may further improve predictive accuracy. By increasing the volume and diversity of data and utilizing the LSTM methodology, more reliable and higher-precision forecasting studies can be conducted.

ACKNOWLEDGEMENTS

This article is based on the master's thesis entitled "Production Forecasting of Solar Power Plants Using Artificial Intelligence" conducted by Ersoy ÖZCAN.

REFERANSLAR

AlShabi M, Assad MEH 2021. Artificial intelligence applications in renewable energy systems. In: Design and performance optimization of renewable energy systems. Academic Press: 251-295.

Bishop CM 2006. Pattern recognition and machine learning. New York: Springer, 738 pp.

Cho K, van Merriënboer B, Gülcehre Ç, Bahdanau D, Bougares F, Schwenk H, Bengio Y 2014. Learning phrase representations using RNN encoder–decoder for statistical machine translation. EMNLP 2014, 1724–1734.

Elman JL 1990. Finding structure in time. Cognitive Science, 14: 179-211.

Esram T, Chapman PL 2007. Comparison of photovoltaic array maximum power point tracking techniques. IEEE Transactions on Energy Conversion, 22(2): 439-449.

Gers FA, Schmidhuber J, Cummins F 2000. Learning to forget: Continual prediction with LSTM. Neural Computation, 12: 2451-2471.

Goodfellow I, Bengio Y, Courville A 2016. Deep learning. Cambridge: MIT Press, 775 pp.

Green MA, Dunlop ED, Levi DH, Hohl-Ebinger J, Yoshita M, Ho-Baillie AWY 2022. Solar cell efficiency tables (version 60). Progress in Photovoltaics: Research and Applications, 30: 687-701.

Hochreiter S, Schmidhuber J 1997. Long short-term memory. Neural Computation, 9(8): 1735-1780.

IEA 2022. World Energy Outlook 2022. Paris: International Energy Agency.

Jordan MI, Mitchell TM 2015. Machine learning: Trends, perspectives, and prospects. Science, 349(6245): 255–260.

Kjaer SB, Pedersen JK, Blaabjerg F 2005. A review of single-phase grid-connected inverters for photovoltaic modules. IEEE Transactions on Industry Applications, 41(5): 1292-1306.

Krizhevsky A, Sutskever I, Hinton GE 2012. ImageNet classification with deep convolutional neural networks. Advances in Neural Information Processing Systems, 25: 1097-1105.

LeCun Y, Bottou L, Bengio Y, Haffner P 1998. Gradient-based learning applied to document recognition. Proceedings of the IEEE, 86(11): 2278-2324.

Makridakis S 2017. The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. Futures, 90: 46–60.

Martínez-López FJ, Casillas J 2013. Artificial intelligence-based systems applied in industrial marketing: An historical overview, current and future insights. Industrial Marketing Management, 42(4): 489-495.

McCulloch WS, Pitts W 1943. A logical calculus of the ideas immanent in nervous activity. Bulletin of Mathematical Biophysics, 5: 115-133.

Parida B, Iniyan S, Goic R 2011. A review of solar photovoltaic technologies. Renewable and Sustainable Energy Reviews, 15: 1625–1636.

Pascanu R, Mikolov T, Bengio Y 2013. On the difficulty of training recurrent neural networks. International Conference on Machine Learning Proceedings of ICML 2013, 1310–1318.

Razykov TM, Ferekides CS, Morel D, Stefanakos E, Ullal HS, Upadhyaya HM 2011. Solar photovoltaic electricity: Current status and future prospects. Solar Energy, 85: 1580-1608.

REN21 2023. Renewables 2023 Global Status Report. Paris: REN21 Secretariat.

Rumelhart DE, Hinton GE, Williams RJ 1986. Learning representations by back-propagating errors. Nature, 323: 533-536.

Schmidhuber J 2015. Deep learning in neural networks: An overview. Neural Networks, 61: 85–117.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Shockley W, Queisser HJ 1961. Detailed balance limit of efficiency of p–n junction solar cells. Journal of Applied Physics, 32: 510-519.

Voyant C, Notton G, Kalogirou S, Nivet ML, Paoli C, Motte F, Fouilloy A 2017. Machine learning methods for solar radiation forecasting: A review. Renewable Energy, 105: 569-582.

Yousef LA, Yousef H, Rocha-Meneses L 2023. Artificial intelligence for management of variable renewable energy systems: A review of current status and future directions. Energies, 16(24): 8057.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANTIBACTERIAL EFFICACY AND CYTOGENETIC ASSESSMENT OF ZINC PYRITHIONE (ZNPT)

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ABSTRACT

In this study, the antibacterial and cytogenetic effects of Zinc Pyrithione (ZnPT) were evaluated. Antibacterial activity was assessed against *Staphylococcus aureus*, *Acinetobacter baumannii*, and *Klebsiella pneumoniae* using the disk diffusion method, and the minimum inhibitory concentration (MIC) values were determined for each microorganism. The MIC values were found to be 0.03 mg/ml for *S. aureus*, 0.47 mg/ml for *A. baumannii*, and 0.12 mg/ml for *K. pneumoniae*. These findings indicate that the antibacterial efficacy of ZnPT is concentration-dependent and varies among different bacterial strains. Cytogenetic analyses were conducted using *Allium cepa* root meristem cells to examine chromosomal abnormalities and the mitotic index (MI). When the data obtained from different ZnPT concentrations (0.007 mg/ml, 0.03 mg/ml, 0.12 mg/ml, 0.47 mg/ml, and 0.94 mg/ml) were compared with the negative control group, a concentration-dependent increase in mitotic abnormalities was observed in *A. cepa* root cells. Among the detected abnormalities, C-mitosis and irregular metaphase were the most frequently observed. Evaluation of the cytotoxic effects of ZnPT on A. cepa root tip cells revealed a decrease in the mitotic index percentage with increasing concentrations. Based on the results of this study, ZnPT does not appear to exert genotoxic effects; however, it may have the potential to induce cytotoxic effects at higher concentrations.

Keywords: *Allium cepa*, Antibacterial Activity, Cytogenetic Effect, Zinc Piriton.

INTRODUCTION

Zinc occurs in nature in combination with many minerals, and its primary sources in ecosystems are industrial and mining waste (Aras, 1998). In addition, atmospheric particles, domestic and agricultural wastes are other factors that increase zinc concentration in aquatic ecosystems (Maity et al., 2008). One of these combinations is zinc pyrithione. Zinc pyrithione is a type of formulated zinc. Zinc pyrithione is one of the popular antifouling biocides used in painting marine vessels (Bray and Bettger, 1990). Zinc pyrithione is used in many sectors due to its antimicrobial activity. Zinc pyrithione (ZnPT)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

is an organometallic compound with bactericidal and fungicidal activity. It is the most used antifungal agent in shampoos for dandruff control. ZnPT was developed in the 1950s and first used as an anti-dandruff agent in 1961 (Arcasoy, 1998; Doğan, 1998). It has been found that a combination of zinc and pyrithione applied at low concentrations in cell cultures inhibits the replication of SARS coronavirus. ZnPT is skin-compatible and eco-safe (Kargın and Erdem, 1992). Non-textile uses, such as the treatment of dandruff, seborrheic dermatitis, and psoriasis, constitute the main proportion of ZnPT consumption volume (Wood, 2001). Other applications include textiles, adhesives, paints, wire/cable insulation, and floor coatings (Venneria et al., 2014). While the use of zinc pyrithione in creams, sprays, and shampoos is significant, its use in the textile field is considerably lower than textile antimicrobials such as Si-QAC and TCS (Bray and Bettger, 1990). Its applications in the textile industry are rapidly increasing in response to rising demand. Zinc is an element found in many enzymes and plays a major role in the synthesis and breakdown of carbohydrates, lipids, proteins, and nucleic acids (Coudray et al., 1993). It has also been noted that zinc plays a role in maintaining membrane integrity and has an antioxidant role (Cuvin-Aralar et al., 1994). Furthermore, zinc has roles in important metabolic processes, including heme synthesis, gene expression, tissue synthesis, and embryogenesis (Kargın and Erdem, 1992). Although it is found in low amounts in living organisms, it is important for many enzyme systems. Zinc is a trace element necessary for the development of the immune system against infections in animals, for the treatment of diseases, and for a healthy life. Although zinc is a relatively non-toxic trace element, high concentrations have been reported by various researchers to have a toxic effect on most organisms (Andrews et al., 2018). It has been stated that zinc plays a role in maintaining membrane integrity and has an antioxidant role (Park, 2015). In addition, Zinc plays important roles in cell division, growth, metabolism, and the immune system (Turley et al., 2000). It has been stated that zinc acts as a protective agent against cell-damaging free radicals such as reactive oxygen species, hydrogen peroxide, hydroxyl radicals, and singlet oxygen in organisms (Can and Körlü, 2011). It has been stated that zinc can easily form complexes with O_2 and Sulfur (S) spinners, plays a role in nucleic acid biosynthesis, and is involved in tissue repair (Gao and Cranston, 2018). However, high concentrations of zinc have been reported by various researchers to cause a toxic effect on aquatic organisms (Altuner, 2014).

This study, designed to both diversify the uses of ZnPT, which is found in the composition of some products used in daily life, and to reveal its cytogenetic effects, and plans to investigate the antimicrobial and cytogenetic effects of ZnPT. Within the scope of antibacterial activity studies, inhibitory activity tests will be conducted against antibiotic-resistant Acinetobacter sp., S. aureus, and Klebsiella sp. bacteria using the well diffusion method with different dosages of ZnPT (5-0.001 ppm). Especially today, the search for new antibacterial metabolites in the fight against resistant pathogens is rapidly continuing. In this context, this study will provide an opportunity to evaluate the possibility of using ZnPT as an alternative antibacterial. Simultaneously, in this study, *Allium cepa* L. will be used

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ISBN: 978-9952-610-30-7

to investigate the cytogenetic effects of ZnPT. The genotoxicity, cytogenetic, and anatomical changes caused by different dosages of ZnPT in *A. cepa* meristem stem cells will be investigated. Higher plants are very useful in evaluating the cytotoxicity and genotoxicity of environmental pollutants because they are readily available, simple and sensitive to analysis. Due to the potential of roots to be exposed to chemicals spreading in soil and water, the root tips of *A. cepa* are one of the plants suitable for genotoxic/cytotoxic studies to determine the effect of chemicals. The *Allium* test has a wide range of applications due to its root structure that can be affected by chemical substances, its fixed chromosome number (2n=16), the size of its chromosomes, and its ability to directly interact with the test material by forming many root tips. It is a cytogenetic material suitable for easily detecting chromosomal damage and determining genotoxicity (Rasgele, 2023). Through this study, the toxic dosage levels of ZnPT will be determined.

MATERIALS AND METHODS

Antibacterial Activity Analysis

Zinc pyrithione (ZnPT) used in this study has the chemical formula $C_{10}H_8N_2O_2S_2Zn$ and a molecular weight of 317.70 g/mol. To evaluate the inhibitory effect of ZnPT, clinical isolates of *Klebsiella pneumoniae*, *Staphylococcus aureus*, and *Acinetobacter baumannii* were used. Antibacterial activity was assessed using both agar well diffusion and disk diffusion methods (Ugras et al., 2024). Bacterial strains were cultured on nutrient agar and incubated at 37 °C for approximately 16–18 h. Following incubation, the test microorganisms were adjusted to a concentration of 1×10^8 CFU/mL, and 100 µL of each bacterial suspension was evenly spread onto the agar surface. Subsequently, wells were created in the solidified agar medium and/or sterile disks were placed onto the agar surface. Different concentrations of ZnPT (5–0.001 ppm) were then loaded into the wells or onto the disks. The plates were incubated again at 37 °C for 16–18 h. After incubation, the inhibition zones formed around the wells or disks were measured and evaluated to determine the antibacterial activity of ZnPT.

Determination of Minimum Inhibitory Concentration (MIC)

The minimum inhibitory concentration (MIC) of ZnPT was determined using the microdilution method (Ugras et al., 2024). For this purpose, different concentrations of ZnPT were prepared in 96-well microplates. Each well contained a specific concentration of ZnPT. Subsequently, 5 µL of the test microorganism suspension (approximately 1×10^5 CFU/mL) was added to each well containing different concentrations of the compound. For the negative control, 200 µL of culture medium without ZnPT was used. MIC was defined as the lowest concentration of ZnPT required to inhibit visible bacterial growth after incubation at 37 °C for 24 h.

Test Material and Experimental Groups

Allium cepa L. (2n = 16) bulbs were commercially obtained from a local market. In this study, seven experimental groups were established, each containing different doses of ZnPT. The groups were

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prepared as Group I: ZnPT (0,007mg/ml), Group II: ZnPT (0,03 mg/ml), Group III: ZnPT (0,12 mg/ml), Group IV: ZnPT (0,47 mg/ml), Group V: ZnPT (0,94 mg/ml), Group VI: Negative control (dH_2O), Group VII: Positive control (H_2O_2). The onion bulbs were placed in sterile tubes and allowed to germinate for 72 h (Goc Rasgele et al., 2025).

Cytological Investigations

At the end of the 72 h treatment period, onion root tips (1–2 cm in length) were excised and fixed overnight at +4 °C in a freshly prepared alcohol:acetic acid solution (3:1, v/v). The fixed root tips were stored in 70% ethanol until microscopic examination. Prior to analysis, the roots were washed with distilled water and hydrolyzed in 1N HCl at 60 °C for 15 min. Squash preparations were prepared using acetocarmine stain. Cell counts were performed under a light microscope to calculate the mitotic index (Goc Rasgele et al., 2025).

Statistical Analysis

The data were analyzed using SPSS 20 for Windows (SPSS Inc., Chicago, IL, USA). Results were expressed as mean ± standard error (SE). The significance of differences between treatment groups and the negative control was evaluated using the non-parametric Kruskal–Wallis test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

ANTIBACTERIAL ACTIVITY STUDIES

Disk Diffusion and Well Diffusion Test

In this study, the antibacterial efficacy of ZnPT at different dosages was evaluated against *Acinetobacter baumannii, Klebsiella pneumoniae*, and *Staphylococcus aureus* bacteria exhibiting multi-antibiotic resistance using agar well diffusion and agar disk diffusion methods (Figure 1). In the well diffusion method, only the presence of antimicrobial activity was evaluated, thus revealing the overall effect of ZnPT. According to the data obtained, it was determined that ZnPT showed antimicrobial activity against resistant bacteria at certain dosages. It was observed that the antibacterial activity increased in parallel with the gradual increase in concentrations.



Figure 1. Well diffusion test and disk diffusion test.

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Minimal Inhibitory Concentration Test

As a result of the Minimum Inhibitory Concentration (MIC) tests, the MIC value of ZnPT for *S. aureus* strain was calculated as 0.03 mg/ml, for *A. baumannii* as 0.47 mg/ml, and for *K. pneumoniae* as 0.12 mg/ml. These data show that ZnPT is effective, especially against *S. aureus*, even at low concentrations (Table 1).

Table 1. Diameters of measured inhibition zones.

Test Microorganisms	Inhibition zone diameters / ZnPT				
	1,88 mg/ml	0,94 mg/ml	0,47 mg/ml	0,24 mg/ml	0,12 mg/ml
S. aureus	23 mm	21 mm	17 mm	12 mm	10 mm
A. baumannii	20 mm	21 mm	07 mm	11 mm	12 mm
K. pneumoniae	25 mm	24 mm	18 mm	15 mm	12 mm

PHYSIOLOGICAL AND CYTOGENETIC STUDIES

In this study, the possible cytogenetic effects of ZnPT on Allium cepa root meristem cells were evaluated. First, germination rates and root development processes were examined in all ZnPT application groups. Before setting up the Allium cepa experiment, which was used as the test material, the initial weight was taken for each group. The weight of the germinated bulbs was taken again after 72 hours. Five roots of similar length were taken from each bulb and their lengths were examined (Table 2).

Table 2. Physiological results of ZnPT application to *Allium cepa* L.

Groups	Weight (gr/0h)	Weight (gr/72h)	Weight Gain (g)	Root Length (cm)
Negative Control	3,460±0,627	4,77±0,800	1,31±0,17	3,012±0,523
Positive Control	3,624±0,467	4,75±0,734	1,126±0,26	4,708±0,196
ZnPT (0,007mg/ml)	3,114±0,547	3,866±0,717	0,752±0,17	0,908±0,379
ZnPT (0,03 mg/ml)	3,482±0,316	4,16±0,314	0,678±0,17	0,756±0,267
ZnPT (0,12 mg/ml)	3,828±0,404	4,59±0,659	0,762±0,25	0,86±0,396

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ZnPT (0,47 mg/ml)	3,544±0,512	4,376±0,589	0,832±0,07	0,948±0,262
ZnPT (0,94 mg/ml)	3,362±0,495	4,236±0,482	0,874±0,01	1,004±0,356

Data is presented as mean ± SD.

The highest weight gain was observed in the negative control group. Weight gain was lower in the ZnPT-treated groups compared to the control groups. A decrease in weight gain was observed at low concentrations of ZnPT (0.007–0.03 mg/ml); an increase in weight gain was observed at medium and high concentrations (0.12–0.94 mg/ml). Above a certain dose, ZnPT may have a growth-promoting or non-toxic effect. ZnPT significantly reduces root length depending on the concentration. This effect was found to be greater at low concentrations and somewhat milder at high concentrations. The results suggest that ZnPT may have potential to suppress root development. Subsequently, cytogenetic studies were performed on the germinated roots. Chromosomal abnormalities and mitotic index (MI) percentage in *A. cepa* root cells are shown in Table 3. Different concentrations of ZnPT (0.007 mg/ml, 0.03 mg/ml, 0.12 mg/ml, 0.47 mg/ml, and 0.94 mg/ml), when compared to a negative control, were found to increase mitotic abnormalities in *A. cepa* root meristem cells as concentration increased. The number of abnormal cells tended to increase as ZnPT concentrations increased. Among the mitotic abnormalities, C-mitosis and irregular metaphase were the most frequently observed.

Table 3. Percentage of chromosomal abnormalities and mitotic index (MI).

	Negative Control	Pozitive Control	ZnPT 0,007mg/ml	ZnPT 0,03 mg/ml	ZnPT 0,12 mg/ml	ZnPT 0,47 mg/ml	ZnPT 0,94 mg/ml
Irreg. Meta.	4.00±1.08	13.75±1.79*	3.25±0.62	0.75±0.47	7.50±3.86	6.00±2.16	10.5±2.84
Stickness	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
C-Mitosis	2.5±1.04	14.50±2.02*	9.25±2.78	12.50±1.75*	11.00±4.02	14.00±2.94*	11.00±1.87
MN	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
Lag. Chr	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
T. Aber. Cel.	6.75±2.28	28.25±3.56*	12.50±2.90	13.25±2.21	18.50±7.83	20.00±4.32	21.50±4.57
MI (%)	10.96±0.74	6.56±0.29*	10.84±1.24	10.25±1.16	9.72±1.73	8.30±1.12	5.29±0.36*

Irreg. Meta: Irregular Metaphase, MN: Micronucleus, Lag. Chr: Lagging Chromosome; T. Aber. Cel.; Total Aberrant

Cells, MI: Mitotic Index. (*) P ≤ 0.05.

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ISBN: 978-9952-610-30-7

When the effects of different concentrations of ZnPT (0.007 mg/ml, 0.03 mg/ml, 0.12 mg/ml, 0.47 mg/ml and 0.94 mg/ml) on Allium cepa stem cells were examined, it was observed that the number of abnormal cells increased as the ZnPT concentration increased (Figure 3.4).

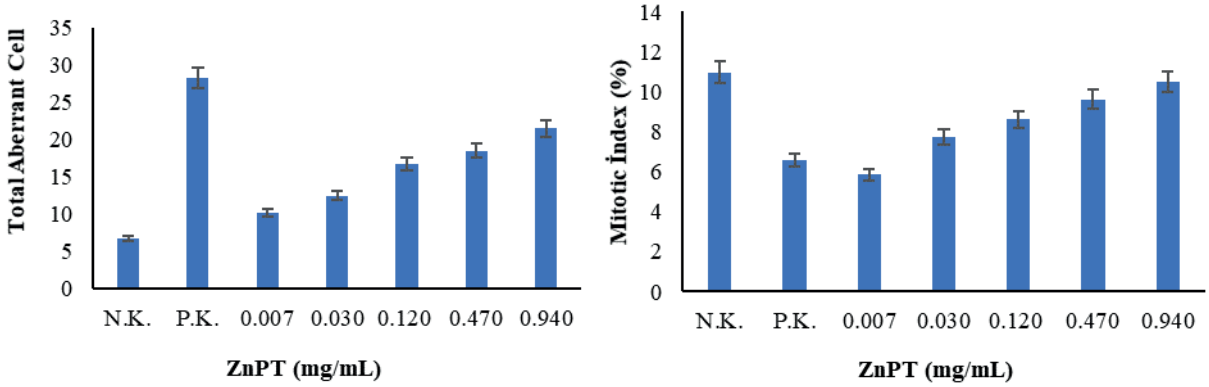


Figure 2. Total abnormal cell numbers and mitotic index distribution in *A. cepa* treated with ZnPT.

When the cytotoxic effect of ZnPT on *A. cepa* root tip cells was evaluated, it was found that the percentage of mitotic index decreased with increasing concentration (Figure 2). Figure 3 (A-D) shows the mitotic division stages obtained from the negative control group. Figure 3 (E-F) shows the chromosomal abnormalities obtained from the positive control group.

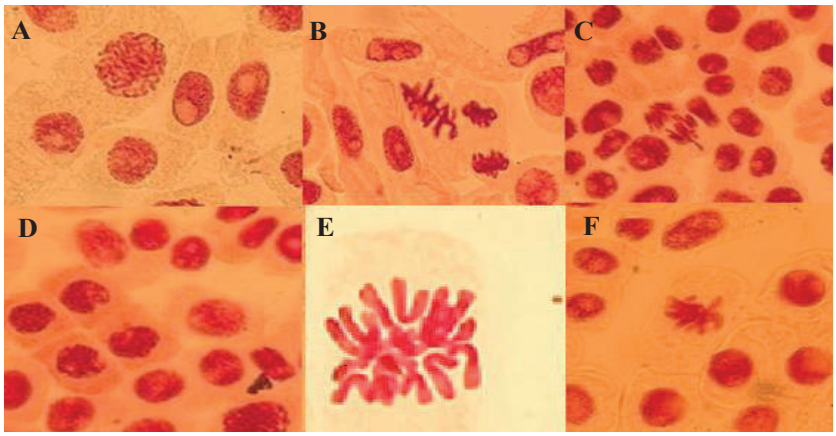


Figure 3. Mitotic stages in negative control (Normal): (A) Prophase, (B) Metaphase, (C) Anaphase, (D) Telophase; Microscope images in positive control: (E) C-mitosis, (F) Irregular metaphase microscope images (x40 magnification).

DISCUSSION

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ISBN: 978-9952-610-30-7

Treatment of infections is becoming more difficult, and the treatment time is increasing due to resistant bacteria. New strategies and testing of new molecules are needed to combat them. With the decrease in the effectiveness of existing antibiotics, the need for new strategies and alternative antimicrobial molecules in the fight against resistant microorganisms is increasing. Investigating the biological effects of existing or newly developed molecules is of great importance. One of these molecules is ZnPT. ZnPT is effective against fungi, bacteria, and some protozoa and is generally used in anti-dandruff shampoos, antiseptic products, and some industrial applications. ZnPT is formed as a compound in which a zinc ion (Zn^{2+}) is bound to a pyritone molecule. Pyritone is a nitrogenous organic compound with a heterocyclic structure and contains sulfur (Reeder et al., 2011). Within the scope of the studies, it has been shown that ZnPT damages iron-sulfur (Fe-S) protein complexes by increasing copper levels in fungal cells and stops fungal growth through this mechanism, thus providing the antifungal effect of ZnPT (Reeder et al., 2011). In their study, Guthery et al. evaluated the antimicrobial preservative and safety of ZnPT used in alcohol-based products for skin antisepsis. Alcohol-based antiseptic products containing ZnPT were compared with other iodine or chlorhexidine-containing products available on the market. As a result, it was stated that ZnPT is not only a safe and effective antimicrobial agent, but also provides a more persistent antimicrobial effect than iodine and chlorhexidine in certain formulations (Guthery et al., 2005). Jain and Tesema aimed to develop a suitable procedure for producing an antimicrobial coating using ZnPT on 100% cotton textile products in their study. It was stated that ZnPT is environmentally friendly and safe for both producers and consumers due to its bacteriostatic nature (Jain and Tesema, 2017).

Blanchard and colleagues investigated the antibacterial effects of ZnPT in their study. In this study, the compatibility of ZnPT with silver sulfadiazine was evaluated against bacteria such as *Pseudomonas aeruginosa, Acinetobacter baumannii*, and *Staphylococcus aureus*, which cause wound infections. The research showed that ZnPT exhibited antibiofilm activity against these bacteria and created a synergistic effect when used together with silver sulfadiazine. In addition, this combination was found to be effective in clearing wound infections in experiments conducted on a mouse model. In conclusion, the combination of ZnPT and silver sulfadiazine shows that it can be an effective agent in the treatment of wound infections (Blanchard et al., 2016).

ZnPT has been used in many different sectors, mainly cosmetics, for about 50 years. However, recent studies have revealed the toxicity of ZnPT and, in this context, have brought to the agenda its negative effects on human health and ecological balance. Although negative data regarding its toxicity has increased, the antimicrobial efficacy of ZnPT still remains attractive for many sectors. In this context, this study, designed to eliminate these uncertainties and reveal the antimicrobial efficacy of ZnPT, aimed to determine its antimicrobial activity against antibiotic-resistant clinical isolates *Staphylococcus aureus, Acinetobacter baumannii*, and *Klebsiella pneumoniae*, and to thoroughly investigate the cytogenetic effect of effective dosage. As a result of this study, the MIC value of ZnPT

was calculated as 0.03 mg/ml for *S. aureus* strain, 0.47 mg/ml for *A. baumannii*, and 0.12 mg/ml for *K. pneumoniae*. These data demonstrate that ZnPT is effective, especially against *S. aureus*, even at low concentrations. However, cytogenetic studies have shown that ZnPT does not damage genetic material at the determined effective dosages, but it can produce a cytotoxic effect at high concentrations (0.94 mg/ml). These findings suggest that ZnPT may be safe to use at low concentrations, but the concentration should be considered.

Similarly, some studies in the literature also report that ZnPT can show antimicrobial effects at low concentrations without causing toxicity. For example, a study by Yang et al. reported that ZnPT did not show cytotoxic effects on human dermal cell lines at concentrations of 0.1–1 µg/mL, but caused a decrease in cellular viability at higher doses (Yang et al. 2020). Another study by Kim et al. stated that ZnPT is effective against fungal and bacterial infections without causing DNA damage (Li et al., 2017). In the study by Güner et al., the cytotoxic and genotoxic effects of ZnPT on human lymphocyte cells were evaluated. Genotoxicity was investigated using parameters such as cell viability, lactate dehydrogenase (LDH) release, mitotic index, cytotoxicity, and micronucleus (MN) tests. The decrease in mitotic index is the parameter used to demonstrate cytotoxic effects, while the increase in chromosomal abnormalities is the parameter used to demonstrate genotoxic effects (Rasgele, 2023; Aslantürk, 2024). ZnPT did not show a genotoxic effect at concentrations up to 1000 nmol/L, and there was no significant change in the cell proliferation index. However, at concentrations of 500 nmol/L and above, LDH release, oxidative stress, and intracellular zinc levels increased, while cell viability and mitotic index decreased. In conclusion, it shows that ZnPT can cause toxic effects through increased oxidative stress at high concentrations (Güner and İlhan, 2020).

CONCLUSION

ZnPT has been used in many sectors for many years due to its strong antimicrobial activity. However, in recent years, the cytotoxic effect of such a powerful molecule has become a subject of debate. This study aimed to determine the effectiveness of ZnPT in combating resistant pathogens and to test the cytogenetic effect of its effective dosage. The results of this study showed that ZnPT has strong antibacterial activity against *S. aureus, A. baumannii*, and *K. pneumoniae*. Cytotoxic activity analyses revealed that ZnPT did not produce a genotoxic effect at the concentrations used; however, it could exhibit a cytotoxic effect by suppressing mitotic activity at some concentrations. These findings indicate that ZnPT can be used at low concentrations without damaging genetic material, but attention should be paid to its effects on cell division.

ACKNOWLEDGEMENTS

This study was derived from a Master's thesis.

REFERENCES

Altuner EE 2014. Nano kremlerin üretimi. Karaelmas Fen ve Mühendislik Dergisi, 4(1): 52-57.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Andrews KA, Brown MD, Clapperton PR 2018. The antimicrobial properties of zinc pyrithione and its application in various industries. Journal of Applied Microbiology, 103: 1621-1633.

Aras NK 1998. Buğday ve ürünlerinde çinko ve aralarındaki ilişkiler. I. Ulusal Çinko Kongresi (Tarım, Gıda ve Sağlık), Anadolu Tarımsal Araştırma Enstitüsü, Eskişehir: 61-64.

Arcasoy A 1998. İnsan sağlığında çinkonun önemi. I. Ulusal Çinko Kongresi (Tarım, Gıda ve Sağlık), Anadolu Tarımsal Araştırma Enstitüsü, Eskişehir: 11-17.

Aslantürk ÖŞ 2024. Cytotoxic and genotoxic effects of triphenyl phosphate on root tip cells of *Allium cepa* L. Toxicology in Vitro, 94: 105734.

Blanchard C, Brooks L, Ebsworth-Mojica K, Didione L, Wucher B, Dewhurst S, Krysan D, Dunman PM, Wozniak RAF 2016. Zinc pyrithione improves the antibacterial activity of silver sulfadiazine ointment. mSphere, 1(5): e00194-16.

Bray T, Bettger WJ 1990. The physiological role of zinc as antioxidant. Free Radical Biology and Medicine, 8: 281-291.

Can C, Körlü A 2011. Antibakteriyel tekstil üretiminde sıkça kullanılan gümüşün etki mekanizması ve toksisitesi. Tekstil Teknolojileri Elektronik Dergisi, 5(3): 54-59.

Coudray C, Rachidi S, Favier A 1993. Effect of zinc on superoxide dependent hydroxyl radical production in vitro. Biological Trace Element Research, 38: 273-287.

Cuvin-Aralar MLA 1994. Survival and heavy metal accumulation of two *Oreochromis niloticus* (L.) strains exposed to mixtures of zinc, cadmium and mercury. Science of the Total Environment, 148: 31-38.

Doğan K 1998. Çinkonun hayvan beslenmesindeki yeri ve önemi. I. Ulusal Çinko Kongresi (Tarım, Gıda ve Sağlık), Anadolu Tarımsal Araştırma Enstitüsü, Eskişehir: 25-30.

Gao Y, Cranston R 2008. Recent advances in antimicrobial treatments of textiles. Textile Research Journal, 78: 60-72.

Goc Rasgele P, Karaguzel A, Ugras S, Emire Z 2025. Carvacrol: A protective agent against cadmium nitrate toxicity in *Allium cepa* L. Pharmaceutical Chemistry Journal, 59(4): 436-444.

Güner A, İlhan S 2020. Cytotoxic, genotoxic, oxidative, and irritant effects of zinc pyrithione in vitro. Toxicological & Environmental Chemistry, 102(9-10): 607-623.

Guthery E, Seal LA, Anderson EL 2005. Zinc pyrithione in alcohol-based products for skin antisepsis: Persistence of antimicrobial effects. American Journal of Infection Control, 33(1): 15-22.

Jain AK, Tesema AF 2017. Development of antimicrobial textiles using zinc pyrithione. Research Journal of Textile and Apparel, 21(3): 188-202.

Kargın F, Erdem C 1992. Bakır-çinko etkileşiminde *Tilapia nilotica* (L.)'nin karaciğer, solungaç ve kas dokularındaki metal birikimi. Turkish Journal of Zoology, 16: 343-348.

Li X, Zhang Y, Wang Z 2017. The genotoxicity of zinc-based compounds in vitro. Environmental Toxicology and Pharmacology, 53: 35-42.

Maity S, Roy S, Chaudhury S, Bhattacharya S 2008. Antioxidant responses of the earthworm *Lampito mauritii* exposed to Pb and Zn contaminated soil. Environmental Pollution, 151: 1-7.

Park JH 2015. Zinc pyrithione as a fungicide and its mechanism of action. Antimicrobial Agents and Chemotherapy, 59(9): 5742-5748.

Rasgele PG 2023. Assessment of geno- and cytotoxic effects of propineb using onion apical root meristem. Cytology and Genetics, 57(1): 95-103.

Reeder NL, Xu J, Youngquist RS, Schwartz JR, Rust RC, Saunders CW 2011. The antifungal mechanism of action of zinc pyrithione. British Journal of Dermatology, 165(S2): 9-12.

Turley PA, Fenn RJ, Ritter JC 2000. Pyrithiones as antifoulants: Environmental chemistry and preliminary risk assessment. Biofouling, 15: 175-182.

Ugras S, Karagul P, Goc Rasgele P, Agyar P, Karagul B, Ugras HI 2024. Using amino acid-silver complexes synthesized by green synthesis to develop a new antimicrobial agent. Pharmaceutical Chemistry Journal, 57(11): 1724-1732.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Venneria E, Intorre F, Foddai MS, Azzini E, Palomba L, Raguzzini A, Polito A, Ciarapica D, Zaccaria M, Toti E, Catasta G, Maiani G 2014. Antioxidant effect of zinc supplementation on both plasma and cellular red-ox status markers in a group of elderly Italian population. The Journal of Nutrition, Health and Aging: 345-350.

Wood CM 2001. Toxic responses of the gill. Target Organ Toxicity in Marine and Freshwater Teleosts, 1: 1-89.

Yang Y, Lin Y, Zhang L, Wu T 2020. Zinc pyrithione induces oxidative stress and mitochondrial dysfunction in human skin cells. Toxicology Letters, 328: 85-93.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A STUDY ON INVESTIGATING THE CYTOGENOTOXICITY AND PROTECTIVE EFFECT OF QUERCETIN AGAINST ALUMINUM TOXICITY IN THE *ALLIUM CEPA* L. MODEL

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ABSTRACT

Aluminum is a toxic metal commonly found in our environment and known for its genotoxic effects on biological systems. In recent years, the potential of compounds with antioxidants, antimicrobial, anti-cancer, and neuroprotective properties to reduce the toxicity of heavy metals has attracted significant attention. This study aimed to evaluate the cytogenotoxic and protective effects of Quercetin on *Allium cepa* cells, a model organism. *A. cepa* roots were exposed to negative (distilled water) and positive (aluminum chloride-$AlCl_3$, 150 ppm) controls, and to Quercetin at three different concentrations (3.125, 6.25, and 12.5 ppm). Furthermore, three treatment groups were created to evaluate the antimutagenicity of Quercetin: Pre-treatment, Simultaneous, and Post-treatment. In the pre-treatment group, the desmutagenic activity of Quercetin before $AlCl_3$ treatment was investigated. In the simultaneous treatment group, the desmutagenic and bioantimutagenic activity of Quercetin with $AlCl_3$ was evaluated; in the post-treatment group, the bioantimutagenic activity of Quercetin after $AlCl_3$ treatment was assessed. No genotoxicity was observed at any concentration of Quercetin. In the pre-treatment, simultaneous, and post-treatment groups, a protective effect against antimutagenicity was observed at all concentrations, and a statistically significant reduction in the overall mean of chromosomal changes was detected compared to $AlCl_3$. Furthermore, our study determined that Quercetin reduced DNA damage caused by $AlCl_3$ in all treatment groups.

Keywords: *Allium cepa*, chromosomal alterations, quercetin, protection against cell damage.

INTRODUCTION

Plants not only provide oxygen and nutrients for the sustainability of human life but also constitute an important resource for health. Humans discovered the medicinal potential of plants thousands of years ago and have used them to treat various diseases. Research into the health benefits of medicinal and

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

aromatic plants has increased interest in these plants and popularized the use of herbal medicines. Studies on the pharmacological properties of plant components have ensured that natural treatments have gained an important place in medicine. In this context, research into the antioxidant and antimicrobial properties of herbal products is increasing day by day. Natural antioxidants are of great interest, particularly because they have the potential to replace synthetic chemical compounds. Polyphenolic compounds found in plants are among the most important of these compounds, playing a key role in protecting human health. Flavonoids are phytochemical compounds commonly found in plants that possess potent antioxidant properties (Bestil et al., 2023). The antioxidant, anti-cancer, anti-inflammatory, and antimicrobial properties of flavonoids ensure their wide use in medicine (Yang et al., 2020). As natural antioxidants, these compounds support health through their ability to scavenge free radicals (Faydaoğlu et al., 2011). Quercetin is an important member of the flavonoid family and is a compound commonly found in fruits and vegetables. Quercetin is particularly notable for its antioxidant, antimicrobial, anti-cancer, and neuroprotective properties (Nguyen et al., 2022). Furthermore, quercetin's biological activities have a wide range of effects due to its phenolic hydroxyl groups and double bond structure (Yang et al., 2020). Studies have shown that quercetin plays an important role in preventing cell damage and reducing mycotoxins. However, the genotoxic effects and toxicity potential of quercetin should not be overlooked (Yalçın et al., 2017).

Aluminium (Al) is a toxic metal that is widely found in our environment and can accumulate in plants. The toxic effects of aluminium on biological systems are known, particularly its damage to the nervous system and genetic material. The toxic effects of aluminium can cause growth retardation in plants, have adverse effects on root development, and lead to genetic changes (Greene et al., 2014). Therefore, various studies are being conducted to understand the effects of aluminium on plants and to minimise these effects. One of the important methods used to evaluate the genotoxic effects of aluminium is the *Allium cepa* L. model. *A. cepa* is frequently preferred in toxicity tests due to its low chromosome number and sensitivity to toxic agents (Silva et al., 2022). Numerous studies have demonstrated that aluminium causes genetic changes and cellular damage in plants (Kontaş et al., 2020). However, various protective agents are being investigated to limit the effects of aluminium. Quercetin stands out among these agents. Previous studies have shown that quercetin has protective effects against aluminium toxicity and can repair damage at the cellular level (Ahmad et al., 2014). The aim of this study is to investigate aluminium chloride ($AlCl_3$)-induced toxicity in the *A. cepa* model and the protective effects of quercetin against this toxicity. The study will examine the genotoxic effects of aluminium in *A. cepa* and how quercetin inhibits and ameliorates these effects.

MATERIALS AND METHODS

Test Material and Experimental Groups

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The chemical formula of the quercetin used (Bioscience, USA) is $C_{15}H_{10}O_7$, with a molecular weight of 302.236 g/mol. Aluminium chloride ($AlCl_3$) (Sigma-Aldrich, USA) was used as a positive control heavy metal to induce toxicity. dH_2O was used as a negative control. *Allium cepa* bulbs were purchased from a commercial market as material. Quercetin was used for its protective effect, while $AlCl_3$ was used to induce toxicity. The concentrations to be used in the study groups were determined by EC_{50}. For aluminium chloride, solutions of 100, 150, 200, and 400 ppm were prepared, an EC_{50} test was set up, and the results were examined after 96 hours, determining the EC_{50} value to be 150 ppm. Similarly, an EC_{50} test was performed for quercetin by preparing solutions of 50, 25, 12.5, 6.25, and 3.125 ppm, and it was decided to use concentrations of 3.125, 6.25, and 12.5 ppm for its protective effect. Fourteen experimental groups were formed, and the experimental groups formed are shown in Table 1. Three treatment groups, Pre-treatment, Simultaneous, and Post-treatment, were formed to evaluate the antimutagenicity of Quercetin in *A. cepa* root tips, which cause DNA damage using $AlCl_3$ (150 ppm). In the Pre-treatment treatment, the desmutagenic effect of Quercetin before $AlCl_3$ treatment: In the Simultaneous treatment, the desmutagenic and bioantimutagenic activity of Quercetin when treated simultaneously with $AlCl_3$ was investigated. In the post-treatment, the bioantimutagenic effect of Quercetin after $AlCl_3$ treatment was investigated.

Table 1. Experimental groups

Groups	**Antimutagenicity**		
	Pre-treatment (Quercetin - $AlCl_3$)	**Simultaneous treatment (Quercetin+ $AlCl_3$)**	**Post-treatment ($AlCl_3$ - Quercetin)**
Quercetin-3.125ppm	3.125ppm - 150ppm	3.125ppm + 150ppm	150ppm - 3.125ppm
Quercetin-6.25ppm	6.25ppm - 150ppm	6.25ppm + 150ppm	150ppm - 6.25ppm
Quercetin-12.5ppm	12.5ppm - 150ppm	12.5ppm + 150ppm	150ppm - 12.5ppm
Negative control	dH_2O		
Positive control		150 ppm $AlCl_3$	

At the end of the treatment period for the Allium cepa assay, after the root tip collection process was completed, the Allium cepa root tips were fixed with ethanol and acetic acid in a 3:1 ratio. After 24 hours of fixation, they were transferred to 70% ethanol and stored at +4 °C. To enable microscopic examination of mitotic abnormalities, the fixed onion root tips were treated with 1M HCl, and then smear preparations were prepared separately for each onion group using aceto-orcein stain. Field scanning was performed on an Olympus CX21 microscope to detect mitotic abnormalities, examine cells, and perform cell counts.

Results and Discussion

When compared to the negative control group, the positive control group exhibited a statistically significant ($p \leq 0.05$) increase in total abnormal cell counts, indicating that $AlCl_3$ may cause a mutagenic effect on *A. cepa* root cells. No genotoxicity was observed at any concentration of Quercetin tested in the meristematic cells of *A. cepa*; no significant difference was found in the number of abnormal cells at the tested concentrations compared to the negative control (Table 2). Therefore, it is considered that the concentrations of Quercetin analysed in *A. cepa* are not mutagenic. A protective effect against antimutagenicity was observed at all concentrations in the pre-treatment, simultaneous and post-treatment groups, and a statistically significant decrease in the total mean of chromosomal aberrations was observed compared to $AlCl_3$ (Table 2). Furthermore, our study determined that Quercetin reduced the DNA damage caused by $AlCl_3$ in all treatment groups.

The reason quercetin has antioxidant properties is due to the hydroxyl group on its third carbon, the double bond on its second and third carbons, the carbonyl group on its fourth carbon, and the aromatic rings with a polyhydroxy structure (Di Petrillo et al. 2022). The results of our study showed that the application of 150 ppm $AlCl_3$ statistically significantly ($p \leq 0.05$) increased chromosomal abnormalities (bridging, stickiness, C-mitosis, etc.) in *A. cepa* meristematic cells. This is consistent with the literature indicating that aluminium has a direct or indirect destructive effect on genetic material. It is thought that aluminium ions (Al^{3+}) bind to the phosphate groups of DNA, stabilising the helical structure or disrupting the functioning of spindle fibres, leading to irregularities such as stickiness and lagging chromosomes. In particular, the increase in micronucleus (MN) formation is a concrete indicator of aluminium's clastogenic (DNA-breaking) effect. One of the noteworthy results of the study is that the tested Quercetin concentrations (3.125, 6.25, and 12.5 ppm) did not show any mutagenic effect on their own. The absence of a significant difference in the incidence of abnormalities compared to the negative control group proves that Quercetin is biologically safe for A. cepa at these doses. This finding is consistent with previous studies (Ahmad et al., 2014) supporting the potential use of Quercetin as a cytoprotective agent. Quercetin's success in reducing $AlCl_3$-induced DNA damage was clearly observed in all three treatment groups (pre-, concurrent, and post-treatment). Pre-treatment: The high damage reduction ratios (%DR) observed in this group suggest that quercetin exhibits a demutagenic effect, preparing cells in advance against the toxic agent or preventing its entry by chelating aluminium ions in the extracellular environment. Simultaneous: Quercetin's capacity to scavenge free radicals minimised the damage triggered by oxidative stress when administered simultaneously with $AlCl_3$. This is due to the powerful antioxidant capacity provided by the phenolic hydroxyl groups and carbonyl structure in the molecule's composition. Post-treatment; the effectiveness of quercetin application after aluminium exposure indicates that the compound may support DNA repair mechanisms with its bioantimutagenic activity. In particular, the high %DR value (%151.32) detected in the 6.25 ppm + 150 ppm pre-treatment group shows that Quercetin can provide optimal protection even at low doses. These results reinforce the hypothesis that flavonoids act as a

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

'natural shield' against heavy metal toxicity and pave the way for Quercetin to be evaluated as a neuroprotective and cytoprotective agent in pharmacological applications.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Table 2. Results of Cytogenotoxicity of Quercetin

Groups	Irregular Metaphase	Stickiness	C-Mitosis	MN	Lagging Chromosome	Bridge	Total Abnormal Cell Number	MI	%DR
Mutagenicity									
Negative control	3.00±1.08	8.25±1.93	5.75±0.62	0.00±0.00	0.00±0.00	0.00±0.00	17.00±3.16	9.30±2.22	-
Positive control (150 ppm $AlCl_3$)	24.33±4.26***	10.33±2.96	2.67±0.33	1.33±1.33	3.67±2.03	0.00±0.00	42.33±6.69	11.27±1.23	-
Quercetin-3.125ppm	8.00±1.15	5.67±1.33	1.33±0.33	0.00±0.00	0.00±0.00	0.33±0.33	15.33±0.33	10.17±0.12	-
Quercetin-6.25ppm	2.00±1.15	6.67±1.86	2.00±0.58	0.00±0.00	0.00±0.00	0.00±0.00	10.67±3.53	10.67±0.33	-
Quercetin-12.5ppm	4.25±2.62	5.50±2.50	1.50±0.95	0.00±0.00	0.50±0.28	0.00±0.00	11.75±4.38	8.62±2.39	-
Antimutagenicity									
Pre-treatment (Quercetin+ $AlCl_3$)									
3.125ppm + 150ppm	9.00±1.68	5.00±2.88	1.50±0.95	0.00±0.00	0.00±0.00	0.25±0.25	15.75±5.43	10.62±0.38	104.93
6.25ppm + 150ppm	3.00±0.58	1.00±1.00	0.00±0.00*	0.00±0.00	0.00±0.00	0.00±0.00	4.00±0.58	10.23±0.38	151.32
12.5ppm + 150ppm	2.25±1.65	6.50±2.10	3.75±1.93	0.00±0.00	0.00±0.00	0.00±0.00	12.50±1.55	7.85±1.79	117.76
Simultaneous treatment (Quercetin+ $AlCl_3$)									
3.125ppm + 150ppm	3.75±0.85	0.00±0.00*	5.50±3.27	0.00±0.00	0.00±0.00	1.00±0.40	10.25±4.42	11.77±0.63	126.64
6.25ppm + 150ppm	4.50±2.50	6.00±6.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	10.50±3.50	13.60±3.10	125.66
12.5ppm + 150ppm	8.67±1.86	7.67±1.45	3.00±0.58	0.00±0.00	0.00±0.00	0.00±0.00	19.33±2.96	10.10±0.00	90.80
Post-treatment ($AlCl_3$+ Quercetin)									
150ppm+Que-3.125ppm	5.25±2.09	2.25±1.93	0.00±0.00	0.25±0.25	0.00±0.00	0.00±0.00	7.75±2.49	11.22±2.28	136.51
150ppm+Que-6.25ppm	4.75±0.25	3.75±0.85	1.00±0.40	0.00±0.00	0.00±0.00	0.00±0.00	9.50±1.04	11.57±0.12	129.60
150ppm+Que-12.5ppm	4.33±1.20	3.67±1.86	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	8.00±3.06	11.27±1.23	135.53

MN: Micronucleus; %DR: Damage reduction percentage; * indicates that the data were compared with the negative control, and + indicates that the data were compared with the positive control. */+ $p \leq 0.05$; **/++ $p \leq 0.01$; ***/+++ $p \leq 0.001$.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Valproic acid (VPA) is among the most used antiepileptic drugs in childhood and adult epilepsy and has toxic and genotoxic effects. A study aimed to evaluate the antigenotoxic protective effect of quercetin as an antioxidant against VPA genotoxicity using the in vitro Comet assay analysis method. The analysis results showed that quercetin improved VPA-induced genetic damage (Canbolat et al. 2023). The medical applications of metals and their complexes have gained great importance during COVID-19. In a study aiming to use quercetin-Zn (Q/Zn) ligation behaviour for its ameliorative effect, an experimental group was formed on albino rats. Hepatotoxicity was induced by cadmium ($CdCl_2$). In addition to the gene expression of SOD as an antioxidant enzyme in hepatic tissues, histology and TEM were evaluated for hepatic tissues. As a result, the Q/Zn complex showed a strong antioxidant effect against oxidative damage and genotoxicity. It was considered a potent ameliorative hepatoprotective agent against $CdCl_2$ hepatotoxicity and concluded that it could be beneficial during the COVID-19 pandemic (Refat et al. 2021). In the study, the dietary compounds rutin (RUT) and quercetin (QRT) were investigated for their ability to protect against genotoxicity caused by ionising radiation (IR) in human lymphocytes. The radiation antagonist potential was tested using the alkaline comet assay and the cytokinesis-block micronucleus (CBMN) assay. As a result, RUT and QRT demonstrated a protective effect against IR-induced DNA damage in human lymphocytes, which can be attributed in part to the scavenging of IR-induced free radicals and the inhibition of IR-induced oxidative stress (Patil et al., 2017).

Another study investigated the potential protective activity of quercetin, a natural antioxidant, against dimethoate-induced cytotoxicity and genotoxicity in meristematic cells of *Allium sativum*. Chromosome breaks, multipolar anaphase, rod chromosomes, and mitotic activity were examined as markers of cytotoxicity and genotoxicity in the study. When groups were established with different doses and the experiment was conducted, it was observed that quercetin was neither cytotoxic nor genotoxic. Pretreatment of Allium sativum with quercetin significantly reduced dimethoate-induced genotoxicity and cytotoxicity in meristematic cells, and these effects were dose-dependent. It was concluded that quercetin plays a protective role, at least in part due to its antioxidant effects, in reducing dimethoate-induced cytotoxicity and genotoxicity in meristematic cells of Allium sativum (Ahmad et al., 2014). Qi and colleagues revealed the antioxidant mechanism and broad-spectrum antibacterial properties of quercetin, which has strong oxidative properties and biological activities. Quercetin's intervention effect on pesticide poisoning and its mechanism of action were investigated, and as a result, the toxic effects of quercetin on the collection and detoxification process were summarized; whether it can reduce the toxicity of mycotoxins was proven; and the harmful effects of heavy metal poisoning on the collection, prevention, and control of quercetin were evaluated. Support from clinical applications is presented for more comprehensive results (Qi et al., 2022). The protective effect of quercetin against mutagenic agents has been reported in detail in the literature. The results

obtained in this study corroborate these data and support the potential protective role of quercetin against mutagenicity.

References

Ahmad W, Shaikh S, Nazam N, Lone MI. 2014. Protective effects of quercetin against dimethoate-induced cytotoxicity and genotoxicity in *Allium sativum* test. International Scholarly Research Notices. 21: 632672.

Barcelos GR, Angeli JP, Serpeloni JM, Grotto D, Rocha BA, Bastos JK, Knasmüller S, Júnior FB 2011. Quercetin protects human-derived liver cells against mercury-induced DNA-damage and alterations of the redox status. Mutation Research 726(2):109-115.

Bestil DN, Uysal H 2023. Flavonoids and Biological Activities. The Journal of Antakya Veterinary Science, *2*(1): 49-55.

Canbolat F, Kenanoğlu NA, Yüksel TN, Berber, AA (2023). Evaluation of the Antigenotoxic Effect of Quercetin Against Antiepileptic Drug Genotoxicity by Comet Analysis. Sakarya University Journal of Science 27(6): 1185-1196.

Di Petrillo A, Orrù G, Fais A, Fantini MC 2022. Quercetin and its derivates as antiviral potentials: A comprehensive review. Phytotherapy Research 36(1):266-278.

Faydaoğlu E, Sürücüoğlu MS 2011. History of the Use of Medical and Aromatic Plants and their Economic Importance. Kastamonu Univ. Journal of Forestry Faculty. 11(1): 52-67.

Greene SB, Dago AE, Leitz LJ, Wang Y, Lee J, Werner SL, Landers M 2016. Chromosomal instability estimation based on next generation sequencing and single cell genome wide copy number variation analysis. PLoS One 11(11): e0165089.

Kontaş S. Bostancı D. 2020. Balıklarda genotoksik hasarın belirlenmesine yönelik bir araştırma: *Capoeta banarescui* örneği. Journal of Limnology and Freshwater Fisheries Research, 6(2):144-152.

Nguyen TLA, Bhattacharya D 2022. Antimicrobial activity of quercetin: an approach to its mechanistic principle. Molecules 27(8):2494.

Parveen N, Akbarsha MA, Latif Wani AB, Ansari MO, Ahmad MF, Shadab GGHA 2023. Protective effect of quercetin and thymoquinone against genotoxicity and oxidative stress induced by ZnO nanoparticles in the Wistar rat model. Mutation Research: Genetic Toxicology and Environmental Mutagenesis, 890: 503661.

Patil SL, Swaroop K, Kakde N, Somashekarappa HM 2017. In vitro Protective Effect of Rutin and Quercetin against Radiation-induced Genetic Damage in Human Lymphocytes. Indian Journal of Nuclear Medicine. 32(4):289-295.

Qi W, Qi W, Xiong D. Long M. 2022. Quercetin: Its Antioxidant Mechanism, Antibacterial Properties and Potential Application in Prevention and Control of Toxipathy. Molecules. 27(19):6545.

Refat MS, Hamza RZ, A. Adam AM, Saad HA, Gobouri AA, Azab E, Al-Salmi FA, Altalhi TA, Khojah E, Gaber A, et al. 2021. Antioxidant, Antigenotoxic, and Hepatic Ameliorative Effects of Quercetin/Zinc Complex on Cadmium-Induced Hepatotoxicity and Alterations in Hepatic Tissue Structure. Coatings. 11(5):501.

Refat MS, Hamza RZ, Adam AMA, Saad HA, Gobouri AA, Al-Salmi FA, Altalhi TA, El-Megharbel SM. 2021. Potential Therapeutic Effects of New Ruthenium (III) Complex with Quercetin: Characterization, Structure, Gene Regulation, and Antitumor and Anti-Inflammatory Studies (RuIII/Q Novel Complex Is a Potent Immunoprotective Agent). Crystals. 11(4):367.

Silva RMGD, Amâncio IFN, Andrade ARD, Marinho Dos Santos, VH, Santiago PS, Oliveira Granero F, Pereira Silva L 2022. Phytotoxic, cytogenotoxic, and insecticidal activities of compounds from extracts of freshwater Lyngbya sp. Journal of Toxicology and Environmental Health, Part A 85(21):881-895.

Yalçın AS, YılmAz AM, Altundağ EM, KoçtürK S. 2017. Anti-cancer effects of curcumin, quercetin and tea catechins. Marmara Pharmaceutical Journal 21(1): 19-29.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Yang D, Wang T, Long M, Li P. 2020. Quercetin: Its Main Pharmacological Activity and Potential Application in Clinical Medicine. Oxidative Medicine and Cellular Longevity. 1:8825387.

Zhang H, Li X, Ge L, Yang J, Sun J, Niu Q. 2015. Methylation of CpG island of p14(ARK), p15(INK4b) and p16(INK4a) genes in coke oven workers. Human and Experimental Toxicology. 34(2):191-197.

Živković L, Bajić V, Topalović D, Bruić M, Spremo-Potparević B. 2019. Antigenotoxic Effects of Biochaga and Dihydroquercetin (Taxifolin) on H_2O_2-Induced DNA Damage in Human Whole Blood Cells. Oxidative Medicine and Cellular Longevity. 11:5039372.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ON PROPERTIES OF HYBRID NUMBERS WITH COMPLEX FIBONACCI COEFFICIENTS

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ABSTRACT

In this study, various types of complex hybrid numbers are explored, and their fundamental properties, such as matrix representation, scalar product, and conjugation, are presented. Building upon on this foundation, we establish a novel and, structurally integrated framework by defining the polynomial types of these numbers. By utilizing the recurrence relations of the classical Fibonacci and Lucas sequences, we construct a polynomial sequence whose terms are defined as complex hybrid Fibonacci and complex hybrid Lucas polynomials, thereby offering a different perspective to the field. Furthermore, we conduct a detailed analysis of their algebraic characteristics, including the norm and inner product, and examine how these concepts behave within the complex hybrid framework. In this context, we derive essential identities such as the generating function and the Binet-type formula for these polynomial structures. The results obtained throughout the study are systematically presented through theorems and rigorous mathematical proofs, providing a comprehensive theoretical foundation for further research on complex hybrid structures.

Keywords: hybrid number, complex Fibonacci number, polynomial, number sequence.

INTRODUCTION

Until the eighteenth century, mathematicians avoided quadratic equations that were not solvable over $\mathbb{R}$. Leonhard Euler changed this situation by introducing the 'number' $\sqrt{-1}$ in his famous book Elements of Algebra, describing it as 'neither nothing, nor greater than nothing, nor less than nothing.' Euler denoted the number $\sqrt{-1}$ by i and called it the imaginary unit. This became one of the most useful symbols in mathematics. Using this symbol, complex numbers are defined in the form $z = a + bi$ where a and b are real numbers (Euler, 2012).

Number sequences are among the most fundamental building blocks of mathematics, and within these structures ordered according to a specific rule, the Fibonacci sequence has the widest range of applications. Although it was introduced by the Italian mathematician Leonardo Fibonacci to model

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

the growth of a rabbit population, the influence of this sequence has since spread to all fields of mathematics. With its connection to the golden ratio, the Fibonacci sequence appears not only in mathematics but also in nature, architecture, and engineering (Koshy, 2012).

Hybrid numbers, which are a combination of complex, dual, and hyperbolic units were defined by Özdemir as a new non-commutative number system, and the author examined various properties of these numbers within the scope of the study (Özdemir, 2018). Among the studies on hybrid numbers, Szynal-Liana defined Horadam hybrid numbers by means of Horadam sequences and investigated some characteristic properties such as the Binet formula and generating function (Szynal-Liana, 2018). Özçevik et al. defined Fibonacci-Lucas hybrid spinors by applying spinor transformations to hybrid numbers with Fibonacci and Lucas coefficients (Özçevik et. al., 2024). Moreover, hybrid numbers are innovative mathematical structures that enhance algebraic flexibility by unifying the properties of multiple number systems within a single framework. By incorporating components such as complex, dual, hyperbolic, or quaternion-like elements under one structure, hybrid numbers offer remarkable advantages, particularly in multidimensional transformations, algebraic modeling, and cryptographic system design.

MATERIALS AND METHODS

Definition 1. Fibonacci number sequence is defined by the recurrence relation

$$F_{n+1} = F_n + F_{n-1}$$

with initial conditions $F_0 = 0, F_1 = 1$ where F_n is nth Fibonacci number for $n \geq 1$.

Some terms of these sequences are as follows.

0,1,1,2,3,5,8,13,21,34 ... .

Definition 2. Complex Fibonacci numbers is defined by $CF_n = F_n + F_{n+1}i$ where F_n n. Fibonacci number for $n \geq 0, F_0 = 0, F_1 = 1$. Then, complex Fibonacci sequence is satisfies recurrence relation

$$CF_{n+1} = CF_n + CF_{n-1}$$

(Horadam, 1963).

The set of hybrid numbers, denoted by $\mathbb{K}$, is defined as

$$\mathbb{K} = \{a + bi + c\varepsilon + dh | a, b, c, d \in \mathbb{R}, i^2 = -1, \varepsilon^2 = 0, h^2 = 1\}$$

(Özdemir, 2018).

The sum of two hybrid numbers $Z, W \in \mathbb{K}$ is defined by summing their components. The product of hybris units is as follows table (Özdemir, 2018).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Table 1. The product of hybrid units

·	1	i	ε	h
1	1	i	ε	h
i	i	-1	$1-h$	$\varepsilon+i$
ε	ε	$h+1$	0	$-\varepsilon$
h	h	$-\varepsilon-i$	ε	1

Definition 3. The conjugate of hybrid number $l = a + bi + c\varepsilon + dh$ denoted by $\bar{l}$, is defined as

$\bar{l} = a - bi - c\varepsilon - dh.$

Additionally, the character of hybrid number is $C(l) = l\bar{l} = a^2 + (b-c)^2 - c^2 - d^2$ real number (Özdemir, 2018).

Generalized hybrid Fibonacci numbers obtained by taking the coefficients of hybrid number units as (p, q) −Fibonacci numbers are defined as follows.

Definition 4. Hybrid Fibonacci number $\mathbb{H}\mathcal{F}_n$ is defined as

$\mathbb{H}\mathcal{F}_n = \mathcal{F}_n + \mathcal{F}_{n+1}i + \mathcal{F}_{n+2}\varepsilon + \mathcal{F}_{n+3}h$

where $\mathcal{F}_n$ is n. (p, q) − Fibonacci number (Cerda- Morales, 2018).

The following recurrence relation is satisfied for these numbers.

$\mathbb{H}\mathcal{F}_{n+1} = p\mathbb{H}\mathcal{F}_n + q\mathbb{H}\mathcal{F}_{n-1}$

Also, a hybrid Fibonacci sequence has been obtained for $p = q = 1,\ n \geq 1$ (Cerda- Morales, 2018).

For example,for $p = q = 1, n = 0$ and $n = 1$ hybrid Fibonacci number is

$\mathbb{H}\mathcal{F}_0 = F_0 + F_1 i + F_2\varepsilon + F_3 h$

$= 0 + i + \varepsilon + 2h,$

$\mathbb{H}\mathcal{F}_1 = F_1 + F_2 i + F_3\varepsilon + 4h$

$= 1 + i + 2\varepsilon + 3h,$

can be written. Then,

$\mathbb{H}\mathcal{F}_0 + \mathbb{H}\mathcal{F}_1 = (0 + i + \varepsilon + 2h) + 1 + i + 2\varepsilon + 3h$

$= 1 + 2i + 3\varepsilon + 5h$

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$= F_2 + F_3 i + F_4 \varepsilon + F_5 h$

$= \mathbb{H}\mathcal{F}_2$

The set of complex hybrid numbers, denoted by $\mathbb{CK}$, is defined as

$$\mathbb{CK} = \{z = z_0 + z_1 i_h + z_2 \varepsilon + z_3 h | z_0, z_1, z_2, z_3 \in \mathbb{C}\}$$

(Seçgin et. al., 2025).

Then, the complex unit and hybrid unit are denoted by i, i_h, respectively. Accordingly, the set of complex hybrid number is $8-$ dimensional algebra and a basis of this algebra is $\{1, i, \varepsilon, h, i_h, ii_h, \varepsilon i_h, hi_h\}$.

The product of complex hybrid units is as follows table (Seçgin et. al., 2025).

.Table 2. The product of complex hybrid units

$\cdot$	1	i_h	ε	h	i	ii_h	$i\varepsilon$	ih
1	1	i_h	ε	h	i	$i_h i$	εi	hi
i_h	i_h	-1	$1-h$	$\varepsilon + i_h$	$i_h i$	$-i$	$(1-h)i$	$(\varepsilon + i_h)i$
ε	ε	$h+1$	0	$-\varepsilon$	εi	$(h+1)i$	0	$-\varepsilon i$
h	h	$-\varepsilon - i_h$	ε	1	hi	$(-\varepsilon - i_h)i$	εi	i
i	i	$i_h i$	εi	hi	-1	$-i_h$	$-\varepsilon$	$-h$
ii_h	$i_h i$	$-i$	$(1-h)i$	$(\varepsilon + i_h)i$	$-i_h$	1	$h-1$	$-\varepsilon - i_h$
$i\varepsilon$	εi	$(h+1)i$	0	$-\varepsilon i$	$-\varepsilon$	$-1-h$	0	ε
ih	hi	$(-\varepsilon - i_h)i$	εi	i	$-h$	$\varepsilon + i$	$-\varepsilon$	-1

Definition 5. $z = z_0 + z_1 i + z_2 \varepsilon + z_3 h$ is a complex hybrid number.The conjugations of this number are defined as hybrid conjugate, complex conjugate and Hermitian conjugate as follows, respectively.

$z^{*_1} = z_0 - z_1 i_h - z_2 \varepsilon - z_3 h,$

$z^{*_2} = \bar{z_0} + \bar{z_1} i_h + \bar{z_2} \varepsilon + \bar{z_3} h,$

$z^{*_3} = \bar{z_0} - \bar{z_1} i_h - \bar{z_2} \varepsilon - \bar{z_3} h.$

The scalar and vectoral parts of complex hybrid number are $S(z)$ and $V(z)$. Then, $S(z) = z_0, V(z) = z_1 i_h + z_2 \varepsilon + z_3 h$ (Seçgin et. al., 2025).

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ISBN: 978-9952-610-30-7

Definition 6. The character of a complex hybrid number is $C(z) = zz^{*_1} = z^{*_1}z$. Then, we give

$$C(z) = (z_0 + z_1 i_h + z_2\varepsilon + z_3 h)(z_0 - z_1 i_h - z_2\varepsilon - z_3 h)$$
$$= {z_0}^2 + (z_1 - z_2)^2 - z_2^2 - z_3^2$$

(Seçgin et. al., 2025).

Definition 7. The vectoral product of two complex hybrid numbers z and w is defined as follows.

$$\times_{\mathbb{CK}}: \mathbb{CK} \times \mathbb{CK} \to \mathbb{CK}$$

$$(z, w) \to z \times_{\mathbb{CK}} w = \frac{zw^{*_1} - wz^{*_1}}{2}$$

(Seçgin et. al., 2025).

Definition 8. The matrix representation of a complex hybrid number z is defined by the φ transforms

$$\varphi : \mathbb{CK} \to \mathbb{C}_{2\times 2}$$

$$z \to \varphi(z)$$

$$\varphi(z) = \begin{bmatrix} z_0 + z_2 & z_1 - z_2 + z_3 \\ z_2 - z_1 + z_3 & z_0 - z_2 \end{bmatrix}.$$

It is can be seen in (Seçgin et. al., 2025) for more details about complex hybrid numbers. In addition, complex Fibonacci and complex Lucas numbers are defined as follows.

In their study, Qarah Bash and Altınkaya defined complex hybrid Fibonacci and complex hybrid Lucas numbers by taking the coefficients of hybrid numbers as complex Fibonacci and complex Lucas numbers; furthermore, they constructed a complex hybrid sequence using these numbers and presented some of their fundamental properties (Bash, Altınkaya, 2025).

Definition 9. The n^{th} complex Fibonacci type and Lucas type hybrid sequences are defined by

$$\widetilde{FH_n} = FH_n + FH_{n+1}i,$$

$$\widetilde{LH_n} = LH_n + LH_{n+1}i$$

respectively. Here, $FH_n = F_n + F_{n+1}i + F_{n+2}\varepsilon + F_{n+3}h$, and $LH_n = L_n + L_{n+1}i + L_{n+2}\varepsilon + L_{n+3}h$. Moreover,

$$\widetilde{FH_n} = \widetilde{F_n} + \widetilde{F_{n+1}}i + \widetilde{F_{n+2}}\varepsilon + \widetilde{F_{n+3}}h,$$

$$\widetilde{LH_n} = \widetilde{L_n} + \widetilde{L_{n+1}}i + \widetilde{L_{n+2}}\varepsilon + \widetilde{L_{n+3}}h$$

can be written. It is can be seen in(Bash, Altınkaya, 2025) for more details.

RESULTS

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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The results obtained in this section are denoted by zF_n and $zL_n$for complex hybrid Fibonacci numbers and complex hybrid Lucas numbers, respectively.

Definition 1. For the complex hybrid Fibonacci number, the complex conjugate, the hybrid conjugate, and the Hermitian conjugate—are given respectively as follows.

$$zF_n^{*_1} = CF_n - CF_{n+1}i_h - CF_{n+2}\varepsilon - CF_{n+3}h,$$

$$zF_n^{*_2} = \overline{CF_n} + \overline{CF_{n+1}}i_h + \overline{CF_{n+2}}\varepsilon + \overline{CF_{n+3}}h,$$

$$zF_n^{*_3} = \overline{CF_n} - \overline{CF_{n+1}}i_h - \overline{CF_{n+2}}\varepsilon - \overline{CF_{n+3}}h.$$

The following results are obtained with the help of the defined conjugates.

Corollary 2. For $n \geq 0$, we have

i. $zF_n + zF_n^{*_1} = 2CF_n,$

ii. $zF_n^{*_2} + zF_n^{*_3} = -2(F_{n+1}i - F_n),$

iii. $zF_n^{*_1} + zF_n^{*_3} = 2\overline{HF_n},$

iv. $zF_n^{*_1} + zF_n^{*_2} = 2i(F_n - F_{n+2}i_h - F_{n+3}\varepsilon - F_{n+4}h).$

Really, for the (i) equation,

$$zF_n + zF_n^{*_1} = (CF_n + CF_{n+1}i_h + CF_{n+2}\varepsilon + CF_{n+3}h) + (CF_n - CF_{n+1}i_h - CF_{n+2}\varepsilon - CF_{n+3}h)$$

$$= 2CF_n.$$

For the (ii),

$$zF_n^{*_2} + zF_n^{*_3} = \overline{CF_n} + \overline{CF_{n+1}}i_h + \overline{CF_{n+2}}\varepsilon + \overline{CF_{n+3}}h + \overline{CF_n} - \overline{CF_{n+1}}i_h - \overline{CF_{n+2}}\varepsilon - \overline{CF_{n+3}}h$$
$$= 2\overline{CF_n} = 2(F_n - F_{n+1}i).$$

For the (iii),

$$zF_n^{*_1} + zF_n^{*_3} = CF_n - CF_{n+1}i_h - CF_{n+2}\varepsilon - CF_{n+3}h + \overline{CF_n} - \overline{CF_{n+1}}i_h - \overline{CF_{n+2}}\varepsilon - \overline{CF_{n+3}}h$$
$$= F_n + F_{n+1}i - F_{n+1}i_h - F_{n+2}ii_h - F_{n+2}\varepsilon - F_{n+3}i\varepsilon - F_{n+3}h - F_{n+4}ih + F_n - F_{n+1}i - F_{n+1}i_h$$
$$+ F_{n+2}ii_h - F_{n+2}\varepsilon + F_{n+3}i\varepsilon - F_{n+3}h + F_{n+4}ih$$

$$= 2(F_n - F_{n+1}i_h - F_{n+2}\varepsilon - F_{n+3}h)$$
$$= 2\overline{HF_n}.$$

Finally,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$$zF_n^{*_1} + zF_n^{*_2} = F_n + F_{n+1}i - F_{n+1}i_h - F_{n+2}ii_h - F_{n+2}\varepsilon - F_{n+3}i\varepsilon - F_{n+3}h - F_{n+4}ih + F_n - F_{n+1}i + F_{n+1}i_h - F_{n+2}ii_h + F_{n+2}\varepsilon - F_{n+3}i\varepsilon + F_{n+3}h - F_{n+4}ih$$

$$= 2i(F_n - F_{n+2}i_h - F_{n+3}\varepsilon - F_{n+4}h).$$

Definition 3. The characteristic of a hybrid complex Fibonacci number is given by

$$C(zF_n) = ZF_n^{*_1}zF_n$$

$$= CF_n^{\,2} - CF_{n+1}^{\,2} + (CF_{n+1} - CF_{n+2})^2 - 2CF_{n+2}^{\,2}.$$

Definition 4. The scalar product of two hybrid complex Fibonacci numbers is as follows.

$$\langle zF_m, zF_n\rangle = \frac{zF_m zF_n^{*_1} + zF_n zF_m^{*_1}}{2},$$

$$= CF_nCF_m + CF_{m+1}CF_n - CF_{n+1}CF_m - CF_{m+3}CF_{n+3}.$$

Definition 5. The matrix representation of complex hybrid Fibonacci numbers M_φ, is defined by φ transform as follows.

$$\varphi(zF_n) = \varphi(CF_n + CF_{n+1}i_h + CF_{n+2}\varepsilon + CF_{n+3}h)$$

$$M_\varphi = \begin{bmatrix} CF_n + CF_{n+2} & CF_{n+3} - CF_n \\ CF_{n+3} + CF_n & CF_n - CF_{n+2} \end{bmatrix}.$$

Then, the determinant of this matrix can be given in terms of Fibonacci numbers as

$$\det(M_\varphi) = -2i(F_{n+2} + F_{n+4})F_{n+3}.$$

The matrix representation of the complex hybrid Fibonacci number can be expressed in terms of its scalar and imaginary parts relative to the complex unit i as follows.

$$\varphi(zF_n) = \begin{bmatrix} HF_n + HF_{n+2} & HF_{n+1} - HF_{n+2} + HF_{n+3} \\ HF_{n+2} - HF_{n+1} + HF_{n+3} & HF_n - HF_{n+2} \end{bmatrix} + \begin{bmatrix} HF_{n+1} + HF_{n+3} & HF_{n+2} - HF_{n+3} + HF_{n+4} \\ HF_{n+3} - HF_{n+2} + HF_{n+4} & HF_{n+1} - HF_{n+3} \end{bmatrix} i$$

Since complex hybrid numbers are, by definition, a multi-layered system that simultaneously carries complex, dual, and hyperbolic properties, re-expressing this structure with different basis elements will make the algebraic relationships more understandable.

$\mathbb{P}_{\mathbb{F}}, \mathbb{C}_{1_{\mathbb{F}}}, \mathbb{C}_{2_{\mathbb{F}}}$, and $\mathbb{D}_{\mathbb{F}}$ types are the different representations of complex hybrid Fibonacci numbers, obtained by means of hybrid units, as follows, respectively.

$$\mathbb{P}_{\mathbb{F}} = \widetilde{CF}_1 + \widetilde{CF}_2 h,$$

$$\mathbb{C}_{1_{\mathbb{F}}} = \widetilde{CF}_3 + \widetilde{CF}_4 i,$$

$$\mathbb{C}_{2_{\mathbb{F}}} = \widetilde{CF}_5 + \widetilde{CF}_6 i,$$

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$\mathbb{D}_{\mathbb{F}} = \widetilde{CF}_7 + \widetilde{CF}_8\varepsilon.$

Then,

$\widetilde{CF}_1 = CF_n + (CF_{n+1} - CF_{n+2})i, \qquad \widetilde{CF}_2 = CF_{n+3} + CF_{n+2}i,$

$\widetilde{CF}_3 = CF_n - CF_{n+3} + CF_{n+2}\varepsilon, \qquad \widetilde{CF}_4 = CF_{n+1} + CF_{n+3}\varepsilon,$

$\widetilde{CF}_5 = CF_n + CF_{n+3}h, \qquad \widetilde{CF}_6 = CF_{n+1} - CF_{n+2} - CF_{n+2}h,$

$\widetilde{CF}_7 = CF_n + CF_{n+3} + CF_{n+1}i, \qquad \widetilde{CF}_8 = CF_{n+2} - CF_{n+3}i.$

The matrix representations for these four different types of complex hybrid Fibonacci numbers are respectively as follows.

$$M_{\mathbb{P}_{\mathbb{F}}} = \begin{bmatrix} \widetilde{CF}_1 & \widetilde{CF}_2 \\ \widetilde{CF}_2 & \widetilde{CF}_1 \end{bmatrix}, M_{\mathbb{C}_{1\mathbb{F}}} = \begin{bmatrix} \widetilde{CF}_3 & \widetilde{CF}_4 \\ -\widetilde{CF}_4 & \widetilde{CF}_3 \end{bmatrix}, M_{\mathbb{C}_{2\mathbb{F}}} = \begin{bmatrix} \widetilde{CF}_5 & \widetilde{CF}_6 \\ -\widetilde{CF}_6 & \widetilde{CF}_5 \end{bmatrix}, M_{\mathbb{D}_{\mathbb{F}}} = \begin{bmatrix} \widetilde{CF}_7 & 0 \\ \widetilde{CF}_8 & \widetilde{CF}_7 \end{bmatrix}.$$

In addition, we define complex polynomials by using hybrid Fibonacci polynomials as follows.

Definition 6. The complex hybrid Fibonacci and complex hybrid Lucas polynomials are defined by

$zF_n(x) = HF_n(x) + HF_{n+1}(x)i,$

$zL_n(x) = HL_n(x) + HL_{n+1}(x)i$

where $HF_n(x) = F_n(x) + F_{n+1}(x)i_h + F_{n+2}(x)\varepsilon + F_{n+3}(x)h,$ $HL_n(x) = L_n(x) + L_{n+1}(x)i_h + L_{n+2}(x)\varepsilon + L_{n+3}(x)h$ are n^{th} are hybrid Fibonacci and hybrid Lucas polynomials , respectively.

Some elements are of these polynomials

$zF_0(x) = HF_0(x) + HF_1(x)i,$

$zF_0(x) = i_h + x\varepsilon + (x^2+1)h + (1 + xi_h + (x^2+1)\varepsilon + (x^3+2x)h)i$

$zF_1(x) = HF_1(x) + HF_2(x)i,$

$zF_1(x) = 1 + xi_h + (x^2+1)\varepsilon + (x^3+2x)h + (x + (x^2+1)i_h + (x^3+3x)\varepsilon + (x^4+4x^2+1)h)i$

$zF_2(x) = HF_2(x) + HF_3(x)i,$

$zF_2(x) = x + (x^2+1)i_h + (x^3+3x)\varepsilon + (x^4+4x^2+1)h$
$+ (x^2+1 + (x^3+3x)i_h + (x^4+4x^2+1)\varepsilon + (x^5+5x^3+4x)h)i$

⋮

and similarly we give

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ISBN: 978-9952-610-30-7

$$zL_0(x) = HL_0(x) + HL_1(x)i,$$
$$zL_0(x) = 2 + xi_h + (x^2+2)\varepsilon + (x^3+3x)h + (x + (x^2+2)i_h + (x^3+3x)\varepsilon + (x^4+4x^2+2)h)i,$$

$$zF_1(x) = HL_1(x) + HL_2(x)i,$$
$$zL_1(x) = x + (x^2+2)i_h + (x^3+3x)\varepsilon + (x^4+4x^2+2)h + (x^2+2) + (x^3+3x)i_h + (x^4+4x^2+1)\varepsilon + (x^5+5x^3+4x)h)i$$

⋮

as examples. Then, we define the complex hybrid Fibonacci and complex hybrid Lucas polynomial sequences are as follows, respectively.

$$zF_n(x) = zF_{n-1}(x) + xzF_{n-2}(x),$$

$$zL_n(x) = zL_{n-1}(x) + xzL_{n-2}(x)$$

for $n \geq 2$.

Theorem 7. The Binet formula for Complex hybrid Fibonacci polynomial sequences is as follows.

$$zF_n(x) = \frac{A(x)\alpha^n(1+\alpha i) - B(x)\beta^n(1+\beta i)}{2(\alpha+\beta)},$$

where $\alpha = \frac{x+\sqrt{x^2+4}}{2}, \beta = \frac{x-\sqrt{x^2+4}}{2}$.

Proof Firstly, we write a hybrid Fibonacci polynomial

$$HF_n(x) = A(x)\alpha^n - B(x)\beta^n$$

with the Binet formula.Then, we obtain

$$A(x) = \frac{1}{2\sqrt{x^2+4}}\left(2HF_1(x) - xHF_0(x) + 2\sqrt{x^2+4}HF_0(x)\right),$$

$$B(x) = \frac{1}{2\sqrt{x^2+4}}(-2HF_1(x) + xHF_0(x))$$

when we write $HF_n(x)$ for $n = 0$ and $n = 1$.

Then, we have

$$zF_n(x) = HF_n(x) + HF_{n+1}(x)i$$

and we can write

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$$zF_n(x) = \frac{1}{2(\alpha-\beta)}(A(x)\alpha(x)^n - B(x)\beta(x)^n) + \frac{1}{2(\alpha-\beta)}(A(x)\alpha(x)^{n+1} - B(x)\beta(x)^{n+1})i$$

by using the Binet formula of the hybrid Fibonacci polynomial sequence. This equation is recognized by necessary operations we obtain the Binet formula is obtained as follows.

$$zF_n(x) = \frac{A(x)\alpha^n(1+\alpha i) - B(x)\beta^n(1+\beta i)}{2(\alpha+\beta)}$$

The Binet formula for the complex hybrid Lucas polynomial can be obtained similarly.

Theorem 8. The generating function for the complex hybrid Fibonacci polynomial is as follows.

$$g_z(t) = \frac{zF_1 + (1-xt)zF_0}{1-xt-t^2}$$

Proof. The generating function for the complex hybrid Fibonacci polynomial is can be written in a general form

$$g_z(t) = \sum_{n=0}^{\infty} zF_n(x)t^n.$$

Then, we have

$$\sum_{n=0}^{\infty} zF_{n+2}(x)t^n = x\sum_{n=0}^{\infty} zF_{n+1}(x)t^n + \sum_{n=0}^{\infty} zF_n(x)t^n,$$

$$\frac{1}{t^2}\left(-zF_0 - zF_1 + g_z(t)\right) = xt\left(-zF_0 + g_z(t)\right) + g_z(t),$$

$$g_z(t)(1-xt-t^2) = zF_0 + zF_1 - xtzF_0.$$

Finally, we write the generating function

$$g_z(t) = \frac{zF_1 + (1-xt)zF_0}{1-xt-t^2}$$

with necessary operations. Similarly, the generating function of the complex hybrid Lucas polynomial is can be obtained.

DISCUSSION

Considering the interdisciplinary application potential of dual, hyperbolic, and hybrid number systems in fields such as physics, engineering, and signal processing, the theoretical framework presented here is expected to pave the way for new practical applications. In particular, the integration of the geometric foundation of these number sets with special sequences opens new avenues for correlations in branches such as algebraic topology and differential geometry.

CONCLUSION

In conclusion, this research does not merely provide a pure mathematical expansion; it also evaluates the interaction of complex number systems with hybrid structures through a novel perspective using special number sequences. Thus, it establishes a theoretical foundation that will guide future interdisciplinary studies.

ACKNOWLEDGEMENTS

The corresponding author is supported by the Scientific and Technological Research Council of Türkiye (TÜBİTAK) under the 2211-A National PhD Scholarship Program.

REFERENCES

Cerda-Morales, G. 2018. Investigation of generalized hybrid Fibonacci numbers and their properties. *arXiv preprint arXiv:1806.02231*.

Dattoli, G., Licciardi, S., Pidatella, R. M., & Sabia, E. 2018. Hybrid complex numbers: the matrix version. *Advances in Applied Clifford Algebras*, *28*(3), 58.

Euler, L. 2012. *Elements of algebra*. Springer Science & Business Media.

Harman, C. J. 1981. Complex fibonacci numbers. *The Fibonacci Quarterly*, *19*(1), 82-86.

Horadam, A. F. 1963. Complex Fibonacci numbers and Fibonacci quaternions. *The American Mathematical Monthly*, *70*(3), 289-291.

Kızılateş, C. 2020. A new generalization of Fibonacci hybrid and Lucas hybrid numbers. *Chaos, Solitons & Fractals*, *130*, 109449.

Koshy, T. 2019. *Fibonacci and Lucas Numbers with Applications, Volume 2* (Vol. 2). John Wiley & Sons.

Özçevik, S. B., Dertli, A., & Karaahmetoğlu, S. 2024. Fibonacci-Lucas Spinors Obtained from Hybrid Numbers. *arXiv preprint arXiv:2406.15393*.

Özdemir, M. 2018. Introduction to hybrid numbers. *Advances in applied Clifford algebras*, *28*(1), 11.

Seçgin, F., İlgüz, Ç. R., & Gök, İ. 2025. On complex hybrid numbers: Algebraic structures, matrix representations, and geometric interpretations. *Kuwait Journal of Science*, 100528.

Szynal-Liana, A. 2018. The Horadam hybrid numbers. *Discussiones Mathematicae-General Algebra and Applications*, *38*(1), 91-98.

Tan, E., & Ait-Amrane, N. R. 2023. On a new generalization of Fibonacci hybrid numbers. *Indian Journal of Pure and Applied Mathematics*, *54*(2), 428-438

Qarah Bash, A., & Altınkaya, A. N. I. L. 2025. On Complex Fibonacci and Lucas Hybrid Numbers.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

H ŞEKLİNE SAHİP BİR RADYE TEMELİN ALTINDAKİ DÜŞEY GERİLME ARTIŞININ AUTOCAD DESTEKLİ 2:1 YÖNTEMİYLE BELİRLENMESİ

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ÖZET

Bu çalışmada, uygulamada sıkça karşılaşılan bileşik dikdörtgen geometriye sahip radye temellerin altında oluşan düşey gerilme artışlarının 2:1 yöntemi kullanılarak belirlenmesinde karşılaşılan geometrik zorlukların giderilmesine yönelik bir yaklaşım sunulmuştur. 2:1 yöntemi, temel tabanından itibaren gerilmelerin derinlikle birlikte 2 düşey:1 yatay (2D:1Y) oranında yayıldığı varsayımına dayanan yaklaşık bir hesap yöntemidir ve özellikle ön tasarım aşamasında pratikliği nedeniyle yaygın olarak kullanılmaktadır. Ancak bileşik dikdörtgen planlı temellerde 2D:1Y kuralına göre genişletilmiş temel alanının belirlenmesi, geometrik karmaşıklık nedeniyle zaman alıcı ve hata yapmaya açık bir süreçtir. Bu çalışmada, H şeklinde plan geometrisine sahip bir radye temel örneği üzerinden, 2D:1Y kuralına göre genişletilmiş alanların AutoCAD yazılımında "polyline, offset" ve "area" komutları kullanılarak hızlı ve doğru bir biçimde elde edilmesi sağlanmıştır. Elde edilen genişletilmiş alanlar yardımıyla her bir derinlik için gerilme artışı değerleri hesaplanmış ve sonuçlar tablo halinde sunulmuştur. Çalışma sonuçları, bileşik dikdörtgen geometriye sahip temellerin altındaki gerilme artışının belirlenmesinde AutoCAD kullanımının 2:1 yönteminin uygulanabilirliğini önemli ölçüde kolaylaştırdığını göstermektedir.

Anahtar Kelimeler: 2:1 yöntemi, Düşey gerilme artışı, Radye temel, Bileşik plan geometrisi

DETERMINATION OF VERTICAL STRESS INCREASE BENEATH AN H-SHAPED RAFT FOUNDATION USING AN AUTOCAD-SUPPORTED 2:1 METHOD

ABSTRACT

This study presents an approach aimed at overcoming the geometric difficulties encountered in determining vertical stress increases beneath raft foundations with composite rectangular geometries, which are frequently encountered in practice, by using the 2:1 method. The 2:1 method is an approximate calculation approach based on the assumption that stresses spread with depth at a ratio of 2 vertical to 1 horizontal (2V:1H) from the foundation base, and it is widely used in preliminary

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

design due to its practicality. However, for foundations with composite rectangular plan geometries, determining the expanded foundation area according to the 2V:1H rule becomes a time-consuming and error-prone process due to geometric complexity. In this study, an H-shaped raft foundation was selected as a case example, and the expanded areas defined according to the 2V:1H rule were efficiently and accurately obtained in AutoCAD using the “polyline, offset” and “area” commands. Based on the calculated expanded areas, vertical stress increases at each depth were determined and presented in tabular form. The results demonstrate that the use of AutoCAD significantly facilitates the practical application of the 2V:1H method in determining stress increases beneath foundations with composite rectangular geometries.

Keywords: 2:1 method, Vertical stress increase, Raft foundation, Composite plan geometry

1. GİRİŞ

Temeller, üstyapı yüklerini güvenli bir biçimde zemine aktaran taşıyıcı sistem elemanlarıdır. Temellerin geoteknik tasarım sürecinde hem taşıma gücü göçmesine karşı yeterli güvenlik sağlanması hem de oturma miktarının kabul edilebilir sınırlar içinde tutulması gerekmektedir. Radye temeller için izin verilebilir oturma miktarı; zemin özelliklerine, yapı tipine ve performans kriterlerine bağlı olarak genellikle 25–75 mm aralığında sınırlandırılmaktadır (Das ve Sivakugan, 2019).

Taşıma gücü esaslı geoteknik tasarımda izin verilebilir taşıma gücü (q_a), nihai taşıma gücünün güvenlik katsayısına bölünmesiyle (q_u/GK) belirlenirken; oturma esaslı geoteknik tasarımda ise izin verilen oturmaya karşılık gelen taşıma gücü değeri esas alınır. Tasarımda bu iki değerden küçük olanı kullanılır.

Birçok uygulamada geoteknik temel tasarımı oturma kriteri tarafından kontrol edilmektedir. Oturmanın hesaplanabilmesi için, temel yüklerinden kaynaklanan düşey gerilme artışının derinlikle birlikte değişiminin doğru bir şekilde belirlenmesi gerekmektedir. Bu amaçla Boussinesq (1885), Westergaard (1938) ve Newmark (1935) tarafından geliştirilen elastisite teorisine dayanan çözümler yaygın olarak kullanılmaktadır. Ancak karmaşık plan geometrisine sahip temellerde bu yöntemlerin uygulanması zaman alıcı ve hesap yoğunluğu açısından zorlayıcı olabilmektedir.

2:1 yöntemi ise daha basit ve pratik bir yaklaşım sunmakta; özellikle ön tasarım aşamasında yeterli doğrulukta sonuçlar sağlamaktadır. Ancak bu yöntemin uygulanmasında da bazı güçlükler söz konusudur. 2:1 yöntemiyle dikdörtgen planlı temellerde gerilme artışının belirlenmesi görece kolay olmakla birlikte, bileşik dikdörtgen geometrilere sahip temellerde 2:1 kuralına göre genişletilmiş temel alanının belirlenmesi, geometrik karmaşıklık arttıkça zorlaşmaktadır. Bu durum, hesapların elle veya elektronik tablo programları ile yapılmasını güçleştirmektedir. Bu nedenle genişletilmiş temel alanının doğru biçimde belirlenmesi, özellikle bileşik plan geometrilerinde kritik bir öneme sahiptir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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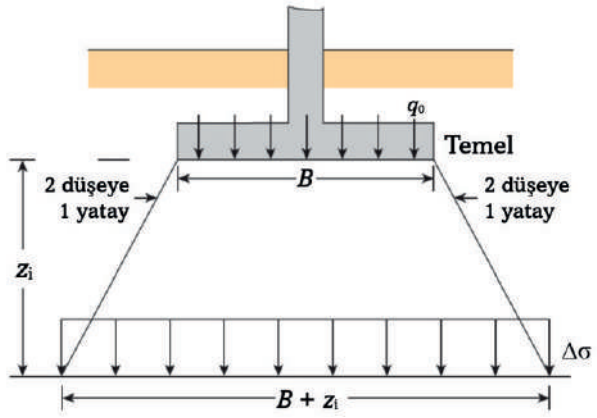
Son yıllarda yapılan araştırmalar, bu yaklaşık yöntemin doğruluğunu artırmaya yönelik çalışmalara odaklanmıştır. Örneğin Dağdeviren (2025), farklı temel en/boy oranları için tahmin hatalarını azaltmak amacıyla optimizasyon temelli yeni bağıntılar geliştirmiştir.

Ayrıca Türedi ve Örnek (2017) tarafından gerçekleştirilen karşılaştırmalı bir çalışmada, 2:1 yönteminin genellikle muhafazakâr (güvenli tarafta kalan) tahminler verdiğini; buna karşın Boussinesq'in elastisite çözümleri gibi daha kuramsal yaklaşımların gerilme dağılımını daha yüksek doğrulukla temsil edebildiğini göstermektedir.

Bu çalışmada, 2:1 yöntemiyle bileşik dikdörtgen geometriye sahip temellerde genişletilmiş temel alanının belirlenmesindeki güçlüğü gidermek amacıyla AutoCAD yazılımının kullanılması ve örnek olarak H şeklinde bileşik dikdörtgen plan geometrisine sahip bir radye temelin altında oluşan düşey gerilme artışlarının hesaplanması amaçlanmıştır.

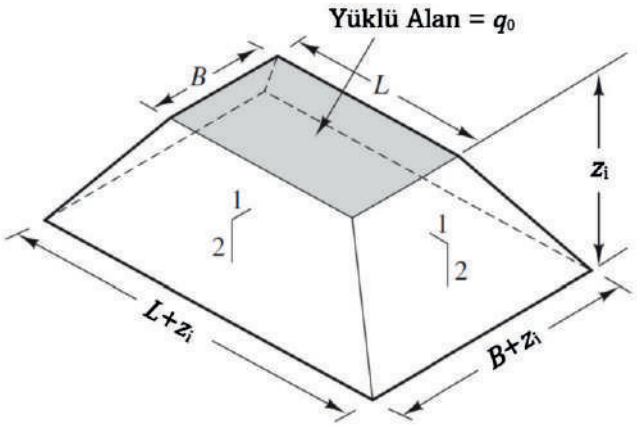
2. YAKLAŞIK YÖNTEMLE DÜŞEY GERİLME ARTIŞININ HESAPLANMASI

Zemin mekaniğinde temellerin altındaki düşey gerilme artışının belirlenmesi amacıyla kullanılan 2:1 yöntemi, hesap kolaylığı sağlaması nedeniyle yaygın olarak tercih edilen bir yaklaşık yöntemdir. Bu yöntemde, gerilmelerin temel tabanından itibaren her 2 birim düşey derinliğe karşılık gerilmenin yatayda 1 birim yayıldığı (2Y:1D) varsayılır. Böylece temel yükünün derinlikle birlikte giderek artan hayali bir alan üzerine dağıldığı kabul edilir (Şekil 1 ve 2). Belirli bir derinlikteki düşey gerilme artışı ($\Delta\sigma$), temele etkiyen net yükün bu genişletilmiş alana bölünmesiyle hesaplanır. Derinlik arttıkça yükün yayıldığı alan büyüdüğünden, gerilme artışı derinlikle birlikte azalmaktadır. 2:1 yöntemi, Boussinesq veya Newmark çözümlerine kıyasla daha yaklaşık sonuçlar vermekle birlikte, özellikle ön tasarım aşamasında yeterli doğruluğu sağlamaktadır.



Şekil 1. İki boyutlu düzlemde 2:1 yönteminin temel ilkeleri (Das ve Sivakugan, 2019)

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Şekil 2. Üç boyutlu düzlemde 2:1 yönteminin temel ilkeleri (Coduto vd. 2016)

2:1 yöntemiyle dikdörtgen planlı temellerin altındaki düşey gerilme artışı aşağıdaki bağıntı ile hesaplanabilmektedir:

$$\Delta\sigma = \frac{q_{net} \times B \times L}{(B + z) \times (L + z)} \quad (1)$$

Bu çalışmada Eş. (1), aşağıdaki gibi daha genel bir biçimde ifade edilerek, dikdörtgen olmayan temeller için de kullanılabilecek bir biçime kullanılmıştır:

$$\Delta\sigma = q_{net} \times \frac{A}{A_i} \quad (2)$$

Buradaki A, temelin plan düzlemindeki alanını; A_i ise 2:1 kuralına göre temel tabanının z_i kadar altındaki genişletilmiş hayali temel alanını ifade etmektedir.

Karmaşık plan geometrisine sahip radye temellerde A_i alanları AutoCAD ortamında "area" komutuyla kolaylıkla belirlenebilmekte ve Eş. (2) kullanılarak bileşik dikdörtgen planlı temellerin altındaki gerilme artışları elle veya elektronik tablo programları yardımıyla rahatlıkla hesaplanabilmektedir.

2.1. Sayısal Uygulama

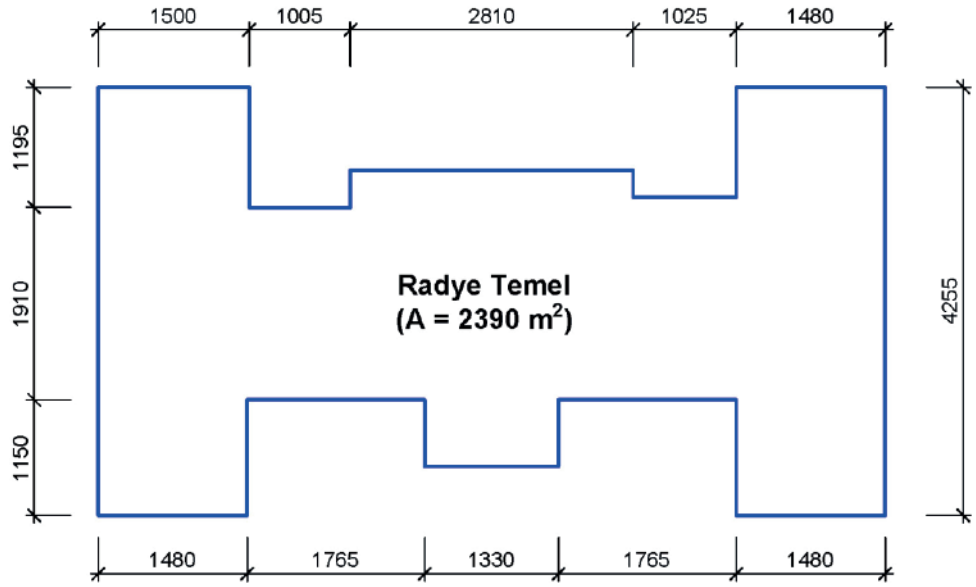
Sayısal uygulama, H harfi biçiminde bileşik dikdörtgen plan geometrisine sahip bir radye temel üzerinde gerçekleştirilmiştir. Plan ölçüleri Şekil 3'te verilen temelin sınırları AutoCAD'de "polyline" komutu ile çizilmiş ve taban alanı "area" komutu kullanılarak A = 2390 m^2 olarak hesaplanmıştır.

Temel zemini, temel tabanından itibaren her biri 1 m kalınlığında toplam 20 katmana ayrılmıştır. 2:1 kuralına uygun olarak, her 1 m düşey derinlik artışı için plan düzleminde temel sınırlarından dışarıya

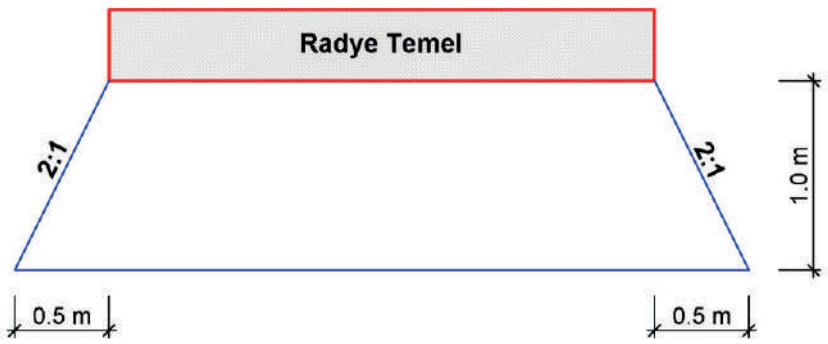
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doğru 0.5 m yatay genişletme uygulanmıştır (Şekil 4). Bu işlem AutoCAD'de "offset" komutu kullanılarak gerçekleştirilmiş ve 20 katman için genişletilmiş temellerin dış sınır çizgileri elde edilmiştir (Şekil 5). Her bir katmana ait genişletilmiş temel alanları (A_i) AutoCAD'de "area" komutu kullanılarak belirlenmiş ve MS Excel'de hazırlanan hesap tablosuna girilmiştir.

Başlangıçtaki temel alanı (A), genişletilmiş temel alanlarına (A_i) oranlanarak her bir katman için gerilme artışı etki katsayısı değerleri ($I_i = A/A_i$) hesaplanmıştır. Gerilme artışı etki katsayısı (I_i) değerleriyle net temel taban basıncı (q_{net} = 50 kPa) çarpılarak her bir katman için gerilme artışı değerleri belirlenmiştir. Hesaplamalar MS Excel'de hazırlanan hesap tablosuyla gerçekleştirilmiş ve elde edilen sonuçlar toplu halde Çizelge 1'de sunulmuştur.

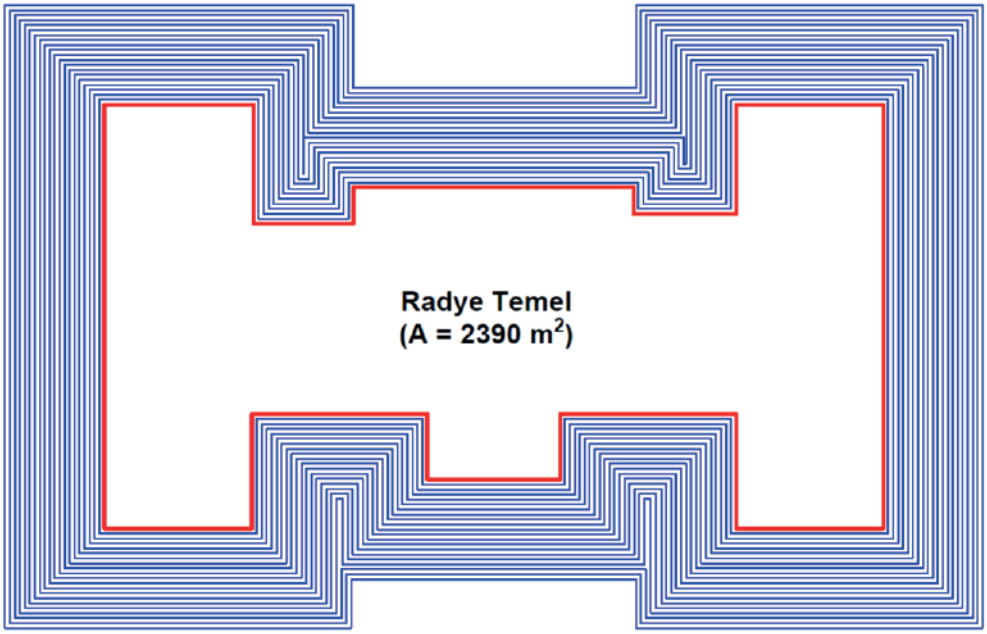


Şekil 3. Hesaplarda kullanılan temel planı



Şekil 4. Gerilme artışının bulunmasında 2:1 kuralının uygulanması

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Şekil 5. AutoCAD'de "offset" komutu kullanılarak 2:1 kuralına göre genişletilmiş temel alanları

Çizelge 1. AutoCAD destekli 2:1 yöntemiyle hesaplanan gerilme artışı değerleri

Katman No	H_i (m)	z_i (m)	A_i (m^2)	$I_i=A/A_i$	Δσ (kPa)
1	1.00	1.00	2545.2	0.9390	46.9
2	1.00	2.00	2701.6	0.8847	44.2
3	1.00	3.00	2860.1	0.8356	41.8
4	1.00	4.00	3020.5	0.7913	39.6
5	1.00	5.00	3183.0	0.7509	37.5
6	1.00	6.00	3347.4	0.7140	35.7
7	1.00	7.00	3513.9	0.6802	34.0
8	1.00	8.00	3682.3	0.6490	32.4
9	1.00	9.00	3852.8	0.6203	31.0
10	1.00	10.0	4025.2	0.5938	29.7
11	1.00	11.0	4194.2	0.5698	28.5

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12	1.00	12.0	4364.4	0.5476	27.4
13	1.00	13.0	4536.5	0.5268	26.3
14	1.00	14.0	4710.7	0.5074	25.4
15	1.00	15.0	4886.8	0.4891	24.4
16	1.00	16.0	5065.0	0.4719	23.6
17	1.00	17.0	5245.1	0.4557	22.8
18	1.00	18.0	5422.6	0.4407	22.0
19	1.00	19.0	5593.6	0.4273	21.4
20	1.00	20.0	5766.5	0.4145	20.7

Çizelge 1'de sunulan değerler kullanılarak, uygun konsolidasyon bağıntıları ve zemin parametreleri yardımıyla toplam konsolidasyon oturması yaklaşık olarak tahmin edilebilmektedir.

3. SONUÇ VE ÖNERİLER

Bu çalışmada, H şeklinde plan geometrisine sahip bileşik dikdörtgen şeklindeki bir radye temel altında oluşan düşey gerilme artışlarının, AutoCAD ve MS Excel yardımıyla 2:1 yöntemi kullanılarak hızlı ve etkin bir biçimde hesaplanabileceği gösterilmiştir.

Elde edilen bulgular, plan geometrisi karmaşık olan bileşik dikdörtgen temellerde genişletilmiş temel alanlarının AutoCAD ortamında "polyline, offset" ve "area" komutları kullanılarak kolaylıkla belirlenebildiğini ve böylece 2:1 yönteminin uygulama sürecinin önemli ölçüde kolaylaştırılabildiğini ve hızlandırılabildiğini göstermiştir.

Bununla birlikte, 2:1 yönteminin yaklaşık bir yöntem olduğu ve elastisite teorisine dayalı Boussinesq, Newmark ve Westergaard gibi çözümlemelere kıyasla belirli bir hata payı içerebileceği göz önünde bulundurulmalıdır. Bu nedenle, özellikle yüksek maliyetli ve kritik öneme sahip projelerde, bileşik dikdörtgen geometriye sahip temellerin altındaki gerilme artışının sonlu elemanlar veya sonlu farklar gibi sayısal analiz yöntemleriyle belirlenmesinin daha güvenilir sonuçlar sağlayacağı değerlendirilmelidir.

TEŞEKKÜR

Yazar, eğitici lisansı ile programın kullanılmasını sağladıkları için Autodesk Inc.'ye ve MS Excel için kurumsal lisans sağladığı için Gazi Üniversitesi Rektörlüğüne teşekkür eder.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KAYNAKLAR

Boussinesq, M.J. (1885), Application des potentiels à l'étude de l'équilibre et du mouvement des solides élastiques, Gauthier-Villars, Paris (in French).

Coduto, D.P., Kitch, W.A., Yeung, Man-chu,R. (2016). Foundation Design: Principles and Practices (3rd ed.). Pearson Education, Inc. USA.

Dağdeviren, U. (2025). Improvement of the Approximate Method for Determining the Average Vertical Stress Increase Below the Rectangular Foundation Using Differential Evolution Algorithm. Arab J Sci Eng., 50, 17133–17152.

Das, B.M., Sivakugan, N. (2019). Principles of Foundation Engineering (9th. ed.). Cengage Learning, Inc., Boston, USA.

Newmark, N.M. (1935). Simplified Computation of Vertical Pressure in Elastic Foundation, Circular 24, University of Illinois Engineering Experiment Station, Urbana, IL.

Türedi, Y., & Örnek, M. (2017). Stress Analyses of Strip and Rectangular Footings Rested on Loose Sands. Natural and Engineering Sciences, 2(3), 93-112.

Westergaard, H.M. (1938).A Problem of Elasticity Suggested by a Problem in Soil Mechanics: Soft Material Reinforced by Numerous Strong Horizontal Sheets," Contributions to the Mechanics of Solids, Dedicated to Stephen Timoshenko, pp. 268–277, Macmillan, New York.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TERZAGHI TAŞIMA GÜCÜ DENKLEMİNDE DİKDÖRTGEN TEMELLER İÇİN ŞEKİL DÜZELTME KATSAYILARI: BİR GALATIMEŞHUR

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ÖZET

Bu çalışmada, Terzaghi (1943) tarafından önerilen taşıma gücü denklemlerinin dikdörtgen temeller için kullanımına ilişkin geoteknik literatüründe yer alan yaygın bir yanlış bilgi ele alınmıştır. Terzaghi (1943), taşıma gücü denklemlerini yalnızca şerit, kare ve dairesel temeller için geliştirmiş olup dikdörtgen temeller için herhangi bir şekil düzeltme katsayısı veya taşıma gücü bağıntısı sunmamıştır. Buna karşın, ülkemizde yaygın olarak kullanılan bazı ders ve başvuru kitaplarında, dikdörtgen temeller için verilen ve "şekil düzeltme katsayıları" olarak adlandırılan k_1 ve k_2 katsayılarının Terzaghi'ye atfedildiği görülmektedir. Bu çalışmada, söz konusu katsayıların kökeni araştırılmış; uluslararası geoteknik literatüründe genel kabul görmüş klasik ve güncel kitaplar incelenmiş; ayrıca Skempton (1951)'in kil zeminler üzerine oturan temeller için önerdiği taşıma gücü yaklaşımı detaylı olarak değerlendirilmiştir. İncelemeler sonucunda, dikdörtgen temeller için verilen $k_1=1 + 0.2B/L$ katsayısının Skempton (1951)'e ait olduğu, $k_2=0.5-0.1B/L$ katsayısının ise Terzaghi veya Skempton kaynaklı olmadığı, ulaşılabilir kaynaklar içerisinde ilk kez Kumbasar ve Kip (1969) tarafından kullanıldığı belirlenmiştir. Sonuç olarak, söz konusu katsayıların Terzaghi (1943)'e ait olmadığı açıkça ortaya konmuş; bu katsayıların kullanılması halinde doğru atıf yapılmasının ve Terzaghi'nin özgün denklemleriyle karıştırılmamasının gerekliliği vurgulanmıştır.

Anahtar Kelimeler: Terzaghi taşıma gücü denklemi, Dikdörtgen temeller, Şekil düzeltme katsayıları,

SHAPE CORRECTION FACTORS FOR RECTANGULAR FOOTINGS IN TERZAGHI'S BEARING CAPACITY EQUATION: A WELL-KNOWN MISCONCEPTION

ABSTRACT

This study addresses a widespread misconception in the geotechnical literature regarding the use of the bearing capacity equations proposed by Terzaghi (1943) for rectangular foundations. Terzaghi (1943) developed his bearing capacity equations exclusively for strip, square, and circular footings and did not propose any shape correction factor or bearing capacity equation for rectangular foundations.

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ISBN: 978-9952-610-30-7

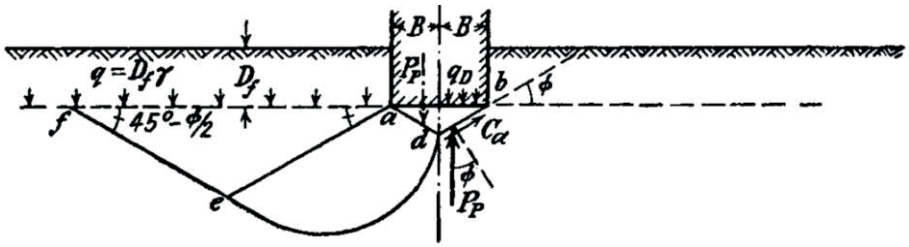
Nevertheless, in several textbooks and reference books widely used in Türkiye, the coefficients k_1 and k_2 which are presented as "shape correction factors" for rectangular foundations are commonly attributed to Terzaghi. In this study, the origin of these coefficients was investigated; classical and contemporary textbooks that are widely recognized in the international geotechnical literature were examined; and the bearing capacity approach proposed by Skempton (1951) for foundations resting on clay soils was evaluated in detail. The investigation reveals that the shape factor $k_1=1+0.2B/L$ attributed to rectangular foundations originates from Skempton (1951), whereas the coefficient $k_2=0.5-0.1B/L$ does not stem from either Terzaghi or Skempton and appears, within the accessible literature, to have been first introduced by Kumbasar and Kip (1969). It is therefore clearly demonstrated that these coefficients do not belong to Terzaghi (1943). The study emphasizes that, if such coefficients are to be used, proper attribution must be provided, and they should not be conflated with Terzaghi's original bearing capacity equations.

Keywords: Terzaghi bearing capacity equation, Rectangular footings, Shape correction factors

1. GİRİŞ

Konut türü binaların yapımı tamamlanıp hizmete açıldıktan sonra yapı elemanlarında çatlakların ve aşırı şekil değiştirmelerin meydana gelmemesi için bina temellerinin geoteknik bakımdan güvenli bir şekilde tasarlanmış olması gerekmektedir.

Konut türü binalarda yaygın olarak kullanılan yüzeysel temeller için taşıma gücü denklemleri ilk kez 1943 yılında K. Terzaghi tarafından geliştirilmiştir (Terzaghi, 1943). K. Terzaghi, ilk taşıma gücü denklemini Prandtl (1920)'nin yenilme mekanizmasını zeminlere uyarlayarak ve limit denge yöntemlerini kullanarak şerit temeller için geliştirmiştir. Terzaghi (1943)'ün kuramsal çözümlemelerinde kullandığı yenilme mekanizması Şekil 1'de verilmiştir.



Şekil 1. Terzaghi'nin yenilme mekanizması (Terzaghi, 1943)

Terzaghi (1943), şerit temelleri "*uzunluğu genişliğine kıyasla oldukça büyük olan temeller*" olarak tanımlamış olup, şerit temeller için geliştirdiği taşıma gücü denklemini, deney sonuçlara dayanarak kare ve dairesel temeller için de uyarlamıştır. Terzaghi (1943) tarafından şerit, kare ve dairesel temeller için geliştirilen taşıma gücü denklemleri Eşitlik (1)-(3)'te verilmiştir.

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$$q_u = cN_c + \gamma D_f N_q + 0.5\gamma B N_\gamma \quad \text{(Şerit temel)} \quad (1)$$

$$q_u = 1.3cN_c + \gamma D_f N_q + 0.4\gamma B N_\gamma \quad \text{(Kare temel)} \quad (2)$$

$$q_u = 1.3cN_c + \gamma D_f N_q + 0.3\gamma B N_\gamma \quad \text{(Dairesel temel)} \quad (3)$$

Eşitlik (1)-(3) incelendiğinde, Terzaghi (1943) tarafından dikdörtgen temeller için herhangi bir taşıma gücü denklemi veya şekil düzeltme katsayısının önerilmediği görülmektedir. Ancak uygulamada, özellikle konut türü binalarda, şerit, kare ve dairesel temellerin kullanım alanı oldukça sınırlıdır. Dairesel temeller genellikle silo ve benzeri dairesel kesitli depolama yapılarında kullanılmakta olup konut yapılarında nadiren tercih edilmektedir. Kare temeller, teorik olarak birçok yapıda uygulanabilir olmakla birlikte, konut türü binalarda yalnızca tekil temel tercih edilmesi durumunda kullanılabilmektedir. Bununla birlikte, tekil temellerin farklı oturma sorunlarına yol açabilmesi ve yapım aşamasında kalıp ve donatı işçiliğinin zor ve maliyetinin yüksek olması gibi nedenlerle, bu temel türünün konut türü binalarda kullanımı özellikle ülkemizde yaklaşık son 20 yıldır büyük ölçüde terk edilmiştir. Şerit temeller ise daha çok fabrika yapılarında tercih edilmektedir.

Uygulamada, özellikle konut türü binalarda dikdörtgen plan geometrisine sahip temeller yaygın olarak kullanılmasına karşın, Terzaghi (1943) tarafından dikdörtgen temeller için herhangi bir taşıma gücü denklemi veya şekil düzeltme katsayısı önerilmediğinden, Terzaghi (1943)'ten sonra birçok araştırmacı tarafından Terzaghi'nin taşıma gücü denklemlerinin dikdörtgen temelleri de kapsayacak şekilde geliştirilmesine yönelik çok sayıda araştırma yapılmıştır. ülkemizde yaygın olarak kullanılan bazı kaynak kitaplarda bu gelişmelerden bahsedilmekle birlikte, dikdörtgen temeller için Terzaghi (1943) tarafından önerilmiş olduğu izlenimini doğuracak ifadeler kullanılarak bazı şekil düzeltme katsayılarının verildiği görülmektedir.

Bu çalışmada, dikdörtgen temeller için Terzaghi (1943)'ün taşıma gücü denklemleriyle birlikte verilen ve sanki Terzaghi tarafından önerilmiş gibi sunulan şekil düzeltme katsayılarının kökeni araştırılmıştır.

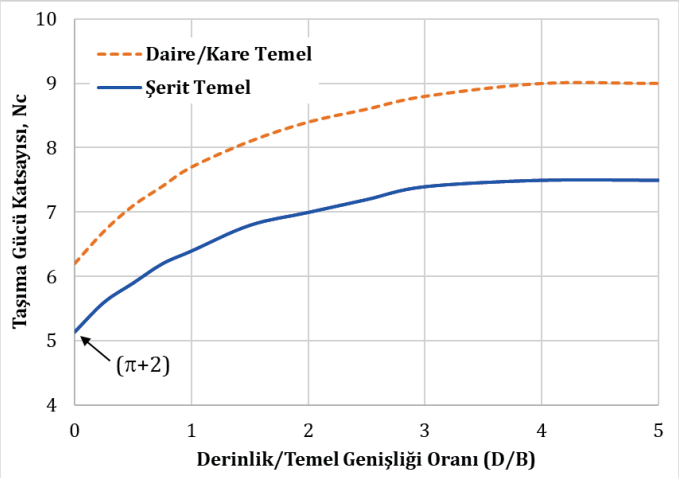
2. KAYNAK ARAŞTIRMASI

Ülkemizdeki bazı kaynak kitaplarda, dikdörtgen temeller için Terzaghi (1943)'e atıf yapılarak verilen şekil düzeltme katsayılarının kaynağını araştırmak amacıyla, uluslararası geoteknik literatüründe genel kabul görmüş klasik ve güncel kitaplar ve ülkemizde yayımlanmış temel ders kitapları incelenmiştir. Bunun yanı sıra, Terzaghi (1943)'ün taşıma gücü denklemindeki terimlerin bazı katsayılar yardımıyla modifiye edilmesi fikrinin öncülerinden biri olan A. W. Skempton (1951)'in, kil zeminler üzerine oturan yüzeysel temellerin taşıma gücü üzerine gerçekleştirdiği çalışma detaylı olarak değerlendirilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

2.1. Temellerin Taşıma Gücü Üzerine Skempton (1951)'in Çalışması

Skempton (1951), kil zeminler ($\phi = 0$) üzerine oturan temellerin taşıma gücünün hesaplanmasında temel derinliğinin ve temel şeklinin etkisini dikkate almak amacıyla taşıma gücü katsayısı N_c'nin modifiye edilmesini önermiştir. Bu kapsamda, laboratuvar ortamında gerçekleştirilen küçük ölçekli model deneylere ve sınırlı sayıdaki arazi gözlemlerine dayanarak, şerit ve kare temeller için D/B oranına bağlı olarak değişen N_c katsayılarını grafikler halinde sunmuştur (Şekil 2).



Şekil 1. Kil zemine (ϕ=0) oturan temeller için N_c taşıma gücü katsayısı (Skempton, 1951)

Skempton (1951), şerit ve kare temeller arasında kalan dikdörtgen temeller için N_c değerlerinin, söz konusu grafikler arasında doğrusal enterpolasyon yapılarak belirlenebileceğini ifade etmiştir. Skempton (1951), grafikler incelendiğinde, şerit temeller için önerilen N_c değerlerinin kare temeller için önerilen değerlere oranının hem yüzeyde hem de derinlikte yaklaşık 0.84 olduğunu gözlemlemiştir. Bu gözleme dayanarak, kare temeller için önerilen N_c değerlerinden hareketle, doğrusal enterpolasyon yapılarak dikdörtgen temeller için N_c değerlerinin aşağıdaki bağıntı ile yaklaşık olarak hesaplanabileceği belirtmiştir:

$$N_c(dikdörtgen) = \left(0.84 + 0.16\frac{B}{L}\right) N_c(kare) \qquad (4)$$

Şekil 1'de verilen grafiklerden ayrıca, kare temeller için önerilen N_c değerlerinin şerit temeller için önerilen N_c değerlerinden yaklaşık %20 (yani 1.2 kat) daha büyük olduğu anlaşılmaktadır. Bu nedenle

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Skempton (1951), daha pratik bir denklem olması nedeniyle, şerit temeller için önerilen N_c değerlerini esas alarak dikdörtgen temeller için aşağıdaki bağıntıyı önermiştir:

$$N_c(dikdörtgen) = \left(1 + 0.2\frac{B}{L}\right) N_c(şerit) \quad (5)$$

Bu bağıntı kullanıldığında, kare temeller için B=L alınması halinde parantez içindeki katsayının 1.2 olduğu görülmektedir. Terzaghi (1943)'ün kare temeller için önerdiği taşıma gücü denkleminde kohezyonlu terimin katsayısının 1.3 olduğu dikkate alındığında, Eş. (5)'in kullanılması durumunda Terzaghi'nin katsayının dolaylı olarak 1.2'ye indirgenmiş olduğu anlaşılmaktadır. Buna karşılık, Eş. (4)'ün kullanılması halinde kare temeller için katsayı 1.0 olmakta ve Terzaghi (1943) tarafından önerilen 1.3 katsayısı değişmeden korunmaktadır. Ancak geoteknik literatüründe Eş. (4) değil, Eş. (5) yaygınlık kazanmıştır.

2.2. Terzaghi ve Peck (1948, 1967)

Terzaghi (1943)'ün Eşitlik (1)-(3)'te verilen taşıma gücü denklemleri ilk kez "*Theoretical Soil Mechanics*" adlı kitabında yayımlanmıştır. Daha sonra Terzaghi, R.B. Peck ile birlikte 1948 yılında "*Soil Mechanics in Engineering Practice*" adlı bir kitap daha yayımlamıştır. Bu kitapta da taşıma gücü denklemleri Terzaghi (1943)'te olduğu gibi yer almıştır. Ancak bu kitabın, Terzaghi'nin vefatından dört yıl sonra, 1967 yılında yayımlanan ikinci baskısında kare ve dairesel temeller için 1.3 olan katsayısının 1.2 ile değiştirildiği görülmektedir (Eş. 6, 7) (Terzaghi ve Peck, 1967). Şerit temeller için önerilen taşıma gücü bağıntısının katsayılarında ise herhangi bir değişiklik yapılmamıştır.

$$q_u = 1.2cN_c + \gamma D_f N_q + 0.4\gamma B N_\gamma \quad \text{(Kare temel)} \quad (6)$$

$$q_u = 1.2cN_c + \gamma D_f N_q + 0.3\gamma B N_\gamma \quad \text{(Dairesel temel)} \quad (7)$$

Terzaghi (1943)'te 1.3 olan bu katsayıların neden 1.2 ile değiştirildiğine dair Terzaghi ve Peck (1967)'de herhangi bir açıklama yapılmamıştır. Ancak bu değişikliğin, Skempton (1951)'in çalışmasına dayandığı değerlendirilmektedir. Terzaghi ve Peck (1967)'de, Terzaghi'nin taşıma gücü denklemlerinde yapılan değişiklik sadece bu katsayılarla sınırlı değildir. Bununla birlikte, taşıma gücü katsayıları N_c, N_q ve N_γ için de Terzaghi (1943) tarafından değil farklı araştırmacılar tarafından önerilen denklemler kullanılmıştır (N_c için Prandtl, 1920; N_q için Reissner, 1924; ve N_γ için Meyerhof, 1955).

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2.3. Uluslararası Geoteknik Literatüründe Terzaghi Taşıma Gücü Denklemi

1950–1970 yılları arasında yayımlanan ve taşıma gücü teorisinin yoğun biçimde ele alındığı uluslararası kaynaklar incelendiğinde, Terzaghi (1943)'ün orijinal denklemlerine sadık kalındığı ve dikdörtgen temeller için Terzaghi'ye atıfla herhangi bir şekil düzeltme katsayısı verilmediği görülmektedir (Örneğin; Capper ve Cassie, 1962, 1969; Henry, 1956, 1986; Teng, 1962).

1990–2020 yılları arasında yayımlanan ve uluslararası camiada yaygın olarak kullanılan temel geoteknik ders kitaplarında da benzer bir yaklaşım benimsenmiş olup, Terzaghi (1943)'ün taşıma gücü denklemleri şerit, kare ve dairesel temeller için verilmiş; dikdörtgen temeller için Terzaghi'ye atıfla herhangi bir bağıntı veya katsayı sunulmamıştır (Örneğin; Coduto, 2001; Rao, 2011; Das, 2011, 2014, 2017; Das ve Sivakugan, 2019; Coduto vd. 2016; Bowles, 1996).

2.4. Türkiye'de Yaygın Kullanılan Kaynaklarda Terzaghi Taşıma Gücü Denklemi

Ülkemizde yaygın olarak kullanılan bazı eski tarihli ve güncel ders kitaplarında Terzaghi (1943)'ün şerit, kare ve dairesel temeller için önerdiği taşıma gücü denklemleri, tek bir denklem biçiminde aşağıdaki gibi sunulmaktadır:

$$q_u = \mathbf{k_1} c N_c + \gamma D_f N_q + \mathbf{k_2} \gamma B N_\gamma \tag{8}$$

Bu denklemde, temel şekline bağlı katsayılar $\mathbf{k_1}$ ve $\mathbf{k_2}$ ile ifade edilmekte ve "*şekil düzeltme katsayıları*" olarak adlandırılmaktadır. Söz konusu katsayılar, şerit, kare ve dairesel temellerin yanı sıra dikdörtgen temelleri kapsayacak şekilde bir çizelge halinde sunulmaktadır (Çizelge 1).

Çizelge 1. Taşıma gücü denkleminde kullanılan $\mathbf{k_1}$ ve $\mathbf{k_2}$ katsayıları

TEMEL TİPİ	$\mathbf{k_1}$	$\mathbf{k_2}$
Şerit	1.0	0.5
Kare	1.2*	0.4
Daire	1.3	0.3
Dikdörtgen	$1 + 0.2\frac{B}{L}$	$0.5 - 0.1\frac{B}{L}$

*Bazı kitaplarda bu katsayı 1.3 olarak verilmektedir.

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ISBN: 978-9952-610-30-7

Çizelge 1 incelendiğinde, şerit ve dairesel temeller için verilen $\mathbf{k_1}$ ve $\mathbf{k_2}$ katsayılarının Terzaghi (1943)'ün denklemlerindeki katsayılarla aynı olduğu ancak kare temeller için verilen k_1 katsayısının Terzaghi (1943)'te verilen katsayı ile değil, Terzaghi ve Peck (1967)'de verilen katsayı ile aynı olduğu görülmektedir.

Çizelge 1'de dikdörtgen temeller için verilen katsayıların Terzaghi (1943) ve/veya Terzaghi ve Peck (1948, 1967) tarafından önerilmediği bilinmektedir. Ancak buna rağmen bu çizelgenin yer aldığı ulusal kaynaklarda çizelgeye atıf yapılırken kullanılan ifadeler, dikdörtgen temeller için verilen bu katsayıların da Terzaghi tarafından önerildiği izlenimini doğurmaktadır.

3. BULGULAR VE TARTIŞMA

Ulaşılabilen Türkiye kökenli kaynaklarda yapılan araştırmalar neticesinde, Terzaghi (1943)'ün taşıma gücü denklemlerinin birleştirilerek $\mathbf{k_1}$ ve $\mathbf{k_2}$ katsayılarıyla birlikte sunulduğu denkleme (Eş. 8) ve bu katsayıların dikdörtgen temelleri de kapsayacak şekilde sunulduğu çizelgeye (Çizelge 1) ilk defa V. Kumbasar ve F. Kip tarafından yazılmış ve 1969 yılında yayımlanmış "*Zemin Mekaniği Problemleri*" isimli kitapta rastlanmıştır. Bu kitap, 1969'dan 1999'a kadar 6 kez basılmış ve tüm baskılarında Terzaghi'nin taşıma gücü denklemi $\mathbf{k_1}$ ve $\mathbf{k_2}$ katsayılarıyla birlikte Eş. (8)'deki gibi, katsayılar ise Çizelge 1'deki gibi sunulmuştur. Kumbasar ve Kip (1969) – (1999)'da dikdörtgen temeller için verilen k_1 ve k_2 katsayılarının da Terzaghi tarafından önerildiği izlenimini doğuracak şekilde sunulduğu görülmüştür.

Ancak bu çalışma kapsamında yapılan araştırmalar neticesinde dikdörtgen temeller için $k_1=1+0.2B/L$ biçiminde verilen katsayının Skempton (1951)'in N_c için önerdiği doğrusal enterpolasyon yaklaşımından alındığı sonucuna varılmıştır. Buna karşılık, dikdörtgen temeller için $k_2=0.5–0.1B/L$ biçiminde verilen katsayının görüldüğü 1969'dan daha eski tarihli ulusal veya uluslararası bir kaynağa geoteknik literatüründe rastlanmamıştır. Bu nedenle dikdörtgen temeller için $k_2=0.5–0.1B/L$ biçiminde verilen katsayının ilk defa Kumbasar ve Kip (1969) tarafından önerildiği kanaatine varılmıştır.

Bu katsayının Kumbasar ve Kip (1969) tarafından nasıl belirlendiğini anlamaya yönelik yapılan incelemeler neticesinde yine Skempton (1951)'in N_c için önerdiği doğrusal enterpolasyon yaklaşımından yararlanılmış olacağı değerlendirilmiştir. Zira Skempton (1951)'in N_c için önerdiği doğrusal enterpolasyon yaklaşımının, N_γ terimine uygulanması durumunda k_2 katsayısının aşağıdaki biçimde elde edilebileceği görülmektedir (Eş. 9).

$$k_2 = \left(1 - 0.2\frac{B}{L}\right)0.5 = 0.5 - 0.1\frac{B}{L} \qquad (9)$$

Eş. (9)'da şerit temelleri temsilen L'ye çok büyük değer verilirse k_2 katsayısı 0.5 olarak elde edileceği görülür ki bu da Terzaghi (1943) tarafından önerilen şerit temellerin katsayısına eşit olur. Benzer şekilde Eş. (9)'da kare temelleri temsilen B=L alınırsa k_2 katsayısı 0.4 olarak hesaplanır ki bu da Terzaghi (1943) tarafından önerilen kare temellerin katsayısına eşit olur. Böylece Eş. (9)'da verilen denklemin şerit temellerle kare temeller arasında kalan dikdörtgen temelleri uygun biçimde temsil ettiği anlaşılmış olur.

Ülkemizdeki bazı kitaplarda dikdörtgen temeller için $k_1 = 1+0.2B/L$ ve $k_2 = 0.5–0.1B/L$ olarak verilen katsayılar, her ne kadar Terzaghi (1943) tarafından önerilmemiş olsa da bu katsayılar kullanılarak Terzaghi'nin taşıma gücü denklemleriyle dikdörtgen temellerin taşıma gücünün hesaplanması esasen hatalı bir yaklaşım değildir. Nitekim Terzaghi (1943)'ten sonra çok sayıda araştırmacının katkısıyla taşıma gücü denklemi çeşitli katsayılar eklenerek geliştirilmiş; dikdörtgen temellerin yanı sıra gömülü temelleri, eğik yükler altındaki temelleri, eğimli zemin yüzeylerine oturan temelleri ve tabanı eğimli temelleri kapsayacak şekilde genelleştirilmiştir. Bu şekilde geliştirilen taşıma gücü denklemi literatürde yaygın olarak "*genelleştirilmiş taşıma gücü denklemi*" olarak adlandırılmaktadır. Bu bağlamda, Kumbasar ve Kip (1969)–(1999)'da dikdörtgen temelleri de kapsayacak biçimde k_1 ve k_2 katsayılarıyla verilen taşıma gücü denkleminin, genelleştirilmiş taşıma gücü denklemiyle aynı çerçevede değerlendirilmesi mümkündür.

Bununla birlikte, taşıma gücü denkleminin birinci teriminde $k_1 = 1+0.2B/L$ katsayısının kullanılması durumunda, kare temeller için Terzaghi (1943) tarafından önerilen 1.3 katsayısının fiilen 1.2'ye indirgenmiş olacağına dikkat edilmelidir. Zira kare temeller için B=L alındığında k_1 değeri 1.2 olmaktadır. Bu durumda, Terzaghi (1943)'ün özgün taşıma gücü denklemi değil, Terzaghi ve Peck (1967) tarafından önerilen taşıma gücü denklemi kullanılmış olmaktadır.

4. SONUÇ VE ÖNERİLER

Bu çalışmadan elde edilen temel sonuçlar aşağıda özetlenmiştir:

1) Terzaghi (1943) veya Terzaghi ve Peck (1948, 1967) tarafından dikdörtgen temeller için önerilmiş herhangi bir taşıma gücü denklemi veya şekil düzeltme katsayısı bulunmamaktadır.

2) Ülkemizde bazı kaynaklarda dikdörtgen temeller için Terzaghi tarafından önerildiği izlenimini doğuracak şekilde sunulan k_1 ve k_2 şekil düzeltme katsayıları Terzaghi'ye ait değildir.

3) Dikdörtgen temeller için sunulan k_1=$1+0.2B/L$ katsayısı Skempton (1951)'in çalışmasına dayanmaktadır.

4) Dikdörtgen temeller için sunulan k_2=$0.5–0.1B/L$ katsayısının ulaşılabilen kaynaklar içerisinde ilk kez Kumbasar ve Kip (1969)'da kullanıldığı görülmüştür. Bu nedenle, bu katsayının ilk kez Kumbasar ve Kip (1969) tarafından önerildiği değerlendirilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

5) 1990'lı yıllardan sonra ülkemizde yayımlanan bazı kitaplarda (Örneğin; Uzuner, 1990-2020), dikdörtgen temeller için kaynak gösterilmeden verilen $\mathbf{k_1}$ ve $\mathbf{k_2}$ katsayılarının Kumbasar ve Kip (1969)-(1999)'dan dolaylı olarak alındığı değerlendirilmektedir. Bu durum, bu katsayıların zamanla Terzaghi (1943) tarafından önerilmiş gibi anlaşılmasına yol açmıştır.

Dikdörtgen temeller için önerilen k_1 ve k_2 şekil düzeltme katsayılarının Terzaghi'nin özgün taşıma gücü denklemleriyle birlikte kullanılması durumunda, bu katsayıların Terzaghi'ye ait olmadığının açıkça belirtilmesi ve doğru referanslarla sunulması önerilmektedir.

KAYNAKLAR

Bowles, J. E. (1996). *Foundation Analysis and Design* (5th ed.). The McGraw-Hill Companies, Inc, USA.

Capper, P.L ve Cassie, W.F., (1962). *The Mechanics of Engineering Soils* (3. Baskı). Çevirenler, Kumbasar, V. ve Kip, F., 1973, *İnşaat Mühendisliğinde Zemin Mekaniği* (3. Baskı), Çağlayan Kitabevi, İstanbul.)

Capper, P.L ve Cassie, W.F., (1969). *The Mechanics of Engineering Soils* (5. Baskı). Çevirenler, Kumbasar, V. ve Kip, F., 1984, *İnşaat Mühendisliğinde Zemin Mekaniği* (4. Baskı), Çağlayan Kitabevi, İstanbul.)

Coduto, D. P. (2001). *Foundation Design Principles and Practices* (2nd ed.). Prentice-Hall Inc. New Jersey.

Coduto, D. P., Kitch, W.A., Yeung, Man-chu, R. (2016). *Foundation Design: Principles and Practices* (3rd ed.). Pearson Education, Inc. USA.

Das, B. M., (2011). *Principles of Foundation Engineering* (7th. ed.). Cengage Learning, Inc., Stamford, USA.

Das, B. M., (2014). *Principles of Foundation Engineering* (8th. ed.). Cengage Learning, Inc., Boston, USA.

Das, B. M., (2017). *Shallow Foundations Bearing Capacity and Settlement* (4th. ed.). CRC Press: Taylor & Francis Group, Boca Raton, Florida, ABD.

Das, B. M., Sivakugan, N. (2019). *Principles of Foundation Engineering* (9th. ed.). Cengage Learning, Inc., Boston, USA.

Henry, F.D.C. (1956). *The Design and Construction of Engineering Foundations*. E.& F.N. Spon Ltd. London.

Henry, F.D.C. (1986). *The Design and Construction of Engineering Foundations*. Chapman and Hall Ltd., New York.

Kumbasar, V., Kip, F. (1969). *Zemin Mekaniği Problemleri* (1. Baskı). Çağlayan Kitabevi, İstanbul.

Kumbasar, V., Kip, F. (1977). *Zemin Mekaniği Problemleri* (3. Baskı). Çağlayan Kitabevi, İstanbul.

Kumbasar, V., Kip, F. (1992). *Zemin Mekaniği Problemleri* (5. Baskı). Çağlayan Kitabevi, İstanbul.

Kumbasar, V., Kip, F. (1999). *Zemin Mekaniği Problemleri* (6. Baskı). Çağlayan Kitabevi, İstanbul.

Meyerhof, G. G. (1955). *Influence of roughness of base and groundwater conditions on the ultimate bearing capacity of foundations*. Géotechnique, Vol. 5, pp. 227-242.

Prandtl, L. (1920). *Über die Harte Plastischer Körper, Nachrichten von der Könighlichen Gesellschaft der Wissenschaften zu Göttingen*. Mathematisch-physikalischen Klasse, pp. 74–85.

Rao, N.S.V.K. (2011). *Foundation Design Theory and Practice*. John Wiley & Sons (Asia), Pte Ltd. Singapore.

Reissner, H. (1924). *Zum Erddruckproblem*, In: Biezeno, C.B., Burgers, J.M. (Eds.) Proceedings of the 1st International Congress for Applied Mechanics, Delft, The Netherlands, pp. 295–311.

Skempton, A.W. (1951). *The Bearing Capacity of Clays*. Building Research Congress., vol. 1, pp 180-189.

Teng, W. C. (1962). *Foundation Design*. Prentice-Hall, Englewood Cliffs, New Jersey.

Terzaghi, K. (1943). *Theoretical Soil Mechanics*. John Wiley & Sons, Inc., New York, USA.

Terzaghi, K., Peck, R.B. (1948). *Soil Mechanics in Engineering Practice* (1st ed.). John Wiley and Sons, Inc. New York, USA.

Terzaghi, K., Peck, R.B. (1967). *Soil Mechanics in Engineering Practice* (2nd ed.). John Wiley and Sons, Inc. New York, USA.

Uzuner, B.A. (1990). *Çözümlü Problemlerle Temel Zemin Mekaniği* (1. Baskı). Teknik Yayınevi, Ankara.

Uzuner, B.A. (1998). *Çözümlü Problemlerle Temel Zemin Mekaniği* (4. Baskı). Teknik Yayınevi, Ankara.

Uzuner, B.A. (2020). *Çözümlü Problemlerle Temel Zemin Mekaniği* (11. Basım). Derya Kitabevi, Trabzon.

TUBULAR SURFACES IN THE 3-DIMENSIONAL LIE GROUP

Anıl ALTINKAYA

Bağlı Kuruluş: Gazi Üniversitesi, Fen Fakültesi, Matematik Bölümü

Özet:

This study investigates tubular surfaces associated with space curves in a three-dimensional Lie group. The geometric properties of these surfaces are analyzed, and explicit expressions for the Gaussian curvature and the mean curvature of the tubular surfaces are obtained. Additionally, the necessary and sufficient conditions for the tubular surfaces to be developable or minimal are examined and characterized. Moreover, an example is presented to support and visualize the theoretical results.

Anahtar Kelimeler:

Lie groups, Tubular surface, Mean curvature, Normal curvature

Kaynakça

[1] Doğan, F. and Yaylı, Y. (2011). On the Curvatures of Tubular Surface with Bishop Frame. Commun Fac. Sci. Univ. Ank. Series A1, 60 (1), 59-69.

[2] Arslan Güven, İ. and Kaya Nurkan, S. (2020). Ruled Surfaces in Three Dimensional Lie Groups. J. Math. Comput. Sci. 10 (4), 936-955.

[3] Nazra, S. H. and Abdel-Baky, R. A. (2022). Sweeping Surfaces in theThree-Dimensional Lie Group. Symmetry, 14, 698.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

OTO-KODLAYICI TABANLI BOYUT İNDİRGEME YAKLAŞIMI VE PCA İLE KARŞILAŞTIRMALI VERİ GÖRSELLEŞTİRME

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Özet

Yüksek boyutlu veri kümelerinin analiz edilmesi ve görselleştirilmesi, veri madenciliği ve makine öğrenmesi çalışmalarında karşılaşılan problemlerden biridir. Özellikle imge verileri gibi çok sayıda öznitelik içeren veri yapılarında, verinin daha düşük boyutlarda anlamlı biçimde temsil edilmesi gerekmektedir. Bu amaçla yaygın olarak kullanılan Temel Bileşen Analizi (PCA), doğrusal bir yöntem olması nedeniyle doğrusal olmayan veri yapılarında her zaman yeterli sonuçlar üretememektedir.

Bu çalışmada, doğrusal bir boyut indirgeme yöntemi olan PCA ile doğrusal olmayan veri yapılarındaki ilişkileri öğrenebilen oto-kodlayıcıların (autoencoder), iki boyutlu veri temsili ve görselleştirme performansları ele alınmıştır. Deneysel çalışmalar, yüksek boyutlu imge verilerinden oluşan Fashion-MNIST veri seti kullanılarak gerçekleştirilmiştir. Her iki yöntemle elde edilen iki boyutlu temsiller, sınıfların uzay içerisindeki dağılımları dikkate alınarak görsel olarak karşılaştırılmıştır.

Elde edilen bulgular, PCA ile elde edilen iki boyutlu temsillerde sınıfların büyük ölçüde üst üste geldiğini göstermektedir. Autoencoder (AE) ile elde edilen iki boyutlu temsillerde, benzer görsel özelliklere sahip sınıfların belirli bölgelerde yoğunlaştığı ve farklı yapısal özelliklere sahip sınıfların ise daha ayırt edilebilir bir dağılım sergilediği gözlemlenmiştir. Bu bulgu, AE mimarilerinin imge verilerinde boyut indirgeme ve veri görselleştirme açısından PCA'ya kıyasla daha esnek ve açıklayıcı temsiller sunabildiğine işaret etmektedir.

Anahtar Kelimeler: Boyut İndirgeme, Görselleştirme, Autoencoder, PCA, Derin Öğrenme.

Autoencoder-Based Dimensionality Reduction Approach and Comparative Data Visualization with PCA

Abstract

The analysis and visualization of high-dimensional datasets pose significant challenges in data mining and machine learning tasks. In particular, for data structures containing a large number of features, such as image data, it is necessary to obtain meaningful representations in lower-dimensional

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

spaces.Principal Component Analysis (PCA), which is widely used for this purpose, is a linear method and thus may not always produce satisfactory results when applied to data with nonlinear structures.

In this study, the two-dimensional data representation and visualization performances of PCA, a linear dimensionality reduction method, and autoencoders, which can learn non-linear relationships in data, are examined. Experimental evaluations were conducted using the Fashion-MNIST dataset, which consists of high-dimensional grayscale clothing images. The two-dimensional representations obtained from both methods were visually compared with respect to the spatial distribution of the classes.

The results indicate that the two-dimensional representations obtained using PCA exhibited a substantial overlap between classes. In contrast, the representations produced by the autoencoder (AE) demonstrated that classes with similar visual characteristics tend to cluster in specific regions, whereas classes with different structural properties exhibit more distinguishable distributions. These findings suggest that autoencoder (AE) architectures can provide more flexible and informative representations than PCA for dimensionality reduction and data visualization tasks involving image data.

Keywords: Dimensionality Reduction, Visualization, Autoencoder, PCA, Deep Learning.

1. Giriş

Günümüzde veri toplama ve depolama teknolojilerindeki hızlı gelişmeler, yüksek boyutlu veri kümelerinin farklı alanlarda yaygın biçimde kullanılmasına olanak sağlamıştır. Özellikle imge verileri, her bir örneğin çok sayıda öznitelik içermesi nedeniyle analiz ve görselleştirme süreçlerinde önemli zorluklar barındırmaktadır. Bu tür verilerin daha düşük boyutlu ve anlamlı temsillere dönüştürülmesi; verinin yapısının anlaşılması, örüntülerin ortaya çıkarılması ve sonraki analizlerin sağlıklı biçimde gerçekleştirilebilmesi açısından büyük önem taşımaktadır.

Boyut indirgeme probleminin çözümünde en yaygın kullanılan yöntemlerden biri Temel Bileşen Analizi (PCA)'dır. PCA, veriyi doğrusal projeksiyonlar yoluyla daha düşük boyutlu bir uzaya aktaran, hesaplama maliyeti düşük ve uygulaması pratik bir boyut indirgeme yöntemidir (Tharwat, 2016). Ancak doğrusal bir yaklaşım olması nedeniyle, özellikle doğrusal olmayan yapılar içeren imge verilerinde karmaşık iç ilişkileri yeterli ölçüde temsil etmekte sınırlı kalabilmektedir (Abdi ve Williams, 2010).

Son yıllarda derin öğrenme tabanlı yöntemler, doğrusal olmayan veri yapılarının modellenmesinde alternatif olarak öne çıkmaktadır. Oto-kodlayıcı (Autoencoder, AE) mimarileri, giriş verisini daha düşük boyutlu bir temsile dönüştürmekte ve bu temsilden orijinal veriyi yeniden üretmeye çalışmaktadır. Doğrusal olmayan dönüşümler içermesi sayesinde AE yapıları, özellikle karmaşık örüntüler barındıran imge verilerinde daha esnek temsil kabiliyeti sunabilmektedir (Hinton ve Salakhutdinov, 2006). Literatürde, AE tabanlı yaklaşımların klasik doğrusal yöntemlere kıyasla daha açıklayıcı ve ayırt edilebilir temsiller sunduğu çeşitli çalışmalarla rapor edilmiştir (Baldi, 2012; Zhang vd., 2019; Çalışan ve Talu, 2020).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Bu çalışmada, PCA ve oto-kodlayıcı yöntemleri iki boyutlu veri temsilleri üzerinden değerlendirilmiş ve görselleştirme sonuçları karşılaştırılmıştır. Deneysel analizler, yüksek boyutlu imge verilerinden oluşan Fashion-MNIST veri seti üzerinde gerçekleştirilmiştir (Xiao vd., 2017). Her iki yöntemle elde edilen iki boyutlu temsiller, sınıfların uzaysal dağılımları dikkate alınarak görsel olarak değerlendirilmiş ve yöntemlerin temsil kabiliyetleri analiz edilmiştir.

Çalışmanın devamında, ikinci bölümde kullanılan yöntemler ayrıntılı olarak açıklanmakta, üçüncü bölümde deneysel sonuçlar sunulmakta ve son bölümde elde edilen bulgular değerlendirilerek genel sonuçlara yer verilmektedir.

2. Yöntem

Bu çalışmada deneysel çalışmalar, imge tabanlı boyut indirgeme ve görselleştirme çalışmalarında yaygın olarak kullanılan Fashion-MNIST veri seti üzerinde gerçekleştirilmiştir. Fashion-MNIST, her biri 28×28 piksel boyutunda gri seviye görüntülerden oluşan ve 10 farklı giyim kategorisini içeren toplam 70.000 örnekten meydana gelmektedir. Veri seti, 60.000 eğitim ve 10.000 test örneği olarak ayrılmıştır (Xiao vd., 2017).

Temel Bileşen Analizi (PCA), yüksek boyutlu verilerin varyansını en iyi şekilde temsil eden doğrusal bileşenleri bulmayı amaçlayan istatistiksel bir boyut indirgeme yöntemidir. PCA, orijinal özellik uzayındaki veriyi, en büyük varyansı açıklayan doğrusal projeksiyonlar aracılığıyla daha düşük boyutlu bir uzaya taşır. Hesaplama açısından verimli ve uygulanması kolay olması nedeniyle birçok uygulamada tercih edilmektedir. Ancak doğrusal bir yöntem olması sebebiyle, özellikle imge verileri gibi doğrusal olmayan yapılar içeren veri kümelerinde, verinin karmaşık iç ilişkilerini tam olarak yansıtmakta sınırlı kalabilmektedir (Abdi ve Williams, 2010). Bu çalışmada PCA, karşılaştırma amacıyla veri iki boyuta indirgenerek uygulanmıştır.

Oto-kodlayıcı (AE) yapıları, giriş verisini daha düşük boyutlu bir temsile dönüştürmeyi ve bu temsilden veriyi yeniden oluşturmaya çalışan denetimsiz öğrenme temelli sinir ağı modelleridir. Çok katmanlı ve doğrusal olmayan dönüşümler içermeleri sayesinde, verinin karmaşık yapısal özelliklerini öğrenebilmekte ve daha esnek temsiller oluşturabilmektedir (Hinton ve Salakhutdinov, 2006; Baldi, 2012).

Bu çalışmada, Fashion-MNIST veri kümesinden düşük boyutlu temsiller elde etmek amacıyla doğrusal bir yöntem olan PCA ile doğrusal olmayan bir yaklaşım sunan AE mimarileri karşılaştırmalı olarak incelenmiştir. Karşılaştırma amacıyla kullanılan PCA yöntemi, veri kümesindeki toplam varyansı en iyi açıklayan iki ana bileşene doğrusal projeksiyon uygulayarak boyut indirgeme gerçekleştirmektedir. Bu yönüyle PCA, çalışmada temel bir referans yaklaşımı olarak değerlendirilmiştir. Bu çalışmada tasarlanan AE modeli, 784 boyutlu giriş vektörünü sırasıyla 256 ve 64 nöronlu gizli katmanlardan geçirerek iki boyutlu bir gizil uzay temsili elde etmektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Kodlayıcı ve çözücü bölümlerden oluşan bu simetrik yapı, düşük boyutlu temsilden giriş verisinin yeniden yapılandırılmasını sağlamaktadır. Kodlayıcı (encoder) bölümünde, giriş verisindeki karmaşık örüntülerin daha etkin biçimde öğrenilebilmesi amacıyla ELU aktivasyon fonksiyonu tercih edilmiştir. Elde edilen latent temsil, görselleştirme sırasında sayısal kararlılığı artırmak için Hiperbolik tanjant (tanh) aktivasyon fonksiyonu tercih edilmiştir.

ELU aktivasyon fonksiyonu, negatif girişler için üstel bir yapı kullanarak nöron çıktılarının ortalamasını sıfıra yakınlaştırmayı ve öğrenme sürecini daha kararlı hale getirmeyi amaçlamaktadır (Clevert vd. 2015).

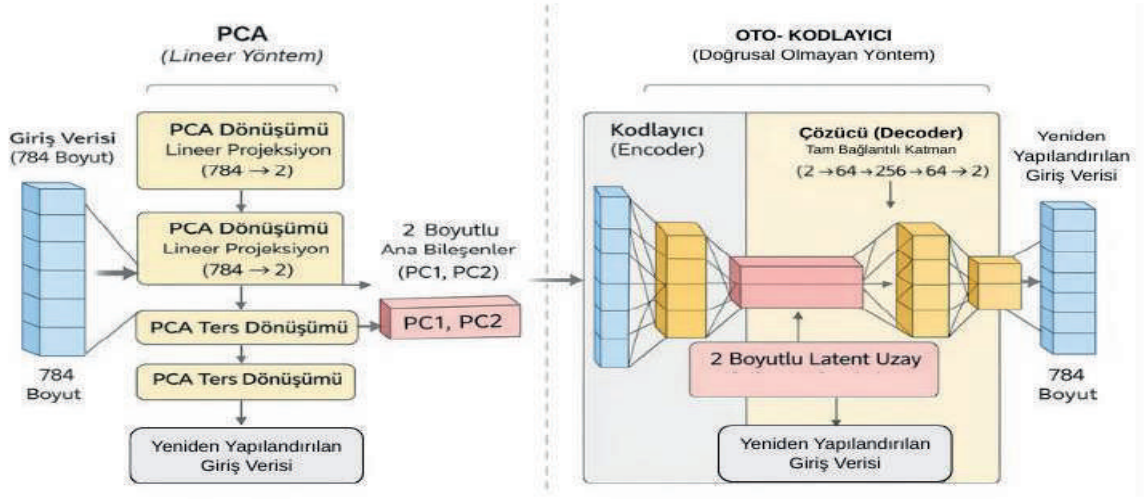
$$\mathrm{ELU}(x) = \begin{cases} x, & x > 0 \\ \alpha(e^{x}-1), & x \leq 0 \end{cases} \quad (1)$$

Burada; x nöron girdisi, $\alpha > 0$ olmak üzere negatif bölgedeki doygunluk seviyesini belirleyen sabit katsayıdır.

Tanh fonksiyonu, giriş değerlerini $[-1,1]$ aralığına sıkıştıran, sıfır merkezli bir aktivasyon fonksiyonudur (Karakurt vd. 2024).

$$f(x) = \frac{e^{x}-e^{-x}}{e^{x}+e^{-x}} \quad (2)$$

Çözücü (decoder) aşamasında ise bu düşük boyutlu temsilden giriş verisinin yeniden yapılandırılması hedeflenmiştir. Elde edilen sonuçlar, oto-kodlayıcı mimarisinin PCA'ya kıyasla latent uzayda sınıflar arasındaki yapısal ayrışmayı görsel olarak daha belirgin hale getirebildiğini göstermektedir.



Şekil 1. Fashion-MNIST veri kümesi üzerinde PCA ve AE yöntemleri kullanılarak gerçekleştirilen boyut indirgeme ve yeniden yapılandırma süreçlerinin şematik gösterim.

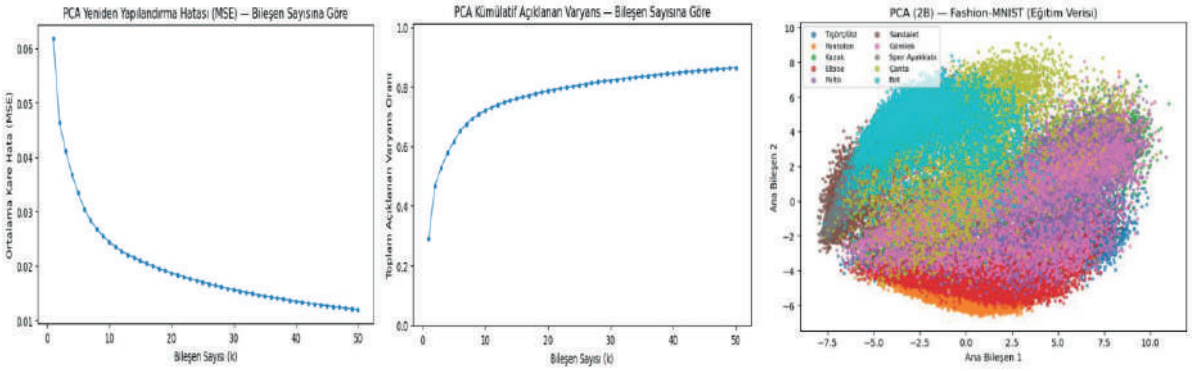
3. Deneysel Sonuçlar

Bu bölümde, deneysel kurulum ve elde edilen sonuçlar sunulmaktadır. Deneyler, Anaconda dağıtımı altında oluşturulan Python tabanlı bir çalışma ortamında, PyTorch ve Scikit-learn kütüphaneleri

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

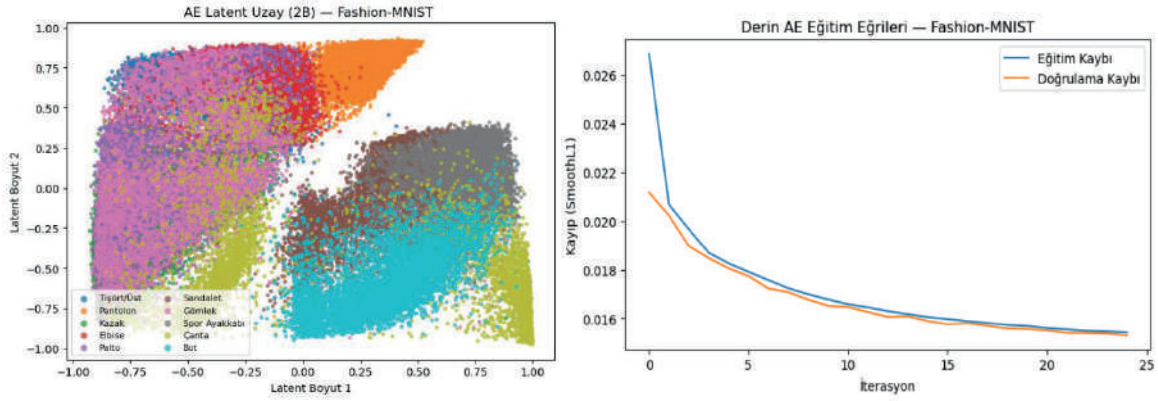
kullanılarak gerçekleştirilmiştir. Fashion-MNIST veri kümesindeki her bir 28×28 boyutlu gri seviye görüntü, öncelikle [0,1] aralığında normalize edilmiş ve ardından 784 boyutlu vektörler hâline getirilmiştir. PCA yöntemi, Scikit-learn kütüphanesi kullanılarak iki ana bileşen olacak şekilde uygulanmıştır. AE modeli ise Adam optimizasyon algoritması ve Smooth L1 kayıp fonksiyonu kullanılarak, 25 iterasyon boyunca yalnızca yeniden yapılandırma hatasını minimize edecek şekilde denetimsiz olarak eğitilmiştir.

Şekil 2 (a) ve (b) incelendiğinde, PCA yöntemi için bileşen sayısının artmasıyla birlikte yeniden yapılandırma hatasının düzenli ve monoton bir şekilde azaldığı görülmektedir. Bu bulgu, veri kümesindeki temel yapısal bilginin az sayıda ana bileşen tarafından büyük ölçüde temsil edilebildiğini; daha yüksek bileşen sayılarının ise hata üzerinde sınırlı bir iyileşme sağladığını göstermektedir. Şekil 2(c)'de PCA ile elde edilen iki boyutlu temsiller incelendiğinde, sınıflara ait örneklerin örtüştüğü ve sınıf sınırlarının belirgin olmadığı görülmektedir. Bu durum, PCA'nın doğrusal yapısının karmaşık imge verilerindeki sınıf ayrımlarını tam olarak ortaya koyamamasıyla açıklanabilir.



a) b) c)

Şekil2. PCA'da bileşen sayısının yeniden yapılandırma hatası (a), açıklanan varyans üzerindeki etkisi (b) ve iki boyutlu temsillerin Fashion-MNIST veri kümesi üzerindeki dağılımı (c).



a) b)

Şekil3. AE ile elde edilen iki boyutlu temsilleri (a) ve eğitim sürecine ait kayıp eğrileri (b)

Şekil 3 (a)'da gösterilen AE kullanılarak elde edilen iki boyutlu latent uzay temsilleri incelendiğinde, PCA tabanlı gösterimlere göre sınıflara ait örneklerin daha yapılandırılmış biçimde dağıldığı görülmektedir. Bazı sınıfların belirli bölgelerde yoğunlaştığı, sınıflar arasında daha belirgin ayrışmaların oluştuğu ve benzer sınıflar arasında kısmi örtüşmelerin devam ettiği görülmektedir. Şekil 3 (b)'de eğitim ve doğrulama kayıp eğrilerinin iterasyon boyunca düzenli biçimde azalması ve aralarındaki farkın sınırlı olması, modelin kararlı bir şekilde yakınsadığını ve aşırı öğrenme eğilimi göstermediğini ortaya koymaktadır.

4. Sonuçlar

Bu çalışmada, Fashion-MNIST veri kümesi üzerinde PCA ve AE yöntemleri karşılaştırmalı olarak incelenmiştir. PCA sonuçları, bileşen sayısının artırılmasıyla yeniden yapılandırma hatasının azaldığını, ancak düşük boyutlu temsillerde belirgin bir bilgi kaybının kaçınılmaz olduğunu göstermiştir. İki boyutlu PCA temsillerinde sınıflara ait örneklerin geniş ölçüde örtüştüğü ve sınıf ayrışımının sınırlı kaldığı gözlemlenmiştir.

AE ile elde edilen iki boyutlu latent uzay temsillerinde ise PCA'ya göre daha yapılandırılmış ve daha yoğun sınıf kümeleri oluştuğu görülmüştür. Eğitim ve doğrulama kayıp eğrileri, modelin kararlı bir şekilde yakınsadığını ve aşırı öğrenme eğilimi göstermediğini ortaya koymaktadır. Genel olarak, elde edilen bulgular AE mimarilerinin düşük boyutlu veri görselleştirme ve keşifsel analiz açısından PCA'ya göre etkili bir alternatif sunduğunu göstermektedir.

KAYNAKÇA

Abdi H, Williams LJ 2010. Principal component analysis. Wiley Interdisciplinary Reviews: Computational Statistics, 2(4): 433–459.

Baldi P 2012. Autoencoders, unsupervised learning, and deep architectures. In: Proceedings of ICML Workshop on Unsupervised and Transfer Learning, pp. 37–49.

Çalışan M, Talu MF 2020. Boyut indirgeme yöntemlerinin karşılaştırmalı analizi. İnönü Üniversitesi Bilimsel ve Kültürel Yayınlar.

Clevert DA, Unterthiner T, Hochreiter S 2015. Fast and accurate deep network learning by exponential linear units (ELUs). arXiv preprint arXiv:1511.07289.

Hinton GE, Salakhutdinov RR 2006. Reducing the dimensionality of data with neural networks. Science, 313(5786): 504–507.

Karakurt M, Saygılı H, Karcı A 2024. Comparison of activation functions in the KarcıFANN method. In: 2024 8th International Artificial Intelligence and Data Processing Symposium (IDAP), pp. 1–6. https://doi.org/10.1109/IDAP64064.2024.10711149

Tharwat A 2016. Principal component analysis-a tutorial. International Journal of Applied Pattern Recognition, 3(3): 197–240.

Xiao H, Rasul K, Vollgraf R 2017. Fashion-MNIST: A novel image dataset for benchmarking machine learning algorithms. arXiv preprint arXiv:1708.07747.

Zhang Y, Lee H, Lee J 2019. Deep autoencoder-based dimensionality reduction for visualization of high-dimensional data. Neurocomputing.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DIGITAL TWIN-BASED GEOMETRIC ERROR DETECTION IN DENTAL IMPLANT MANUFACTURING

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ABSTRACT

Dental implants are medical products that directly interact with human health, where mechanical integrity is critically important for patient safety. Even very small geometric deviations during manufacturing may lead to implant fracture, loosening, or long-term failure in the oral environment. Therefore, detecting manufacturing errors during the production process rather than after production is of great importance. Early detection not only increases patient safety but also reduces defective production and associated costs.

In this study, a software infrastructure was developed to establish a digital twin of the manufacturing process of dental implants produced on CNC machines. The system analyzes the G-code commands entered by the operator into the CNC machine and extracts the actual geometry of the implant directly from production data without requiring technical drawings. Critical geometric parameters such as thread root diameters, the abutment connection region, internal thread depth, and implant length are automatically calculated, and mechanically risky regions are identified.

Three mechanically critical regions of the implant were defined, and wall thicknesses in these regions were calculated using geometric data derived from G-code. Based on these calculations, the software automatically evaluates whether the implant is in a safe or risky condition. The system also records operator, tool, and production information, providing the foundation for production traceability.

The extracted geometric data are designed to be transferred into the ANSYS environment to validate the software's evaluations through finite element analysis. This study presents a digital twin approach capable of detecting errors based on actual production geometry and aims to improve patient safety by identifying potential manufacturing defects during the process.

Keywords: Digital twin, Dental implant, G-code analysis, Geometric safety

INTRODUCTION

Dental implants are load-bearing biomechanical structures that interact directly with alveolar bone. Their long-term clinical success depends not only on osseointegration but also on mechanical stability

and structural durability (Sailer et al., 2009; Raikar et al., 2017). During mastication, occlusal forces generally range between 100–300 N and may exceed 800 N under parafunctional conditions (Geng et al., 2001; Raikar et al., 2017). These forces induce axial compression, bending moments, and cyclic fatigue stresses at the implant–bone interface.

Even minor geometric variations may significantly influence stress distribution, since stress magnitude is inversely related to cross-sectional area ($\sigma = F/A$). Previous finite element investigations have shown that implant diameter, length, and connection design strongly affect stress concentration, particularly in the cervical region (Geng et al., 2001; González-Mederos et al., 2025). Finite element analysis (FEA) is therefore widely used for evaluating biomechanical behavior under simulated loading conditions (Gök & Gök, 2020).

Digital twin technology has recently gained attention as a framework for linking physical production systems with virtual analytical models. Early studies demonstrated that data-driven digital twin architectures can support predictive monitoring and process optimization in manufacturing environments (Ghosh et al., 2019). Subsequent research extended this concept to online quality control applications in process industries (Zhu & Ji, 2022) and to dynamic manufacturing cycle optimization (Pereverzev et al., 2019).

Despite these advancements, the use of G-code-based geometry reconstruction for pre-production mechanical risk evaluation in dental implant manufacturing has received limited attention. This study proposes a digital twin framework that reconstructs implant geometry directly from CNC machining instructions and evaluates structural safety before physical production.

MATERIALS AND METHODS

System Architecture

The proposed digital twin system was designed as a modular framework consisting of three interrelated components: the Traceability and Production Identity Module, the G-code Analysis and Geometry Reconstruction Module, and the Critical Section Analysis and Mechanical Risk Classification Module. Together, these modules establish a structured workflow that connects production data, geometric reconstruction, and biomechanical evaluation within a unified analytical environment.

The overall system architecture is illustrated in Figure 1, where the data flow begins with production identity registration and proceeds through virtual geometry generation and mechanical validation stages. This modular structure ensures seamless digital linkage between geometric reconstruction and mechanical validation while preserving full production traceability and enabling scalability for future real-time CNC data integration.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

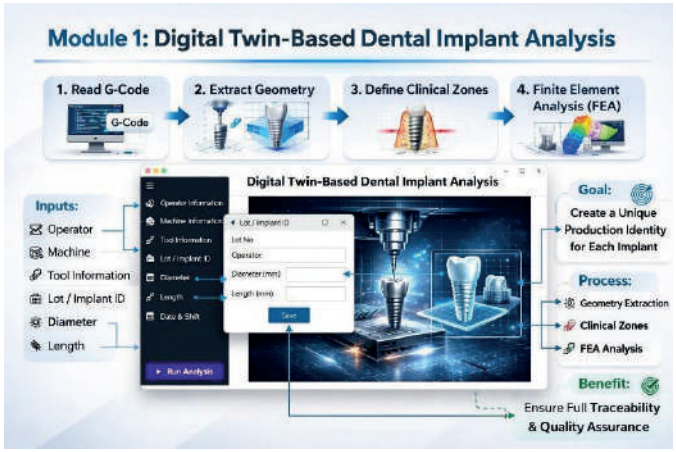


Figure 1. Overall architecture of the proposed G-code-based digital twin system and the Traceability and Production Identity module interface.

G-Code-Based Geometry Reconstruction

The developed software analyzes MAIN and SUB G-code commands line by line to reconstruct the theoretical implant geometry prior to physical machining. By mathematically interpreting tool path instructions, the system generates a virtual geometric model directly from the programmed manufacturing data.

The G-code analysis interface is presented in Figure 2, where MAIN and SUB commands are processed either independently or simultaneously to ensure complete geometric reconstruction. This approach enables verification of machining instructions and detection of potential geometric inconsistencies before production.

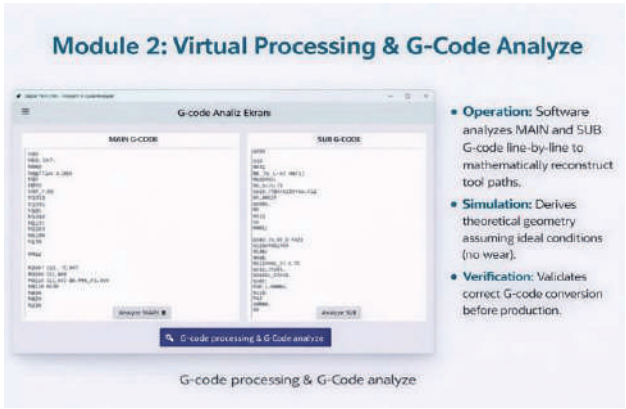


Figure 2. Line-by-line analysis of MAIN and SUB G-code commands for virtual geometry reconstruction prior to machining.

Following geometric reconstruction, three mechanically critical regions were defined based on biomechanical loading principles: the cervical neck region, the internal connection section, and the

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ISBN: 978-9952-610-30-7

apical tip region. These areas were selected due to their susceptibility to stress concentration under axial and oblique loading conditions. The spatial distribution of these regions is presented in Figure 3.

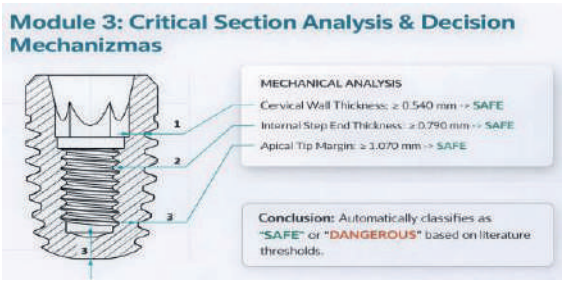
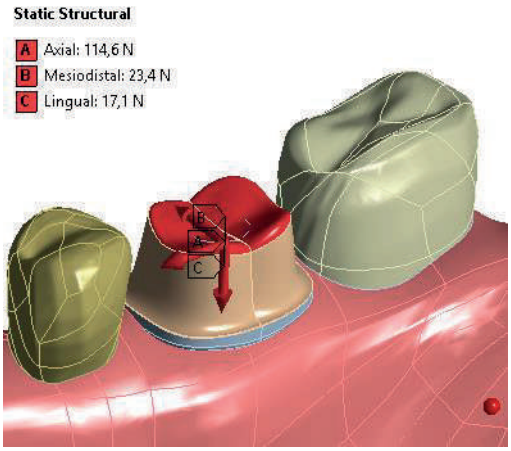


Figure 3. Critical section analysis and automatic mechanical risk classification.

Minimum wall thickness values were calculated for each region and compared against predefined biomechanical threshold criteria. Implants with wall thickness values falling below predefined safety thresholds were classified as high-risk, whereas those meeting the criteria were labeled as mechanically safe, enabling early-stage risk identification prior to mechanical validation.

Finite Element Validation

Implants identified as geometrically critical were transferred to the ANSYS finite element environment for mechanical verification. A static structural analysis was performed to evaluate whether reduced cross-sectional parameters resulted in stress amplification under simulated loading conditions. A linear elastic material model was adopted. Three-dimensional (3D) loading was applied to the implants: 17.1 N in the lingual direction, 114.6 N in the axial direction, 23.4 N in the mesiodistal direction (Kayabaşı et al., 2006). The loading configuration and force directions are illustrated in Figure 4. Von Mises stress distribution was used as the primary evaluation criterion to identify stress concentration regions and assess mechanical safety. Representative stress distribution results are shown in Figure 5.



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ISBN: 978-9952-610-30-7

Figure 4. Three-dimensional loading configuration showing axial, lingual, and mesiodistal force components applied to the implant.

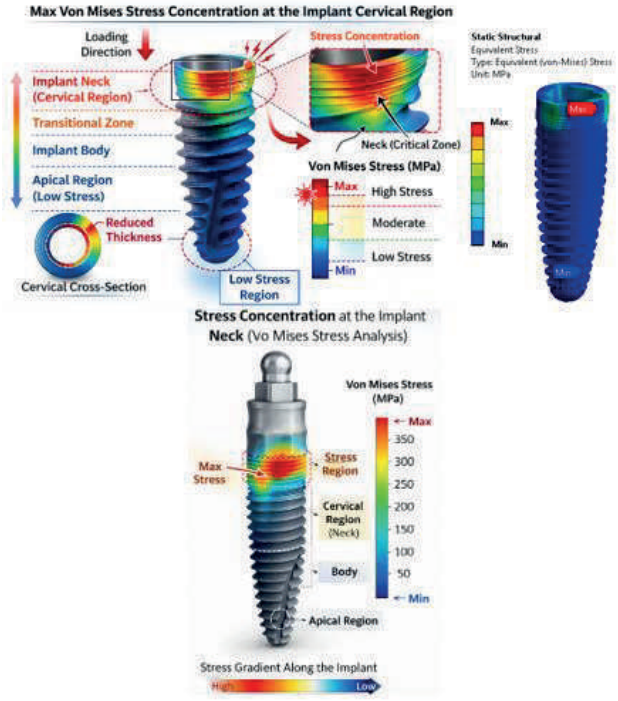


Figure 5. Representative Von Mises stress distribution under combined lingual, axial and mesiodistal loading conditions

RESULTS

Geometric reconstruction based on G-code parsing identified localized reductions in cross-sectional wall thickness, particularly in the cervical region of certain implant models. These geometries, characterized by narrow diameter–length ratios or limited material margins at the implant neck, were automatically classified as mechanically risky according to predefined threshold criteria.

Finite element simulations confirmed that these geometrically critical regions corresponded to elevated Von Mises stress concentrations under applied loading conditions. Stress amplification was predominantly observed at the cervical transition zone, indicating a clear relationship between reduced cross-sectional thickness and increased mechanical vulnerability. The strong agreement between geometric analysis and FEA results supports the predictive reliability of the proposed digital twin framework for early-stage mechanical risk detection.

DISCUSSION

This study proposes a proactive quality control framework for dental implant manufacturing by integrating G-code-based geometric reconstruction with mechanical risk evaluation. Unlike conventional finite element studies that predominantly focus on implant design optimization under idealized conditions, the present work shifts attention toward production-oriented geometric deviations

derived directly from machining instructions. By analyzing G-code prior to physical manufacturing, the system enables early detection of potentially critical geometric configurations and allows mechanical risk prediction before material removal occurs. This approach has the potential to reduce material waste, minimize production-related failures, and contribute indirectly to patient safety by preventing mechanically vulnerable implants from entering the clinical workflow.

Within the current scope of the study, several simplifying assumptions were adopted to establish a stable analytical baseline. Tool offset values were considered constant, and tool wear effects were not incorporated into the geometric reconstruction model. Additionally, material behavior in the finite element simulations was assumed to be linear elastic. While these assumptions allow for controlled evaluation of the proposed framework and isolate the influence of programmed geometry, they may not fully capture the complex, time-dependent variations present in real manufacturing environments. Therefore, the current system should be interpreted as a foundational digital twin architecture focused primarily on geometry-driven mechanical assessment.

Future Work

Future developments will focus on integrating real-time CNC machine data into the proposed architecture to establish a fully dynamic digital twin system. Monitoring parameters such as offset variations, tool wear progression, and machining conditions will enable continuous geometry updating and more realistic mechanical simulations. The inclusion of nonlinear material models and experimental validation under clinical loading conditions will further enhance predictive reliability. Ultimately, coupling real-time manufacturing data with mechanical analysis is expected to transform the system from a static pre-production evaluator into a continuously adaptive quality assurance platform.

CONCLUSION

The proposed digital twin framework enables geometric reconstruction directly from CNC machining instructions and links production data with mechanical performance evaluation. The findings demonstrate that localized reductions in wall thickness correspond to increased stress concentrations under simulated loading.

By identifying mechanically sensitive configurations before machining is completed, the system supports early-stage decision making and reduces the likelihood of producing structurally vulnerable implants. This approach contributes to improved production reliability and establishes a foundation for integrating real-time manufacturing data with biomechanical validation in future developments.

In traditional manufacturing processes, part geometry is first designed in a CAD environment (using software such as SolidWorks), then toolpaths and NC/G-code commands are generated via CAM systems based on this geometry, and physical production is carried out by CNC machines; that is, the process follows a geometry-based manufacturing approach. In this study, however, this flow is

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ISBN: 978-9952-610-30-7

reversed, the G-code commands entered into the CNC machine are mathematically analyzed, the geometry of the part to be produced is reconstructed from these commands, and the mechanical safety of the resulting geometry is evaluated before production. Thus, the aim is to detect geometric deviations that may arise from production parameters at an early stage and to develop a preventive quality control mechanism for the production process.

REFERENCES

Geng, J. P., Tan, K. B., & Liu, G. R. (2001). Application of finite element analysis in implant dentistry: a review of the literature. *The Journal of Prosthetic Dentistry*, *85*(6), 585-598. https://doi.org/10.1067/mpr.2001.115251

Ghosh, A. K., Ullah, A. S., & Kubo, A. (2019). Hidden Markov model-based digital twin construction for futuristic manufacturing systems. *AI EDAM*, *33*(3), 317-331. https://doi.org/10.1017/S089006041900012X

González-Mederos, P., Rodríguez-Guerra, J., González, J. E., Picardo, A., & Torres, Y. (2025). A Finite Element Analysis of a New Dental Implant Design: The Influence of the Diameter, Length, and Material of an Implant on Its Biomechanical Behavior. *Materials*, *18*(12), 2692. https://doi.org/10.3390/ma18122692

Gök, K., & Gök, A. (2020). İnsan Femur Modeli Üzerinde Flambaj Etkisinin Sonlu Elemanlar Metodu Kullanılarak Biyomekanik Olarak İncelenmesi. *Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi*, *22*(64), 21-27. https://doi.org/10.21205/deufmd.2020226403

Kayabaşı O, Yüzbasıoğlu E and Erzincanlı F. Static, dynamic and fatigue behaviors of dental implant using finite element method. *Advances in Engineering Software* 2006; 37: 649-658. https://doi.org/10.1016/j.advengsoft.2006.02.004.

Pereverzev, P. P., Akintseva, A. V., Alsigar, M. K., & Ardashev, D. V. (2019). Designing optimal automatic cycles of round grinding based on the synthesis of digital twin technologies and dynamic programming method. *Mechanical Sciences*, *10*(1), 331-341. https://doi.org/10.5194/ms-10-331-2019

Raikar, S., Talukdar, P., Kumari, S., Panda, S. K., Oommen, V. M., & Prasad, A. (2017). Factors affecting the survival rate of dental implants: A retrospective study. *Journal of International Society of Preventive and Community Dentistry*, *7*(6), 351-355.

Sailer, I., Philipp, A., Zembic, A., Pjetursson, B. E., Hämmerle, C. H., & Zwahlen, M. (2009). A systematic review of the performance of ceramic and metal implant abutments supporting fixed implant reconstructions. *Clinical Oral Implants Research*, *20*, 4-31. https://doi.org/10.1111/j.1600-0501.2009.01787.x

Zhu, X., & Ji, Y. (2022). A digital twin–driven method for online quality control in process industry. *The International Journal of Advanced Manufacturing Technology*, *119*(5), 3045-3064. https://doi.org/10.1007/s00170-021-08369-5

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SUITABILITY ANALYSIS OF EMERGENCY ASSEMBLY AREAS USING MULTI CRITERIA DECISION MAKING (MCDM) METHODS: A CASE STUDY OF KONYA

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Effective disaster management and urban resilience depend heavily on the strategic identification of Emergency Assembly Areas (EAA). Traditional selection processes often suffer from subjective biases that can compromise public safety during crises.

This study aims to propose a robust Multi Criteria Decision Making (MCDM) framework to optimize the selection process of EAA in the Konya Selçuklu district.

The research utilizes a two-stage hybrid model integrating the MEREC (Method based on the Removal Effects of Criteria) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) methods. To eliminate subjective bias, the MEREC stage calculates objective criteria weights by measuring the effects of removing each criterion from the decision matrix. Subsequently, the TOPSIS stage ranks candidate sites based on their geometric distance from the positive and negative ideal solutions.

The model evaluates potential sites across critical dimensions: accessibility, physical suitability and demographic demand. The integration of MEREC and TOPSIS allows for a balanced assessment where objective weighting meets compensatory ranking. The results provide a highly reliable decision support tool that enhances transparency and accuracy in site selection. This approach ultimately contributes to resilient urban infrastructure and improved public safety, offering a replicable model for other urban areas facing similar disaster risks.

Keywords: Emergency Assembly Areas, MCDM, MEREC, TOPSIS, Disaster Management.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

LENGTH-WEIGHT AND LENGTH-LENGTH RELATIONSHIPS OF YELLOWSTRIPE BARRACUDA (*SPHYRAENA CHRYSOTAENIA* KLUNZINGER, 1884) IN İSKENDERUN BAY

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ABSTRACT

In this study, the length-weight relationship (LWR) and length-length relationship (LLR) of Yellowstripe barracuda (*Sphyraena chrysotaenia* Klunzinger, 1884) were determined. The 272 specimens were sampled from İskenderun Bay in 2025. Total lengths of all samples ranged from 19.8 to 30.2 cm and their weight ranged from 43.14 to 143.45 g. Sex composition of examined specimens were 50.73% females (138) and 49.27% males (134). Length-weight relationships for female, male and all samples were found as $W= 0.0194.TL^{2.622}$ ($r^2= 0.922$), $W= 0.0106.TL^{2.815}$ ($r^2= 0.907$) and $W= 0.0165.TL^{2.673}$ ($r^2= 0.925$), respectively. The b values estimated for females, males, and all individuals were all significantly different from the isometric value of 3 (t-test, $p < 0.05$ for all groups). These results indicate negative allometric growth for female, male and all individuals, showing that increases in length are proportionally greater than increases in weight.

All relationships among total length, fork length and standard length were highly significant ($P<0.001$).

Keywords: Yellowstripe barracuda, Length-weight relationship, length-length relationship, İskenderun Bay, Turkey.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

HEIGHT PROFILE OF THE FULL CONDUCTIVITY TENSOR (Σ_{rr}–$\Sigma\Phi\Phi$) IN GLOBAL COORDINATES FOR THE MID-LATITUDE IONOSPHERE

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Abstract

The ionosphere is a plasma environment composed of layers where ionized and neutral components coexist and the degree of collisions and interactions with the magnetic field varies significantly with altitude. This change causes the particle motion to vary with direction and results in the macroscopic behavior of the medium exhibiting anisotropic properties. Therefore, due to the complexity of conductivity, which cannot be represented by a single coefficient, it must be defined by a tensor structure that includes directional dependence. The variation of components with height is one of the fundamental factors determining in which regions the current systems will concentrate and by which physical mechanisms the interlayer transitions will be shaped. This study examines the electrical response of the mid-latitude ionosphere through all components of the conductivity tensor defined in a spherical coordinate system. Additionally, it reveals the direction-dependent and height-variable structure, which simplified single-coefficient approaches cannot capture, within a parametric framework. Graphs derived from the components of the spherical conductivity tensor quantitatively identify the directional dependence of local current systems. Additionally, it reveals how the Hall contribution strengthens with height and clarifies the tensor nature of the transitions between the lower and upper ionosphere. This approach provides a viable physical foundation for evaluating HF wave propagation and attenuation, understanding regional ionospheric energy transfer, and especially for local coordinate electrical solutions.

Keywords: Ionosphere, Conductivity tensor, Spherical coordinates

References

Koskinen, H. E. J. (2011). *Physics of space storms: From the solar surface to the Earth*. Springer. https://doi.org/10.1007/978-3-642-00319-6

Richmond, A. D. (1995). Ionospheric electrodynamics using magnetic apex coordinates. *Journal of Geomagnetism and Geoelectricity, 47*(2), 191–212. https://doi.org/10.5636/jgg.47.191

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Schunk, R. W., Nagy, A. F. (2009). *Ionospheres: Physics, plasma physics, and chemistry* (2nd ed.). Cambridge University Press.

ENGINEERING A PORTABLE PLASMONIC BIOSENSOR PLATFORM FOR DETECTION OF BACTERIAL SEXUALLY TRANSMITTED INFECTION

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ABSTRACT

Sexually transmitted infections (STIs) caused by *Chlamydia trachomatis* (CT) and *Neisseria gonorrhoeae* (NG) continue to pose a major global public health challenge, highlighting the need for rapid and decentralized diagnostic solutions. In this study, we present a portable plasmonic biosensor platform enabling label-free, on-site detection of these pathogens directly from urine samples. The system integrates a gold-coated plasmonic nanohole array with lens-free computational imaging and a microfluidic module for controlled sample delivery to antibody-functionalized sensing regions. Bacterial binding induces diffraction-based intensity variations that are captured using LED illumination and a CMOS sensor, followed by automated image analysis through custom software. The proposed platform achieves sensitive and selective detection without labeling, nucleic acid amplification, or complex sample preparation. Its compact, cost-effective, and multiplex-capable design supports point-of-care testing and deployment in resource-limited settings.

Keywords: Plasmonic biosensor; Label-free detection; Portable diagnostics; STI detection.

INTRODUCTION

Sexually transmitted infections (STIs) remain a significant global health burden, with *Neisseria gonorrhoeae* (NG) and *Chlamydia trachomatis* (CT) among the most prevalent bacterial pathogens worldwide (Dalby & Stoner, 2022; Newman et al., 2015; Vallejo-Ortega et al., 2022). Because these infections frequently progress asymptomatically, delayed diagnosis is common, often leading to severe reproductive complications and continued transmission (Davidson et al., 2021). Although nucleic acid amplification tests (NAATs) provide high analytical sensitivity and specificity (LeFevre & Force*,

2014; Van Dyck et al., 2001), their reliance on centralized laboratory infrastructure, trained personnel, and multistep sample preparation restricts their use in decentralized or resource-limited settings. These constraints underscore the need for compact diagnostic platforms capable of delivering reliable performance at the point of care.

Label-free biosensing technologies offer promising alternatives to conventional labeled assays by eliminating fluorescent or enzymatic markers and reducing assay complexity (Samuel & Rao, 2022). Among various transduction mechanisms, optical plasmonic sensors are particularly attractive due to their high sensitivity arising from resonance-based light–matter interactions (Chalklen et al., 2020; Sumitha & Xavier, 2023). Subwavelength plasmonic nanohole arrays enable enhanced optical confinement and controlled spectral transmission under simplified illumination conditions (Belushkin et al., 2020; Hill, 2015). Their compatibility with imaging sensors such as CCD (charge-coupled device) or CMOS (complementary metal-oxide semiconductor) cameras enables spatially resolved and multiplexed detection without bulky spectrometers, thereby reducing hardware footprint and alignment requirements (Qavi et al., 2022). Although nanohole-based plasmonic sensing has demonstrated strong potential for biomolecular and pathogen detection, many implementations remain dependent on laboratory-scale optical and fluidic instrumentation, limiting their portability and field applicability (Brolo, 2012; Jackman et al., 2015). Consequently, integrating nanostructured plasmonics, compact optics, and controlled microfluidics into a unified handheld device remains an important engineering challenge.

In this study, we report a fully integrated handheld plasmonic biosensor for simultaneous detection of NG and CT directly from urine samples (Cetin, 2023). The system combines: a periodic nanohole plasmonic chip for label-free optical transduction, a lens-free diffraction imaging module for compact signal acquisition, a piezo-driven microfluidic unit for precise sample delivery, and embedded software for automated control and computational analysis. The camera-based readout enables parallel interrogation of multiple sensing regions, eliminating sequential spectral scanning and increasing throughput. Spatially separated functionalized sensing sites permit independent detection of each pathogen, while integrated control regions suppress biological, mechanical, and optical noise to enhance robustness. The principal contribution of this work lies in the system-level co-design and integration of plasmonic nanostructures, simplified optics, microfluidic regulation, and computational imaging within a single portable diagnostic platform, thereby bridging the gap between laboratory-grade plasmonic sensing and practical point-of-care deployment.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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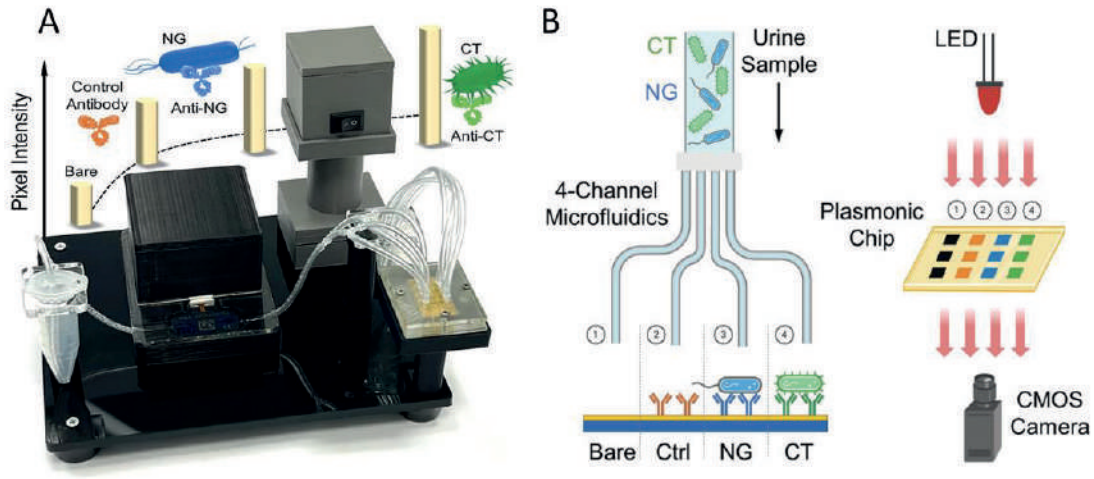


Fig. 1. **(A)** Photograph of the portable biosensor platform. **(B)** Schematic illustration of the microfluidic delivery module and lens-free optical imaging unit of the portable plasmonic biosensor platform, which enables simultaneous detection of *N. gonorrhoeae* (NG) and *C. trachomatis* (CT) bacteria, while incorporating control regions to improve test reliability. Created with BioRender.com.

MATERIALS AND METHODS

A portable plasmonic biosensor platform was engineered as a fully integrated diagnostic system combining a nanostructured plasmonic sensing substrate, a controlled microfluidic delivery module, a lens-free optical imaging unit, and embedded computational analysis software within a mechanically stabilized handheld enclosure **(Fig. 1)**. As shown in **Fig. 1A**, the fully assembled device integrates all functional components within a compact 3D-printed housing. The overall system architecture, including the microfluidic delivery module and the lens-free optical imaging unit, is schematically illustrated in **Fig. 1B**, highlighting the parallel channel configuration that enables simultaneous detection of *N. gonorrhoeae* (NG) and *C. trachomatis* (CT) bacteria together with integrated control regions to enhance measurement reliability. The enclosure was fabricated using high-resolution 3D printing to ensure fixed optical alignment between the illumination source, plasmonic chip, and detector while minimizing ambient light interference, mechanical vibration, and thermal drift.

The plasmonic sensing chip consisted of periodic nanohole arrays fabricated on a 120 nm gold layer deposited onto a silicon nitride–coated fused silica wafer with an intermediate 5 nm chromium adhesion layer. The nanohole diameter (200 nm) and periodicity (550 nm) were selected based on finite-difference time-domain (FDTD) simulations to position the transmission resonance within the visible spectrum and optimize sensitivity to refractive index changes induced by bacterial binding. Periodic boundary conditions were applied in the lateral directions and perfectly matched layers along the propagation axis during simulation to evaluate field confinement and resonance behavior. The simulation results confirmed hybridized localized and propagating surface plasmon modes with strong

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ISBN: 978-9952-610-30-7

near-field enhancement concentrated at the nanohole rims, enabling high sensitivity to surface-bound analytes. Nanopatterning was performed using deep-ultraviolet lithography followed by SF_6/Ar plasma dry etching to define nanohole apertures, and residual photoresist was removed via oxygen plasma treatment **(Fig. 2A).** The processed wafers were diced into 2 cm × 1 cm chips and cleaned prior to surface functionalization. For selective pathogen capture, sensing regions were functionalized using protein A/G-mediated antibody immobilization to ensure controlled antibody orientation and maximize antigen-binding efficiency, while non-sensing regions were passivated with bovine serum albumin (BSA) to suppress non-specific adsorption.

Controlled analyte transport was achieved using a piezoelectric micropump (mp6-liq) regulated by a microcontroller-driven board providing voltage-modulated flow between 1.0–4.5 V. Pulse-width modulation at a constant frequency of 100 Hz ensured stable and linear flow regulation while minimizing pulsation-induced fluctuations. The microfluidic module consisted of a dual-layer polydimethylsiloxane (PDMS) flow cell incorporating four independent microchannels that partitioned the plasmonic chip into two active sensing regions and two control regions for baseline monitoring and noise compensation **(Fig. 2B)**. The top PDMS layer contained patterned microchannels aligned with defined sensing pixels, whereas the recessed bottom layer provided mechanical support for chip placement. Instead of permanent bonding, a mechanically clamped assembly using acrylic caps and screw fastening ensured reversible sealing, leak-free operation, and prevention of mechanical stress on the glass substrate. Flow rate and incubation time were experimentally optimized to balance convective mass transport and surface binding kinetics, with approximately 20 minutes of low-flow exposure selected to maximize bacterial capture efficiency while minimizing shear-induced detachment.

Optical signal acquisition was performed using a narrowband LED source spectrally positioned near, but slightly offset from, the nanohole transmission resonance to enhance intensity sensitivity to small resonance shifts. The LED spectral bandwidth was selected to maintain sufficient overlap across all functionalization states while preventing detector saturation. A CMOS camera (Thorlabs DCC1545M) was positioned directly beneath the plasmonic chip in a lens-free configuration, eliminating bulky optical components and reducing system complexity. Detector quantum efficiency characteristics were evaluated to ensure uniform sensitivity within the operational spectral range. Exposure time and gain parameters were systematically optimized to maximize the signal-to-noise ratio while preserving dynamic range and preventing pixel saturation. Diffraction intensity variations induced by refractive index changes upon bacterial binding were captured as spatial intensity distributions across the sensing regions. Embedded control software enabled synchronized regulation of the microfluidic pump, LED illumination, and image acquisition sequence. Acquired images were processed using custom computational algorithms that quantified region-of-interest (ROI)-based intensity changes relative to control channels, enabling automated extraction of resonance-induced signal shifts and real-time

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

quantitative analysis. Internal referencing using control regions compensated for environmental fluctuations, mechanical drift, and non-specific background variations, thereby improving measurement robustness and repeatability.

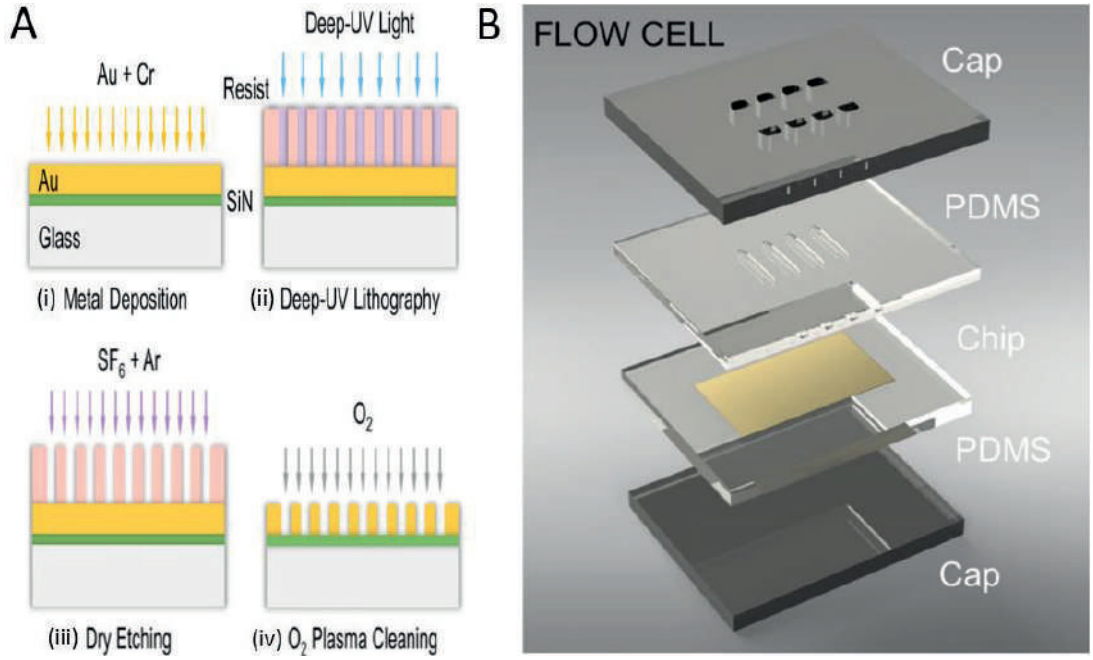


Fig. 2. (A) Sequential stages of the high-throughput fabrication process illustrated using deep-UV lithography. **(B)** Schematic representation of the structural components of the flow cell.

RESULTS

The engineered platform enabled selective detection of NG and CT in urine by integrating protein A/G-mediated antibody functionalization with a four-channel microfluidic architecture providing baseline monitoring and non-specific binding control. Molecular printing and bovine serum albumin (BSA) passivation confined bacterial capture to designated plasmonic pixels, preventing adhesion to non-sensing areas and fluidic components. CMOS-based diffraction imaging revealed distinct intensity changes corresponding to resonance shifts of approximately 38 nm for NG and 46 nm for CT, while control and bare regions remained stable, confirming high selectivity. Calibration experiments conducted over a concentration range of 10–10^6 CFU/mL in synthetic urine demonstrated strong linear correlations (R^2 = 0.9947 for NG; R^2 = 0.9999 for CT). The limits of detection were determined as 452 CFU/mL for NG and 121 CFU/mL for CT, both within clinically relevant ranges. Multiplexed assays at 10^5 CFU/mL demonstrated simultaneous and interference-free detection of both pathogens, with negligible signal observed in control channels. These findings validate the integrated

sensor–microfluidic design, highlighting precise antibody orientation, effective surface passivation, and robust diffraction-based readout as key engineering features enabling sensitive, selective, and multiplexed detection under physiologically relevant conditions.

CONCLUSION

We have developed a portable plasmonic biosensor platform for rapid, label-free detection of *Chlamydia trachomatis* and *Neisseria gonorrhoeae* in urine. By integrating antibody-functionalized plasmonic nanohole arrays, controlled microfluidic delivery, and lens-free diffraction imaging within a compact handheld architecture, the system achieves sensitive and selective detection with limits of 452 CFU/mL for NG and 121 CFU/mL for CT. The simplified optical configuration, multiplex capability, and cost-effective design support high-throughput point-of-care diagnostics. This integrated engineering approach advances the translation of plasmonic biosensing technologies toward practical clinical deployment in decentralized and resource-limited settings.

REFERENCES

Belushkin, A., Yesilkoy, F., González-López, J. J., Ruiz-Rodríguez, J. C., Ferrer, R., Fàbrega, A., & Altug, H. (2020). Rapid and digital detection of inflammatory biomarkers enabled by a novel portable nanoplasmonic imager. Small, 16(3), 1906108. https://doi.org/10.1002/smll.201906108

Brolo, A. G. (2012). Plasmonics for future biosensors. *Nature Photonics 2012 6:11*, *6*(11), 709–713. https://doi.org/10.1038/nphoton.2012.266

Cetin, A. E. (2023). A Portable Plasmonic Biosensor Kit for Diagnostics of Sexually Transmitted Infection. *Plasmonics 2023 19:2*, *19*(2), 753–764. https://doi.org/10.1007/s11468-023-02035-0

Chalklen, T., Jing, Q., & Kar-Narayan, S. (2020). Biosensors Based on Mechanical and Electrical Detection Techniques. *Sensors 2020, Vol. 20, Page 5605*, *20*(19), 5605. https://doi.org/10.3390/s20195605

Dalby, J., & Stoner, B. P. (2022). Diagnosis and Treatment of Sexually Transmitted Infections: A Review. *JAMA*, *327*(2), 161–172. https://doi.org/10.1001/jama.2021.23487

Hill, R. T. (2015). Plasmonic biosensors. *Wiley Interdisciplinary Reviews: Nanomedicine and Nanobiotechnology*, *7*(2), 152–168. https://doi.org/10.1002/wnan.1314

Jackman, J. A., Linardy, E., Yoo, D., Seo, J., Ng, W. B., Klemme, D. J., Wittenberg, N. J., Oh, S. H., & Cho, N. J. (2015). Plasmonic Nanohole Sensor for Capturing Single Virus-Like Particles toward Virucidal Drug Evaluation. *Small (Weinheim an Der Bergstrasse, Germany)*, *12*(9), 1159–1166. https://doi.org/10.1002/smll.201501914

LeFevre, M. L., & Force*, on behalf of the U. S. P. S. T. (2014). Screening for Chlamydia and Gonorrhea: U.S. Preventive Services Task Force Recommendation Statement. *Https://Doi.Org/10.7326/M14-1981*, *161*(12), 902–910. https://doi.org/10.7326/M14-1981

Newman, L., Rowley, J., Hoorn, S. Vander, Wijesooriya, N. S., Unemo, M., Low, N., Stevens, G., Gottlieb, S., Kiarie, J., & Temmerman, M. (2015). Global Estimates of the Prevalence and Incidence of Four Curable Sexually Transmitted Infections in 2012 Based on Systematic Review and Global Reporting. *PLOS ONE*, *10*(12), e0143304. https://doi.org/10.1371/journal.pone.0143304

Qavi, A. J., Wu, C., Lloyd, M., Zaman, M. M. U., Luan, J., Ballman, C., Leung, D. W., Crick, S. L., Farnsworth, C. W., & Amarasinghe, G. K. (2022). Plasmonic Fluor-Enhanced Antigen Arrays for High-Throughput, Serological Studies of SARS-CoV-2. *ACS Infectious Diseases*, *8*(8), 1468–1479. https://doi.org/10.1021/acsinfecdis.2c00086

Samuel, V. R., & Rao, K. J. (2022). A review on label free biosensors. *Biosensors and Bioelectronics: X*, *11*(6), 100216. https://doi.org/10.1016/j.biosx.2022.100216

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Sumitha, M. S., & Xavier, T. S. (2023). Recent advances in electrochemical biosensors – A brief review. *Hybrid Advances*, *2*, 100023. https://doi.org/10.1016/j.hybadv.2023.100023

Vallejo-Ortega, M. T., Gaitán Duarte, H., B. Mello, M., Caffe, S., & Perez, F. (2022). *A systematic review of the prevalence of selected sexually transmitted infections in young people in Latin America*. https://iris.paho.org/handle/10665.2/56091

Van Dyck, E., Ieven, M., Pattyn, S., Van Damme, L., & Laga, M. (2001). Detection of Chlamydia trachomatis and Neisseria gonorrhoeae by enzyme immunoassay, culture, and three nucleic acid amplification tests. *Journal of Clinical Microbiology*, *39*(5), 1751–1756. https://doi.org/10.1128/JCM.39.5.1751-1756.2001

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A PROCESS-INTEGRATED CHEMICAL RISK ASSESSMENT FRAMEWORK FOR ELECTROPLATING LINES

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ABSTRACT

Electrochemical plating lines are typically assessed based on the hazardous properties of the chemicals they contain. In practice, however, exposure conditions are shaped by how the process operates. Open bath configurations, inter-stage transfers, replenishment steps, and maintenance interventions continuously modify containment and ventilation performance. Static substance-based risk scoring therefore does not fully capture where and when exposure intensifies during routine operation.

This study develops a process-integrated chemical risk analysis model tailored to electroplating systems. Instead of beginning with individual substances, the plating line is decomposed into exposure-critical operational nodes: chemical preparation and dosing, open tank operation, transfer and replenishment between baths, and maintenance or shutdown activities. These nodes represent stages where system boundaries and human–equipment interaction change.

HAZOP is applied to identify deviation scenarios such as extraction loss, abnormal agitation, dosing errors, and transfer leakage. Selected initiating events are further examined using event tree analysis to evaluate barrier performance along consequence pathways. Engineering controls, administrative measures, and PPE are assessed within an integrated barrier framework rather than as isolated safeguards.

The analysis indicates that exposure amplification correlates strongly with operational transitions. Transfer and maintenance phases emerge as high-sensitivity states where temporary barrier degradation may outweigh baseline toxicity considerations. The proposed framework complements conventional substance-based assessment by structuring chemical risk evaluation around process state and interface behavior, supporting engineering prioritization of controls in electroplating environments.

Keywords: Process-Based Risk Analysis; HAZOP; Event Tree Analysis; Process Safety

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ORTA GERILIM KABLOLARDA KAPASITANSIN İNCELENMESI VE KARŞILAŞTIRILMASI

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ÖZET

Bu çalışmada çapraz bağlı polietilen (XLPE) izoleli orta gerilim (OG) kabloların kapasitif davranışı bütüncül bir çerçevede ele alarak tasarım, işletme ve koruma perspektifleri açısından sistematik olarak incelenmiştir. Çalışmada üç farklı iletken kesiti (95/150/240 mm²) ve sabit kesitte üç anma gerilimi (6/10–12/20–18/30 kV) incelenerek, kesit ve izolasyon kalınlığının kapasitans, şarj akımı ve eşdeğer empedans üzerindeki yönlendirici etkileri gösterilmiştir. Çalışma özellikle yeraltı OG hatlarında kapasitif etkinin reaktif güç akışı, gerilim profili, enerji kalitesi, kesici/ayırıcı zorlama (TRV) ve kompanzasyon gereksinimleri için bir tasarım parametresi olarak ele alınması gerektiğini; eşdeğer devre tabanlı sayısal doğrulamanın saha ölçümleriyle yüksek tutarlılıkta ilerlediğini ortaya koymuştur. Sonuçlar kablo seçimi, hat uzunluğu planlaması ve koruma röle koordinasyonunda kapasitansın "yalnızca bir hat sabiti" değil, doğrudan işletme ve ömür maliyeti belirleyicisi olduğunu göstermiştir.

Anahtar Kelimeler: Orta gerilim kablosu, XLPE, kapasitans, şarj akımı, reaktif güç, eşdeğer RLC devresi, LTSpice, ölçüm doğrulaması

Investigation and Comparison of Capacitance in Medium Voltage Cables

ABSTRACT

This study systematically examines the capacitive behavior of cross-linked polyethylene (XLPE) insulated medium voltage (MV) cables within a comprehensive framework, considering design, operation, and protection perspectives. Three different conductor cross-sections (95/150/240 mm²) and three rated voltages (6/10–12/20–18/30 kV) at a fixed cross-section were examined, demonstrating the guiding effects of cross-section and insulation thickness on capacitance, charging current, and equivalent impedance. The study particularly emphasized that the capacitive effect in underground MV lines should be considered as a design parameter for reactive power flow, voltage profile, power quality, circuit breaker/disconnector stress (TRV) and compensation requirements; it also revealed that equivalent circuit-based numerical verification progressed with high consistency with field

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

measurements. The results demonstrate that capacitance is not merely a line constant but a direct determinant of operational and lifetime costs in cable selection, line length planning, and protection relay coordination.

Keywords: Medium voltage cable, XLPE, capacitance, charging current, equivalent RLC circuit

1. Giriş

Orta gerilim (OG) kablolar, 1 kV ile 36 kV arasındaki elektrik enerjisi iletim ve dağıtımında kullanılan güç kablolarıdır. Genellikle şehir şebekelerinde, sanayi tesislerinde, enerji üretim santrallerinde ve büyük altyapı projelerinde elektrik enerjisinin güvenilir bir şekilde taşınması amacıyla tercih edilir. Yüksek gerilim kablolarına göre daha kısa mesafelerde kullanılırken, alçak gerilim kablolarına göre daha yüksek kapasite ve izolasyon gerektirir. Orta gerilim kablolarda kapasitans, kablonun iletkeni ile metal ekranı (veya toprak) arasında meydana gelen elektrik alanın bir sonucu olarak ortaya çıkar ve kablonun davranışını belirleyen en önemli elektriksel parametrelerden biridir. Kablo yapısı gereği, silindirik bir kondansatör modeline benzetilebilir; iç iletken aktif kutup, metal ekran ise topraklanmış karşı kutup işlevi görür. Bu nedenle kapasitans değeri, **yalıtkan malzemenin dielektrik sabiti (ε), yalıtım kalınlığı (d), iletken yarıçapı (r_1) ve ekran yarıçapı (r_2)** gibi geometrik ve malzeme özelliklerine bağlıdır. Kapasitif sistemlerde, yalıtım malzemesinin dielektrik sabiti arttıkça veya yalıtım kalınlığı azaldıkça kapasitans değeri yükselmektedir. Orta gerilim seviyelerinde özellikle XLPE (çapraz bağlı polietilen) ve EPR (etilen propilen kauçuk) gibi yüksek kaliteli yalıtkan malzemeler kullanıldığından, kapasitans değerleri hem elektriksel hem de termal açıdan belirleyici bir rol oynamaktadır. Yüksek kapasitans, kabloya bağlı sistemlerde şarj akımlarının artmasına yol açar; bu durum özellikle uzun mesafeli kablolarda ciddi bir reaktif güç yükü oluşturur ve kompanzasyon ihtiyacını beraberinde getirir[2].

Orta gerilim kablolarda kapasitansın etkileri, özellikle enerji iletim kalitesi, işletme güvenliği ve sistem kararlılığı açısından kritik öneme sahiptir. Kablo kapasitansı nedeniyle, iletken ile ekran arasındaki elektrik alan sonucu şarj akımları oluşur. Bu akımlar, kablo uzunluğu ile doğru orantılı olarak artar ve yük bağlı olsun ya da olmasın sürekli olarak akar. Bu durum, özellikle uzun mesafeli yer altı kablolarında reaktif güç yükü oluşturarak, şebekede gerilim yükselmeleri ve güç faktörü bozulmaları meydana getirebilir. Ayrıca kapasitif akımlar, kesici ve ayırıcıların anma kapasitelerini aşındırıcı bir stres unsuru haline getirerek anahtarlama sırasında aşırı geçici gerilimler ve ferrorezonans olguları gibi istenmeyen transiyent olaylara sebep olabilir. Kapasitansın artışı aynı zamanda kablonun dielektrik kayıplarını yükseltir; bu durum kablo izolasyonunun termal yaşlanma sürecini hızlandırarak ömür beklentisini olumsuz yönde etkileyebilir. Enerji kalitesi açısından değerlendirildiğinde, OG kablolarda kapasitansın neden olduğu kapasitif reaktif güç, özellikle yenilenebilir enerji santralleri ve dağıtık üretim sistemleri ile bütünleşen modern şebekelerde ciddi bir planlama parametresi haline gelmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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2. Orta Gerilim Kablolarda Kapasitans Kaynaklı Sorunlar

Orta gerilim kablolarda kapasitansın etkisi, elektriksel parametrelerin yanı sıra şebeke işletmesi, güç kalitesi ve teçhizat dayanımı üzerinde doğrudan sonuçlar doğurmaktadır. Orta gerilim kablolarda kapasitansın etkisi ile şarj akımları, reaktif güç üretimi ve gerilim yükselmesi, kesici ve ayırıcıların zorlanması, dielektrik kayıplar ve ısınma, koruma ve röle koordinasyonunda sapmalar, enerji kalitesi gibi sorunlarla karşılaşılmaktadır.

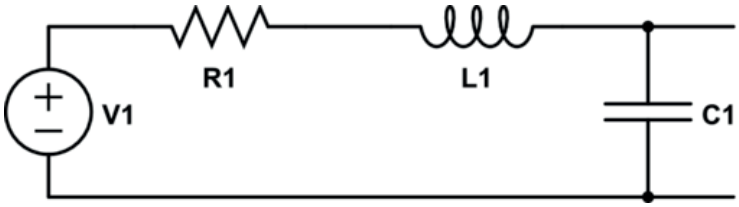
Kablo kapasitansı nedeniyle yük bağlı olsun olmasın sürekli akan şarj akımları, özellikle uzun kablo hatlarında önemli boyutlara ulaşır. Bu akımlar, transformatör ve şalt teçhizatını gereksiz yere yükleyerek kayıpları artırır ve işletme verimini düşürür. Kapasitif etki, kabloların sisteme reaktif güç beslemesine yol açar. Hafif yüklü veya boşta çalışan hatlarda bu durum, özellikle kablo uçlarında **gerilim yükselmesi (Ferranti etkisi)** olarak ortaya çıkar ve şebekenin kararlılığını olumsuz etkileyebilir. Kapasitansın neden olduğu şarj akımları, OG kesici ve ayırıcıların anahtarlama anında **geçici toparlanma gerilimlerini (TRV)** yükseltir. Bu durum, anahtarlama sırasında **yüksek frekanslı gerilim salınımları, ferrorezonans** ve **ani dielektrik zorlanmalar** oluşturarak teçhizatın ömrünü kısaltabilir. Kapasitif yüklenme, kablonun dielektrik malzemesinde kayıplar yaratır. Bu kayıplar, özellikle XLPE ve EPR yalıtımlı kablolarda **ısınma** ve dolayısıyla **yalıtım ömrünün kısalması** ile sonuçlanır. Uzun vadede termal yaşlanma mekanizmasını hızlandırarak arıza riskini artırır. Kapasitans nedeniyle oluşan akımlar, diferansiyel koruma, **toprak kaçağı ve yönlü rölelerin** doğru çalışmasını zorlaştırabilir. Özellikle düşük akımlı hat arızalarında röleler hatalı tetikleme yapabilir ya da gecikmeli tepki gösterebilir. Kapasitansın etkisiyle şebekede reaktif güç dengesizliği, gerilim dalgalanmaları ve harmonik rezonans riskleri ortaya çıkabilir. Bu durum, özellikle yenilenebilir enerji kaynaklarıyla bütünleşmiş modern şebekelerde kritik bir mühendislik sorunudur.

3. Kablo Eşdeğer Devresi

3.1. Modelleme

Orta gerilim XLPE kablolar; güç frekansında dağıtılmış parametreler içeren bir yapı gibi davranır. Bu yapı akım-gerilim ilişkisini doğru koruyacak şekilde sadeleştirilerek bir eşdeğer devreyle temsil edilebilir. Bu yapı R(direnç), L(endüktans), C(kapasitans) parametrelerini içerdiği için, RLC devreleri olarak adlandırılır. Bir OG kablonun en sade RLC eşdeğer devresi **Şekil 1**'de görüldüğü gibi çizilebilir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 1: Kablo Eşdeğer RLC Devresi

3.2. Kapasitansın Hesaplanması

Yalıtkan bir madde ile birbirinden ayrılmış bulunan herhangi iki iletken plaka kondansatörü meydana getirmektedir. Bu gibi iki plaka arasına bir gerilim uygulandığı zaman, plakalarda ters polaritede elektrik yükleri toplanır veya iki plağa ters polaritede elektrik yükleri verilirse, plakalar arasında bir gerilim meydana gelir. Bir kondansatörün kapasite diye tarif edilen büyüklüğü plakalar arasındaki gerilim farkına karşılık plakalarda toplanan elektrik yükü ile verilmiştir. Bu iki parametrenin değeri bilindiğinde, kapasitenin değeri aşağıdaki denklem 1 ile hesaplanabilir.

$$C = \frac{Q}{V} \tag{1}$$

Bir iletkenin metre boy başına taşıdığı yük miktarı q ise, x mesafedeki elektrik akı yoğunluğu,

$$D = \frac{q}{2.\pi.x} \tag{2}$$

denklem 2 şeklinde olacaktır. Bu mesafede potansiyel gradiyenti ise,

$$E = \frac{D}{\varepsilon_r.\varepsilon_0} = \frac{q}{2.\pi.x.\varepsilon_r.\varepsilon_0} \tag{3}$$

Denklem 3'deki gibi olacaktır. Denklem 3'de ε_0, vakumun dielektrik sabitidir ve değeri $8{,}85418\times10^{-12}$ C/Vm'ye eşittir. ε_r ise kullanılan yalıtım malzemesinin dielektrik katsayısıdır. XLPE tipi kablolarda ε_r genellikle 2,3 alınır. İç yarı iletken yarıçapı r, izolasyon yarıçapı R olan bir OG kabloda; iletkenle kılıf arasındaki gerilim farkı, [3]

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$$V = \frac{q}{2.\pi.\varepsilon_r.\varepsilon_0}\int_r^R \frac{dx}{x} = \frac{q}{2.\pi.\varepsilon_r.\varepsilon_0}\ln(\frac{R}{r}) \quad (4)$$

denklem 4'e göre bulunur. Kablonun metre boy başına kapasitesi [1],

$$C = \frac{q}{V} = \frac{2.\pi.\varepsilon_r.\varepsilon_0}{\ln(\frac{R}{r})} \quad (5)$$

Denklem 5 ile elde edilir. Verilen parametreler denklem 5'de yerine konulduğunda,

$$C = \frac{\varepsilon_r}{18\times\ln(\frac{R}{r})}\ nF \quad (6)$$

denklem 6'daki gibi yazılabilir. Eğer kablonun kilometre başına kapasitans değeri sorulursa, aynı formül kullanılabilir fakat çıkan sonucun birimi ''µF'' olarak yazılmalıdır. Kablonun AC gerilimine karşı uyguladığı kapasitif reaktans, denklem 7'de ile hesaplanır.

$$X_C = \frac{1}{2\pi fc} \quad (7)$$

3.3. Devre Dizaynı ve Simülasyon

Anma gerilimi 12/20 kV olan, XLPE izoleli, tek damarlı, bakır iletkenli kablonun; farklı iletken kesit alanlarına sahip örneklerinin direnç, endüktans ve kapasitans değerleri ölçümler ve hesaplamalar sonucu bulunarak, **Tablo 1'**de verilmiştir.

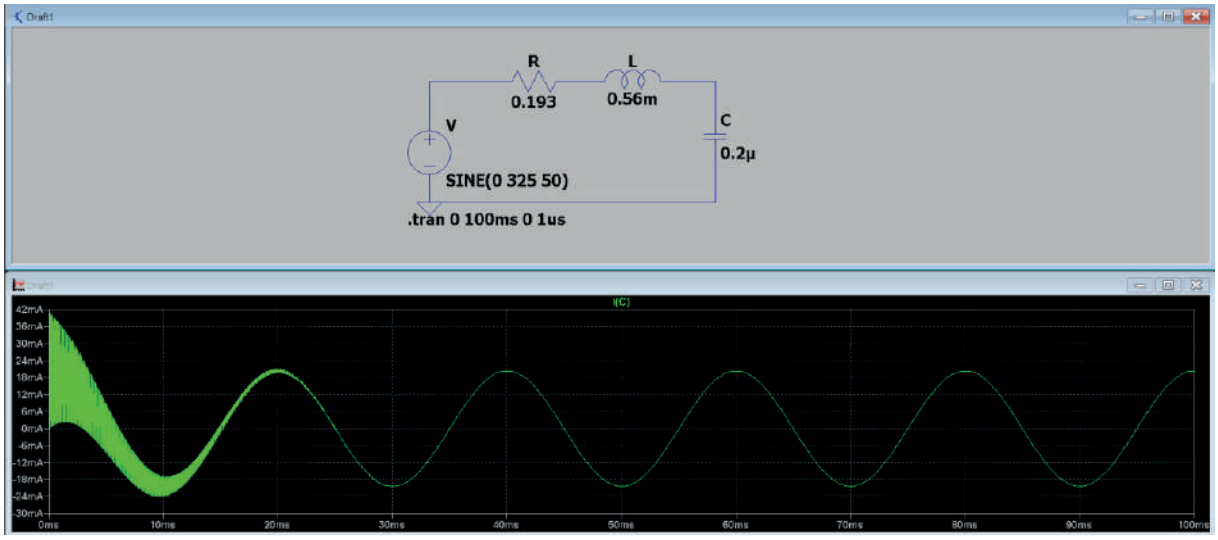
Tablo 1: N2XSY(IEC) 12/20 kV kablonun farklı kesitlerinin R, L ve C değerleri

Nominal İletken Kesiti (mm^2)	İç Yarı İletken Yarıçapı (mm)	İzolasyon Yarıçapı (mm)	20°C'de AC direnci (Ω/km)	Çalışma Endüktansı* (mH/km)	Çalışma Kapasitansı (µF/km)
1x95	12,4	22,8	0,195	0,566	0,210
1x150	15,2	25,6	0,126	0,542	0,244
1x400	24,2	34,6	0,0511	0,492	0,357

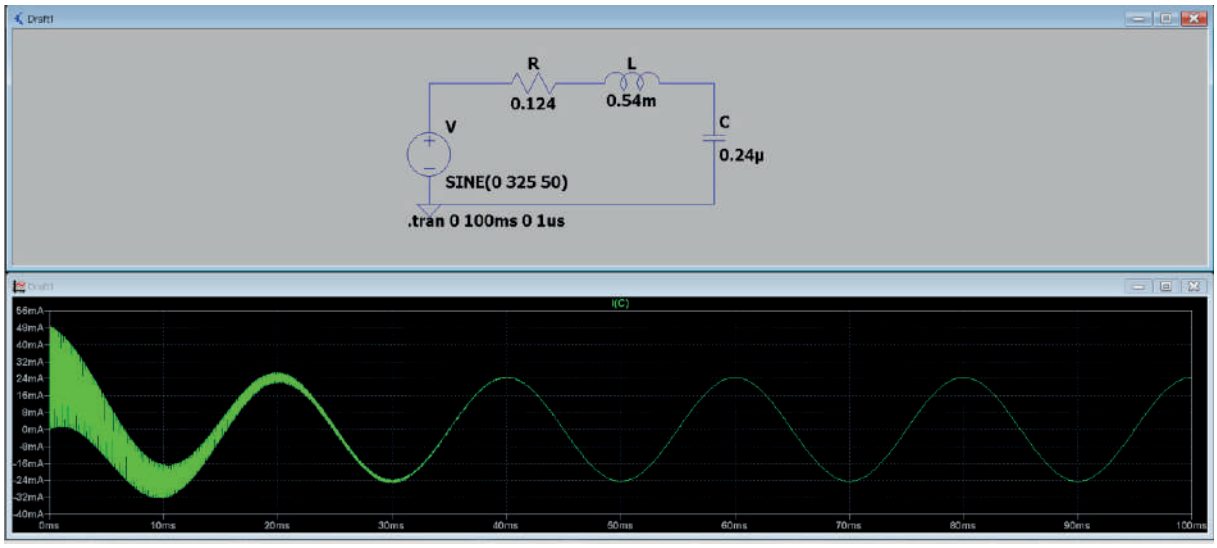
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* *Kablonun yassı boşluklu döşendiği durum göz önüne alınmıştır.*

Tablo 1'deki veriler kullanılarak kablonun üç farklı kesit alanına eşdeğer üç adet RLC devresi, LTSpice kullanılarak dizayn edilip simüle edilmiş ve kapasitörün üzerinden geçen akımın zamana göre grafikleri çıkarılmıştır. Sonuçlar **Şekil 2, Şekil 3 ve Şekil 4**'de görüldüğü gibidir.

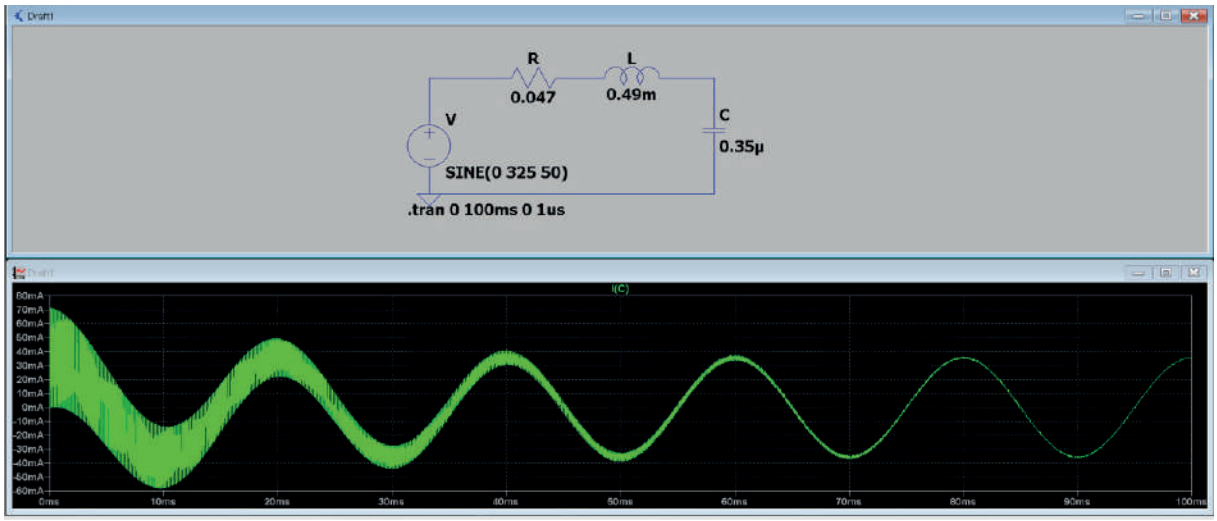


Şekil 2: İletken kesit alanı 95 mm^2 olan kablonun eşdeğer devresi ve simülasyon grafiği



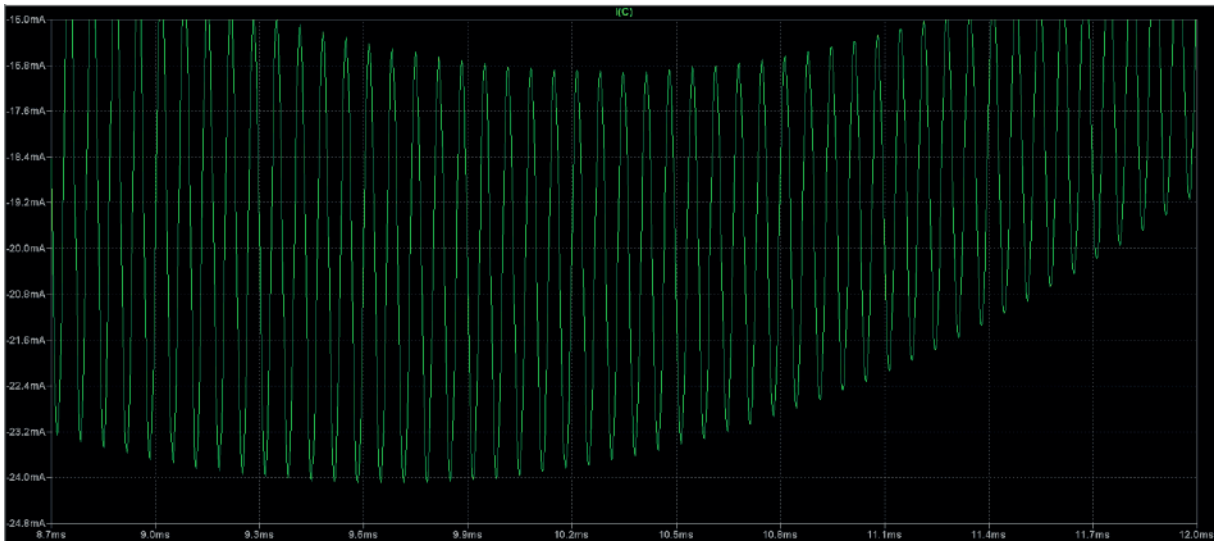
Şekil 3: İletken kesit alanı 150 mm^2 olan kablonun eşdeğer devresi ve simülasyonu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 4: İletken kesit alanı 400 mm^2 olan kablonun eşdeğer devresi ve simülasyonu

Şekil 2-4'de sinüs dalgalarının belli bir saniyeye kadar, yüzey alanı geniş ve genliği sabit olmayan dalgalardan oluştuğu göze çarpmaktadır. Bunun sebebi, sistemin henüz kararsız halde olmasıdır. Grafiğin bu kısmı büyütüp yakınlaştırıldığında, **Şekil 5**, kararsız hale sebep olan yapının, frekansı çok yüksek sinüs dalgalarının bir araya gelerek büyük bir dalga görünümü oluşturması olduğu görülmüştür.



Şekil 5: Grafiğin yakınlaştırılmış hali

Sinüzoidal dalga grafiklerinde, dalganın genliğinin zaman içinde değişim eğrisine genlik zarfı denir. RLC devrelerde genlik zarfı, geçen zamana göre $e^{-t/\tau}$ ile orantılıdır. Bu işlemde τ ile gösterilen parametre zaman katsayısıdır ve seri RLC devrelerde değeri $\frac{2L}{R}$ 'ye eşittir. Geçen süre 4τ değerine ulaştığında, genlik zarfı e^{-4} =0,018 yani %1,8'e eşit olur. Mühendislik hesaplamalarında %2'nin

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

altında hata bandı göz ardı edilir ve pratikte yok sayılır. Yani t değeri 4τ değerine ulaştığında, devre kararlı hale geçer.

İlk devrede τ değeri,

$$\frac{2L}{R} = \frac{2 \times 0.56 \times 10^{-3}}{0,193} \cong 5,8ms$$

olarak hesaplanır. Zaman katsayısı bulunduktan sonra, devrenin kararlı hale gelmesi için geçmesi gereken süre bulunabilir.

$$4\tau = 4 \times 5,8 = 23,2ms$$

Devrenin 23 ms'den sonra kararlı hale geldiği grafik üzerinden de okunabilir. Devre kararlı hale geldikten sonra, maksimum akım değeri,

$$I = \frac{V}{X_c} = \frac{V}{\frac{1}{2\pi fc}} \cong \frac{325}{15,9 \times 10^3} \cong 20mA$$

olarak hesaplanabilir. Her 20 ms'lik periyotta (frekans 50 Hz. olduğu için), akımın maksimum değer olan 20 mA'ya ulaştığı grafik üzerinden okunabilir.

Kesit alanı büyüdükçe; direnç değeri endüktans değerine göre daha fazla azaldığı için zaman katsayısı yükselmiş, bu da devrenin kararlı hale gelme süresini uzatmıştır. Kapasitans değeri yükseldiği için de endüktif reaktans azalır, devrenin maksimum akım değeri artar.

Aynı kablonun, iletken kesit alanı sabit 240 mm^2 olacak şekilde anma gerilimleri 10 kV, 12/20 kV ve 18/30 kV'luk örneklerinin de ölçümler yapılarak değerleri bulunmuş ve **Tablo 2** oluşturulmuştur.

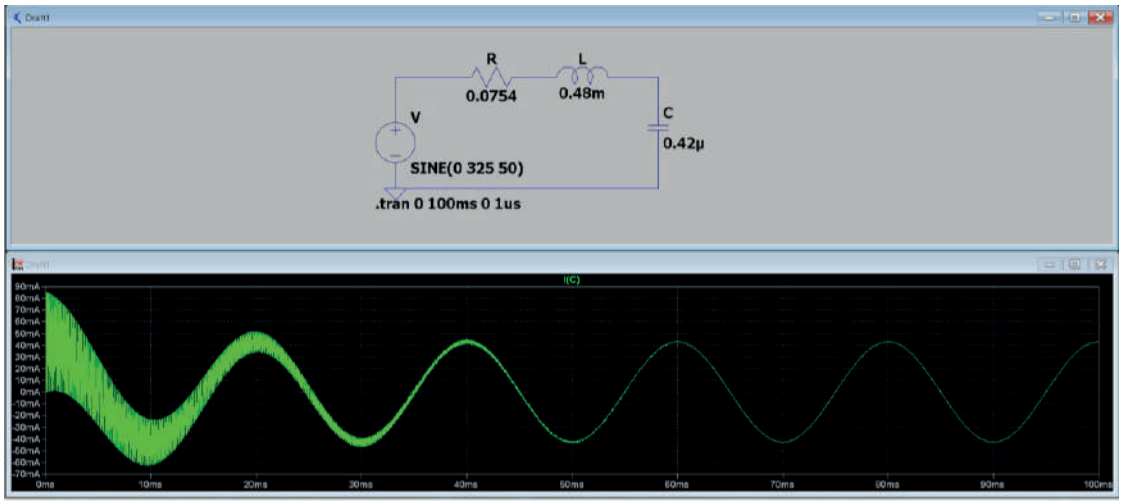
Tablo 2: N2XSY kablonun sabit kesit alanı farklı anma gerilimlerinde R, L ve C değerleri

Anma Gerilimi (kV)	İç Yarı İletken Yarıçapı (mm)	İzolasyon Yarıçapı (mm)	20ºC'de AC direnci (Ω/km)	Çalışma İndüktansı* (mH/km)	Çalışma Kapasitansı (µF/km)
6/10	19,3	25,7	0,0773	0,490	0,446
12/20	19,3	29,7	0,0773	0,513	0,296
18/30	19,3	34,5	0,0773	0,539	0,22

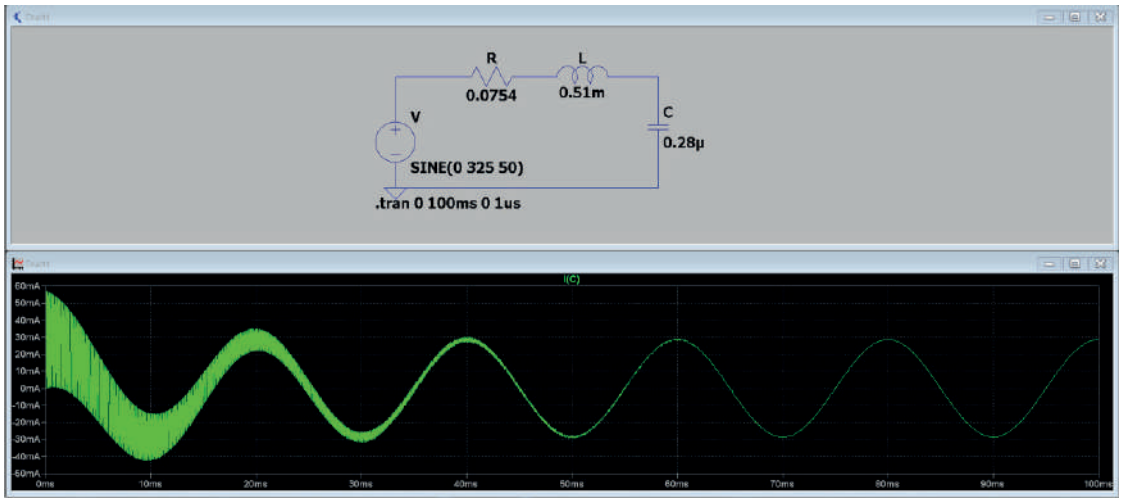
* *Kablonun yassı boşluklu döşendiği durum göz önüne alınmıştır.*

Yine Tablo 2'deki veriler kullanılarak, LTSpice üzerinden devre şemaları çizilmiş ve simüle edilmiştir, **Şekil 6**, **Şekil 7** ve **Şekil 8**.

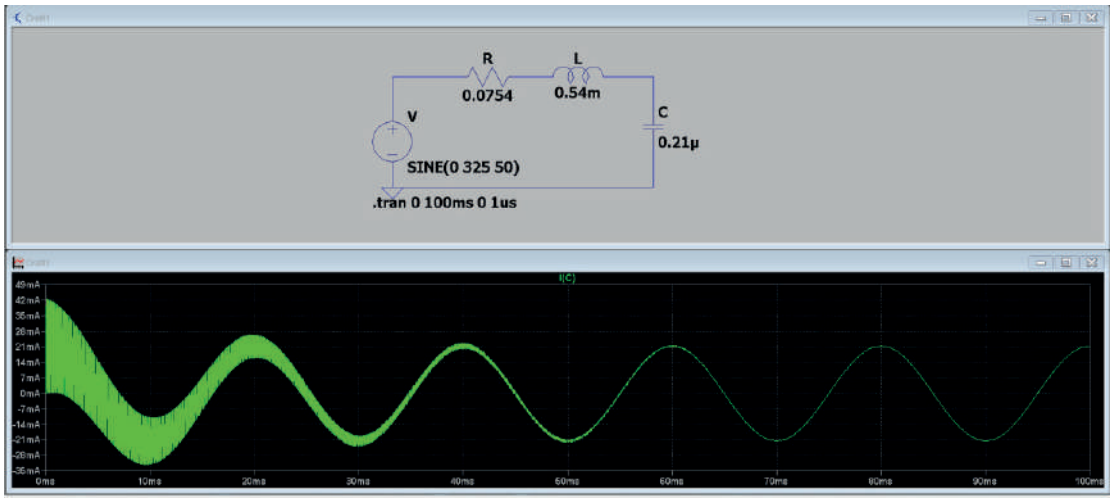
DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 6: 6/10 kV anma gerilimine sahip kablonun eşdeğer devresi ve simülasyonu



Şekil 7: 12/20 kV anma gerilimine sahip kablonun eşdeğer devresi ve simülasyonu



Şekil 8: 18/30 kV anma gerilimine sahip kablonun eşdeğer devresi ve simülasyonu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

4. Deneysel Çalışma

Fabrikanın test sahasında analog multimetre ile yapılan ölçümlerde; kesit alanı 1x400 mm^2, anma gerilimi 35kV, XLPE tipi, çelik tel zırhlı, alüminyum iletkenli kablonun 1024 metrelik kısmının iletkenle ekran (a) ve iletken zırh (b) arasındaki kapasitans değerleri ayrı ayrı ölçülmüştür, **Şekil 9a ve b.**



a b

Şekil 9: NA2XSYR(AL)Y 23.5/35 kV kablonun iletkenle ekran (a) ve iletken zırh (b) arasındaki kapasitans değeri

Kablonun tasarım değerleri [4] formülde yerine konulup km başına iletkenle ekran arasındaki kapasitans değeri,

$$C = \frac{\varepsilon_r}{18 \times \ln(\frac{R}{r})} = \frac{2,3}{18 \times \ln(\frac{41,2}{20,6})} \cong 0,244 \mu F = 244\ nF$$

olarak hesaplanır. Ölçüm yapılan kısım kablonun 1024 metrelik bir kesiti olduğu için, ölçüm yapılan kısmın teorik değeri aşağıda işlem kullanılarak bulunur.

$$C = 244 \times \frac{1024}{1000} \cong 250\ nF$$

Şekil 9a'da görüleceği üzere bu değer 252,4 nF olarak ölçülmüştür. Kablonun tel zırhı ile ekran arasında ayırıcı kılıf işlevi gören PVC yalıtkan madde bulunur ve bu yapı, iletkenle ekran arasındaki kondansatöre seri bağlı ikinci bir kondansatör gibi davranır. Seri bağlı kondansatörlerde eşdeğer kapasitans değeri, aşağıdaki formülle bulunur.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

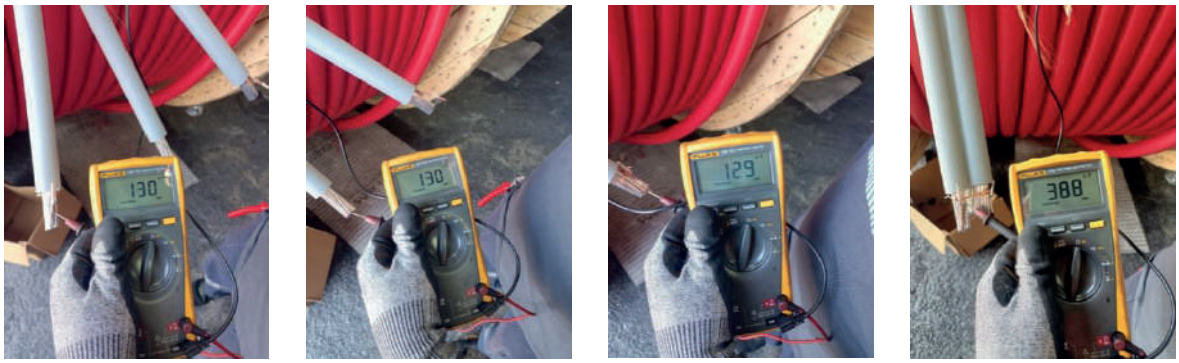
$$C_{eşdeğer} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \cdots \frac{1}{C_n}}$$

Bu formüle göre, iletken ile tel zırh arasındaki kapasitans değeri,

$C = \frac{1}{\frac{1}{392,2} + \frac{1}{252,4}} \cong 236,8\ nF$ olarak hesaplanır.

Değer analog multimetreyle 237,5 nF olarak ölçülmüştür, **Şekil 9b**.

Anma gerilimi 20 kV, XLPE izoleli, üç damarlı, alüminyum iletkenli kablonun 150 mm^2 iletken kesit alanına sahip 1024 metre uzunluğundaki kesitinin her bir damarının iletkenle ekran arasındaki kapasitans değerleri analog multimetreyle sırasıyla 130, 130 ve 129 nF ölçülmüştür, **Şekil 10a, b ve c**. Bu üç damarın birbirine bağlanmış ve iletken ile ekran arasındaki kapasitans değeri tekrar ölçülmüş ve 388 nF bulunmuştur, **Şekil 10d.**



a b c d

Şekil 10: NA2XSYR(AL)Y 23.5/35 kV kablonun birinci (a), ikinci (b), üçüncü (c) ve üç damarın birlikte(d) kapasitans değerleri

5. Sonuçlar ve Değerlendirme

Aynı kablo tipinde (N2XSY/NA2XSY, XLPE izolasyon) iletken kesiti artırıldığında çalışma kapasitansının geometriden beklenen şekilde (r/R oranının büyümesine bağlı olarak) logaritmik olarak yükseldiği; buna karşılık AC direncin ve çalışma endüktansının azaldığı deneysel, analitik ve LTSpice simülasyon sonuçlarıyla birlikte teyit edilmiştir; R'deki düşüş L'ye göre daha hızlı gerçekleştiğinden τ=L/R zaman katsayısı artmış ve 50 Hz'de kararlı hâle geçiş süresi uzamıştır; kapasitansın artmasıyla kapasitif reaktans |Xc| küçülmüş, toplam empedans azalmış ve akım genliği yükselmiştir. İletken kesiti sabit tutulup anma gerilimi 6/10 kV → 12/20 kV → 18/30 kV artırıldığında izolasyon kalınlığının artmasına bağlı olarak kapasitans azalmış, dolayısıyla |Xc| büyümüş ve akım genliği düşmüştür; AC direnç yaklaşık sabit kalırken endüktansın hafif artışıyla τ da aynı oranda artmıştır. Fabrika test sahasında 1×400 mm², 23.5/35 kV NA2XSYR(AL)Y kablonun 1024 m'lik numunesinde iletken–ekran kapasitansının hesaplanan değerle uyumlu olduğu; iletken–zırh kapasitansınınsa (ekran–zırh

arası ikinci kondansatörün seri etkisi nedeniyle) ölçümde hesaplamadan yalnızca %0,3 yüksek çıktığı ve bu farkın ölçüm amacıyla kablonun ucunun açılması ve uzunluğunun bir kısmını kaybetmesinden kaynaklanan kabul edilebilir mühendislik hatası sınırları içinde kaldığı doğrulanmıştır. Üç damarlı 20 kV kabloda her bir damarın iletken–ekran kapasitanslarının birbirine eşit olduğu ve damarların birbirine paralel bağlı kondansatörler gibi davranarak toplam kapasitansın yaklaşık üç katına çıktığı gözlenmiştir. Bu bulgular, uzun yeraltı OG kablolarında şarj akımı ve kapasitif reaktif güç artışının gerilim profili, kesici/ayırıcı TRV zorlanmaları ve kompanzasyon gereksinimleri üzerinde doğrudan etkili olduğunu; kablo seçimi ve ağ planlamasında kapasitansın yalnızca bir "hat sabiti" değil, koruma koordinasyonu, termal yaşlanma ve güç kalitesi açısından da tasarım belirleyicisi olduğunu göstermektedir.

Kaynaklar

[1] Millî Eğitim Bakanlığı, Elektrik-Elektronik Teknolojisi Yeraltı Enerji Hatları. MEGEP Yayınları, Ankara, 2012, 131 s.

[2] Salih Bilgiç, Cemile Bardak, (2021), Erzincan Üniversitesi Fen Bilimleri Enstitüsü Dergisi, Cilt 14, Sayı 2, 2021, 605 - 619, 10.18185/erzifbed.949269

[3] Demirkut, B. Elektrikle Enerji Taşınması. İstanbul Devlet Mühendislik ve Mimarlık Akademisi Yayınları, İstanbul, 1971, 727 s.

[4] Nexans Ürün Kataloğu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KONVANSİYONEL VE DONUK HAMUR PROSESLERİNDE AMİLOLİTİK ENZİMLERİN HAMUR VE EKMEK KALİTESİ ÜZERİNE ETKİLERİ

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ÖZET

Ekmek; buğday ununun su, tuz ve maya ile yoğrulması sonucu oluşan hamurun fermantasyon, pişirme ve soğutma aşamalarından geçerek tüketime hazır hale gelmesiyle elde edilen temel gıda maddesidir. İç yapısını büyük ölçüde nişasta ve gluten matrisinin oluşturduğu ekmek, hem fiziko-kimyasal hem de teknolojik özellikleri nedeniyle enzim uygulamalarına oldukça duyarlıdır. Dolayısıyla ekmek kalitesinin geliştirilmesinde amilolitik enzimlerin kullanımı yaygın ve stratejik bir yaklaşımdır.

Bu çalışmada, ekmek formülasyonuna eklenen maltojenik amilaz, amiloglikozidaz (AMG), standart enzim karışımı ve bunların kombinasyonlarının hamur ve ekmek özelliklerine etkisi değerlendirilmiştir. Denemeler donuk hamur prosesi ve konvansiyonel ekmek üretim sürecinde gerçekleştirilmiş, bu sayede enzimlerin proses koşullarına bağlı işlevsel davranışları karşılaştırmalı olarak incelenmiştir. Enzim içermeyen kontrol formülasyonu referans olarak kullanılmıştır.

Numunelerde nişastanın ısıl geçiş özellikleri DSC ile analiz edilmiş; jelatinizasyon entalpisi ve retrogradasyon eğilimleri belirlenmiştir. Tekstür profil analizi ile ekmek içi sertlik, esneklik ve iç yapı bütünlüğü ölçülmüş; spesifik hacim rapeseed displacement yöntemiyle hesaplanmıştır. Kabuk ve iç renk CIE L*a*b* sistemine göre belirlenmiş, gözenek yapısı duyusal panel ile desteklenmiştir.

Sonuçlara göre AMG ilaveli ekmekler hacim, spesifik hacim, doku yumuşaklığı ve renk gelişimi açısından en yüksek performansı göstermiştir. AMG'nin nişasta hidroliziyle fermantasyon substratlarını artırdığı, bunun da gaz tutulumunu ve ekmek içi elastisitesini iyileştirdiği görülmüştür. Diğer taraftan maltojenik amilaz içeren ekmekler DSC analizlerinde en düşük retrogradasyon entalpisi ile sonuçlanmış; bu enzimin depolama sırasında nişasta kristallenmesini en etkili şekilde baskılayarak bayatlamayı geciktirdiği belirlenmiştir.

Genel değerlendirme, farklı enzim türlerinin ekmek kalite parametrelerini farklı yönlerde optimize ettiğini göstermektedir. AMG hacim ve doku iyileştirmede öne çıkarken, maltojenik amilaz raf ömrü ve nişasta stabilitesi açısından en etkili enzim olarak belirlenmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Ekmek hamurunda yapılan reolojik analizler devam etmektedir.

Anahtar Kelimeler: ekmek enzimleri, amiloglikozidaz, maltojenik amilaz, donuk hamur, nişasta retrogradasyonu

EFFECTS OF AMYLOLYTIC ENZYMES ON DOUGH AND BREAD QUALITY IN CONVENTIONAL AND FROZEN DOUGH PROCESSES

ABSTRACT

Bread is a staple food obtained by fermentation, baking, and cooling of dough prepared from wheat flour, water, salt, and yeast. Due to its structure mainly composed of starch and gluten matrix, bread is highly sensitive to enzyme applications because of its physicochemical and technological properties. Therefore, the use of amylolytic enzymes is a common and strategic approach to improve bread quality.

In this study, the effects of maltogenic amylase, amyloglucosidase (AMG), a standard enzyme blend, and their combinations on dough and bread properties were evaluated. Trials were carried out in frozen dough processing and conventional bread production processes. Thus, the functional behaviors of enzymes under different processing conditions were comparatively investigated. An enzyme-free formulation was used as the control sample.

Thermal transition properties of starch were analyzed by DSC, and gelatinization enthalpy and retrogradation tendencies were determined. Bread crumb firmness, elasticity, and structural integrity were evaluated by texture profile analysis. Specific volume was determined using the rapeseed displacement method. Crust and crumb color were measured according to the CIE Lab* system, and pore structure was supported by sensory panel evaluation.

According to the results, breads containing AMG showed the highest performance in terms of loaf volume, specific volume, crumb softness, and color development. AMG increased fermentable substrates through starch hydrolysis, which improved gas retention and crumb elasticity. On the other hand, breads containing maltogenic amylase showed the lowest retrogradation enthalpy values in DSC analysis, indicating effective inhibition of starch crystallization during storage and delayed staling.

Overall, different enzyme types optimized bread quality parameters in different aspects. AMG was prominent in improving volume and texture, whereas maltogenic amylase was the most effective enzyme in extending shelf life and improving starch stability. Rheological analyses of bread dough are ongoing.

Keywords: bread enzymes, amyloglucosidase, maltogenic amylase, frozen dough, starch retrogradation

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BALIK KILÇIĞI YÖNTEMİYLE ŞEHİR İÇİ TOPLU TAŞIMA ARAÇLARINDA BAKIM KAPAĞI AÇILMA-KAPANMA GÜVENLİĞİNİN KÖK NEDEN ANALİZİ

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ÖZET

Şehir içi toplu taşıma araçlarında kullanılan bakım kapaklarının güvenli açılma–kapanma davranışı, bakım ergonomisi ve operasyonel güvenlik açısından kritik öneme sahiptir. Bu çalışmada, Akia Ultra LF12 EV model aracın bakım kapağında gözlemlenen düzensiz açılma–kapanma problemlerinin kök nedenleri Balık Kılçığı (Ishikawa) yöntemi kullanılarak analiz edilmiştir. Kapak toplam kütlesi (yaklaşık 20 kg) ve moment gereksinimleri dikkate alınarak seçilen iki adet 200 N kapasiteli gazlı amortisörün açma kuvveti bakımından yeterli olduğu doğrulanmış; problemi tetikleyen temel etkenin braket ve FRP kapak arabiriminde lokal rijitlik yetersizliği olduğu belirlenmiştir. Bu kapsamda sonlu elemanlar analizi (FEM) ile braket gerilme dağılımları değerlendirilmiş ve emniyet katsayısının çalışma koşullarında güvenli aralıkta kaldığı görülmüştür. FRP kapak uç bölgelerinde meydana gelen lokal deformasyon riskine karşı karkas güçlendirmesi tasarlanmış ve yapısal performans iyileştirilmiştir. Çalışma, amortisör bağlantı tasarımının yalnızca kuvvet seçimi ile sınırlı kalmaması, geometrik yerleşim ve rijitlik optimizasyonu ile birlikte bütüncül mühendislik yaklaşımıyla ele alınması gerektiğini ortaya koymaktadır.

Anahtar Kelimeler: Ergonomi, gazlı amortisör, Ishikawa diyagramı, kök neden analizi, otomotiv

1. GİRİŞ

Son yıllarda teknoloji alanındaki hızlı gelişmeler, otomotiv ve toplu taşıma sektörlerinde kullanılan bileşenlerin tasarım ve doğrulama süreçlerinde önemli değişikliklere yol açmıştır. İleri malzeme bilimi, üretim teknikleri ve sistematik tasarım yöntemleri sayesinde araç bileşenleri daha hafif, daha dayanıklı ve daha güvenilir hale getirilmektedir. Bu gelişmeler doğrultusunda mevcut yapıların performansı, farklı malzeme seçenekleri ve yeni tasarım yaklaşımları açısından yeniden değerlendirilmektedir (Zhang ve Xu, 2022). Ancak tasarım parametrelerinin çokluğu ve bileşen davranışını etkileyen faktörlerin birbiriyle ilişkili olması, ortaya çıkan problemlerin kök nedenlerinin

doğru şekilde belirlenmesini gerekli kılmaktadır. Bu noktada mühendislik sistemlerinde yaygın olarak kullanılan Balık Kılçığı (Ishikawa) yöntemi, çok değişkenli tasarım hatalarının sistematik olarak analiz edilmesi ve uygun çözüm stratejilerinin belirlenmesi için etkili bir araç olarak öne çıkmaktadır (Ishikawa, 1986).

Balık kılçığı diyagramının kökeni 1940'lı yıllara kadar uzanmakta olup, bu yaklaşım ilk olarak 1943 yılında Tokyo Üniversitesi'nde sistematik problem çözme amacıyla geliştirilmiştir. Daha sonra Prof. Kaoru Ishikawa tarafından Japon sanayisindeki kalite kontrol uygulamalarında yapısal bir analiz aracı olarak benimsenmiş ve yaygınlaştırılmıştır (Akın, 1996). Diyagram, görünümünden dolayı balık kılçığı diyagramı, neden–sonuç ilişkilerini ortaya koyma işlevi nedeniyle sebep–sonuç diyagramı, yöntemin geliştirilmesindeki öncü rolü nedeniyle ise Ishikawa diyagramı olarak literatürde farklı adlarla anılmaktadır (Erbaş ve Kolak, 2015). Bu yöntem, ele alınan bir problem ya da durumun ortaya çıkmasına katkıda bulunan tüm olası faktörleri sistematik biçimde belirlemek amacıyla kullanılmaktadır. Hem bireysel hem de kurumsal ölçekteki sorunlara uygulanabilen, kullanımı pratik, kapsamlı ve etkili bir analiz tekniği olarak problem çözme süreçlerinde önemli bir yere sahiptir (Atalay ve Kılıç, 2015). Diyagram yapısında, araştırılması hedeflenen temel problem "balığın başı" olarak adlandırılan bölümde gösterilirken, probleme yol açtığı değerlendirilen kategoriler ve alt nedenler "kılçık" olarak ifade edilen dallara yerleştirilir (Çavuş, 2020).

Bu çalışmada, literatürde yer alan benzer tasarım ve analiz yaklaşımlarından yola çıkılarak Ulaşım İç ve Dış Ticaret A.Ş. bünyesinde kullanılan şehir içi toplu taşıma araçlarındaki dış kapak yapıları incelenmiştir. Değerlendirmenin odak noktasını, aracın arka bölümünde yer alan motor bakım kapağı oluşturmaktadır. Motor bakım kapağı, boyut ve kütle açısından diğer servis kapaklarına kıyasla daha büyük olduğundan, kapağın güvenli ve kontrollü biçimde açılmasını sağlayan gazlı amortisörlerin doğru seçimi kritik önem taşımaktadır. Yanlış kuvvet, hatalı montaj geometrisi veya uygun olmayan strok seçimi; kapağın kontrolsüz şekilde açılmasına ya da açık konumda stabil kalmamasına neden olabilmekte ve bakım personeli için ciddi güvenlik riskleri oluşturabilmektedir (Ulaşım, 2025).

Bu nedenle çalışmada, motor bakım kapağı özelinde ortaya çıkan sorunların yalnızca tek bir parametreye bağlı olmadığı, aksine malzeme özellikleri, üretim toleransları, montaj uygulamaları, çalışma çevresi, kapak geometrisi ve kullanıcı etkileşimleri gibi çok sayıda değişkenin bir arada etkili olduğu görülmüştür. Bu çok değişkenli problem yapısı, hataların kaynağını doğru tanımlayabilmek için sistematik bir kök neden analiz yöntemine ihtiyaç olduğunu göstermektedir. Bu amaçla, kalite ve problem çözme süreçlerinde yaygın olarak kullanılan Balık Kılçığı (Ishikawa) yöntemi, motor bakım kapağına ait gazlı amortisör seçimini etkileyen tüm faktörlerin bütüncül olarak sınıflandırılması ve kök nedenlerin belirlenmesi için temel metodolojik araç olarak tercih edilmiştir. Böylece amortisör seçimine ilişkin tasarım hatalarının görünür kılınması, sistematik olarak analiz edilmesi ve doğru mühendislik kararlarının oluşturulması hedeflenmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Bu çalışma kapsamında, balık kılçığı (Ishikawa) yönteminin otomotiv başta olmak üzere farklı sektörlerde nasıl uygulandığını ele alan araştırmalar incelenmiş; yöntemin kullanım biçimleri, problem sınıflandırma yaklaşımları ve analiz süreçleri dikkatle değerlendirilmiştir. Bu incelemeler, yöntemin kapsamı ve uygulanabilirliği açısından çalışmaya yön vermiş, ayrıca tasarım hatalarının sistematik olarak ele alınmasında yol gösterici bir temel oluşturmuştur.

Özçelik ve Cinoğlu'nun çalışmasında sebep–sonuç diyagramının otomotiv yan sanayinde hataların sınıflandırılması ve süreç iyileştirmelerinde etkili biçimde uygulandığı gösterilmiştir. Çalışmada yöntem, yalın üretim araçlarıyla bütünleştirilmiş; insan, yöntem, malzeme ve makine kaynaklı hataların sistematik olarak ortaya çıkarılması sağlanmıştır. Bulgular, Ishikawa yaklaşımının karmaşık üretim süreçlerinde hata oranlarını düşürmede ve problem çözme sürecine analitik bir çerçeve kazandırmada güçlü bir araç olduğunu göstermektedir (Özçelik ve Cinoğlu, 2013).

Yavuz ve arkadaşlarının çalışmasında Balık Kılçığı (Ishikawa) yöntemi, endüstriyel bir üretim sürecinde hata türlerinin kök nedenlerini belirlemek için uygulanmıştır. Çalışmada yöntem, insan, ekipman, malzeme, çevre ve yöntem kategorileri üzerinden sistematik bir problem çözme aracı olarak ele alınmıştır. Analiz sonucunda üretim hatalarının büyük bölümünün süreç içi parametre kontrol eksikliğinden, operatör hatalarından ve uygun olmayan malzeme koşullarından kaynaklandığı belirlenmiştir. Elde edilen bulgular, Ishikawa yönteminin çok değişkenli endüstriyel problemlerde neden–sonuç ilişkilerinin düzenli biçimde ortaya konmasında etkili bir yöntem olduğunu göstermektedir. Çalışma ayrıca, iyileştirme aksiyonlarının belirlenmesinde sebep–sonuç diyagramının yalın ve anlaşılır bir yol haritası sağladığını ortaya koymaktadır (Yavuz ve ark, 2021).

Cho ve Han çalışmasında, araç bagaj kapaklarında kullanılan gazlı amortisörlerin açılma ve kapanma performansını doğrudan etkileyen optimum yerleşim (layout) tasarımının önemini ele almaktadır. Araştırmada, bir tailgate'in operasyon davranışını belirleyen temel parametreler—ilk açma kuvveti, otomatik yükselme açısı, ilk kapama kuvveti, ters kuvvet ve otomatik düşüş açısı—ayrıntılı biçimde analiz edilmiştir. Çalışma, gazlı amortisör yerleşiminin yanlış tasarlanması hâlinde kullanıcı deneyiminin olumsuz etkilendiğini, kapak kontrolünün zorlaştığını ve hatta gövde bileşenlerinde deformasyon, çarpma ve korozyon gibi kalite problemlerinin ortaya çıktığını göstermektedir. Elde edilen sonuçlar, gazlı amortisör tasarımında doğru yerleşim ve kuvvet seçiminin mühendislik açıdan kritik olduğunu ve ergonomi, güvenlik ile araç algısını doğrudan etkilediğini ortaya koymaktadır (Cho ve Han, 2012).

Atalay ve Kılıç çalışmasında, bir mobil vinç kazasının kök nedenlerinin sistematik olarak belirlenmesi amacıyla Balık Kılçığı (Ishikawa) yöntemi kullanılmıştır. Araştırmada, kazanın tek bir nedenden değil; insan, makine, yönetimsel süreçler ve çevresel koşulların birleşiminden doğan çok boyutlu bir problem olduğu ortaya konmuştur. Yöntem, çeşitli faktörler arasındaki ilişkilerin görsel ve analitik biçimde değerlendirilmesini sağlayarak, karmaşık olayların anlaşılmasını kolaylaştırmıştır. Çalışmanın

bulguları, Balık Kılçığı yönteminin özellikle iş sağlığı ve güvenliği alanında, benzer kazaların önlenmesi için etkili bir kök neden analizi aracı olduğunu göstermektedir. Ayrıca yöntemin, süreçlerdeki belirsizlikleri azaltma, potansiyel riskleri görünür kılma ve iyileştirme çalışmalarına yön verme açısından önemli katkılar sağladığı vurgulanmıştır (Atalay ve Kılıç, 2015).

Taşlı'nın çalışmasında, M/T Independenta kazasına yönelik yapılan çalışmada Balık Kılçığı (Ishikawa) yöntemi, olayın kök nedenlerini sistematik biçimde belirlemek için uygulanmıştır. Analiz sonucunda kazanın; insan hatası, iletişim eksikliği, çevresel koşullar ve seyir güvenliğine ilişkin yetersizlikler gibi birden çok faktörün birleşimiyle ortaya çıktığı gösterilmiştir. Çalışma, Ishikawa yönteminin karmaşık kazaların neden–sonuç ilişkilerini ortaya çıkarmada etkili bir araç olduğunu vurgulamaktadır (Taşlı, 2024).

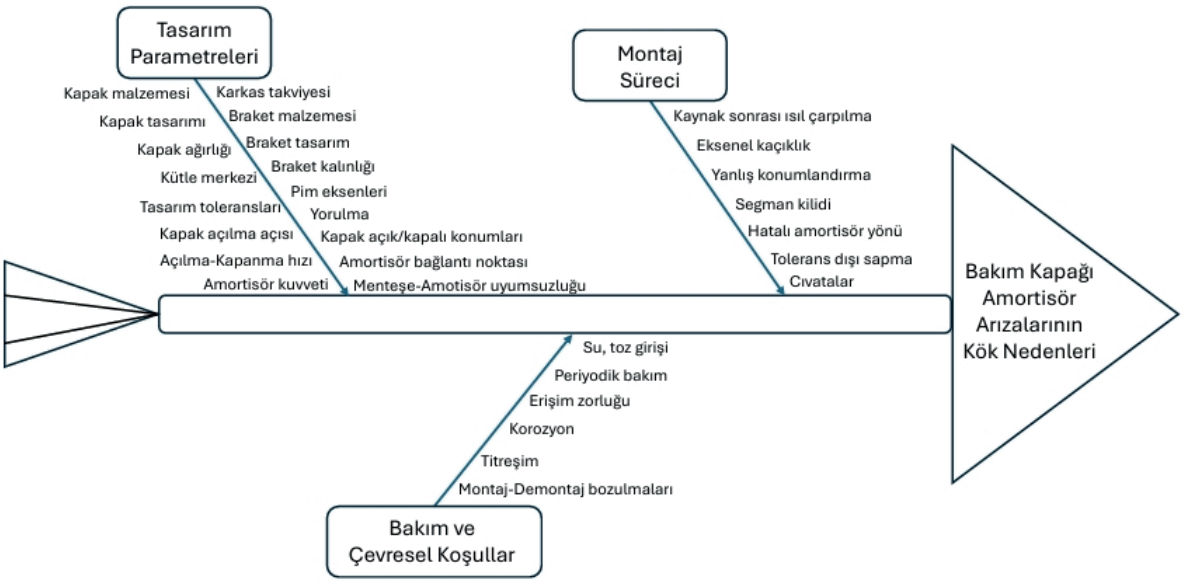
Özbakır'ın çalışmasında, Iğdır'da gerçekleşen bir hafriyat kazası Balık Kılçığı (Ishikawa) yöntemi kullanılarak analiz edilmiştir. Araştırmada, kazanın oluşumuna katkıda bulunan insan, ekipman, çevre, yöntem ve yönetimsel faktörler sistematik olarak incelenmiştir. Sonuçlar; yetersiz iş sağlığı ve güvenliği önlemleri, çalışan eğitimi eksikliği, iletişim kopukluğu, uygunsuz ekipman kullanımı ve çalışma alanının yanlış düzenlenmesi gibi nedenlerin kazanın temel kök nedenlerini oluşturduğunu göstermiştir. Çalışma, Balık Kılçığı yönteminin iş kazalarının analizinde etkili bir araç olduğunu ortaya koymakta ve proaktif güvenlik yönetimi açısından önemli bir referans sunmaktadır (Özbakır, 2024).

Uluskan ve Özyalıner çalışmasında, otomotiv yan sanayinde üretim sürecindeki hataları analiz ederek Kaizen yöntemiyle tesis yerleşimini iyileştirmiştir. Çalışmada iş akışı bozuklukları ve ergonomik riskler REBA yöntemiyle değerlendirilmiş; önerilen düzenlemeler sonucunda çevrim süresinde yaklaşık %25 iyileşme ve çalışma alanı veriminde %22 artış sağlanmıştır. Araştırma, Kaizen yaklaşımının otomotiv sektöründe hem kalite hem de iş sağlığı açısından etkili bir iyileştirme aracı olduğunu göstermektedir (Uluskan ve Özyalıner, 2021).

2. MATERYAL METOT

Bu çalışmada, şehir içi toplu taşıma araçlarında kullanılan bakım kapağı amortisörlerinde gözlemlenen düzensiz açılma–kapanma davranışlarının temel nedenlerini ortaya koymak amacıyla Balık Kılçığı (Ishikawa) diyagramına dayalı bir kök neden analizi gerçekleştirilmiştir. Kök nedenler, sistematik bir çerçeve sağlamak üzere üç ana kategoride incelenmiştir: Şekil 1'de Tasarım Parametreleri, Montaj Süreci ve Bakım/Çevresel Koşullar ve alt kırınımlar yer almaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 1. Bakım Kapağı Amortisör Arızalarının Kök Nedenleri

Tasarım Parametreleri kapsamında; kapak malzemesi, braket tasarımı, karkas takviyesi, pim eksenlerinin doğrultusu, braket kalınlığı, kütle merkezi ve kapak ağırlığı gibi yapısal bileşenlerin kapak rijitliğini doğrudan etkilediği belirlenmiştir. Ayrıca kapak açılma açısı, açık–kapalı konum toleransları, amortisör kuvveti, açılma–kapanma hızı ve amortisör bağlantı noktalarının konumlandırılması gibi geometrik ve kinematik değişkenlerin, amortisörün moment kolu üzerindeki etkisi nedeniyle kapak hareket karakteristiğini belirleyici nitelikte olduğu görülmüştür. Menteşe–amortisör uyumsuzluğu ise tasarım bütünlüğünü bozan kritik bir etken olarak ortaya çıkmıştır.

Montaj Süreci kategorisinde; kaynak işlemleri sonrasında oluşan ısıl çarpılmalar, eksenel kaçıklıklar, yanlış konumlandırma, tolerans dışı yerleşim hataları, segman kilidinin doğru uygulanmaması ve cıvata bağlantılarında gevşeme gibi montaj kaynaklı kusurların amortisörün yük aktarımını bozarak kapakta dengesiz kuvvet dağılımına yol açtığı tespit edilmiştir. Bu hataların özellikle amortisörün çalışma doğrultusunu etkileyerek açılma ve kapanma sırasında istenmeyen direnç, titreşim ve sürtünme artışına neden olduğu değerlendirilmiştir.

Bakım/Çevresel Koşullar kategorisinde ise su ve toz girişi, korozyon, erişimi zor bakım noktaları, periyodik bakım eksiklikleri, titreşim kaynaklı gevşemeler ve montaj–demontaj işlemlerinde oluşan yapısal bozulmaların amortisör performansını uzun vadede olumsuz etkilediği belirlenmiştir. Bu faktörlerin bağlantı elemanlarında gevşeme, braket deformasyonu ve amortisör karakteristiklerinde performans kaybı gibi sonuçlar doğurarak kapak davranışını zaman içerisinde kararsız hale getirdiği görülmüştür.

Elde edilen tüm bulgular, bakım kapağı amortisör arızalarının tasarım, montaj ve çevresel etkilerden kaynaklanan çok boyutlu bir problem olduğunu göstermektedir. Sunulan Balık Kılçığı diyagramı

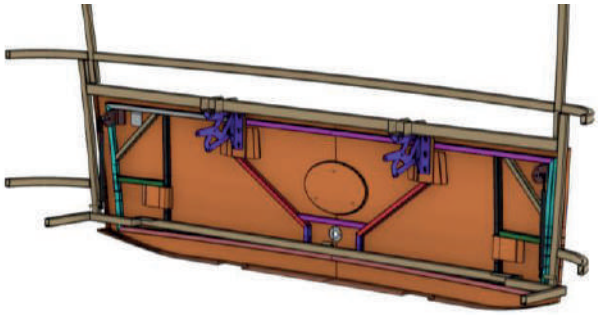
(Şekil 1), amortisör performansını etkileyen etkileşimli mekanizmaların bütüncül bir şekilde ortaya konmasını sağlamış olup, ilerleyen tasarım revizyonları, üretim süreçlerinin standardizasyonu ve bakım prosedürlerinin geliştirilmesi için kapsamlı bir mühendislik referansı niteliği taşımaktadır.

Bakım kapağı amortisör arızalarının kök nedenleri Balık Kılçığı (Ishikawa) yöntemi ile değerlendirildiğinde, sürecin başlangıç noktası olan tasarım aşamasının sistem performansını belirleyici nitelikte olduğu görülmektedir. Bu kapsamda, Şekil 2'de bakım kapağının kapalı konumu, Şekil 3'te ise açık konumu modellenmiş olup, her iki durumda da kapağın açılma–kapanma hareketini sağlayan temel bileşenin gazlı amortisör olduğu açıkça görülmektedir.

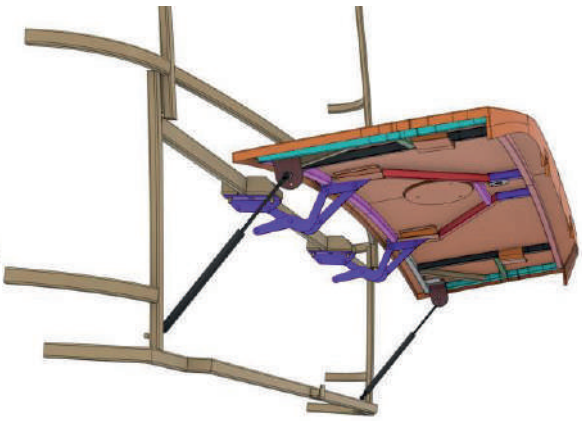
Amortisörün, kapağın güvenli ve kontrollü bir şekilde açılıp kapanmasını sağlaması; kapanma sonrasında tasarım geometrisini koruması, dışa doğru çıkıntı oluşturmaması ve kullanıcı açısından ergonomik bir kullanım ile iş güvenliği gerekliliklerini karşılaması beklenmektedir. Bu çerçevede sistem performansının doğru değerlendirilebilmesi için ilk olarak doğru gazlı amortisör kuvveti seçmek gerekmektedir. Bakım kapağı için seçilen gazlı amortisör kuvvetinin uygunluğunu belirlemek amacıyla kapak ağırlığı ve kütle merkezi konumu dikkate alınarak moment analizleri yapılmıştır. Kapak toplam ağırlığı, yaklaşık 20 kg olup bunun 12 kg'lık kısmını karkas, 8 kg'lık kısmını ise cam elyaf takviyeli kompozit (FRP) kapak oluşturmaktadır. Kullanılan FRP yapı için literatürde 1,55–1,60 g/cm³ yoğunluk aralığı yaygın olarak kabul edilmektedir (Gümüş, 2025). Bu değerler doğrultusunda, kapak açılmasını sağlayacak minimum moment ihtiyacını karşılamak üzere seçilen iki adet 200 N kapasiteli gazlı amortisörün, kapak kaldırma kuvvetini güvenli sınırlar içerisinde sağladığı hesaplanmıştır. Böylece amortisör kuvvetinin yetersizliği durumunun kapak davranışında gözlemlenen problemler arasında yer almadığı doğrulanmıştır.

Bir diğer kritik nokta ise gazlı amortisörün bağlandığı kapak braketinin incelenmesi gerekmektedir. Gazlı amortisörün braketi (Şekil 4) üzerinde oluşturduğu kuvvet bileşenlerinin, kapak açılma davranışını olumsuz etkileyip etkilemediği; braket ve kapak yapısında lokal gerilme artışına, geometrik deformasyona veya tasarım çizgisinden sapmalara yol açıp açmadığı, sonlu elemanlar analizi (FEM) yöntemiyle değerlendirilmiştir. Bu analizler doğrultusunda, amortisör ile kapak yapısı arasındaki etkileşimlerin mühendislik kriterleri açısından uygunluğu belirlenmiş ve sistem iyileştirme stratejilerinin oluşturulması için teknik yol haritası geliştirilmiştir.

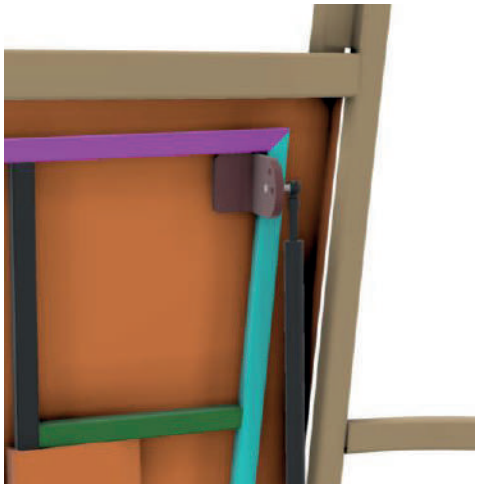
DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 2. Bakım kapağı kapalı konum



Şekil 3. Bakım kapağı açık konum



Şekil 4. Gazlı amortisör kapak bağlantı braketi

2.1. Sonlu Elemanlar Analizi FEM Metodolojisi

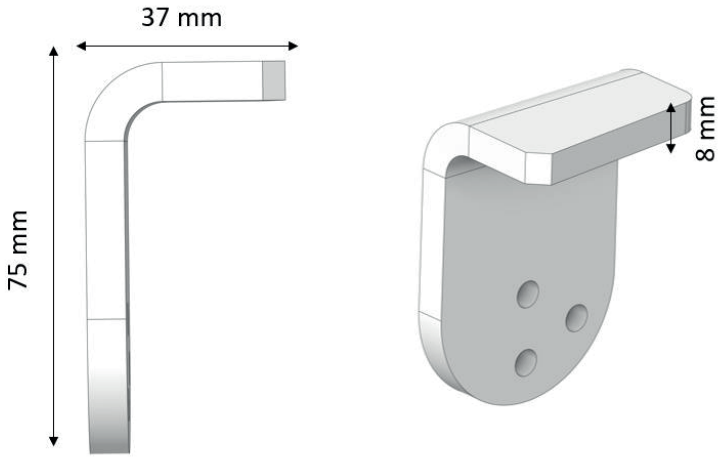
Bu çalışma kapsamında Ulaşım İç ve Dış Ticaret A.Ş. tarafından üretilen Ultra LF12 EV (Ulasim, 2025) model toplu taşıma aracında kullanılan bakım kapağı amortisör arızaları Balık Kılçığı yöntemi ile kök neden analizi yapılarak değerlendirilmiş ve tasarımın yapısal davranışı sonlu elemanlar yöntemi (FEM) ile analiz edilmiştir. Çalışmanın metodolojik adımları iki ana aşamadan oluşmaktadır: (i) Balık kılçığı temelli kök neden sınıflandırması ve (ii) yapısal performansın sonlu elemanlar analizi ile doğrulanması.

2.2.1. CAD Modeli ve Geometrik Tanımlamalar

Analizlerde kullanılan braket modeli, üretim verilerinden alınan üç boyutlu CAD modeli esas alınarak oluşturulmuştur. Model, analiz süresini optimize etmek amacıyla küçük radyuslar, montaj detayları ve fonksiyonel etkisi olmayan yüzey özellikleri sadeleştirilerek düzenlenmiştir. Brakete ait kritik

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

geometrik özellikler korunmuş ve mukavemet davranışını etkileyebilecek bölgelerde detay kaybı yapılmamıştır (Şekil 5).



Şekil 5. Gazlı amortisör kapak bağlantı braketin ölçüleri

2.2.2. Malzeme Özellikleri

Braket malzemesi imalat datasından doğrulanmış olup analizlerde ST37 çeliği tanımlanmıştır. Malzemeye ait elastik-plastik mekanik özellikler Tablo 1'de verilmiştir (Yüce, 2013).

Tablo 1. ST37 malzeme özellikleri

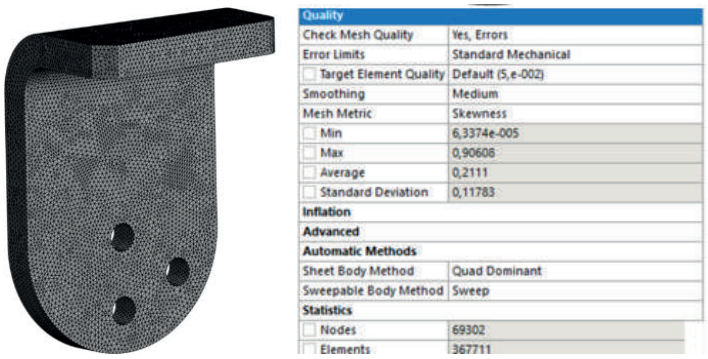
Özellik	**Değer**
Malzeme	ST37
Elastisite Modülü (E)	210 GPa
Poisson Oranı (ν)	0.3
Akma Gerilmesi (σ_γ)	255 MPa
Çekme Dayanımı	360 MPa
Yoğunluk	7850 kg/m³

2.2.3. Mesh Ağ Yapısı

Braket geometrisi, ANSYS Mechanical ortamında "Patch Conforming" yöntemi kullanılarak sonlu elemanlara bölünmüştür. Model üzerinde ağırlıklı olarak üçgensel yüzey elemanlarından türetilen

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

tetrahedral hacim elemanları oluşturulmuş, böylece karmaşık geometrilerde yüzey uyumunu koruyan yüksek kalite bir mesh elde edilmiştir. Kritik gerilme gradyanı beklenen bağlantı pimi çevresi ve eğrisel yüzeylerde eleman boyutu düşürülerek çözüm hassasiyeti artırılmış; daha az kritik bölgelerde ise hesaplama süresini azaltmak amacıyla daha geniş eleman boyutları tercih edilmiştir. Mesh kalitesi skewness metriği üzerinden değerlendirilmiş olup minimum 6.3×10^{-5}, maksimum 0.906 ve ortalama 0.2111 değerleri ile kabul edilebilir aralıklarda sonuçlanmıştır. Son durumda model 69,302 düğüm ve 367,711 tetrahedral elemandan oluşmaktadır. Braketin sonlu elemanlar ağ yapısı ve kalite istatistikleri Şekil 6'te sunulmuştur.



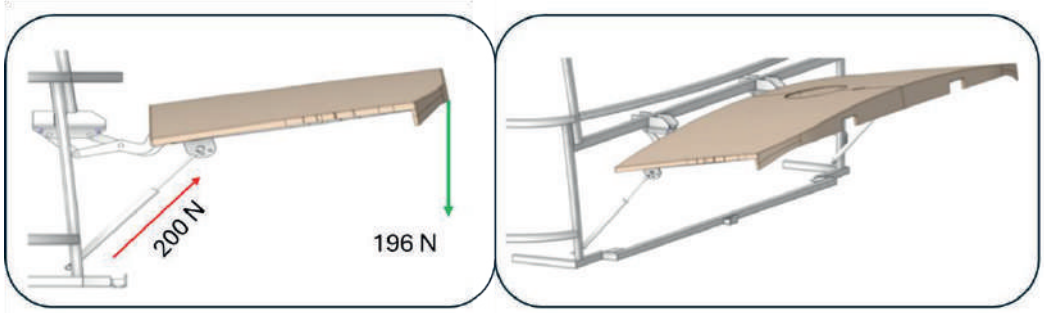
Quality	
Check Mesh Quality	Yes, Errors
Error Limits	Standard Mechanical
Target Element Quality	Default (5,e-002)
Smoothing	Medium
Mesh Metric	Skewness
Min	6,3374e-005
Max	0,90608
Average	0,2111
Standard Deviation	0,11783
Inflation	
Advanced	
Automatic Methods	
Sheet Body Method	Quad Dominant
Sweepable Body Method	Sweep
Statistics	
Nodes	69302
Elements	367711

Şekil 6. Sonlu Elemanlar Ağ Yapısı

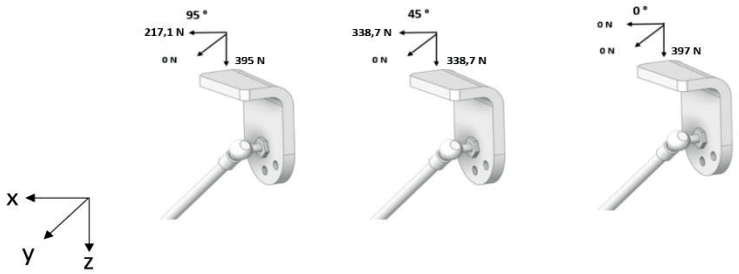
2.2.4. Sınır Şartları ve Yükleme Durumu

Sınır şartları aşağıdaki koşullara göre ayarlanmıştır.

1. Kapağın açıldığı max konumun açısı: 95°
2. Ara değer açısı: 45°
3. Kapağın kapalı konumunun açısı 0° (Şekil 7).
4. Gazlı amortisör kuvveti: 200 Newton
5. Kapak Kütlesi 20kg = 196,12 kg



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Şekil 7. Sınır şartları ve yükleme durumu

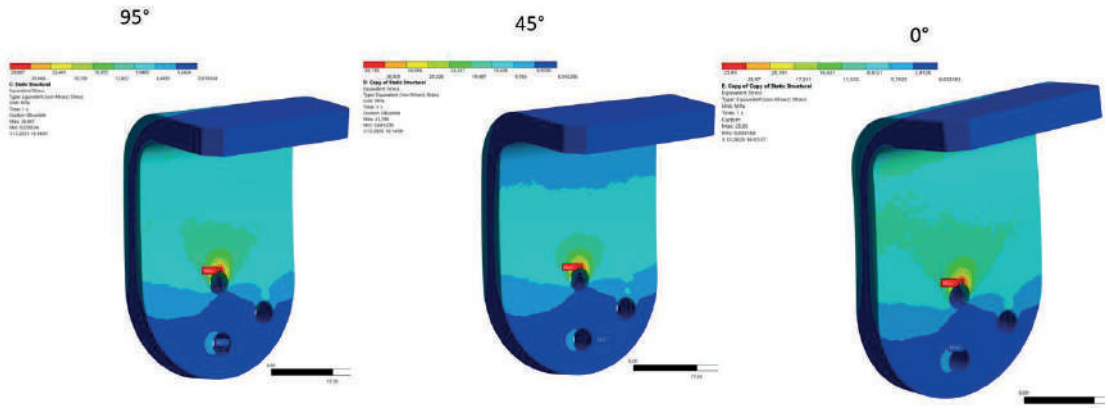
3. BULGULAR

Bu çalışmada, Ultra LF12 EV model toplu taşıma aracında kullanılan gazlı amortisör kapak bağlantı braketine ait sonlu elemanlar analizi, bakım ve servis sırasında kapak açılma konumu ile ilişkili farklı yükleme açılarında gerçekleştirilmiştir. Braket üzerinde oluşan gerilme davranışlarının belirlenmesi amacıyla 20 kg'lık kapak kütlesi (*karkas ağırlığı 12 kg, frp kapak ağırlığı 8 kg*), bağlantı yönünü temsil eden eksen boyunca üç farklı açıda ve piston kapanma kuvveti 200 N toplanarak uygulanmıştır. Yükleme açıları; 0°, 45° ve mühendislik açısından kritik değerlendirme için seçilen 95° konumlarıdır. Bu yaklaşım ile braketin hem normal hem de kesme yönlü bileşenlere maruz kaldığı koşullar altında taşıma performansı değerlendirilmiştir.

Analiz sonuçları incelendiğinde, gerilme dağılımının özellikle bağlantı pimi çevresinde ve yük aktarma yüzeylerinde yoğunlaştığı görülmüştür. Bu bölgelerde beklenen şekilde kesme gerilmeleri baskın olmuş, ancak gerilme yığılmalarının malzemenin akma sınırının altında gerçekleştiği belirlenmiştir. Yapısal deformasyonların ise belirgin şekilde elastik sınırlar içerisinde kaldığı ve yük kaldırıldığında geometrinin ilk haline döndüğü gözlemlenmiştir.

Uygulanan üç farklı yükleme senaryosu sonucunda elde edilen maksimum Von-Mises gerilme değerleri; 45° yükleme açısında 102.71 MPa, 95° yükleme açısında 31.27 MPa ve 0° yükleme açısında 51 MPa olarak hesaplanmıştır. Bu değerlere karşılık gelen emniyet katsayıları ise sırasıyla 2.43, 7.99 ve 4.90 olarak belirlenmiştir. Analiz sonuçları Tablo 2'de özetlenmiş olup maksimum gerilme dağılımları Şekil 8'de sunulmuştur.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 8. Üç farklı açı korelasyonu için gerilme dağılımı

Tablo 2. Üç farklı açı korelasyonu için gerilme ve emniyet katsayısı değişimi

Yükleme Açısı (°)	Maksimum Gerilme (MPa)	Emniyet Katsayısı
45°	102.71 MPa	2.43
95°	31.27 MPa	7.99
0°	51 MPa	4.90

Elde edilen sonuçlar, üç yükleme koşulunda da braketin akma gerilmesi sınırının altında kaldığını ve tasarımın güvenli çalışma aralığında olduğunu göstermektedir. Ayrıca mühendislik açısından en kritik yükleme açısı olarak değerlendirilen 45° senaryosu, yapısal davranışı en fazla zorlayan durum olmasına rağmen braket üzerinde herhangi bir plastik deformasyon, yerel göçme eğilimi veya yorulma başlangıcına işaret eden bir bölgesel yoğunlaşma oluşturmadığı görülmüştür.

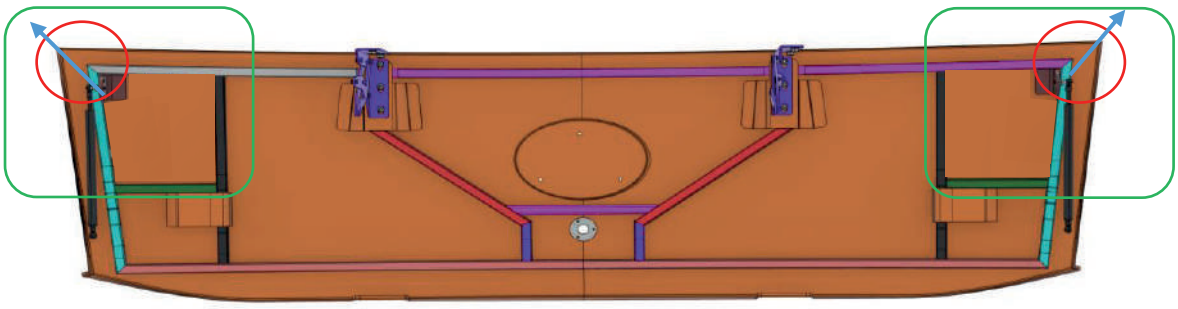
Bu doğrultuda, analiz bulguları gazlı amortisör kapak bağlantı braketinin mevcut geometrisi ve malzeme özellikleriyle operasyonel koşullara uygun olduğunu, tasarımın ek yapısal güçlendirmeye ihtiyaç duymadığını ve braketin hem normal hem de açısal yük transferlerinde güvenli performans sergilediğini ortaya koymaktadır.

Yapılan incelemeler sonucunda, gazlı amortisörün kapak bağlantı braketine farklı açılardan uyguladığı yüklemelerde kritik bir yapısal risk oluşmadığı belirlenmiştir. Mevcut tasarımda kullanılan 200 N kapasiteli gazlı amortisörün, kapak açılma–kapanma hızını hedeflenen sınırlar içerisinde sağladığı tespit edilmiştir. Bununla birlikte, amortisörün kapalı konumdayken uyguladığı kuvvet doğrultusunun, fiber takviyeli kapak üzerinde noktasal gerilmeye sebep olduğu görülmüştür.

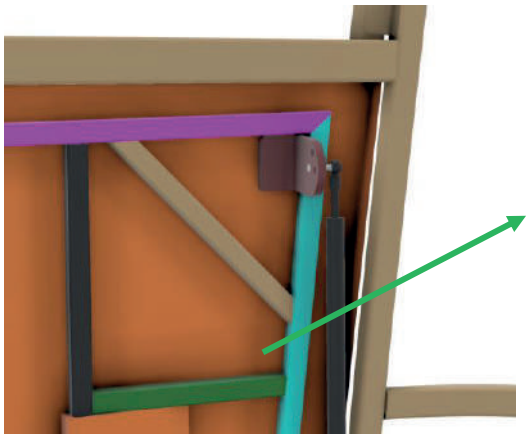
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Fiber malzemenin esnek davranış karakteristiği nedeniyle, amortisör bağlantı braketinin kapak karkasına aktardığı kuvvet, kapağın üst kenar uçlarında dışa doğru deformasyon oluşturmaktadır. Deformasyon oluşan bölgeler ve yönü Şekil 9'da gösterilmektedir. Bu durum, kapak tam kapalı pozisyondayken dış yüzeyde tasarım çizgisinden sapma meydana getirerek hem görsel kalite hem de uzun dönem dayanım açısından istenmeyen sonuçlar doğurmaktadır.

Analiz sonuçları doğrultusunda, kapakta kullanılan karkas yapısının güçlendirilmesi ve yerel rijitliğin artırılması gerekliliği tespit edilmiştir.



Şekil 9'da yeşil renk ile gösterilen bölgelerde, FRP kapakta üst köşe noktalarında yerel rijitlik ihtiyacının ortaya çıktığı belirlenmiş olup, bu bölgelerde karkas güçlendirme tasarımı öngörülmüştür. Her iki köşe için de geçerli olacak bu iyileştirme kapsamında, Şekil 10'da yeşil renkli ok ile gösterildiği üzere, 20×20 mm kesitli çelik profil, mevcut karkas sisteminde mor ve mavi renklerle belirtilen 20×20 mm profillere çapraz takviye elemanı olarak bağlanmıştır. Bu bağlantı kaynaklı bir yöntemle gerçekleştirilecek ve ilgili profil kapak iç yüzeyine montajlanmıştır.



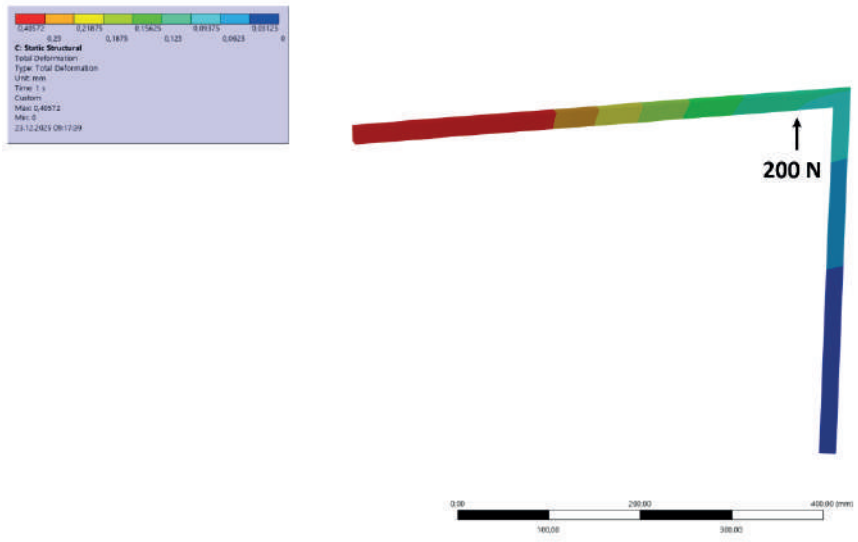
Şekil 10. Karkas ile güçlendirilmiş frp kapak – yeni durum

Karkas güçlendirme tasarımının, kapak davranışına etkisini mühendislik olarak doğrulamak amacıyla ek bir sonlu elemanlar analizi gerçekleştirilmiştir (Şekil 11 ve 12). Bu analizde Şekil 9 da yer alan yeşil bölge ile sınırlandırılmıştır:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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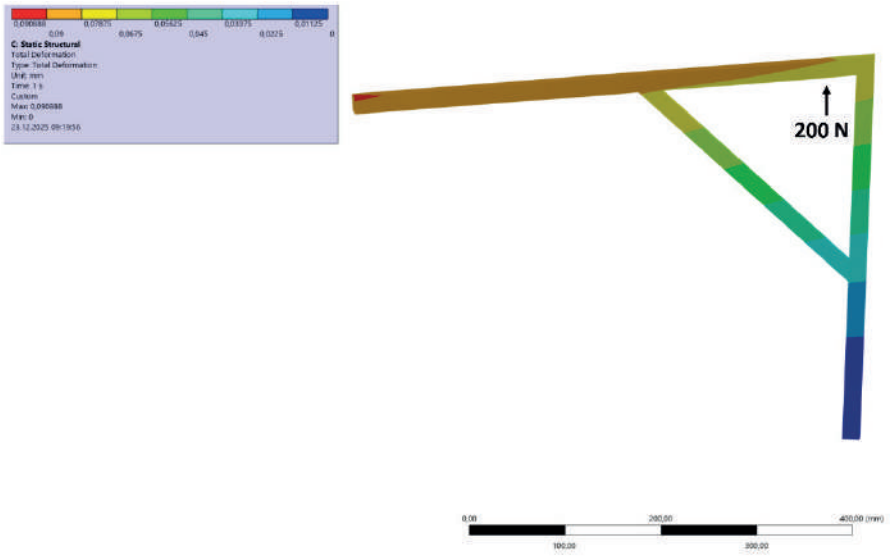
- Karkas takviyesi eklenmiş ve eklenmemiş iki model karşılaştırmalı olarak değerlendirilmiştir.
- Kapak uç bölgelerindeki maksimum deplasman ve yerel gerilme dağılımları karşılaştırılmıştır.

Yapıya eklenen çapraz takviye elemanının düşey rijitlik üzerindeki etkisini belirlemek amacıyla, gazlı amortisörün kapak braketine ilettiği kuvveti temsil edecek şekilde amortisör bağlantı noktasına 200 N büyüklüğünde yukarı yönlü statik yük uygulanmıştır. Çapraz elemanın bulunmadığı referans durumda, braket bağlantısına yakın bölgedeki serbest uçta maksimum deplasman 0,405 mm olarak elde edilmiştir. Bu sonuç, sistemin eğilme kontrollü davrandığını ve köşe birleşiminin dönmeye yatkın bir yapı sergilediğini göstermektedir. Çapraz elemanın eklenmesiyle gerçekleştirilen analizde ise aynı yükleme koşullarında maksimum deplasmanın 0,090 mm seviyesine gerilediği görülmüştür. Buna karşılık, aynı yük altında eşdeğer düşey rijitlik ($k = F/\delta$) deplasmanla ters orantılı olduğundan, rijitlik oranı 0,405/0,090 = 4,50 olarak hesaplanmış; bu da sistemin düşey rijitliğinin yaklaşık 4,50 katına çıktığını ve %350 düzeyinde arttığını ortaya koymuştur. (Aynı zamanda maksimum deplasman %77,8 oranında azalmıştır.) Söz konusu iyileşme, yük aktarım mekanizmasının yalnızca üst kiriş üzerinde yoğunlaşan eğilme etkisinden çıkarak üçgen taşıyıcı sistem karakterine dönüştüğünü; böylece kuvvetin çapraz eleman ve düşey taşıyıcı üzerinden daha geniş bir alana dağıtılarak karkas yapısına daha etkin biçimde iletildiğini göstermektedir.



Şekil 11. Karkas Eski Durum

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 12. Karkas Yeni Durum

Bu çapraz takviye uygulaması sayesinde, kapak kapalı pozisyondayken gazlı amortisörden gelen kuvvetin tek bir noktada yoğunlaşarak FRP kapak yüzeyinde deformasyon oluşturması engellenmiş olacaktır. Kuvvet, güçlendirilmiş karkas yapısı boyunca daha geniş bir alana dağıtılacak; böylece bağlantı bölgesinin yapısal dayanımı artırılacak, tasarım çizgisi korunacak ve uzun vadede yorulma kaynaklı deformasyon riskleri azaltılmış olacaktır.

4. SONUÇLAR ve TARTIŞMALAR

Bu çalışmada, şehir içi toplu taşıma araçlarında kullanılan motor bakım kapağında gözlemlenen açılma–kapanma düzensizlikleri, Balık Kılçığı (Ishikawa) yöntemi ile sistematik olarak değerlendirilmiş ve belirlenen kök nedenlerin yapısal performansa etkileri sonlu elemanlar analizi (FEM) ile detaylı biçimde doğrulanmıştır. Analizler sonucunda, amortisör kaynaklı problemlerin yalnızca yanlış kuvvet seçimine indirgenemeyecek kadar çok boyutlu bir mühendislik problemi olduğu ortaya bileşenlerin, FRP kapak üst köşe bölgelerinde yerel rijitlik yetersizliği nedeniyle dışa yönlü deformasyona sebep olduğu belirlenmiştir. Bu deformasyon hem tasarım çizgisinden sapma hem de uzun dönem yorulma riski açısından kritik bir problem teşkil etmektedir.

Braket için gerçekleştirilen FEM analizinde, 45° yükleme senaryosunda 102.71 MPa seviyesinde maksimum Von-Mises gerilmesi elde edilmiş olup, tüm yük koşullarında emniyet katsayısının güvenli sınırlar içinde kaldığı belirlenmiştir. Bu durum, brakette yapısal bir güvenlik problemi bulunmadığını, asıl zayıflığın kuvvet aktarımının kapak yüzeyindeki sınırlı bir bölgeye yoğunlaşmasından kaynaklandığını göstermektedir.

Bu kapsamda geliştirilen 20×20 mm kesitli çelik çapraz profil ile uygulanan karkas güçlendirme çözümü, yapının yük taşıma mekanizmasını kökten değiştirerek belirgin bir rijitlik kazanımı

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sağlamıştır. Gazlı amortisör yükünü temsil eden 200 N yukarı yönlü statik yük altında, çapraz elemanın bulunmadığı referans durumda serbest uçta 0,405 mm maksimum deplasman elde edilirken; çapraz eleman ilavesi ile deplasman 0,090 mm seviyesine düşmüştür. Aynı yük altında eşdeğer düşey rijitlik $k = F/\delta$ bağıntısı ile tanımlandığından, deplasmandaki bu azalma rijitliğin ters orantılı olarak artmasına neden olmuş ve rijitlik oranı $k_2/k_1 = 0{,}405/0{,}090 = 4{,}50$ olarak hesaplanmıştır (yaklaşık %350 rijitlik artışı). Bu iyileşme; köşe birleşimdeki dönme serbestliğinin kısıtlanması, üst kirişte baskın olan eğilme momentinin azaltılması ve sistemin üçgenleme (triangulation) etkisi ile aksiyal kuvvet taşıyan bir kafes/üçgen taşıyıcı davranışa evrilmesi sayesinde gerçekleşmiştir. Böylece amortisör kuvveti, yalnızca üst kirişte lokal eğilme ve şekil değiştirme üretmek yerine, çapraz eleman üzerinden çekme/basma eksenel yük yolu oluşturarak düşey taşıyıcı ve ana karkasa daha homojen aktarılmış; sonuç olarak kapak bölgesinde oluşabilecek yerel deformasyon ve buna bağlı yapısal kararsızlık (lokal burkulma/gevşeklik kaynaklı oynama) riski anlamlı ölçüde azaltılmıştır.

Genel değerlendirme sonucunda çalışma;

- Amortisör kuvvetinin doğru seçilmesinin tek başına yeterli olmadığını, bağlantı geometrisinin ve kapak rijitliğinin aynı anda optimize edilmesi gerektiğini,
- Montaj toleransları ve bakım koşullarının kapak davranışını uzun vadede ciddi ölçüde etkilediğini,
- Balık Kılçığı yönteminin tasarımdaki görünmeyen ilişkileri ortaya çıkaran etkin bir mühendislik aracı olduğunu,
- FEM doğrulamasının ise önerilen tasarım değişikliklerinin performans etkisini nesnel olarak kanıtladığını ortaya koymuştur.

Sonuç olarak bu çalışma, amortisörlü kapak tasarımlarında sistematik kök neden analizi + yapısal doğrulama yaklaşımının birlikte kullanılması gerektiğini göstermekte ve benzer kapak sistemlerinin geliştirilmesinde genişletilebilir bir mühendislik metodolojisi sunmaktadır.

KAYNAKÇA

Ulaşım İç ve Dış Ticaret A.Ş. (2025). Akia 2025. Ulaşım İç ve Dış Ticaret A.Ş. https://www.ulasim-as.com/tr/ Erişim Tarihi: [10.11.2025]

Ishikawa, K. (1986). Guide to Quality Control (2nd ed.). Asian Productivity Organization.

Zhang, W., & Xu, J. (2022). Advanced lightweight materials for automobiles: A review. Materials & Design, 221, 110994. https://doi.org/10.1016/j.matdes.2022.110994

Akın, B. (1996). İşletmelerde istatistik proses kontrol –ipk- teknikleri. İstanbul: Bilim Teknik Yayınevi.

Erbaş, A. & Kolak, F. (2015). Toplam kalite yönetiminin muhasebe eğitimine uygulanması. Dumlupınar Üniversitesi Sosyal Bilimler Dergisi, (23),. Retrieved from

http://dergipark.gov.tr/dpusbe/issue/4765/65509

Atalay, O. & Kılıç, Ö. (2015). Balık kılçığı yöntemi ile mobil vinç kazası olası nedenlerinin incelenmesi. Çukurova Üniversitesi Mühendislik-Mimarlık Fakültesi Dergisi, 30 (1), 73-78. DOI: 10.21605/cukurovaummfd.242808

Çavuş, Ş., Tam öğrenme modeline dayalı hazırlanan "bilinçli tüketici aritmetiği" ders planlarının öğrencilerin akademik başarısına etkisi ve bu etkinin balık kılçığı tekniğiyle irdelenmesi. Bartın Üniversitesi, Lisansüstü Eğitim Enstitüsü, Eğitim Bilimleri Anabilim Dalı, Eğitim Programları ve Öğretim Bilim Dalı, Bartın, 2020.

Yüce, C., Yeni Nesil Ticari Araçlar İçin Hafifletilmiş Yolcu Koltuğu Tasarımı ve Prototip İmalatı, Yüksek Lisans Tezi, Uludağ Üniversitesi, Fen Bilimleri Enstitüsü, Bursa, 2013.

Gümüş, F. (2025). *Kompozit malzeme ile otobüs koltuk braketlerinin üretimi ve sonlu elemanlar yöntemi ile mekanik analizi* (Yüksek lisans tezi). Bursa Uludağ Üniversitesi, Fen Bilimleri Enstitüsü, Makine Mühendisliği ABD.

Över Özçelik, T., & Cinoğlu, F. (2013). Yalın felsefe ve bir otomotiv yan sanayi uygulaması. İstanbul Ticaret Üniversitesi Fen Bilimleri Dergisi, 12(23), 79–101.

Yavuz, Ş., Gür, B. & Seder, M. (2021). "5x5 Matris Risk Değerlendirmesi Yöntemi İle Otomotiv Parçası Üretimi Yapan Bir İşletmenin İncelenmesi" International Social Sciences Studies Journal, (e-ISSN:2587-1587) Vol:7, Issue:86; pp:3457-3464. http://dx.doi.org/10.26449/sssj.3421

Cho, Y. H., & Han, B. K. (2012). Study of an optimized gas strut layout to improve opening and closing quality. International Journal of Automotive Technology, 13(6), 999–1004. https://doi.org/10.1007/s12239-012-0102-8.

Gümüş, F., & Aktürk, V. (2024). Bir otobüs akü kızağının hafifletilmesine yönelik sonlu elemanlar analiz çalışması. 18th Internatıonal Istanbul Scientific Research Congress On Life, Engineering, Architecture, And Mathematical Sciences, 664 677. https://doi.org/10.5281/zenodo.13378762.

Atalay, O., & Kılıç, Ö. (2015). Balık kılçığı yöntemi ile mobil vinç kazası olası nedenlerinin incelenmesi. Çukurova Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 30(1), 73–78.

Taşlı, B. (2024). İstanbul Boğazı Faciası M/T Independenta Kazasının Balık Kılçığı Yöntemiyle Kök Neden Analizi. Denizcilik Araştırmaları Dergisi: Amfora, 3(5), 19–27.

Özbakır, O. (2024). Identifying causes of accidents and enhancing safety using the fishbone method: An application in excavation. Kahramanmaraş Sütçü İmam University Social Sciences Journal, 21(2), 972–982.

Uluskan, M., & Özyalıner, M. T. (2021). Otomotiv sektöründe Kaizen yöntemi ile tesis yerleşim tasarımı ve REBA analizi. ESOGÜ Mühendislik ve Mimarlık Fakültesi Dergisi, 29(1), 1–19.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

UHPC AND UHPRC IN CIVIL ENGINEERING

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ABSTRACT

Ultra High-Performance Concrete (UHPC) and Ultra High-Performance Fiber-Reinforced Concrete (UHPFRC) bring to innovations to civil engineering. They show advanced mechanical properties compared to usual concrete. UHPC has stands out with its 250-250Mpa compressive strength and UHPFRC has 200MPa. UHPC has low absorbency and high strength. UHPFRC differs from conventional concrete due to its high binder dosage and low water/binder ratio, and can be enriched with industrial waste (fly ash, slag) for sustainability purposes. Accordingly, a thorough review of recent advancements in Ultra High Performance Concrete (UHPC) is essential to clarify material testing requirements and methodologies, as well as to support the broader implementation of UHPC in practical applications When steel fibers are added to UHPC, its tensile and flexural strength increases. This increase in capacity allows for versatile applications of UHPC. UHPC can be used in various fields. For example, it is used in bridges, high-rise buildings, and seismic strengthening. This extends the lifespan of bridges and high-rise buildings and reduces maintenance costs. The accuracy of these statements is confirmed by a synthesis of literature, experimental data, ASTM tests, and finite element analysis (FEA) simulations. The potential of Türkiye in reconstruction has emphasized. The study also discussed economic and employment barriers.

Keywords: UHPC, UHPCRC, ultra-high-performance concrete

INTRODUCTION

Technological advancements and the use of various additives have brought High-Performance Concrete (UHPC) and its fiber-reinforced derivatives (especially steel fiber-reinforced UHPCC) to new dimensions in civil engineering. Research has shown that the use of conventional concrete, particularly in our country which is prone to earthquakes, results in insufficient strength, ductility, and load-carrying capacity. Graybeal (2011) demonstrated in his study that conventional concrete struggles to exceed 60 MPa. Analysis of the study results showed that this leads to insufficient strength, ductility, and load-carrying capacity in earthquakes or challenging environments.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

On the other hand, the study found that when dense packing was applied to UHPC, it reached a value exceeding 150 MPa. Richard & Cheyrezy (1995) showed in their study that UHPC reached 150 MPa when cement, silica fume, quartz powder, and superplasticizers were used. Variants like UHPC/UHPCRC have increased tensile strength to 20 MPa with steel fibers and improved the behavior of concrete after cracking. This study will examine existing case studies and consider experimental data. Thus, the study aims to investigate the properties, production, and applications of UHPC/UHPCRC.

Prefabricated building elements constitute an important application area for UHPC due to its ability to produce thin-section and lightweight structural elements. The use of UHPC/UHFPRC in facade panels, shell elements, stairs, and architectural concrete products provides high strength and long service life along with aesthetic design flexibility. In prefabricated production, its high early strength also increases production efficiency.

Repair and strengthening works are among the areas where UHPC/UHFPRC can be effectively applied thanks to its high adhesion and low shrinkage properties. Thin UHPC/UHFPRC layers can be used for strengthening purposes in columns, beams (Kennedy, Habel and Fraser, 2015; Li et al., 2020a) and slabs of existing reinforced concrete structures, and it also offers long-lasting solutions in the rehabilitation of damaged bridge elements. Industrial and special engineering structures prefer UHPC/UHFPRC due to its high resistance to abrasion, impact, and chemical effects. Industrial floors, defence structures, elements requiring blast and impact resistance, and nuclear and energy structures are among the specific application areas where UHPC/UHFPRC is used.

UHPC and UHPFRC/UHPRC have become key materials for robust infrastructure in bridge and seismic engineering. Initial reactive powder concretes targeted 150 MPa+ with dense packing without coarse aggregates, forming the basis of modern UHPC (Richard & Cheyrezy, 1995). Novel studies are reducing clinker and adding alternative binders for sustainability (Piro, 2025). In parallel, steel fiber innovations – geometry, surface treatment, volume ratio – have improved tensile ductility, crack control, and energy absorption. Optimized fiber UHPCs manage micro/macro cracks through fiber bridging (Dingqiang et al., 2021; Yoo, Banthia & Yoon, 2024). They have proven effective at the structural scale in bridges with long span decks, joints, and cast-in-place connections (Benjamin et al., 2020; Graybeal, 2011). In seismic design, UHPC columns are ahead of conventional concrete in ductility and damage control (Wakjira & Alam, 2024). Beyond casting, they integrate with 3D concrete printers, cutting material waste and time into complex shapes (Batikha et al., 2022). Lii (2003) stated that ECC resulted in a different application to the hardening phenomenon with adjustments at the micromechanical level. This study examines how particles come together and how the entire structure reacts. Teoh et al. (2026) and Yang et al. (2026) have conducted studies to clarify these connections. In the literature, there are studies showing that UHPC and UHPRC perform better than older methods, especially after earthquake disasters in Türkiye, through comparisons. Using

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

UHPC and UHPRC allows for safer, faster construction of structures and is environmentally friendly. Kurtoğlu, Mehdizade, and Bakar (2025) examined the properties and uses of UHPC and UHPRC in their study.

This study synthesizes material science principles, structural engineering applications, sustainability considerations, and computational modeling approaches to provide a comprehensive framework for the practical implementation of UHPC and UHPFRC in modern civil engineering.

MATERIALS AND METHODS

This study includes a detailed analysis of numerical modelling approaches and real-world application examples from experimental studies. The study compares UHPC/UHPFRC with conventional concrete and presents the conceptual framework of UHPC/UHPFRC for structural applications.

This study brings together materials science, structural problems, digital manufacturing methods, and the entire computer aspect. Thus, this study offers a framework that should be useful in real life. Firstly, Richard & Cheyrezy (1995), Wille et al. (2011), and Matiushin et al. (2024) suggested that the concepts of UHPC and UHPRC mixes, based on dense particle packing theory, eliminating coarse aggregates, and simplifying them for practical production based on reactive powder concretes. Piro (2025) analysed the effects of additional cementitious materials, recycled components, and low clinker brick on fluidity, strength, and durability. Structural-scale behavior was assessed through performance-based seismic design case studies for UHPC bridge columns and field-cast UHPC connections (Benjamin et al., 2020; Wakjira & Alam, 2024).

Advanced computational tools were incorporated into the methodology. Machine-learnning models were employed to correlate mixture proportions and curing conditions with mechanical and durability outcomes, while meso-scale discrete elements models simulated crack initiation and propagation under uniaxial and flexural loading conditions (Teoh et al. 20206; Yang et al. 2026). Comparative evaluation with conventional systems was conducted using performance indicators such as comprehensive strength, tensile/flexural behavior, permeability, and life-cycle efficiency.

RESULTS

This is a technical infographic describing Ultra-High-Performance Concrete (UHPC) technology and its role in modern urban infrastructure (Figure 1).

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Figure1. Comparision of UHPC and /UHPFRC

The central bridge and dense skyscraper silhouette highlight the use of this material, particularly in long-span bridges, high-rise buildings, and load-bearing systems requiring high strength. The representations of the concrete mixer, cement components, and steel fibers demonstrate that UHPC differs from conventional concrete in its special mix design and steel fiber reinforcement. These fibers provide the material with high compressive and tensile strength, ensure crack control, and significantly increase durability. Thanks to its low permeability and corrosion resistance, UHPC stands out as an innovative engineering material preferred in bridge decks, prefabricated elements, marine structures, and long-lasting infrastructure projects. The overall composition elevates concrete from an ordinary building material to a high-tech product and a fundamental component of the resilient cities of the future.

Mixing parameters were water/binder ratio, binder type, aggregate volume, steel fiber ratio, aspect ratio, and surface properties. Dingqiang et al. (2021) and Yoo et al. (2024) showed that all these parameters were all enhanced and actual from UHPC fiber composites within the suggested selections. The second stage meets sustainability: using surface response methods. Graybeal, (2011) suggested that performance indicators include compressive strength, bending/tensile behavior, and permeability metrics– suitable for bridge and earthquake applications (Benjamin et al., 2020). Third, structural-scale behavior investigated through performance-based seismic design examples for UHPC bridge columns and through case studies on field-cast UHPC joints and decks, using published design procedures and test data (Wakjira & Alam, 2024; Benjamin et al., 2020).

Finally, the methods incorporate advanced computational tools: machine-learning models used to map mix composition and curing conditions to mechanical and durability outcomes, while discrete element meso-scale models simulate crack initiation and propagation under uniaxial and flexural loading (Teoh et al., 2026; Yang et al.,(2026). Comparative assessment with conventional technologies and modular construction strategies conducted using criteria derived from post-disaster reconstruction studies (Kurtoğlu et al., 2025) and from 3D concrete printing benchmarks for economic and environmental performance (Batikha et al., 2022).

The synthesized results are clear: UHPC and UHPRC blends remain sufficiently fluid for both casting and digital fabrication when maintaining a compressive strength of 150-200 MPa. Dense packing and

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aggregate ratios reduce porosity in UHPC and UHPRC, particularly due to chloride leaching, freeze-thaw resistance, and long-term hardness (Matiushin et al., 2024; Piro, 2025). Adding advanced steel fibers (such as surface-treated, high-strength plain fibers) dramatically increases tensile strength, ductility, and post-cracking energy absorption; the hardening behavior of UHPFRC becomes similar to that of ECC systems (Dingqiang et al., 2021; Li, 2003; Yoo et al., 2024). Structural-level international bridge projects demonstrate that UHPC additions, deck panels, and prefabricated on-site cast connections extend service life and improve usability compared to conventional high-performance concrete (Graybeal, 2011; Benjamin et al., 2020). In seismic design examples, UHPC bridge columns reduce residual shear and localize damage – thus, they are a superior material for critical infrastructure in high-risk earthquake zones (Wakjira & Alam, 2024). Case studies on 3D printed UHPC-like systems indicate potential reductions in material consumption and construction time, if printing parameters and rheology calibrated to maintain structural integrity (Batikha et al., 2022). Machine-learning and **meso-**scale DEM models reproduce experimentally observed stress–strain and load–deflection responses with good accuracy, highlighting the feasibility of data-driven design tools for next-generation UHPC and UHPRC applications (Teoh et al., 2026; Yang et al., 2026).

DISCUSSION

The results underscore UHPC and UHPCRC's superior mechanical properties, driven by optimized gradation and UHPC and UHPCRC truly excel in mechanical properties, as clearly demonstrated. This is due to optimized aggregates and the fiber bridging effect – which prevents **micro cracks** (Wille et al., 2011). UHPCRC increases flexural strength, allowing for thinner bridge designs, reducing material usage by 30-50%, as seen in the Mars Hill Bridge (Graybeal, 2011). However, its cost is 2-3 times higher than HSC, and because it requires special mixing and steam curing, it hasn't become widespread enough.

UHPC has 3-5 times higher compressive strength than conventional concrete and exhibits better work hardening behavior under tensile loading (Seibert et al., 2019; Ismail, Hassan and Lachemi, 2018). UHPC and UHPCRC should be viewed as a broader family: engineered cement-based materials. The microstructure, fiber arrangement, and structural details are designed together to achieve the target performance under multiple loads. Compared to ordinary concrete, UHPC and UHPCRC are much stronger, more ductile, and more durable, but their design and quality control are more complex (Kurtoğlu et al., 2025). When combined with modular systems or 3D printers, reconstruction can be accelerated and lifetime environmental impact can be reduced (Batikha et al., 2022; Piro, 2025). Advances in dense matrix design, innovative steel fibers, and sustainability-oriented optimization have enabled concrete systems with remarkably high strength, ductility, and durability, suitable for critical bridge and seismic applications (Richard & Cheyrezy, 1995; Wille et al., 2011; Dingqiang et al., 2021; Yoo et al., 2024; Piro, 2025). International practice and recent performance-based seismic studies confirm that these materials can significantly enhance the resilience and service life of infrastructure, particularly in disaster-prone regions (Graybeal, 2011; Benjamin et al., 2020; Wakjira & Alam, 2024; Kurtoğlu et al., 2025).

Future research should focus on expanding experimental databases for region-specific materials, integrating UHPC and UHPRC with modular and 3D printed construction systems, and further developing explainable machine-learning and meso-scale models to support design and code development (Batikha et al., 2022; Li, 2003; Teoh et al., 2026; Yang et al., 2026; Matiushin et al., 2024). Future work should explore recycled aggregates and 3D-printing scalability for broader adoption.

The optimization and design of these materials (Teoh et al., 2026; Yang et al., 2026) and the reliability of the models depend on high-quality experimental databases (different regions, supply chains, e.g.). Therefore, standardized testing and reporting are still necessary (Richard & Cheyrezy, 1995; Wille et al., 2011; Matiushin et al., 2024). International bridge engineering guidelines are a good reference for local adaptations. However, region-specific seismic conditions, environment, and regulations should be considered in the design guidelines (Benjamin et al., 2020; Wakjira & Alam, 2024). Otherwise, negative consequences may occur.

CONCLUSION

Comparing the mechanical properties of conventional concrete with UHPC and UHPFRC reveals significant performance differences. UHPC, and especially steel fiber-reinforced UHPFRC, exhibits much higher compressive and tensile strength compared to conventional concrete; moreover, thanks to its superior ductility and energy absorption capacity, it significantly reduces brittle fracture behavior. While conventional concrete generally tends to exhibit sudden and brittle fracture due to its limited tensile strength and low deformation capacity, UHPFRC, thanks to its fiber reinforcement, controls

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

crack formation, slows crack propagation, and offers more controlled deformation behavior under load.

When stress-strain curves are examined, it is seen that UHPC/UHPFRC reaches a higher peak stress and can carry load over a wider deformation range before failure. This shows that these materials can be safely used not only in load-bearing systems requiring high strength but also in systems subjected to impact, repeated loading, and overload conditions.

This study consolidates material-level, structural, digital fabrication, and computational insights to outline a contemporary framework for the use of UHPC and UHPRC in civil engineering. Continued research should focus on expanding experimental databases for regional materials, enhancing sustainability through alternative binders and recycled components, and further developing explainable machine learning and meso-scale models to support code development and large-scale implementation.

REFERENCES

Batikha, M., Jotangia, R., Baaj, M.Y., & Mousleh, I. (2022). 3D concrete printing for sustainable and economical construction: A comparative study. *Automation in Construction*, 134, 104087. 10.1016/j.autcon.2021.104087

Benjamin G, Eugen B, Byung-Suk K, François T, Lei VY, Arash Z (2020) International perspective on uhpc in bridge engineering. *J Bridge Eng* 25(11). https://doi.org/10.1061/(ASCE)BE.1943-5592.0001630

Dingqiang F, Yu R, Kangning L, Junhui T, Zhonghe S, Chunfeng W, Shuo W, Zhenfeng G, Zhengdong H, Qiqi S (2021) Optimized design of steel fibres reinforced ultra-high-performance concrete (uhpc) composites: towards to dense structure and efficient fibre application. *Constr Build Mater* 273:121698. https://www.sciencedirect.com/science/article/pii/S0950061820337028

Graybeal, B. A. (2011).*Ultra-high performance concrete bridge deck/pavement demonstration project using field cast panels*. Federal Highway Administration. (Technical note), HDR-40, 202-493-3122

https://www.fhwa.dot.gov/publications/research/infrastructure/structures/bridge/11060/11060.pdf

Kurtoğlu, D., Mehdizade, A. & Bakar, S. (2025). Afet sonrası yapılanmada konvansiyonel ve ileri teknolojilerin karşılaştırılması. *Modular Journal*, 8(2), 587-611. 10.59389/modular.1700238

Li, V. C. (2003). On engineered cementitious composites (ECC): A review of the material and its applications. *Journal of Advanced Concrete Technology*, 1(3), 215–230. https://doi.org/10.3151/jact.1.215

Matiushin, E.; Sizyakov, I.; Shvetsova, V.; Soloviev, V. (2024). The effects of aggregate volume content and particle size on the properties of UHPC and UHPFRC. Buildings 2024,14, 2891.

Piro, N.S. (2025). Predictive Modeling and Optimization of Sustainable Ultra-High-Performance Concrete with Response Surface Methodology, Progress in Engineering Science 3(1): 100201. 10.1016/j.pes.2025.100201.

Richard, P., & Cheyrezy, M. (1995). Composition of reactive powder concretes. *Cement and Concrete Research, 25*(7), 1501-1511.https://doi.org/10.1016/0008-8846(95)00144-2

Teoh, K.B., Hiew, S.Y., Banthia, N. &. Yoo, D-y (2026). Machine learning in ultra-high-performance concrete (uhpc): a multiscale review of applications, challenges, and prospects. Archieves of Computational Methods in Engineering, fifty-six pages. Springer. 10.1007/s11831-026-10494-x

Wakjira TG, Alam MS (2024) Performance-based seismic design of ultra-high-performance concrete (uhpc) bridge columns with design example – powered by explainable machine learning model. *Eng Struct* 314:118346. https://www.sciencedirect.com/science/article/pii/S0141029624009088

Wille, K., Naaman, A. E., Parra-Montesinos, G. J., (2011). Ultra-high performance concrete with compressive strength exceeding 150 Mpa (22 ksi): A simpler way. ACI Materials Journal, Technical Paper, 108 (1), 46-54. https://doi.org/10.1617/s11527-011-9767-5.

Yang, P., Arora, A., Hoover, C. G, & Mobasher, B. (2026). A Meso-Scale Modeling Framework Using the Discrete Element Method (DEM) for Uniaxial and Flexural Response of Ultra-High Performance Concrete (UHPC). *Applied Sciences*, 16(3), 1230. 10.3390/app16031230

Yoo DY, Banthia N, Yoon YS (2024) Recent development of innovative steel fibers for ultra-high-performance concrete (uhpc): a critical review. Cem Concr Compos 145:105359. https://www.sciencedirect.com/science/article/pii/S095894652300433X

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STRUCTURAL VALIDATION AND WEIGHT OPTIMIZATION OF THE LE8 URBAN BUS BODY USING FINITE ELEMENT ANALYSIS

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ABSTRACT

In this study, the load-bearing body frame of an LE8 diesel city bus was examined through finite element analysis, and a lightweight-driven redesign workflow was presented. The structural response of the chassis, sidewalls, and roof was evaluated under nine static load cases that represent key in-service conditions, including full-load (1G), rapid acceleration/braking, right/left cornering, and a 50-mm pothole event applied to each wheel. The results indicate that the dominant load paths are carried mainly by the chassis beams and lower connection lines, while the most critical response is governed by torsional effects during single-wheel pothole cases. For mass reduction, components that remained at consistently low stress levels and contributed marginally to the global load path were targeted; 109 parts were screened, 52 components were redesigned via section/geometry updates, and 57 components were removed. As a result, a 126-kg (4.69%) reduction in frame mass was achieved, while verification analyses confirmed elastic behavior and acceptable safety margins across all loading scenarios. Overall, the proposed workflow provides a practical engineering route to reduce structural mass in bus body frames without compromising safety.

Keywords: Finite Element Analysis; Lightweighting; Stiffness; Lightweight Design

1. GİRİŞ

Ulaştırma sektöründe enerji verimliliği ve emisyon azaltımı, güncel mühendislik çalışmalarının en kritik hedeflerinden biri hâline gelmiştir. Özellikle ağır hizmet ve toplu taşıma araçlarında, gövde ve şasi sistemleri hem yüksek kütleye sahip olması hem de uzun hizmet ömrü boyunca yoğun kullanım çevrimlerine maruz kalması nedeniyle enerji tüketimi üzerinde doğrudan belirleyicidir. Avrupa Komisyonu tarafından ağır hizmet araçları için hazırlanan değerlendirmelerde, "hafifletme" yaklaşımının özgül yakıt tüketimini düşürerek taşımacılık verimliliğini artırdığı vurgulanmaktadır [1].

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Benzer şekilde, hafifletmenin enerji tasarrufuna etkisi malzeme ve sistem düzeyinde ele alınmış; kütle azaltımının işletme enerjisi ve yaşam döngüsü etkileri üzerindeki rolü raporlanmıştır [2]. Teknik brifing niteliğindeki çalışmalarda ise taşıt hafifletmenin sadece malzeme eksiltme olarak değil; tasarım, üretilebilirlik ve güvenlik kısıtlarıyla birlikte yönetilmesi gereken bir mühendislik problemi olduğu belirtilmektedir [3].

Enerji talebinin orta–uzun vadede artış eğilimini koruyacağına ilişkin öngörüler, ulaştırma kaynaklı verimlilik stratejilerini daha da önemli kılmaktadır [4]. Bunun yanında yolcu taşımacılığı faaliyetinin (özellikle kentsel ölçekli hareketlilik talebinin) sürdürülebilirlik hedefleriyle birlikte değerlendirilmesi, toplu taşıma araçlarının tasarımında enerji ve maliyet odaklı iyileştirmeleri zorunlu kılmaktadır [5]. Bu bağlamda, şehir içi otobüslerde kütlenin azaltılması yalnızca yakıt tüketimi/işletme maliyeti açısından değil; aynı zamanda yeni nesil platformlarda menzil, batarya boyutlandırması ve toplam sahip olma maliyeti gibi metrikler açısından da kritik bir kaldıraçtır.

Otobüs taşıyıcı gövde karkası, ince cidarlı profillerin kaynaklı birleşimleriyle oluşan ve çok sayıda düğüm noktası içeren karmaşık bir taşıyıcı sistemdir. Bu sistem; tam yük (1G) altında düşey yük taşımayı, viraj manevralarında yanal ivmelerden doğan eğilme/torsiyon bileşenlerini ve ani fren/hızlanma gibi boylamsal yüklemeleri güvenli biçimde karşılamak zorundadır. Bu nedenle hafifletme çalışmaları, “hangi elemanın kütlesi azaltılabilir?” sorusundan önce “yük yolu nereden geçiyor ve hangi elemanlar bu yük yoluna gerçekten katkı veriyor?” sorusunu temel almak durumundadır. Aksi hâlde, lokal gerilme yığılmaları, rijitlik kaybı veya kaynaklı düğümlerde dayanım/durabilite riskleri gibi istenmeyen sonuçlar doğabilir. Bu noktada sonlu elemanlar analizi (SEA/FEA), prototip öncesi tasarım aşamasında hem global deformasyon davranışını hem de kritik bağlantılardaki gerilme seviyelerini görünür kılarak hafifletme kararlarının mühendislik temelli verilmesine imkân tanır.

Literatürde otobüs gövde/şasi sistemlerinin analiz ve optimizasyonuna yönelik farklı metodolojiler rapor edilmiştir. Devrilme güvenliği odağında ECE-R66 temelli topoloji optimizasyonu yaklaşımları ile kütle azaltımı sağlanabildiği gösterilmiştir [6]. Doğal frekans kısıtını dikkate alan hafifletme çalışmaları, taşıyıcı karkasta dinamik davranışın da tasarım kriteri olarak yönetilebileceğini ortaya koymuştur [7]. Bunun yanında, mafsallı kentsel otobüs şasisinin çeşitli yükleme koşulları altında FEM ile değerlendirilmesi; kritik gerilme bölgelerinin ve yer değiştirme karakterinin yükleme tipine göre nasıl değiştiğini göstermesi açısından temel referans niteliğindedir [8].

Güncel eğilimlerden biri de çok malzemeli (multi-material) tasarım yaklaşımlarıdır. Çelik–alüminyum kombinasyonu içeren elektrikli otobüs gövde yapılarında, statik rijitlik kısıtları korunarak kayda değer kütle azaltımları raporlanmıştır [9]. Benzer doğrultuda, çok malzemeli topoloji optimizasyonundan kesit boyut optimizasyonuna uzanan ardışık yaklaşımların, ince cidarlı karkas yapılarda rijitlik/ağırlık oranını artırma potansiyeli taşıdığı gösterilmiştir [10]. Konsept tasarım aşamasında devrilme dayanımı

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

için analiz ve optimizasyon yaklaşımları da, otobüs karkaslarında güvenlik gerekleri ile hafifletmenin birlikte ele alınabileceğini desteklemektedir [11].

Öte yandan, bazı çalışmalarda kompozit/sandviç yapıların düşük tabanlı otobüslerde çarpışma ve devrilme performansına katkı sunduğu; özellikle enerji sönümleme kapasitesi açısından avantaj sağlayabildiği belirtilmiştir [12]. Ancak seri üretim gerçekliğinde, her platform için çok malzemeli dönüşüm her zaman kısa vadede uygulanabilir olmayabilir. Bu nedenle mevcut çelik karkas mimariler üzerinde; yük yoluna katkısı sınırlı kalan elemanların sistematik olarak belirlenmesi, kesit/geo revizyonlarının uygulanması ve gereksiz elemanların elimine edilmesi gibi "parça bazlı tarama" stratejileri pratik açıdan yüksek değer taşır. Bu tarz yaklaşımlarda kritik nokta; yalnızca "maksimum gerilme"ye bakmak yerine, farklı işletme senaryolarında yük yolunun sürekliliğini ve global rijitliği koruyacak şekilde karar verebilmektir.

Ayrıca, sayısal modellerin güvenilirliği için ölçüm/veri temelli referansların önemi giderek artmaktadır. Kentsel trafikte çalışan elektrikli otobüslerde ölçülen dinamik yük ve ivme verilerinin, model doğrulaması için kritik bir temel oluşturduğu rapor edilmiştir [13]. Statik durabilite koşullarında şasi/karkas optimizasyonuna yönelik çalışmalar ise, deformasyon seviyelerinin ve dayanımın yönetilmesi açısından pratik çıktılar sunmaktadır [14]. Bununla birlikte, şehir içi kullanımda kaynaklı düğümlerin yorulma davranışı da kritik bir sınır koşulu olduğundan, elektrikli otobüs gövde yapılarında yorulma ömrü değerlendirmesine yönelik vaka çalışmaları, tasarım kararlarının yalnızca statik dayanım ile sınırlandırılmaması gerektiğini hatırlatmaktadır [15].

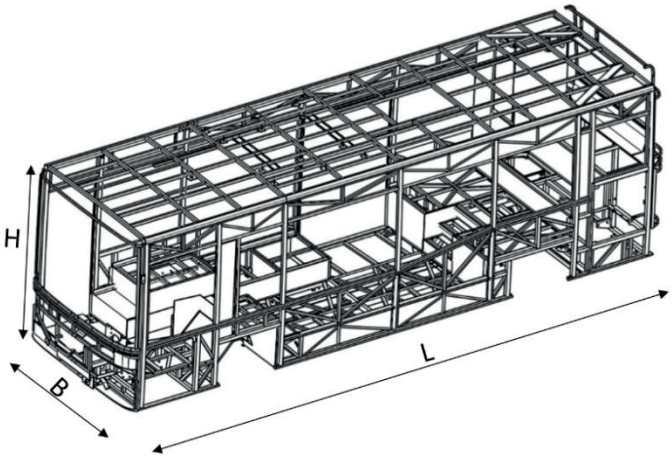
Bu bildiride, şehir içi taşımacılıkta kullanılan LE8 iki akslı dizel bir otobüsün taşıyıcı gövde karkası; entegre (şasi–yan duvarlar–çatı) bir sonlu eleman modeli üzerinden değerlendirilmekte ve hafifletme odaklı bir iyileştirme iş akışı sunulmaktadır. Yaklaşım; (i) şehir içi işletmeyi temsil eden tam yük (1G), ani hızlanma/frenleme, sağ/sol dönüş ve her bir teker için 50 mm çukur geçişini kapsayan yük senaryoları altında gerilme–deformasyon davranışının ortaya konması, (ii) yük yoluna katkısı sınırlı ve sürekli düşük gerilme seviyelerinde kalan elemanların belirlenmesi ve (iii) kesit/geo revizyonları ile eleman eliminasyonunun mühendislik kriterleriyle yönetilmesi adımlarına dayanmaktadır. Amaç, güvenlik ve rijitlik gereksinimlerini koruyarak kütle azaltımının üretilebilir bir çerçevede nasıl gerçekleştirilebileceğini, izlenebilir ve tekrarlanabilir bir yöntem olarak ortaya koymaktır.

2. MATERYAL VE METOT

2.1. Araç tanımı ve kütle bileşenleri

Bu çalışmada incelenen taşıyıcı gövde karkası; şasi, sağ/sol yan duvarlar ve çatı alt sistemlerinin ayrı imalat aşamalarından sonra kaynaklı birleştirme ile tek bir yapı hâline getirildiği bütünleşik bir sistem olarak ele alınmıştır. İncelenen araç, şehir içi işletme koşullarına yönelik LE8, iki akslı dizel bir otobüstür. Geometrik olarak araç; yaklaşık 8450 mm uzunluk, 3130 mm genişlik ve 2400 mm yükseklik değerlerine sahiptir (Şekil 1).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 1. LE8 Aracın Geometrik Özellikleri

Tam yüklü işletme koşulunda toplam kütle 12 000 kg olarak kabul edilmiş; taşıyıcı gövde karkası kütlesi 2685 kg olarak modele tanımlanmıştır. Kalan kütle bileşenleri güç aktarma sistemi, iç donanım ve yolcu yükünü temsil edecek şekilde ayrıştırılmış; literatürde yaygın varsayımla yolcu birim kütlesi 68 kg/kişi alınarak toplam yolcu yükü model girdilerine eklenmiştir. Bu kütle bileşenleri, sınır şartlarının kurulmasında ve ivme tabanlı yükleme senaryolarının uygulanmasında doğrudan kullanılmıştır (Tablo 1).[8],[16].

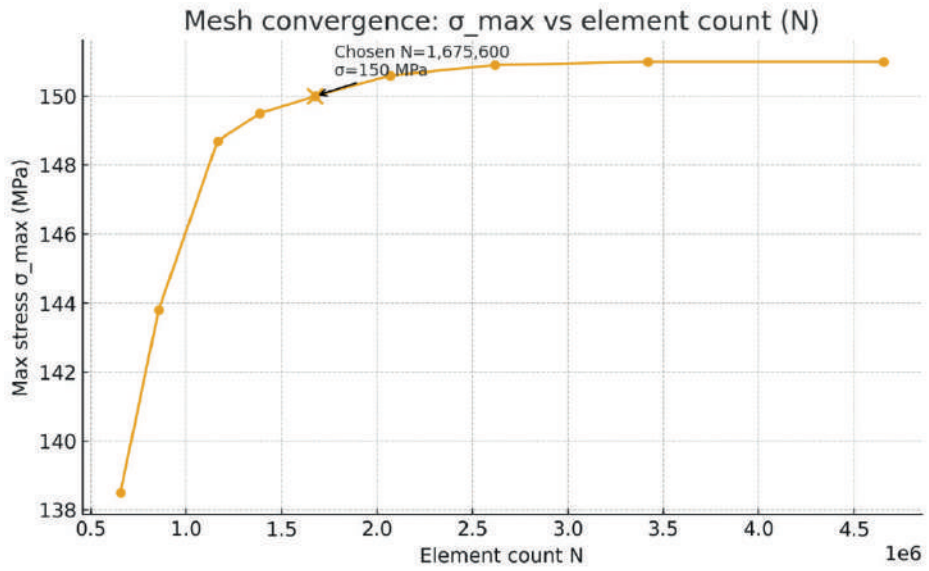
Table 1. Araç Kütle Bilgileri

Komponent	**Sembol**	**Değer**	**Açıklama**
Araç Uzunluğu	L	8450 mm	Ön ve Arka Tamponlar arası mesafe
Genişlik	B	3130 mm	Dıştan Dışa
Yükseklik	H	2400 mm	Zeminden Tavana
Tam yüklü durum	W_{tot}	12000 kg	Toplam Kütle + Yolcular
Gövde Karkas Kütlesi	W_{frame}	2685 kg	Yapısal karkas
Yolcu Kütlesi	W_p	68 kg	Yolcu başı kabul edilen kütle
Yolcu Sayısı	N_p	59 kg	Oturan ve Ayakta Yolcu sayısı
Güç aktarım Organ kütlesi	W_{pt}	2248 kg	Motor şanzıman vb.

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2.2. Geometri hazırlığı, ağ (mesh) yapısı ve malzeme tanımları

Analiz modeli, taşıyıcı karkası temsil eden bütünleşik CAD geometrisi üzerinden oluşturulmuştur. İnce cidarlı/kaplama karakterli bölgeler kabuk (shell) elemanlarla, blok bağlantılar ve yerel birleşim bölgeleri ise katı (solid) Quad–Hex elemanlarla modellenerek hibrit ağ yapısı kurulmuştur. Ağ kalitesi için ortalama eleman kalitesinin ≥0.90 seviyesinde tutulması hedeflenmiş; karakteristik eleman boyutu 8–12 mm aralığında incelenerek ağ duyarlılığı kontrol edilmiştir (Şekil 2).



Şekil 2. Sonlu Elemanlar Ağ Bağımsızlığı

Malzeme atamalarında, ana taşıyıcı profiller için S350GD+Z, sac/ince elemanlarda St37 ve destek elemanlarında St44 çelikleri kullanılmış; elastisite modülü 210 GPa ve yoğunluk 7850 kg/m³ alınmıştır. Akma dayanımları sırasıyla S350GD+Z: 350 MPa, St44: 275 MPa, St37: 235 MPa olarak modele tanımlanmıştır.

Tablo 2. Araç Üzerinde Kullanılan Malzemelerin Mekanik Özellikleri

Malzeme	Akma Dayanımı	Çekme Dayanımı	Elastik Modülü	Yoğunluk
S350GD+Z	350 MPa	420-510 MPa	210 GPa	7850 kg/m³
St52	355 MPa	510-680 MPa	210 GPa	7850 kg/m³
St44	275 MPa	410-580 MPa	210 GPa	7850 kg/m³
St37	235 MPa	360-510 MPa	210 GPa	7850 kg/m³

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Şehir içi işletmede karşılaşılan temel durumları kapsamak amacıyla toplam dokuz adet statik yükleme senaryosu tanımlanmıştır. Bu senaryolar;

- 1G tam yük (9.81 m/s²),
- Ani hızlanma ve ani frenleme (±5 m/s² bileşeni ile),
- Sağ/sol dönüş (±3.9 m/s² yanal ivme bileşeni ile),
- Ve her bir tekerin ayrı ayrı 50 mm çukura girmesi durumlarını içermektedir.

Sınır şartları, gövde–aks etkileşimini temsil edecek şekilde aks/bağlantı bölgeleri üzerinden tanımlanmış; ivme tabanlı yüklemeler ile farklı sürüş manevralarının gövde üzerindeki eğilme–kesme–torsiyon etkileri sayısal modele aktarılmıştır. Çukur senaryolarında ise ilgili teker konumunda 50 mm'lik düşey yol seviyesi farkı oluşturacak kinematik durum hedeflenerek özellikle torsiyon ağırlıklı yük aktarımı tetiklenmiştir (Tablo 3). [10],[16],[17].

Tablo 3. Yükleme Senaryoları ve Açıklamaları

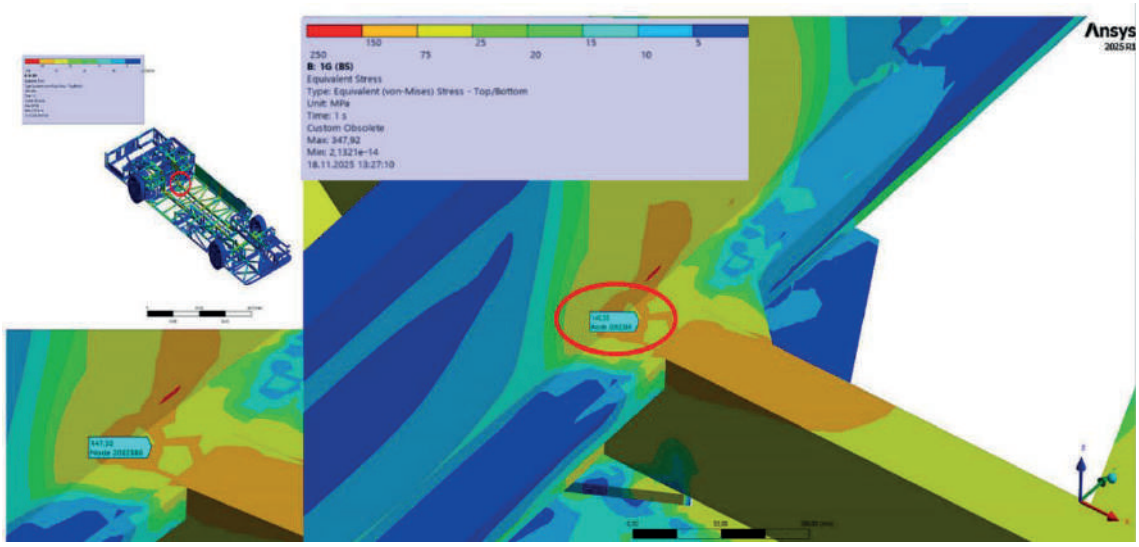
No	Senaryo	Yükleme	Hedef
1	1G	9,81 m/s^2	Eğilme + Burulma
2	Ani hızlanma	9,81 m/s^2+5 m/s^2	Düzlemsel Eğilme + Kesme
3	Ani frenleme	9,81 m/s^2-5 m/s^2	Düzlemsel Eğilme + Kesme
4	Sağ viraj	9,81 m/s^2+3,9 m/s^2	Yanal Eğilme + Burulma
5	Sol viraj	9,81 m/s^2-3,9 m/s^2	Yanal Eğilme + Burulma
6	Çukura girme	9,81 m/s^2+50 mm Çukur	Yüksek Burulma

3. BULGULAR

1G yükleme senaryosu için tanımlanan sınır şartları altında yürütülen analizler, yük aktarımının karakteri nedeniyle en kritik bölgelerin ağırlıklı olarak şasi ve çatı çevresinde toplandığını göstermiştir. Gövdeye ait sonlu eleman modeli oluşturulurken karkası meydana getiren profil elemanların tüm radyüs geçişleri sadeleştirildiğinden, çözüm sırasında bazı noktalarda çentik etkisine bağlı yerel gerilme yığılmaları ortaya çıkmıştır. Bu tip yüksek tepe değerlerinin "tekillik (singularity)" kaynaklı olabileceği değerlendirilerek, raporlanan maksimum gerilmeler yerel pikleri dışlamak amacıyla en yüksek ikinci düğüm (nodal) değerleri üzerinden alınmıştır. Elde edilen sonuçlara göre şasi bölgesindeki maksimum eşdeğer gerilme yaklaşık 147 MPa mertebesindedir. Bu gerilmenin, arka

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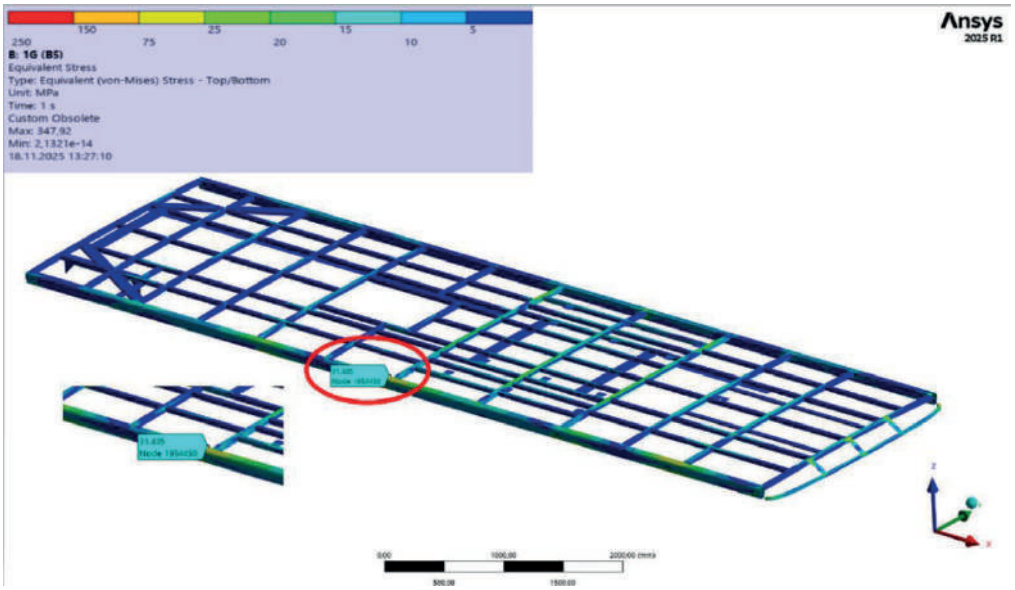
aks bağlantı noktaları ile şasi havuz (pool) bölgesi arasındaki bağlantıları içeren ve "mid-floor" olarak tanımlanan alanda oluştuğu belirlenmiş; ilgili gerilme dağılımı Şekil 2'de sunulmuştur. Malzeme olarak S350 yapısal çeliğinin kullanıldığı dikkate alındığında, hesaplanan gerilme değerlerinin akma sınırının belirgin şekilde altında kaldığı ve yapının yaklaşık 2.38 emniyet katsayısına sahip olduğu görülmüştür.



Şekil 3. 1G Yükleme Koşulunda Şasi Bölgesine Ait Yapısal Analiz Sonuçları

Tavan yapısındaki gerilme dağılımları incelendiğinde, yük aktarımı etkisiyle bu bölgede yaklaşık 33 MPa mertebesinde yerel gerilmelerin oluştuğu görülmüştür. Çatı bölgesi için hesaplanan emniyet katsayısı 10'dur. (Şekil 4).

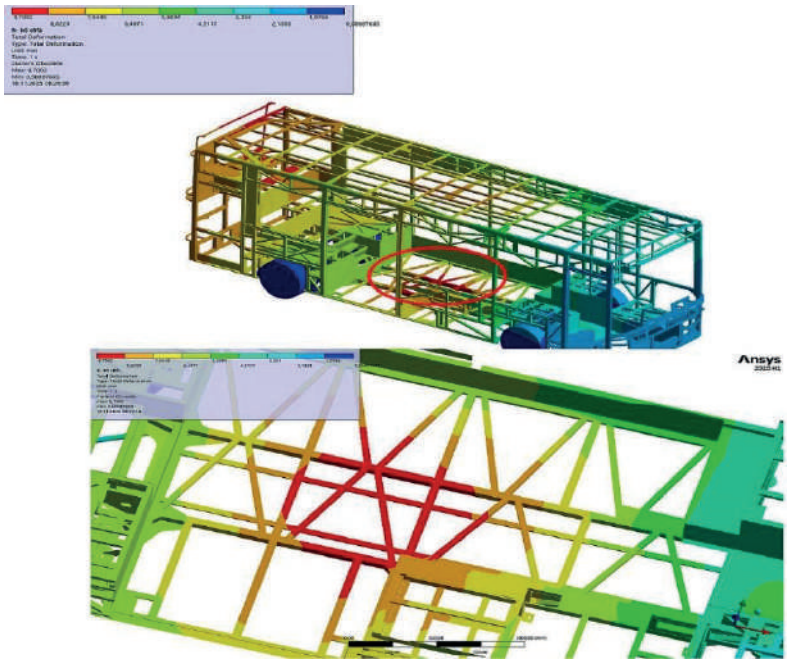
Aynı yükleme koşulu altında sağ ve sol yan duvar bölgelerinde ise ortalama gerilme seviyeleri 60–132 MPa aralığında değişmiş; bu bölgeler için emniyet katsayıları sırasıyla 5.83 ve 2,65 olarak belirlenmiştir.



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Şekil 4. Tavan Yapısı Gerilme Dağılımı

Uygulanan yükler altında oluşan şekil değiştirmeler açısından sonuçlar değerlendirildiğinde, aracın taşıyıcı sisteminin ana omurgasını oluşturan şasi bölgesinde yaklaşık 9.7 mm mertebesinde bir deformasyon meydana geldiği belirlenmiştir (Şekil 5). Elde edilen yer değiştirme seviyelerinin, literatürde raporlanan benzer yapısal analiz çalışmalarındaki bulgularla uyumlu olduğu görülmüştür [16].

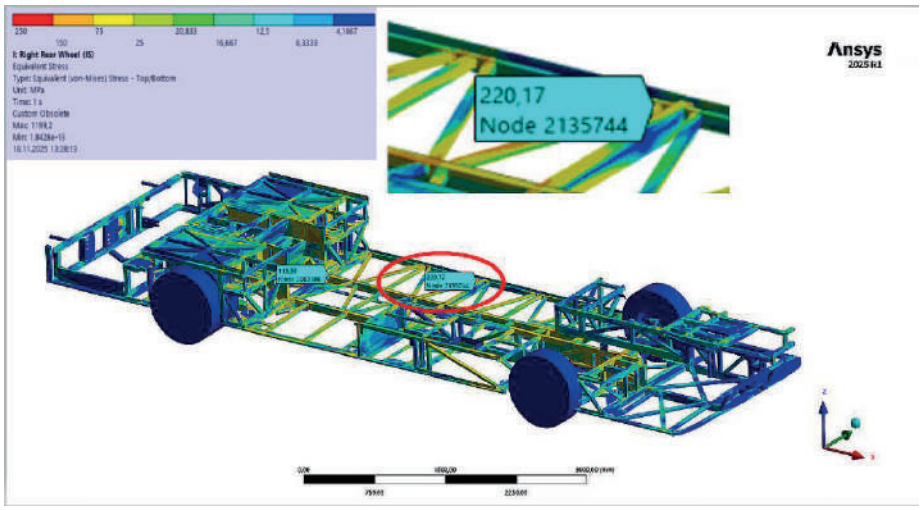


Şekil 5. 1G Yapısal Analiz Senaryosunda Araç Gövde Karkasının Yer Değiştirme Dağılımı

3.1. Arka-Sağ Tekerin Çukura Girmesi Senaryosunun Analizi

Dokuz yükleme senaryosu içinde en kritik yapısal yanıt, arka-sağ tekerin çukura girmesi durumunda elde edilmiştir. Bu koşulda şasi sistemi, düşey torsiyon ve yerel eğilme etkilerinin birleşimi altında çalışmış; yük taşıyan kirişler boyunca gerilme dağılımlarının belirgin şekilde yoğunlaştığı görülmüştür. Analiz sonuçlarına göre şasi bölgesindeki maksimum eşdeğer gerilme yaklaşık 220 MPa seviyesine ulaşmış ve bu değer, 1G statik yükleme koşuluna kıyasla yaklaşık %50 oranında artışa karşılık gelmiştir (Şekil 6).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 6. 50 mm Çukur Senaryosunda (Arka-Sağ Teker) Şasi Üzerindeki Eşdeğer (von Mises) Gerilme Dağılımı

3.2. Gövde Karkasında Hafifletme Çalışmaları

Mevcut tasarım için dokuz farklı yükleme senaryosu altında gerçekleştirilen yapısal analizler, gövde karkasında bazı bölgelerin sürekli düşük gerilme seviyelerinde kaldığını ortaya koymuştur. Bu bölgelerde kütle azaltımı amacıyla tasarım sadeleştirmeleri ve kesit optimizasyonları uygulanmıştır. Analizlerin ayrıntılı incelenmesinde, sağ ve sol yan duvar profillerinin belirli kısımlarında hem düşük gerilme seviyeleri hem de tekrarlayan kesit düzenleri bulunduğu görülmüştür. Bu alanlarda profil kesitleri yeniden düzenlenerek gereksiz rijitlik ortadan kaldırılmış; böylece yapı, yük aktarım hattıyla daha uyumlu bir taşıyıcı forma dönüştürülmüştür.

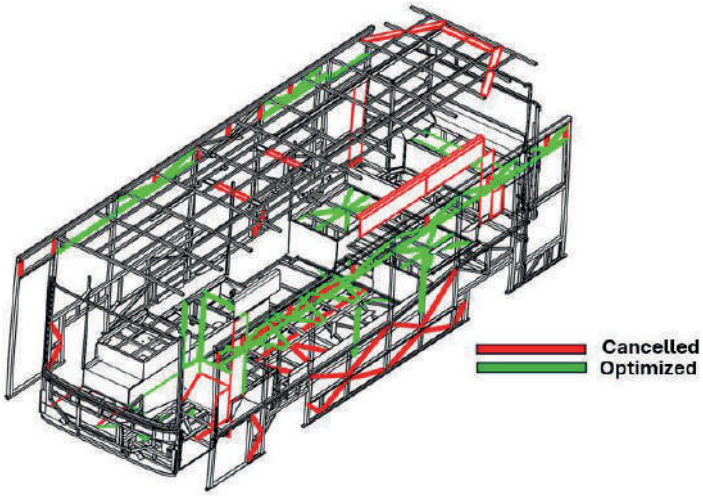
Optimizasyon kapsamında toplam 109 bileşen değerlendirmeye alınmıştır. Bu bileşenlerin seçilmesindeki temel gerekçe, dokuz senaryonun tamamında ya çok düşük gerilme taşımaları (dolayısıyla sınırlı yapısal katkı) ya da yük yolu açısından gereğinden fazla rijitlik oluşturmaları nedeniyle kütle optimizasyonu için uygun aday olmalarıdır. Analiz sonuçları; özellikle yan duvarlar, iç panel destekleri, ikincil taşıyıcı profiller ve yerel bağlantı elemanlarının bulunduğu bölgelerde, yük aktarımına anlamlı katkı vermeyen bileşenlerin mevcut olduğunu göstermiştir. Bu doğrultuda, dokuz senaryonun tamamında belirgin gerilme taşımadığı, rijitliğe kayda değer katkı sağlamadığı ve yük yolu üzerinde kritik bir rol üstlenmediği değerlendirilen 57 bileşen yapıdan kaldırılmıştır. Devamında yapılan doğrulama analizleri, bu elemanların kaldırılmasının şasi, yan duvar ve çatı bölgelerinde global rijitlik kaybına yol açmadığını ve yerel gerilme artışları oluşturmadığını doğrulamıştır.

Bununla birlikte, yük aktarım hattı boyunca yerel rijitlik katkısı bulunan 52 bileşen korunmuş; ancak kütle optimizasyonu hedefi doğrultusunda özellikle yan duvar bölgelerinde seçili profil kaldırmaları ve tasarım revizyonları gerçekleştirilmiştir. Şasi bölgesinde ise profil sadeleştirmeleri, kesit inceltmeleri ve geometrik iyileştirmeler uygulanarak taşıyıcı sistem daha verimli hâle getirilmiştir. Optimizasyon

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sonrası bu elemanların davranışı aynı dokuz yükleme senaryosu altında yeniden değerlendirilmiş; taşıyıcı sistemin genel dayanımının olumsuz etkilenmediği teyit edilmiştir.

Sonuç olarak, yapılan kapsamlı tarama ve tasarım güncellemeleri ile gövde genelinde %4.69 oranında kütle azaltımı sağlanmıştır. Bu hafifletme, taşıyıcı karkasın rijitliğini koruyacak şekilde gerçekleştirilmiş; böylece yapısal emniyetten ödün vermeden kütle kazancı elde edilerek aracın enerji verimliliği potansiyeli desteklenmiştir. Optimizasyon sonrası doğrulama analizleri, yeni tasarımın tüm senaryolarda akma sınırlarının altında kaldığını, emniyet katsayılarının güvenli aralıkta korunduğunu ve gerilme dağılımlarının daha homojen bir karakter kazandığını göstermiştir. Kaldırılan ve revize edilen bileşenlerin detaylı görünümü Şekil 7'de sunulmuştur.



Şekil 7. Optimizasyon Kapsamında Değerlendirilen Bileşenler

RESULTS

Bu çalışmada, şehir içi taşımacılıkta kullanılan LE8 dizel bir otobüsün taşıyıcı gövde karkasının yapısal dayanımı ve hafifletme potansiyeli değerlendirilmiştir. Şasi, yan duvarlar ve çatı bölgelerini kapsayan sonlu eleman modeli üzerinden; farklı sürüş koşullarını temsil eden toplam dokuz statik yükleme senaryosu altında gerilme ve deformasyon dağılımları incelenmiştir. Elde edilen bulgular, yük aktarımının büyük ölçüde şasi kirişleri ve alt bağlantı hatları üzerinden gerçekleştiğini ve bu bölgelerin yapısal davranış üzerinde belirleyici rol oynadığını göstermiştir.

Hafifletme yaklaşımı, analizlerde sürekli düşük gerilme seviyelerinde kalan bölgelerde kütle azaltımına odaklanacak şekilde kurgulanmış; bu kapsamda geometrik sadeleştirmeler ve kesit optimizasyonları uygulanmıştır. Çalışma boyunca toplam 109 bileşen değerlendirilmiş; yük yoluna sınırlı katkı sunduğu belirlenen bileşenlerden 52'si yeniden tasarlanmış, 57'si ise işlevsel katkısının düşük olması nedeniyle yapıdan çıkarılmıştır. Bu düzenlemeler sonucunda, taşıyıcı gövdede yaklaşık %4.69 oranında kütle azaltımı sağlanmıştır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Kütle kazanımının bölgesel dağılımı incelendiğinde; sol yan duvarda 34.25 kg, sağ yan duvarda 15.23 kg, çatı bölgesinde 20.44 kg ve şasi ile diğer bölgelerde 56.08 kg olmak üzere toplamda 126 kg ağırlık azaltımı elde edilmiştir. Bu sonuç, büyük ölçekli yük taşıyan karkas yapılarda kütle azaltımının; yük yolu esaslı bir yaklaşımla, hedefli kesit/geom. revizyonları ve gereksiz eleman eliminasyonları üzerinden gerçekleştirilebileceğini göstermektedir.

Genel olarak çalışma, otobüs gövde yapılarında rijitlik ve dayanım gereksinimleri gözetilerek kütle azaltımının mühendislik açısından uygulanabilir olduğunu ortaya koymaktadır. Bu çerçevede elde edilen bulguların, gelecekte yakıt tüketimi ve üretim maliyetlerini azaltmaya yönelik araç gövde tasarımlarında yol gösterici bir mühendislik referansı sunacağı değerlendirilmektedir.

REFERENCES

[1] European Commission (DG CLIMA). Light weighting as a means of improving Heavy Duty Vehicles' energy efficiency (2015).

[2] International Aluminium Institute – Helms, H., Kräck, J. Energy savings by light-weighting — 2016 Update (ifeu).

[3] ICCT. Passenger-vehicle lightweighting technical briefing (2017).

[4] EIA. International Energy Outlook 2021 — Narrative (2021).

[5] European Environment Agency. Passenger transport activity (EU-27) (2024).

[6] Kongwat, S., Jongpradist, P., Hasegawa, H. (2020). Lightweight bus body design and optimization for rollover crashworthiness. International Journal of Automotive Technology 21, 981–991.

[7] Haryanto, I. vd. (2018). Optimization of Bus Body Frame Structure for Weight Minimizing with Constraint of Natural Frequency. Int. J. Sustainable Transportation Technology 1(1), 9–14.

[8] Croccolo, D., De Agostinis, M., Vincenzi, N. (2011). Structural analysis of an articulated urban bus chassis via FEM. Strojniški vestnik – Journal of Mechanical Engineering 57(11), 799–809.

[9] Fu, C.L., Bai, Y.C., Lin, C., Wang, W.W. (2019). Design optimization of a newly developed aluminum–steel multi-material electric bus body structure. Struct. Multidiscip. Optim. 60(5), 2177–2187. DOI:10.1007/s00158-019-02292-w

[10] Lu, S., Ma, H., Xin, L., Zuo, W. (2019). Lightweight design of bus frames from multi-material topology optimization to cross-sectional size optimization. Engineering Optimization 51(6), 961–977.

[11] Bai, J., Meng, G., Zuo, W. (2019). *Rollover crashworthiness analysis and optimization of bus frame for conceptual design*. Journal of Mechanical Science and Technology 33(7), 3363–3373.

[12] Ko, H.Y., Shin, K.B., Jeon, K.W., Cho, S.H. (2009). *A study on the crashworthiness and rollover characteristics of low-floor bus made of sandwich composites*. J. Mech. Sci. Technol. 23, 2686–2693.

[13] Walczak, B., Malaca, P., Michalak, D., Staszewski, W.J. (2023). *Measurements of loads acting on an electric bus in urban traffic*. Procedia Structural Integrity 47, 723–731.

[14] Tam, N.T., Le, T.P., Huynh, N.T., Nguyen, Q.M. (2023). *Optimization of frame structure coach 29/34 seats in static durability state*. Engineering Science and Technology, an International Journal 47, 101523.

[15] Kepka, M., Kepka Jr, M., Minich, R. (2024). *A case study on fatigue life assessment of an electric bus bodywork*. International Journal of Fatigue 179, 108040.

[16] Özcan, A., Yüce, C. (2024). *M3 Sınıfı Bir Elektrikli Otobüsün Farklı Senaryolar Altında Sonlu Elemanlar Analizleri ile Hafifletilmesi*. Çukurova University Journal of the Faculty of Engineering 39(1).

[17] Kepka, M., Kepka Jr, M., Minich, R. (2022). *Strength calculations and fatigue tests of welded bus bodywork nodes*. Procedia Structural Integrity 42, 687–693.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SYNTHESIS OF NEW HETEROARYL CHALCONE DERIVATIVES AND INVESTIGATION OF THEIR BIOLOGICAL ACTIVITIES

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ABSTRACT

Chalcone derivatives constitute an important class of α,β-unsaturated carbonyl compounds that are widely investigated due to their versatile structural frameworks and significance in medicinal chemistry. Structural modification of the chalcone backbone through heteroaryl substitution represents an effective strategy for altering electronic distribution, conjugation, and heteroatom-mediated interactions, which are key factors influencing biological activity [1].

Within this framework, a series of new heteroaryl-substituted chalcone derivatives were designed, synthesized, and structurally characterized. The target compounds were obtained via Claisen–Schmidt condensation of selected heteroaryl aldehydes with substituted acetophenone derivatives under basic conditions at room temperature. Structural characterization was carried out using FTIR, ^{1}H NMR, ^{13}C NMR, and Q-TOF spectroscopic techniques (Figure 1).

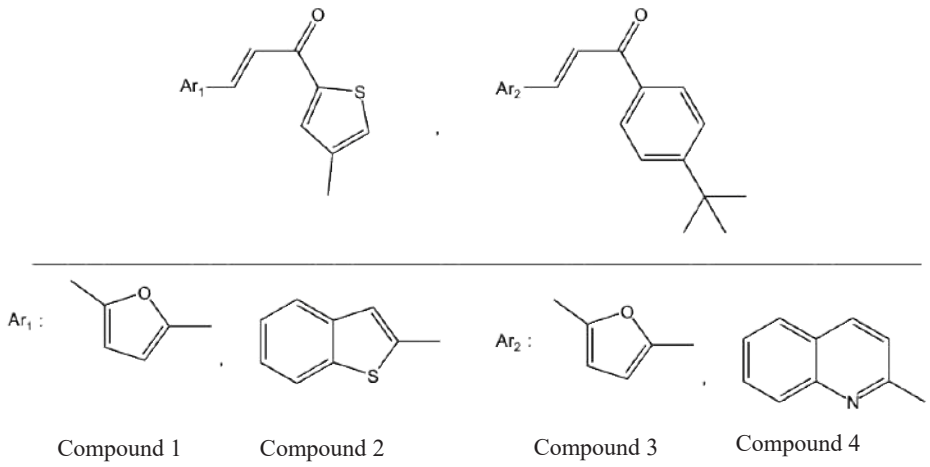


Figure 1. Synthesized chalcone molecules

The incorporation of heteroaryl units into the chalcone skeleton is expected to modulate conjugation, molecular polarity, and heteroatom-driven interactions with biological targets. The novelty of this

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

work lies in the synthesis of previously unreported heteroaryl chalcone derivatives and in the preliminary evaluation of their biological activity potential based on structure-activity considerations. The results provide a foundation for future in vitro biological assays and further optimization studies.

Keywords: Heteroaryl, chalcone, biological activity

References

1) Elkanzi, N. A., Hrichi, H., Alolayan, R. A., Derafa, W., Zahou, F. M., & Bakr, R. B. (2022). Synthesis of chalcones derivatives and their biological activities: a review. *ACS omega*, *7*(32), 27769-27786.

"This work has been supported by Yildiz Technical University Scientific Research Projects Coordination Unit under project number FYL-2026-7538."

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CLICK CHEMISTRY BASED SYNTHESIS OF NOVEL COUMARIN–INDOLE DERIVATIVES AS POTENTIAL DRUG CANDIDATES

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ABSTRACT

Molecular hybridization is a strategy in medicinal chemistry that involves combining two or more pharmacophoric units within a single molecular framework. This approach aims to integrate the beneficial properties of different bioactive moieties into one structure. As a result, hybrid molecules may exhibit enhanced biological activity, improved selectivity, or reduced side effects compared to their parent compounds [1]. Coumarins are natural heterocyclic compounds containing oxygen that have been known for more than a century, with many of their derivatives exhibiting medicinal and pharmaceutical activities. Triazole rings, on the other hand, are widely used in drug design due to their metabolic stability, hydrogen bond forming ability, and high affinity for biological targets. The hybridization of these two pharmacophores, that is, their combination within a single molecule, has the potential to enhance diverse biological activities. The indole core, which constitutes the basic structure of biomolecules such as tryptophan, serotonin, and melatonin, possesses a very broad spectrum of biological activity. It is thought that the incorporation of the indole moiety into coumarin–triazole molecules will improve target specificity. This study aims to synthesize derivatives by bringing together indole, coumarin, and triazole rings within a single molecular framework [2].In the experimental section, the coumarin core was synthesized using the Pechmann condensation, followed by derivatization of the indole moiety, and finally, indole, coumarin, and triazole rings were combined into a single molecule via a click reaction. The characterization of the products was carried out using spectroscopic methods such as ^{1}H NMR, ^{13}C NMR, and FT-IR. The study is still ongoing, and the biological activities of the synthesized compounds are planned to be investigated in future studies.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

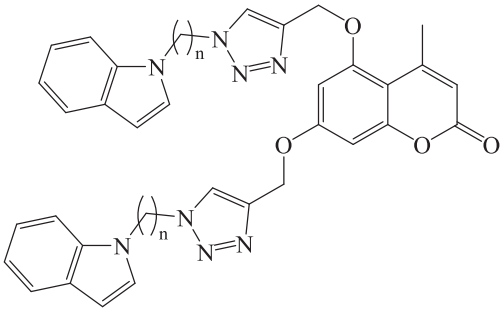


Figure 1. The general structure of synthesized coumarin-triazole-indole hybrids

Keywords: Indole, Coumarin, Triazole, Biological activity, Hybridization

This work was supported by YTU Scientific Research Foundation [Project number FYL-2025-7397].

References:

[1] Kerru, N., Gummidi, L., Maddila, S., Gangu, K. K., & Jonnalagadda, S. B. (2020). A review on recent advances in nitrogen-containing molecules and their biological applications. *Molecules*, *25*(8), 1909.

[2] Devi, T. L., Devi, M. M., & Singh, O. M. (2025). DES Mediated Regioselective and Domino Synthesis of Indole-Coumarin Hybrids with Investigations of Their Photophysical Properties. *ChemistrySelect*, *10*(27), e03785.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INVESTIGATION OF THE EFFECTS OF CUTTING CONDITIONS ON GRINDING BURNS IN GEAR GRINDING PROCESS

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ABSTRACT

This study presents a systematic investigation into the effects of feed rate and depth of cut on burn, residual stress, surface roughness, and dimensional accuracy in gear grinding. A series of tests was conducted on a Kapp Niles gear grinding machine using an Al_2O_3 grinding wheel at a constant cutting speed of 35 m/s, four feed rates (300, 350, 400 and 450 mm/min) and five depths of cut (10, 15, 20, 25 and 30 µm). The following performance criteria were investigated for each condition: grinding burn, surface roughness, residual stress and dimensional accuracy. The test results showed that increasing the depth of cut and the feed rate values by up to 30 µm and 300 mm/min, respectively resulted in a gradual increase in surface roughness and dimensional accuracy. However, at a depth of cut of 30 µm and a feed rate of 350 mm/min, the transition to the critical regime is initiated, resulting in the onset of grinding burn, significant deterioration in surface roughness, and dimensional accuracy. At a depth of cut 30 µm and feed rates of 400 and 450 mm/min, the size and type of burn become more pronounced, and the residual stresses in the hoop and axial directions change from compressive to tensile. This also suggests that the test conditions represent an unsafe process region. The test results showed that grinding burns were formed at a depth of cut of 30 µm and feed rates of 350, 400 and 450 mm/min, in the form of temper burn, over-temper burn and re-hardening burn, respectively. Consequently, within the examined parameter range, it can be concluded that a depth of cut of 25 µm or less can be identified as a safe grinding zone in terms of grinding burn, dimensional accuracy, surface roughness, and the type and size of residual stress.

Keywords: Gear grinding, Al_2O_3 grinding wheel, grinding burn, residual stress

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DİŞLİ TAŞLAMA İŞLEMİNDE KESME ŞARTLARININ TAŞLAMA YANIKLARI ÜZERİNDEKİ ETKİLERİNİN ARAŞTIRILMASI

ÖZET

Bu çalışma, dişli taşlamada ilerleme hızı ve kesme derinliğinin yanık, kalıntı gerilme, yüzey pürüzlülüğü ve boyutsal doğruluk üzerindeki etkilerini sistematik olarak incelemektedir. Kapp Niles dişli taşlama tezgahında, sabit 35 m/s kesme hızında, dört ilerleme hızında (300, 350, 400 ve 450 mm/dk) ve beş kesme derinliğinde (10, 15, 20, 25 ve 30 µm) Al_2O_3 taşlama taşı kullanılarak bir dizi test gerçekleştirilmiştir. Her koşul için aşağıdaki performans kriterleri incelenmiştir: taşlama yanığı, yüzey pürüzlülüğü, kalıntı gerilme ve boyutsal doğruluk. Test sonuçları, kesme derinliği ve ilerleme hızı değerlerinin sırasıyla 30 µm ve 300 mm/dk'ya kadar artırılmasının, yüzey pürüzlülüğü ve boyutsal doğrulukta kademeli bir artışa neden olduğunu göstermiştir. Ancak, 30 µm kesme derinliği ve 350 mm/dk ilerleme hızında, kritik rejime geçilmekte ve bu da taşlama yanığının görülmesine ve yüzey pürüzlülüğünde ve boyutsal doğrulukta önemli bir bozulmaya neden olmaktadır. 30 µm kesme derinliği ve 400 ve 450 mm/dk ilerleme hızlarında, yanığın boyutu ve türü daha belirgin hale gelmekte ve çember ve eksenel yönlerdeki kalıntı gerilmeler, basınçtan çekme yönüne dönmekledir. Bu da test koşullarının güvenli olmayan bir işlem bölgesini temsil ettiğini göstermektedir. Test sonuçları, 30 µm kesme derinliğinde ve 350, 400 ve 450 mm/dk ilerleme hızlarında sırasıyla temperleme yanığı, aşırı temperleme yanığı ve yeniden sertleşme yanığı şeklinde taşlama yanıkları oluştuğunu göstermiştir. Sonuç olarak, incelenen parametre aralığı içinde, 25 µm veya daha az kesme derinliğinin taşlama yanığı, boyutsal doğruluk, yüzey pürüzlülüğü ve kalıntı gerilmenin türü ve boyutu açısından güvenli bir taşlama bölgesi olarak tanımlanabileceği sonucuna varılabilir.

Anahtar kelimeler: Dişli taşlama, Al_2O_3 taşlama taşı, taşlama yanığı, kalıntı gerilme

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EVALUATION of SURFACE DOSES in COMPUTED TOMOGRAPHY USING TLD: A COMPARATIVE PHANTOM STUDY with SSDE and $CTDI_{VOL}$

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ABSTRACT

Purpose: Console-based dose indicators such as Computed Tomography Dose Index volume (CTDIvol), Dose–Length Product (DLP), and Size-Specific Dose Estimate (SSDE) are widely used in computed tomography (CT); however, they do not directly reflect localized surface doses. This study aimed to measure surface doses using thermoluminescent dosimeters (TLDs) on an Alderson Rando anthropomorphic phantom and to compare these values with CTDIvol and SSDE. Materials and Methods: Thoracic CT scans were performed on an Alderson Rando phantom. Console-reported dose parameters were CTDIvol = 1.80 mGy, SSDE = 3.10 mGy, and DLP = 118.59 mGy·cm. TLDs were placed on the anterior and posterior surfaces of both lungs at apical, middle, and basal levels, with two TLDs at each location. Measurements were recorded in mSv, assuming numerical equivalence between mSv and mGy for diagnostic X-ray energies. Results: The mean surface dose was 4.22 mSv anteriorly and 3.05 mSv posteriorly, with an overall mean of 3.64 mSv. TLD-measured surface doses exceeded CTDIvol values but showed closer agreement with SSDE. Higher anterior doses were attributed to primary beam exposure and tissue attenuation. Conclusion: CTDIvol underestimated surface dose, whereas SSDE demonstrated better agreement with TLD measurements. These findings support SSDE as a more reliable indirect indicator for assessing surface dose in CT examinations.

Keywords: Computed tomography, TLD, surface dose, SSDE, CTDIvol

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

IN-SITU ALLOYING PROCESS OF ER70S-6 LOW ALLOY STEEL WITH ER309L AUSTENITIC STAINLESS STEEL VIA WAAM

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ABSTRACT

Wire arc additive manufacturing (WAAM), as one of the metal additive manufacturing techniques, offers the advantage of controlling each layer during production. It allows for the use of multiple metal wires during the process and enables the regulation of wire types and their deposition rates. Thanks to this ability, this study presents an example of an in-situ alloying process using two different wires with different properties. The alloying process was carried out with ER70S-6 low-alloy steel and ER309L austenitic stainless steel added at different ratios. The ER309L ratio was applied at 5%, 10%, and 15% during the WAAM process, and ER70S-6 was successfully alloyed. Macro structure and cross-sectional examinations revealed that ER70S-6 and ER309L were metallurgically bonded in the in-situ alloying process and the fabricated parts were free from macro defects. Cross-sectional analyses showed that the average layer width and height and the total layer surface area of the samples increased with increasing ER309L ratio. The microstructure of the new alloyed structures differed from the single-wire productions in the previous studies regarding the wire materials used in the WAAM process. In the sample containing 5% ER309L, acicular ferrite was found predominantly, while in those containing 10% and 15% ER309L, bainite and martensite structures were observed. The average hardness of the samples manufactured with 5%, 10%, and 15% ER309L were calculated as 275 HV, 352 HV and 368 HV, respectively. The results showed that in-situ alloying process in the WAAM could be successfully implemented with ER70S-6 and ER309L wires, and the new material resulting from this combination of two materials has the potential to be a part with improved mechanical properties.

Keywords: additive manufacturing, cold wire feeding, GMAW, wire arc additive manufacturing.

1. INTRODUCTION

In recent years, wire arc additive manufacturing (WAAM) has gained popularity (Iqbal et al., 2025). WAAM offers advantages in terms of the ability to produce large structures (Xu et al., 2022), material

savings (Jurić et al., 2019), and low production costs (Chen et al., 2022). Furthermore, it has the capability to produce qualified components named as bimetal (Hwang et al., 2023) and FGM (Ayan & Kahraman, 2022b). Furthermore, WAAM has a distinct feature compared to traditional methods. It allows direct control over the layers during the process. In this way, it enables material changes per layer for a specific part, the use of multiple similar or different wire materials, and the dynamic modification of wire feed rates (Ayan, 2024). This make possible utilization of using two wires with different properties and thus allows the production of new material structures by alloying (Paul et al., 2022).

Some previous studies have reported in-situ alloying processes using the WAAM technique. In these research, gas tungsten arc welding (GTAW) (Paul et al., 2022), plasma arc welding (PAW) (Zhou et al., 2024) and gas metal arc welding (GMAW) (Kong et al., 2024) technologies were employed. Depending on the welding method applied in the in-situ alloying process, a dual welding unit was used (Kong et al., 2024), cold wires deposited via a single tungsten electrode (Paul et al., 2022), or cold wire was supplied by an external wire feeding system (Ayan, 2024) with GMAW torch.

Upon reviewing previous studies, it was observed that there are limited work on in-situ alloying process via GMAW and second wire feeding. Additionally, there is a need in the implementation for alloying with low-alloy steel and different grades of austenitic stainless steel. This study deals with in-situ alloying process using the WAAM technique by the addition of different proportions of ER309L austenitic stainless steel to low-alloy ER70S-6 steel wire. Parts were produced with 5%, 10%, and 15% ER309L additions and characterized by macro examinations, microstructure evaluations, and hardness tests. Based on the results obtained, the compatibility of the two selected material combinations with each other and their suitability for the WAAM process were evaluated.

2. MATERIALS AND METHODS

In the alloying process, wires with diameters of 1.2 mm ER70S-6 (one with higher Mn and Si) and 1.0 mm ER309L were used. A St-37 plate with dimensions of 25 mm x 25 mm x 300 mm was utilized as a substrate. The chemical composition of the materials given in Table 1.

Table 1. Chemical compositions of materials (wt.%).

		C	Si	Mn	Cr	Ni	Fe
Wire	ER70S-6	0.10	1.00	1.70	-	-	Bal.
	ER309L	0.03	0.45	1.80	23.50	13.00	Bal.
Substrate	St-37	0.17	1.40	0.30	-	-	Bal.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The production processes were carried out using a custom-designed machine with an integrated Fronius TPS 400i GMAW unit. The machine moves the GMAW torch and has a second external wire feeder system that works independently from the GMAW unit. The alloying process is performed using the ER70S-6 welding wire (first wire) provided by the GMAW torch and the ER309L wire (second wire) supplied by the external wire feeding system. The second wire is applied cold without any heating. The second wire feeding system works in full coordination with the WAAM machine, and the wire ratio can be adjusted as desired on the machine. This allows control of the ratio of the second wire in production and adjustment of the alloying proportion. The production process is shown schematically in Figure 1.

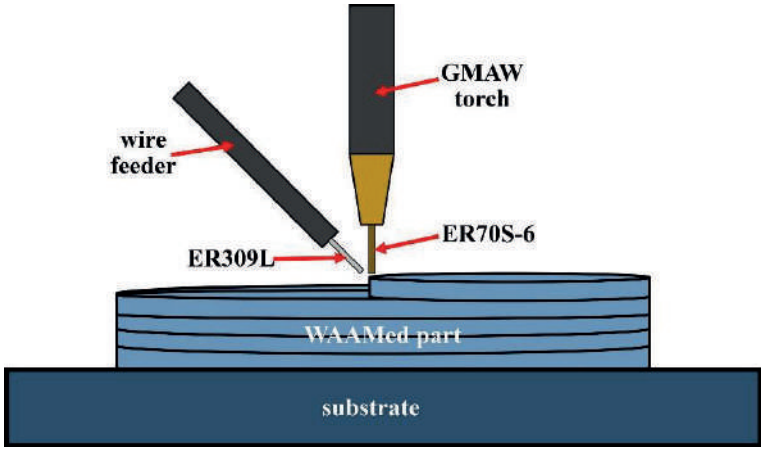


Figure 1. Schematic illustration of the WAAM process.

The alloying ratio was determined based on the volumetric feeding ratio between the wires supplied per unit time during production. The feed rate of the first wire, which has a large proportion from the GMAW torch, was adjusted in the GMAW unit. The feed rate of the second wire was calculated in ratio to the first wire, considering the difference in wire diameters. The proportions of the second wire were specified as 5%, 10%, and 15%, respectively. In this manner, three different parts were produced: 95% ER70S-6–5% ER309L, 90% ER70S-6–10% ER309L and 85% ER70S-6–15% ER309L. The process parameters are given in Table 2.

Table 2. Process parameters.

Parameters	Value
Travel speed (m/min)	0.2
Mean current (A)	169

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Mean voltage (V)	20.1
Shielding gas	98% Ar+2% CO_2
Shielding gas flow rate (L/min)	15
Interlayer temperature (°C)	100-120
Wire feed rate of ER70S-6 (m/min)	5
Wire feed rate of ER309L (m/min)	0.38, 0.8, 1.27

The parts were produced in a back-and-forth sequence in five layers with a layer length of 100 mm. The parts were first evaluated for whether they contained macro defects. Then, they were cut from their stable middle sections of the weld seam using an abrasive disc and molded into samples. Subsequently, standard metallographic techniques were applied to prepare them for further macro and microstructure examinations. The samples were sanded with SiC papers ranging from 320 to 2500 grit and polished with 3 µ and 1 µ diamond paste, respectively. They were etched in a 3% Nital solution for 8 seconds. Then, multiple images taken from the samples with an optical microscope at 6.7X magnification and combined to obtain a cross-sectional image of the samples at the macro scale. The width, the total layer height, and the total surface area of the layers were measured. The average layer width and height values of the layers were evaluated. Figure 2 illustrates the cross-sectional dimensions measured according to layers. For microstructure analysis, Nikon Epiphot 200 optical microscope was used. The same samples were subsequently subjected to Vickers microhardness testing. Hardness measurements were performed using a Shimadzu HMV-2 device, applying a load of 1000 g for 15 seconds. The measurements were taken at 1 mm intervals from the middle of the cross-section of the samples, starting from the bottom layer and up to the top layer.

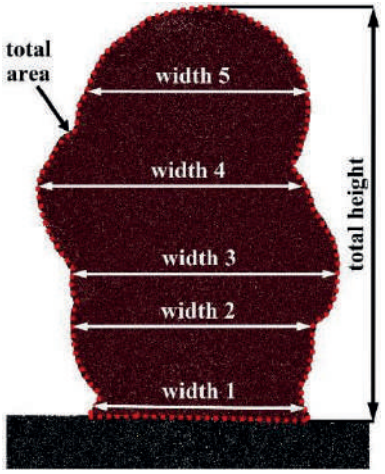


Figure 2. Illustration of the cross-section dimensions.

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3. RESULTS and DISCUSSIONS

3.1. Macro structure

Figure 3 shows the parts after production. The parts were obtained successfully with the specified second wire feed rates. Upon examination of all parts, no macro defects were observed on or between the layers. The ER70S-6 and ER309L wires, which were deposited at different rates, were found to have bonded together on the macro scale. The second wire (ER309L) melted in the weld pool, and no melting defects were observed in the layers. Furthermore, defects such as macro pores and cracks were not detected on the layers. However, at the initial and final regions of the parts, irregular melting due to the start and end of the arc caused some form distortions. Furthermore, partial sagging was observed in some layer regions. It was thought that these situations could be reduced by optimizing the welding parameters. Considering all these, a successful alloying process was achieved with ER70S-6 and ER309L wires, except for partial form defects.

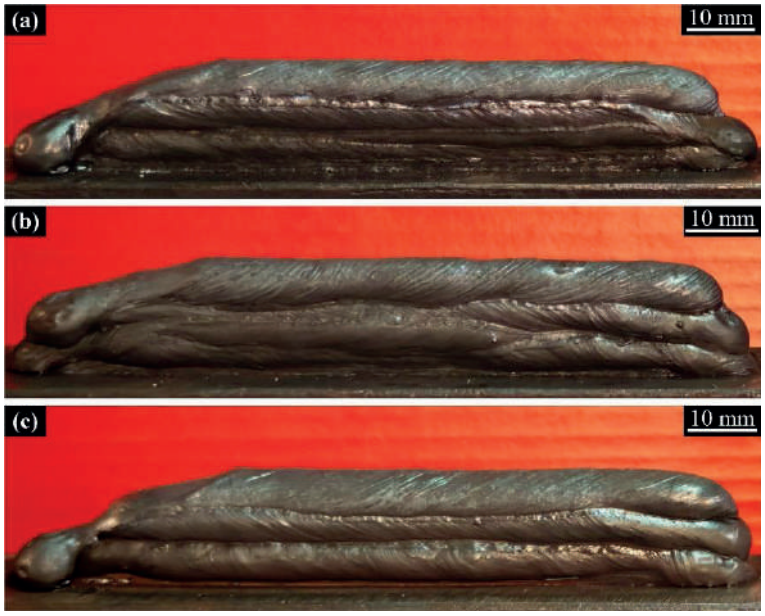


Figure 3. Fabricated parts a) 95% ER70S-6–5% ER309L, b) 90% ER70S-6–10% ER309L, c) 85% ER70S-6–15% ER309L.

Figure 4 shows the cross-section of three different parts with different compositions. When examining the cross-section surfaces and interfaces of the layers, no defects such as cracks or lack of fusion were observed. However, due to the repeated heat input applied during the WAAM process and the variation in the amount of heat accumulation depending on the layer, it was found that the width and height of the layers within the parts changed. In particular, it was observed that this variation level increased with the increase in the ER309L ratio from 5% to 15%. To minimize these variations,

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systematic optimization of the welding parameters is required for the production of two-wire combinations.

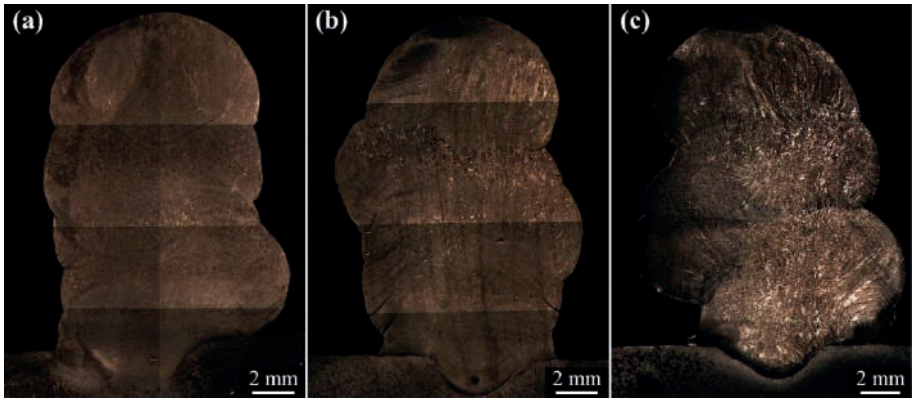


Figure 4. Cross-section images of parts a) 95% ER70S-6–5% ER309L, b) 90% ER70S-6–10% ER309L, 85% c) ER70S-6–15% ER309L.

Figure 5 shows the cross-sectional dimensions of the parts. The average layer width, height, and total cross-sectional area increase with increasing ER309L ratio. When comparing the 5% ER309L and 15% ER309L deposited alloys, the change in average layer height was lower than the others, while the increase in average layer width and total cross-sectional area was more noticeable. The increase in layer dimensions with increasing ER309L content indicates that the alloying process was successful with varying rates. However, when evaluating the results, it should be noted that dimensional changes may occur depending on the region from where the samples were taken due to partial layer sagging. The cross-section samples shown in Figure 4 were taken from the stable, continuous layer regions of each part. Therefore, it was considered that the results can reflect a general characteristic of the parts.

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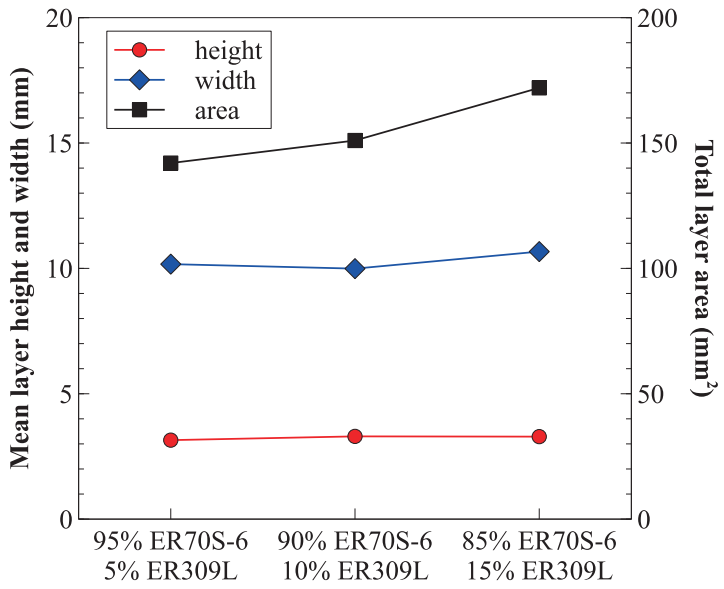


Figure 5. Dimensional results of the parts.

3.2. Microstructure

Figure 6 shows microstructure images of the produced parts. It was observed that the microstructure of all three parts differed from those produced with %100 ER70S-6. The microstructure of the part produced from %100 ER70S-6 using WAAM was reported to consist predominantly of polygonal ferrite, with variations depending on the part regions (Ayan & Kahraman, 2022a). In the case of the %100 ER309L containing WAAM samples, it was noted that the microstructure consisted of delta ferrite in an austenite matrix (Motghare et al., 2024). However, in this study, the parts produced with in-situ alloying exhibited a microstructure that was different from these. This situation was largely due to the alloying elements transferred from ER309L to ER70S-6 during the in-situ alloying process.

Figure 6a and b shows that the structure produced with 5% ER309L alloying is predominantly composed of acicular ferrite. Acicular ferrite can occur in the weld metal of steel structures subjected to welding processes. The formation of it is influenced by alloying elements, cooling rate, and non-metallic inclusions (Loder et al., 2016). In addition, the high heat input and rapid cooling resulting from the WAAM also contributed to this formation.

When the ER309L ratio increased from 5% to 10% and 15%, the microstructure changed. From Figure 6c, d, e, and f, it can be seen that the microstructure contains bainite and martensite. The main reason for this formation was attributed to the effect of the elements transferred from the ER309L to the produced parts. Particularly, Cr and Ni transferred from ER309L changed the microstructure of the new alloy structure formed with ER70S-6. Cr (Wang et al., 2000) and Ni (Bacalhau & Moreira Afonso, 2021) shift the CCT diagram of steel to the right and, by preventing ferrite-perlite transformation, promote bainite and martensite formation. However, the presence of bainite and

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

martensite clearly began at 10% ER309L addition. According to Figure 6c and e, the microstructures of the 10% and 15% ER309L samples were generally similar. However, the hard phases were found to be denser in the 15% ER309L deposited part.

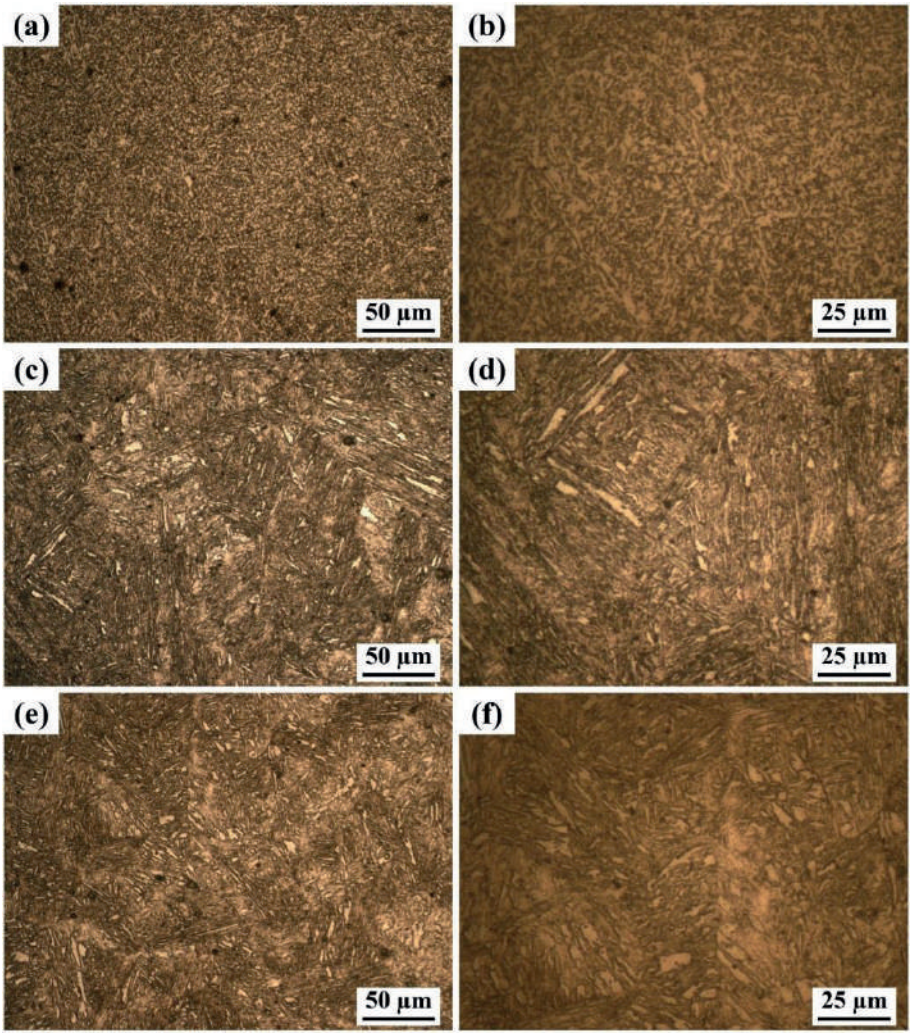


Figure 6. Microstructure images of the fabricated parts a)-b) 95% ER70S-6–5% ER309L, c)-d) 90% ER70S-6–10% ER309L, e)-f) 85% ER70S-6–15% ER309L.

3.3. Microhardness

The hardness results of the three different structures produced are shown in Figure 7. When each part was evaluated individually, the hardness varied according to the changing layer regions. This situation is based on the microstructural variations between the layers, which are common in the nature of the WAAM process. In the WAAM process, the amount of repeated heat input to each layer and their cooling rates vary from layer to layer. The lower layers are exposed to more heating and cooling. Consequently, differences in microstructure could occur, and thud hardness varies from layer to layer.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The average hardness of the samples produced with 5% ER309L, 10% ER309L, and 15% ER309L were calculated as 275 HV, 352 HV, and 368 HV, respectively. From this, it was seen that hardness increased with increasing ER309L ratio. While the average hardness increased by 77 HV when the ER309L ratio was increased from 5% to 15%, it increased by 16 HV when it was changed from 10% to 15%. Therefore, it was concluded that the increase in hardness could be limited to a certain level depending on the ER309L ratio. The hardness of the 100% ER70S-6 structure produced via WAAM was reported as 165 HV (Ayan & Kahraman, 2022a), regardless of the different parameters used in its production. In processes using different multi pass welding parameters with ER309L, the average hardness was calculated on the weld metal of ER309L as 230 HV (Mogano & Madyira, 2021). This indicates that the hardness of the structure produced by combining these two materials (ER70S-6 and ER309L) increased significantly. Microstructural investigations revealed acicular ferrite, bainite, and martensite structures, which significantly increased the hardness of the parts composed of the new material. Based on the microstructural changes and the increase in hardness, it was concluded that WAAM structures produced from ER70S-6 and ER309L have the potential to yield products having high mechanical properties.

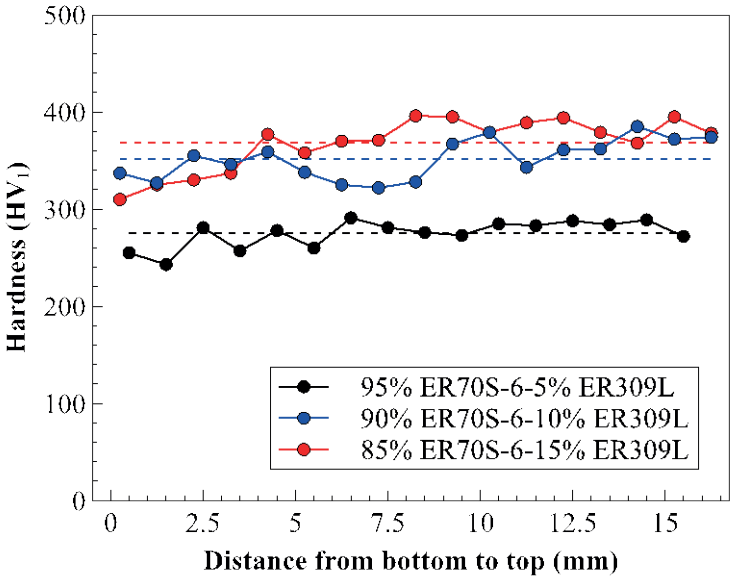


Figure 7. Microhardness results of the fabricated parts.

CONCLUSION

In this study, ER70S-6 and ER309L wires with different properties were subjected to in situ alloying process using the WAAM technique at varying wire feed rates. The following results were obtained from the examinations and tests performed on the manufactured parts.

- Parts free from macro defects were successfully produced by adding ER309L at ratios of 5%, 10% and 15% to ER70S-6 using the WAAM technique. By combining both wires in the in-situ

alloying process, metallurgical bonding was achieved. The method applied in this study demonstrated that in-situ alloying can be performed on these two different wires.

- As a result of cross-section analyses, with an increase in the ER309L rate from 5% to 15%, the average layer width and height of the parts and the total surface areas of the layers showed an increasing trend.

- The microstructure of parts produced with ER70S-6 and ER309L combinations changed significantly compared to WAAM processes previously performed on a single wire. The alloying elements transferred from ER309L to ER70S-6 resulted in microstructural changes. While acicular ferrite structures were generally found in the microstructure of the 5% ER309L deposited sample, a structure containing bainite and martensite was obtained in the 10% and 15% ER309L deposited structures.

- The hardness of the fabricated parts varied considerably compared to single-wire structures produced in previous studies. The hardness of the samples manufactured by in-situ alloying increased due to the hard phases observed in the microstructure. While the hardness increased significantly when the ER309L ratio increased from 5% to 10%, a smaller increase was observed when the ratio increased from 10% to 15%.

REFERENCES

Ayan, Y. (2024). Fabrication and characterization of a new high-strength alloy via WAAM using GMAW+cold wire feeding. *Materials Chemistry and Physics*, *328*. https://doi.org/10.1016/j.matchemphys.2024.130038

Ayan, Y., & Kahraman, N. (2022a). Bending fatigue properties of structural steel fabricated through wire arc additive manufacturing (WAAM). *Engineering Science and Technology, an International Journal*, *35*. https://doi.org/10.1016/j.jestch.2022.101247

Ayan, Y., & Kahraman, N. (2022b). Fabrication and characterization of functionally graded material (FGM) structure containing two dissimilar steels (ER70S-6 and 308LSi) by wire arc additive manufacturing (WAAM). *Materials Today Communications*, *33*. https://doi.org/10.1016/j.mtcomm.2022.104457

Bacalhau, J. B., & Moreira Afonso, C. R. (2021). Effect of Ni addition on bainite microstructure of low-carbon special bar quality steels and its influence on CCT diagrams. In *Journal of Materials Research and Technology* (Vol. 15, pp. 1266–1283). Elsevier Editora Ltda. https://doi.org/10.1016/j.jmrt.2021.07.114

Chen, C., He, H., Zhou, J., Lian, G., Huang, X., & Feng, M. (2022). A profile transformation based recursive multi-bead overlapping model for robotic wire and arc additive manufacturing (WAAM). *Journal of Manufacturing Processes*, *84*, 886–901. https://doi.org/10.1016/j.jmapro.2022.10.042

Hwang, Y. H., Lee, C. M., & Kim, D. H. (2023). The Effects of the Variable-Pressure Rolling of a Wire Arc Additively Manufactured Inconel625-SS308L Bimetallic Structure. *Applied Sciences (Switzerland)*, *13*(18). https://doi.org/10.3390/app131810187

Iqbal, H., Ascari, A., Liverani, E., & Fortunato, A. (2025). Analysis of process parameters, deposition strategies and build orientations in wire-arc additive manufacturing (WAAM). *Progress in Additive Manufacturing*, *10*(8), 5711–5729. https://doi.org/10.1007/s40964-024-00938-w

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Jurić, I., Garašić, I., Bušić, M., & Kožuh, Z. (2019). Influence of Shielding Gas Composition on Structure and Mechanical Properties of Wire and Arc Additive Manufactured Inconel 625. *JOM*, *71*(2), 703–708. https://doi.org/10.1007/s11837-018-3151-2

Kong, H., Liu, Y., Li, F., Ren, H., Song, C., Kang, K., & Sun, Q. (2024). In-situ fabrication of martensitic stainless steel via heterogeneous double-wire arc-directed energy deposition. *Virtual and Physical Prototyping*, *19*(1). https://doi.org/10.1080/17452759.2024.2350610

Loder, D., Michelic, S. K., & Bernhard, C. (2016). Acicular Ferrite Formation and Its Influencing Factors-A Review. *Journal of Materials Science Research*, *6*(1), 24. https://doi.org/10.5539/jmsr.v6n1p24

Mogano, K., & Madyira, D. (2021). Study of Microstructure and Hardness of Austenitic Stainless Steel 309L Multipass Weld Beads. *Proceedings of 2021 IEEE 12th International Conference on Mechanical and Intelligent Manufacturing Technologies, ICMIMT 2021*, 19–24. https://doi.org/10.1109/ICMIMT52186.2021.9476214

Motghare, S. V., Ashtankar, K. M., & Lautre, N. K. (2024). Experimental investigation of electrochemical and mechanical properties of stainless steel 309L at different built orientation by cold metal transfer assisted wire arc additive manufacturing. *Materials Today Communications*, *39*. https://doi.org/10.1016/j.mtcomm.2024.109382

Paul, M. J., Klein, T., Simson, C., Niedermayer, J., Kruzic, J. J., & Gludovatz, B. (2022). Strength and fracture resistance of in-situ alloyed compositionally-graded Al-Si processed by dual-wire arc directed energy deposition. *Additive Manufacturing*, *60*. https://doi.org/10.1016/j.addma.2022.103291

Wang, J., Van Der Wolk, P. J., & Van Der Zwaag, S. (2000). On the influence of alloying elements on the bainite reaction in low alloy steels during continuous cooling. *Journal of Material Science*, *35*, 4393–4404. https://doi.org/10.1023/A:1004865209116

Xu, M., Chen, S., Yuan, T., Jiang, X., & Zhang, H. (2022). Effect of thermal cycles on the microstructure and properties of the Al–Zn–Mg–Cu alloy during wire-arc additive manufacturing. *Journal of Alloys and Compounds*, *928*. https://doi.org/10.1016/j.jallcom.2022.167172

Zhou, W., Shen, C., Wang, L., Zhang, T., Li, Y., Xin, J., Zhang, Y., Li, F., Ding, Y., Wu, K., Zhang, D., & Hua, X. (2024). High cycle fatigue properties of Ti-48Al-2Cr-2Nb alloy additively manufactured via twin-wire directed energy deposition-arc. *Materials Characterization*, *218*. https://doi.org/10.1016/j.matchar.2024.114526

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TÜRKİYE TARIM TEKNOLOJİLERİ EKOSİSTEMİ: TARIMSAL MEKANİZASYONUN DÜZEYİ VE YAPISAL SORUNLARI, AR-GE/İNOVASYON DİNAMİKLERİ, TEŞVİK MİMARİSİNİN ANALİZİ VE YOL HARİTASI

Figen Taşcı Durgut

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ÖZET

Günümüz, teknolojik ilerlemenin ivmelendiği; bilimsel üretimin hem hız hem de kapsam bakımından derinleşerek bilgi sınırlarını sürekli genişlettiği bir dönüşüm evresi olarak tanımlanabilir. Bu dönüşüm, bilginin stratejik bir kaynak olarak konumlandırılması; sistematik biçimde üretilmesi, kurumsal süreçlere entegre edilmesi, yönetilmesi ve süreklilik içinde yenilikçi çıktılara dönüştürülmesi kapasitesiyle açıklanmaktadır. Bu perspektif, tarım gibi tarihsel olarak emek–sermaye yoğun kabul edilen sektörlerde dahi rekabetçiliğin; üretim kararlarının veri temelli optimizasyonu, teknoloji yoğun süreç yönetimi, inovasyon ve sürdürülebilirlik kapasitesinin ölçeklenmesi üzerinden yeniden tanımlandığını ve "geleneksel üretim" paradigmasından "bilgiye dayalı üretim" paradigmasına geçişin hızlandığını göstermektedir. Bu dönüşüm bağlamında Türkiye'de tarım teknolojileri ekosistemi; tarımsal üretimde verimlilik, kaynak etkinliği ve gıda arz güvenliği hedeflerine erişimde tarımsal mekanizasyon altyapısının modernizasyonunu stratejik bir kaldıraç olarak konumlandırmakta; mekanizasyonu dijital teknolojiler ve yenilikçi çözümlerle bütünleştiren çok bileşenli bir dönüşüm gündemi ortaya koymaktadır. Bununla birlikte, işletme/parsel yapısının parçalı karakteri ve makine parkının yaşlanması; ölçek ekonomilerini zayıflatarak modern ekipman yatırımlarının ve mekanizasyona bütünleşmiş dijital uygulamaların sahaya yayılımını sınırlayan temel yapısal bariyerler olarak öne çıkmaktadır.

Bu bildirinin amacı; Türkiye tarım teknolojileri ekosistemini tarımsal mekanizasyonun düzeyi ve yapısal sorunları, Ar-Ge/İnovasyon dinamikleri, teşvik mimarisinin etkinliği ve erişilebilirliği, fikri mülkiyet/teknoloji transferi bağlantısı eksenlerinde bütüncül olarak analiz ederek uygulanabilir bir yol haritası önermektir. Yöntem, politika belgeleri ve sektör raporları ile akademik literatür üzerinden yürütülen belge analizi ve tematik sentez yaklaşımına dayanmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Bulgular; mekanizasyon yatırımlarının etkinliğinin ölçek/parçalanma sorunu kadar, dijital okuryazarlık ve farkındalık eksikliği ile de sınırlanabildiğini göstermektedir. Ayrıca tarım makineleri imalatında yenilik türlerinin firma performansı üzerinde etkili olduğu, ancak çıktıların ticarileştirme ve ölçeklenme hattında süreklilik gerektirdiği bulgulamaktadır. Teşvik mimarisi açısından ise çoklu destek setlerinin varlığına rağmen prosedürel karmaşıklığın kullanım etkinliğini düşürebildiği; patent/test/kalibrasyon ve markalaşma gibi tamamlayıcı unsurların koordinasyonlu kurgulanmasının kritik olduğu vurgulanmaktadır. Türkiye'nin GII 2025'te 43. sırada yer alması ve üst-orta gelir grubunda güçlü performans gösteren ülkeler arasında konumlanması, tarımsal mekanizasyonda yenileme programlarını Ar-Ge/ticarileştirme ve teşvik mimarisiyle entegre eden "aşamalı dönüşüm" yaklaşımını stratejik olarak desteklemektedir.

Anahtar Kelimeler: Tarım teknolojileri; Ar-Ge ve inovasyon; teşvik mimarisi; dijital okuryazarlık; fikri mülkiyet; yol haritası

Turkish Agricultural Technology Ecosystem: Level and Structural Problems of Agricultural Mechanization, R&D/Innovation Dynamics, Analysis of Incentive Architecture and Roadmap

ABSTRACT

Today can be defined as a transformative phase where technological progress is accelerating; scientific production is deepening in both speed and scope, constantly expanding the boundaries of knowledge. This transformation is explained by the positioning of knowledge as a strategic resource, its systematic production, integration into institutional processes, management, and continuous transformation into innovative outputs. This perspective shows that even in sectors historically considered labor-capital intensive, such as agriculture, competitiveness is being redefined through data-driven optimization of production decisions, technology-intensive process management, and scaling of innovation and sustainability capacity, and that the transition from the "traditional production" paradigm to the "knowledge-based production" paradigm is accelerating. In this context, the agricultural technologies ecosystem in Turkey positions the modernization of agricultural mechanization infrastructure as a strategic leverage in achieving productivity, resource efficiency, and food supply security goals in agricultural production; This presents a multi-component transformation agenda integrating mechanization with digital technologies and innovative solutions. However, the fragmented nature of the farm/plot structure and the aging machinery park stand out as key structural barriers that weaken economies of scale and limit the spread of modern equipment investments and digitally integrated applications in mechanization.

The aim of this paper is to analyze the Turkish agricultural technologies ecosystem holistically in terms of the level and structural problems of agricultural mechanization, R&D/Innovation dynamics, the effectiveness and accessibility of the incentive architecture, and the link between intellectual property and technology transfer, and to propose a feasible roadmap. The method is based on

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

document analysis and thematic synthesis approach conducted through policy documents, sector reports, and academic literature. The findings show that the effectiveness of mechanization investments can be limited not only by the scale/fragmentation problem but also by a lack of digital literacy and awareness. Furthermore, it has been found that types of innovation in agricultural machinery manufacturing have an impact on firm performance but require continuity in the commercialization and scaling up of outputs. In terms of incentive architecture, it is emphasized that despite the existence of multiple support sets, procedural complexity can reduce the efficiency of use; and that the coordinated design of complementary elements such as patents/testing/calibration and branding is critical. Turkey's ranking as 43rd in GII 2025 and its position among countries demonstrating strong performance in the upper-middle income group strategically supports the "phased transformation" approach that integrates renewal programs in agricultural mechanization with R&D/commercialization and incentive architecture.

Keywords: Agricultural technologies; R&D and innovation; incentive architecture; digital literacy; intellectual property; roadmap

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ARTIFICIAL INTELLIGENCE–BASED RISK ASSESSMENT MODELS IN HALAL FOOD CERTIFICATION: A CONCEPTUAL FRAMEWORK FOR DIGITAL DECISION SUPPORT SYSTEMS

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ABSTRACT

The global halal food industry has expanded significantly in response to increasing consumer awareness, population growth, and growing expectations for transparency in food production systems. Halal food certification is essential for ensuring compliance with Islamic dietary principles throughout the food supply chain, from raw material sourcing to processing, packaging, storage, and distribution. However, the certification process is complex and subject to various risk factors, including cross-contamination with non-halal substances, unclear origins of additives and enzymes, limited traceability, and inconsistencies in auditing practices. Conventional halal certification systems rely largely on periodic inspections, manual documentation, and expert judgment, which may be insufficient to manage the dynamic and data-intensive nature of modern food supply chains.

Artificial intelligence (AI) has emerged as a powerful tool for risk assessment and decision support in food safety and quality management. Although AI-based models have been successfully applied in areas such as food fraud detection and supply chain optimization, their application in halal food certification remains limited. This study proposes a conceptual framework for integrating AI-based risk assessment models into halal certification processes to enhance consistency, transparency, and proactive risk management.

The proposed framework identifies critical halal risk points across the food supply chain, including raw material origin, processing aids and additives, shared production lines, packaging materials, and logistics. Artificial intelligence methodologies such as machine learning algorithms, fuzzy logic systems, and rule-based expert systems are discussed as suitable tools for modeling these risks. Machine learning enables the analysis of large datasets from certification records, supplier information, and audit reports to predict potential non-compliance. Fuzzy logic systems allow the incorporation of qualitative judgments and uncertainty inherent in halal assessments, while rule-based expert systems support transparent and standardized decision-making.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

In conclusion, AI-based risk assessment models offer a promising approach for strengthening halal food certification systems. By enabling predictive, data-driven, and standardized decision support, these models can improve risk detection, resource allocation, and overall credibility of halal certification in complex global food supply chains. The conceptual framework presented provides a foundation for future empirical studies and practical implementation of AI-supported halal assurance systems.

Keywords: Halal food certification, artificial intelligence, risk assessment models, decision support systems, food supply chain, digital traceability.

INTRODUCTION

The global halal food industry has experienced a transformative expansion, evolving from a localized market catering to specific religious enclaves into a multi-trillion-dollar economic powerhouse that intersects with global trade, international law, and advanced food science (Sunmola et al., 2025; Ab Talib et al., 2024; Hidayat & Nugraha, 2023). As of the current period, the global market for halal products exceeds two trillion U.S. dollars, with projections suggesting a rise to approximately 2.8 trillion U.S. dollars in the near future (Ab Talib et al., 2024). This growth is not merely a reflection of the expanding Muslim population but is also driven by increasing demand among non-Muslim consumers, who associate halal products with superior standards of food safety, hygiene, and ethical integrity, encapsulated in the principle of halalan tayyiban (Hidayat & Nugraha, 2023; Firdaus, 2023; Yılmaz & Kaya, 2024). However, the escalating complexity of globalized food supply chains (FSCs) has surpassed the operational capacity of traditional halal certification systems, which predominantly depend on periodic manual audits, paper-based documentation, and subjective expert judgment (Azmi & Hassan, 2023; Putra & Suryani, 2024; Sunmola et al., 2025).

The contemporary halal certification landscape therefore faces a critical challenge: preserving the integrity of halal claims across extended and fragmented supply chains involving multiple supplier tiers, shared processing facilities, and multimodal logistics networks (Khan et al., 2024; Al-Qaradawi & Omar, 2022). Empirical evidence suggests that food fraud incidents within the halal sector have increased by approximately 15% over the past five years, manifesting primarily through mislabeling, ingredient substitution, and the misrepresentation of non-halal products (Khan et al., 2024). Conventional certification models often characterized as uniform, checklist-driven, and non-risk-differentiated frequently fail to distinguish between high-risk and low-risk actors, resulting in inefficient allocation of auditing resources and increased vulnerability to compliance breaches (Azmi & Hassan, 2023). In response to these systemic shortcomings, the integration of artificial intelligence (AI) and digital decision support systems (DDSS) has emerged not merely as an innovation but as a strategic necessity for enhancing transparency, traceability, and risk-based halal assurance (Yusof & Ismail, 2023; Rahman & Zailani, 2024).

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Theoretical Foundations of Halal 4.0 and Digital Assurance

The transition toward Halal 4.0 signifies the systematic integration of Industry 4.0 technologies particularly artificial intelligence (AI), blockchain, and the Internet of Things (IoT) into the halal assurance system (HAS), thereby redefining conventional certification paradigms (Ab Talib et al., 2024; Sulaiman & Karim, 2024). This digital transformation aims to shift halal certification from a predominantly reactive, inspection-based approach toward a proactive, predictive, and data-driven framework capable of continuous monitoring and adaptive control (Sunmola et al., 2025; Rahman & Zailani, 2024; Halal Practitioner Editorial Board, 2023). At its core, the application of AI within halal assurance enables the processing and analysis of large, heterogeneous datasets to detect latent patterns of non-compliance and to anticipate potential risks before they materialize as violations of halal integrity (Yusof & Ismail, 2023; Halal Practitioner Editorial Board, 2023; Putra & Suryani, 2024).

The fundamental value of a digitalized halal supply chain lies in its capacity to prevent direct contact with prohibited (haram) substances and to manage cross-contamination risks while remaining aligned with the theological expectations and moral perceptions of consumers (Ab Talib et al., 2024). Unlike conventional food safety and quality management systems, halal certification operates at the confluence of theological doctrine, legal regulation, and ethical governance, necessitating a delicate balance between Shariah compliance and institutional oversight (Azmi & Hassan, 2023; Rahman & Zailani, 2024). Within this complex ecosystem, AI functions as an intelligent communication and interpretation agent, capable of mapping Shariah principles onto regulatory requirements, facilitating real-time risk visibility, and supporting stakeholders through automated reporting systems and dynamic decision dashboards (Rahman & Zailani, 2024).

Table 1. Core Digital Technologies Supporting Halal 4.0 and Their Contributions to System Integrity (Sunmola et al., 2025; Hidayat & Nugraha, 2023; Yusof & Ismail, 2023; Rahman & Zailani, 2024; Putra & Suryani, 2024)

Technology Component	Primary Function in Halal Certification	Impact on System Integrity
Artificial Intelligence	Predictive analytics, pattern recognition, automated verification	Increases accuracy and reduces human error in audit results
Blockchain	Immutable ledger for transaction and certificate records	Prevents fraud and ensures end-to-end traceability
IoT (Internet of Things)	Real-time monitoring of facilities and logistics	Detects cross-contamination and segregation breaches immediately
Cloud Computing	Centralized data storage and stakeholder	Enhances accessibility and transparency across

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ISBN: 978-9952-610-30-7

	collaboration	global networks

Characterization of Critical Risk Points in the Halal Supply Chain

The development of an effective AI-based risk assessment model necessitates a granular identification of critical halal risk points (CHRPs) throughout the supply chain. These risk points represent stages at which the halal integrity of a product is most susceptible to compromise and therefore require continuous surveillance supported by intelligent data analytics and predictive modeling (Sunmola et al., 2025; Khan et al., 2024; Hassan & Noor, 2023).

Raw Material Sourcing and Ingredient Complexity

The most critical halal-related risks frequently emerge at the upstream stages of the supply chain, particularly during raw material sourcing and ingredient procurement. Contemporary food products often incorporate complex additives, enzymes, and processing aids whose biological or technological origins may be opaque or insufficiently disclosed (Sunmola et al., 2025; Rashid & Hamzah, 2024). Ingredients such as gelatin, emulsifiers, and flavoring agents may be derived from porcine sources, animals slaughtered in non-halal conditions, or synthetic substrates that raise Shariah-related concerns (Sunmola et al., 2025; Azmi & Hassan, 2023). The credence quality nature of halal attributes implies that consumers are unable to verify compliance after purchase, thereby rendering the integrity of initial sourcing decisions critically important (Al-Qaradawi & Omar, 2022). Within this context, AI-driven risk assessment models can systematically analyze supplier registries, ingredient taxonomies, and historical compliance records to generate dynamic risk scores for specific inputs and vendors, enabling the proactive identification and escalation of materials associated with ambiguous documentation or elevated non-compliance risk (Yusof & Ismail, 2023; Rahman & Zainuddin, 2024).

Manufacturing and Processing Hazards

Within the processing stage of the halal supply chain, the predominant risk arises from cross-contamination, particularly in facilities operating shared production lines for both halal and non-halal products (Hassan & Noor, 2023; Azmi & Abdullah, 2020). Even when standard sanitation and cleaning-in-place (CIP) protocols are implemented, residual traces of prohibited substances may persist on equipment surfaces, potentially resulting in najis (ritual impurity) contamination (Rashid & Hamzah, 2024; Azmi & Abdullah, 2020). In this context, AI-integrated sensing technologies and smart manufacturing systems can continuously monitor CIP cycles, equipment status, and production scheduling to verify strict adherence to segregation requirements. Such systems generate immutable, time-stamped digital compliance records that offer significantly greater reliability and auditability than

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ISBN: 978-9952-610-30-7

conventional manual logs (Rahman & Zailani, 2024; Halal Practitioner Editorial Board, 2023; Halim & Fauzi, 2023).

Logistics, Distribution, and the "Last Mile"

Logistics represents a major “invisible” risk in halal integrity (Spink & Moyer, 2019). Cross-contamination can occur during transportation if halal products are stored in the same containers as non-halal items without proper physical segregation (Rahman & Zainuddin, 2024; Spink & Moyer, 2019). Furthermore, there is often no robust mechanism to disseminate the halal status of goods through traditional freight documents or legacy information systems, leading to accidental co-mingling (Yusof & Ismail, 2023). Digital decision support systems can optimize distribution routes and storage plans using linear programming and predictive analytics to minimize these risks while simultaneously reducing operational costs (Putra & Suryani, 2024; Hassan & Noor, 2023).

Machine Learning Architectures for Halal Risk Assessment

Machine learning (ML) functions as the analytical engine of the proposed conceptual framework, enabling the systematic processing of heterogeneous data streams for halal fraud detection, anomaly identification, and continuous compliance monitoring (Yusof & Ismail, 2023; Spink & Moyer, 2019). By leveraging supervised, unsupervised, and semi-supervised learning architectures, ML models can integrate structured data (e.g., supplier certifications, audit histories, ingredient taxonomies) with unstructured inputs such as inspection reports, sensor logs, and textual documentation to uncover latent risk patterns that may elude traditional rule-based systems (Spink & Moyer, 2019; Rahman & Zainuddin, 2024). Supervised learning techniques are particularly effective in classifying known fraud typologies and non-compliance cases, while unsupervised clustering and anomaly detection models support the identification of novel or emerging risk behaviors within complex halal supply networks (Sunmola et al., 2025; Putra & Suryani, 2024). Through iterative learning and feedback from audit outcomes, ML-driven systems can dynamically recalibrate risk scores at the ingredient, supplier, and process levels, thereby enabling proactive intervention and evidence-based decision-making within digital halal assurance ecosystems (Rahman & Zailani, 2024).

Deep Learning for Visual Authentication

Computer vision Technologies particularly Convolutional Neural Networks (CNNs) have become central to the visual authentication of halal logos, packaging elements, and labeling claims within digital halal assurance systems (Spink & Moyer, 2019; Abdullah & Rahim, 2024; Ismail & Latif, 2022). The proliferation of counterfeit or misleading halal logos represents a critical threat to consumer trust and market integrity, especially in cross-border trade environments where regulatory enforcement and logo standardization vary significantly (Abdullah & Rahim, 2024; Ismail & Latif, 2022). Unlike conventional manual inspection methods, CNN-based models are capable of extracting

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

high-level spatial and textural features from packaging images, enabling automated differentiation between authentic, expired, modified, or unauthorized halal logos in real time (Ismail & Latif, 2022).

Deep learning driven visual authentication systems can be trained on large, geographically diverse datasets containing certified halal logos issued by multiple national and international authorities. This diversity enhances model robustness against variations in logo design, printing quality, color degradation, and intentional obfuscation tactics used in fraudulent labeling (Abdullah & Rahim, 2024). When deployed through mobile or embedded applications, such systems enable consumers, auditors, and supply chain actors to perform instantaneous verification at points of sale or inspection, thereby reducing information asymmetry and reinforcing transparency across the halal supply chain (Spink & Moyer, 2019).

Comparative evaluations of CNN architectures including VGG, ResNet, Inception, and lightweight mobile-oriented networks demonstrate that model performance varies significantly with respect to accuracy, computational efficiency, and deployment context (Ismail & Latif, 2022). While deeper architectures may achieve higher classification accuracy, lightweight models offer advantages in real-time, resource-constrained environments such as smartphones or handheld inspection devices. Consequently, the selection of an optimal deep learning architecture for halal logo authentication must balance predictive performance with scalability, interpretability, and operational feasibility within broader AI-enabled halal risk assessment frameworks (Spink & Moyer, 2019; Abdullah & Rahim, 2024).

Table 2. Comparative Performance of Deep Learning Architectures for Halal Visual Authentication Tasks (Spink & Moyer, 2019; Ismail & Latif, 2022; Sun & Liu, 2024)

Deep Learning Architecture	Performance Metric (F1-Score/Accuracy)	Practical Application
Back Propagation Neural Network	0.949 F1-score	Preferred for logo recognition due to computational efficiency
CNN (Standard)	95% Accuracy	Used in distinguishing between authentic and counterfeit rice
YOLOv5	High-speed real-time detection	Ideal for mobile "point-and-scan" consumer apps
MobileNetV2-SSD	Optimized speed/accuracy balance	Suitable for edge computing in warehouse monitoring

Multi-Modal Authentication Systems

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Beyond visual inspection alone, advanced halal assurance frameworks increasingly adopt multi-modal authentication strategies that integrate computer vision techniques with laboratory-based analytical data, thereby strengthening the evidentiary basis of halal verification (Rashid & Hamzah, 2024; Abdullah & Rahim, 2024). While visual analysis of packaging and logos is effective in identifying counterfeit or misleading claims, it remains insufficient for verifying the biological origin of food products particularly meat and processed foods where visual cues are inherently limited. In this regard, laboratory techniques such as DNA barcoding and molecular authentication provide a complementary and objective layer of verification by directly identifying species composition and detecting the presence of prohibited biological materials (Rashid & Hamzah, 2024).

A representative multi-modal system may therefore combine CNN-based packaging and logo analysis with DNA sequencing results to validate both symbolic compliance (logo authenticity and labeling integrity) and biological compliance (species-level halal status) within a unified analytical pipeline (Abdullah & Rahim, 2024). This integration is particularly valuable in mitigating sophisticated fraud scenarios in which authentic halal logos are deliberately applied to non-halal or adulterated products, a practice that cannot be reliably detected through visual inspection alone. By fusing heterogeneous data sources, multi-modal systems significantly reduce false positives and false negatives, thereby enhancing the overall robustness of halal authentication mechanisms (Rashid & Hamzah, 2024).

At the decision-making layer, artificial intelligence algorithms can synthesize these disparate inputs such as logo authenticity scores, DNA barcoding outcomes, historical supplier compliance records, and geographically inferred risk indicators into a unified and interpretable “halal confidence score” assigned to a specific product batch (Rahman & Zainuddin, 2024; Abdullah & Rahim, 2024). This composite score supports risk-based prioritization by auditors and certification bodies, enabling targeted interventions where uncertainty or non-compliance risk is highest. Consequently, multi-modal authentication systems represent a critical evolution toward evidence-based, scalable, and AI-driven halal assurance, aligning technological rigor with the theological and ethical imperatives of halal certification (Rahman & Zainuddin, 2024).

Fuzzy Logic Frameworks for Managing Uncertainty

A distinctive characteristic of halal certification lies in the presence of epistemic and theological uncertainty associated with specific data points, such as trace-level contamination, incomplete ingredient disclosure, or divergent religious interpretations of certain additives categorized as mashbooh (doubtful) (Rashid & Hamzah, 2024; Rahman & Noor, 2023; Molina & García, 2024). Unlike conventional food safety parameters that often rely on binary classifications (safe/unsafe), halal compliance frequently operates along a spectrum of permissibility, where absolute certainty is difficult to achieve. This inherent ambiguity poses significant challenges for traditional rule-based or checklist-driven certification systems, which are poorly equipped to model gradations of risk and uncertainty.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Fuzzy logic (FL) offers a theoretically robust and practically suitable artificial intelligence methodology for addressing such imprecision by enabling degrees of truth rather than binary decision boundaries (Rashid & Hamzah, 2024). Through the use of linguistic variables (e.g., low risk, moderate contamination, high confidence halal) and membership functions, FL systems can translate qualitative expert judgments and partial evidence into computable forms. This capability is particularly valuable in halal contexts where Shariah rulings may differ across jurisdictions or schools of thought, allowing certification bodies to encode flexible, context-sensitive decision rules without oversimplifying complex religious and ethical considerations (Rahman & Noor, 2023).

Within AI-enabled halal assurance frameworks, fuzzy inference systems can be integrated with machine learning and laboratory data to support risk-weighted and explainable decision-making. For example, fuzzy rule sets may combine inputs such as contamination probability, additive origin confidence, and supplier trust scores to generate a graded halal compliance output rather than a rigid pass fail outcome (Rashid & Hamzah, 2024; Molina & García, 2024). Such hybrid fuzzy systems not only enhance robustness under uncertainty but also improve transparency and interpretability key requirements for gaining acceptance among religious authorities, auditors, and consumers. Consequently, fuzzy logic frameworks serve as a critical bridge between computational rigor and the nuanced theological reasoning inherent in halal certification practices (Molina & García, 2024).

Modeling Porcine DNA Concentration

A critical application of fuzzy logic (FL) within halal assurance systems involves the interpretation of cycle threshold (Ct) values obtained from quantitative polymerase chain reaction (qPCR) assays used for the detection of porcine DNA (Rashid & Hamzah, 2024; Rashid & Hamzah, 2024b). In qPCR analysis, lower Ct values correspond to higher concentrations of target DNA; however, Ct ranges between approximately 35 and 40 cycles are widely recognized as analytically ambiguous due to stochastic amplification effects and background noise (Rashid & Hamzah, 2024; Rahman & Noor, 2023). Conventional binary interpretations struggle to resolve this uncertainty, particularly in cases of trace-level contamination. The FL framework addresses this limitation by employing membership functions that translate numerical Ct values into linguistically meaningful categories, such as low, medium, or high contamination likelihood (Rashid & Hamzah, 2024).

In practical implementations, the system commonly adopts a Mamdani-type fuzzy inference structure, incorporating multiple input variables corresponding to different genetic markers used in porcine DNA identification, including Cytochrome B, 18S rRNA, 12S rRNA, and D-loop mitochondrial regions (Rashid & Hamzah, 2024). During the input categorization stage, Ct values are mapped to predefined fuzzy sets; for example, in the case of Cytochrome B, Ct values ranging from 1 to 20 may be classified as low (indicating strong DNA presence), whereas values between 21 and 40 are assigned to medium or low-confidence membership functions (Rashid & Hamzah, 2024).

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At the rule execution layer, the system applies expert-derived IF–THEN rules that integrate multiple gene signals into a coherent biological interpretation. A representative rule may be expressed as: IF the Ct value of 18S rRNA is low, THEN the presence of porcine DNA is YES and the contamination level is high (Rashid & Hamzah, 2024). Following inference, the output determination stage employs defuzzification most commonly via the centroid method to yield a crisp, actionable decision indicating whether the product complies with halal requirements or warrants additional confirmatory testing (Rashid & Hamzah, 2024b).

This fuzzy logic based interpretation framework significantly enhances auditors' decision-making capacity by enabling consistent, transparent, and reproducible evaluation of molecular diagnostic data. Its particular strength lies in handling trace-level contamination scenarios that would otherwise be dismissed or misclassified by rigid pass fail systems, thereby reinforcing both scientific rigor and Shariah-compliant risk sensitivity within halal certification processes (Molina & García, 2024; Rashid & Hamzah, 2024).

Rule-Based Expert Systems and Shariah Logic Translation

Rule-based expert systems constitute the knowledge base of digital decision support systems (DDSS) in halal assurance, serving as a formal mechanism for translating religious jurisprudence (fiqh al-halal) and regulatory standards into executable, machine-interpretable logic (Azmi & Hassan, 2023; Firdaus, 2023). By encoding Shariah rulings, certification guidelines, and regulatory constraints as structured rules, these systems provide a consistent and auditable foundation for decision-making that aligns technological operations with theological and legal requirements. This capability is particularly critical in halal contexts, where compliance is not solely a technical matter but also a function of doctrinal interpretation and governance.

Functionally, rule-based expert systems emulate human expert reasoning by operating on a repository of facts and a predefined set of IF–THEN inference rules that reflect established halal standards and expert consensus (Kumar & Patel, 2023). For example, a rule may specify that IF an ingredient is derived from an animal source AND the slaughter method is uncertified, THEN the ingredient status is non-halal. Such explicit logic structures enhance transparency and explainability, allowing auditors and certification bodies to trace each system decision back to specific rules and evidentiary inputs a feature that is often lacking in purely data-driven machine learning models (Kumar & Patel, 2023).

Within integrated halal assurance architectures, rule-based systems frequently operate in tandem with machine learning and fuzzy logic components, forming a hybrid decision framework that combines doctrinal certainty with data-driven adaptability. While ML models excel at detecting patterns and predicting risks under uncertainty, rule-based expert systems ensure that final determinations remain anchored to Shariah principles and regulatory mandates, thereby safeguarding theological legitimacy and institutional accountability (Azmi & Hassan, 2023; Firdaus, 2023). As a result, rule-based expert

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systems play a pivotal role in maintaining trust, consistency, and interpretability within AI-enabled halal certification ecosystems.

Standardizing the Audit Process

Traditional halal audits are frequently characterized by procedural variability and interpretive inconsistency, largely stemming from differences in auditors' experience levels, domain expertise, and subjective judgment (Rahman & Zailani, 2024). Such heterogeneity can lead to uneven audit outcomes, reduced reproducibility, and potential gaps in compliance assurance, particularly in complex supply chains involving novel ingredients and processing technologies. The absence of a unified analytical framework further limits the ability of conventional audits to systematically capture and compare risk profiles across facilities and certification cycles.

In this context, rule-based expert systems embedded within digital decision support platforms can operationalize a standardized "halal decision tree", guiding auditors step by step through the evaluation of ingredients, processing methods, and control points (Latif & Ismail, 2022). By encoding established halal control point (HCP) logic into executable rules, such systems ensure that critical checks are applied consistently, regardless of the individual auditor conducting the inspection. This structured approach not only enhances procedural uniformity but also facilitates training and capacity building for less experienced auditors.

For example, when the system identifies cheese as an ingredient, it automatically activates a specialized subroutine to verify the origin of rennet or enzymes used during coagulation (Latif & Ismail, 2022). If the enzymes are determined to be animal-derived, the system requires the submission and validation of an appropriate halal slaughter certificate. Conversely, if the enzymes are microbial in origin, the expert system extends the audit pathway to assess the fermentation media, explicitly checking for the use of porcine-derived nutrients or other non-halal substrates (Sunmola et al., 2025; Latif & Ismail, 2022). Through this logic-driven escalation mechanism, expert systems minimize the risk of oversight, reinforce traceability, and ensure that audit decisions remain aligned with both Shariah principles and regulatory expectations.

Forward and Backward Chaining in Compliance

Rule-based expert systems embedded within halal digital decision support systems (DDSS) employ two complementary inference mechanisms forward chaining and backward chaining to operationalize Shariah-compliant reasoning in a structured and auditable manner (Kumar & Patel, 2023; Azmi & Hassan, 2023). Forward chaining follows a data-driven logic, initiating the inference process from available factual inputs such as ingredient lists, processing parameters, or supplier certifications, and iteratively applying IF–THEN rules to derive intermediate conclusions and, ultimately, the halal status of a product. This reasoning strategy is particularly effective in routine certification workflows where

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complete datasets are available and rapid, standardized evaluations are required (Kumar & Patel, 2023).

Conversely, backward chaining adopts a goal-oriented reasoning approach that begins with a predefined objective such as determining whether a product satisfies halal requirements and works backward to identify the specific evidence, documentation, or verification steps necessary to justify that conclusion (Azmi & Hassan, 2023; Firdaus, 2023). This method is especially valuable in complex or ambiguous certification scenarios involving novel ingredients, imported raw materials, or incomplete records, as it enables auditors to systematically pinpoint missing or critical information rather than conducting exhaustive, non-targeted inspections.

By automating both forward and backward reasoning pathways, DDSS significantly reduces the administrative burden on halal certification bodies while minimizing the risk of human error inherent in manual, cognitively demanding evaluations of complex ingredient and process interactions (Rahman & Zailani, 2024; Putra & Suryani, 2024). Moreover, when integrated with AI-based risk scoring and traceability modules, these inference mechanisms support adaptive audit workflows in which high-risk cases trigger deeper backward-chaining investigations, whereas low-risk products are efficiently processed through forward-chaining routines, thereby enhancing both consistency and scalability in halal compliance assessment (Sunmola et al., 2025).

Risk-Based Auditing and Strategic Resource Allocation

One of the most significant theoretical advancements underpinning the proposed framework is the transition toward risk-based auditing (RBA). In many existing halal certification systems, audit procedures are applied uniformly, with limited differentiation based on the inherent risk profiles of specific raw materials, processing technologies, or supply chain configurations (Azmi & Hassan, 2023; Azmi & Hassan, 2023b). Such standardized, checklist-oriented approaches may lead to inefficient use of auditing resources and an increased likelihood of overlooking high-risk control points within complex halal supply chains.

In contrast, RBA conceptually aligned with international risk management principles such as those articulated in ISO 31000 enables certification bodies to prioritize audit activities according to the probability and severity of potential non-compliance events (Azmi & Hassan, 2023; Putra & Suryani, 2024). By systematically assessing risk exposure at the ingredient, process, and supplier levels, RBA supports more strategic allocation of limited resources, including auditor time, technical expertise, and financial capacity. This targeted approach not only enhances audit effectiveness but also improves transparency, consistency, and defensibility of certification decisions, particularly in environments characterized by high product diversity and globalized sourcing networks (Sunmola et al., 2025).

The risk assessment model employs a semi-quantitative formula to calculate a Risk Score (*RS*):

$RS = L \times I$

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In this framework, L denotes the likelihood of non-compliance, while I represents the impact or severity of a potential breach of halal integrity (Azmi & Hassan, 2023). Both parameters are commonly operationalized using ordinal rating scales ranging from 1 (rare or negligible) to 5 (very likely or catastrophic), enabling systematic comparison and prioritization of risks across heterogeneous processes and supply chain actors (Azmi & Hassan, 2023; Putra & Suryani, 2024).

Table 3. Audit Prioritization Framework Based on Likelihood–Impact Risk Scores (Azmi & Hassan, 2023; Putra & Suryani, 2024).

Risk Score ()	Risk Tier	Audit Strategy and Intensity
1–5	Low Risk	standard document checks; infrequent remote audits
6–12	Moderate Risk	detailed documentation review; annual on-site inspections
13–25	High Risk	full traceability audit; semi-annual inspections; real-time IoT monitoring

This tiered prioritization mechanism ensures that high-risk entities such as facilities utilizing animal-derived additives, handling mashbooh ingredients, or operating shared production lines are subjected to the most stringent levels of audit scrutiny (Azmi & Hassan, 2023). Artificial intelligence tools further enhance the effectiveness of risk-based auditing by continuously recalibrating risk scores in response to incoming data from the supply chain, including changes in suppliers, processing conditions, or historical compliance performance. This dynamic updating enables an “audit triage” approach, whereby inspections are triggered by meaningful shifts in risk profiles rather than rigid, calendar-based schedules, thereby improving both audit efficiency and the preventive capacity of halal assurance systems (Rahman & Zailani, 2024; Sunmola et al., 2025).

The Synergistic Role of Blockchain and IoT

AI-based risk assessment frameworks reach their full operational potential only when the underlying data streams are accurate, reliable, and resistant to manipulation. This prerequisite is effectively fulfilled through the synergistic integration of blockchain technology and the Internet of Things (IoT), which together establish a trusted digital ecosystem for halal assurance (Sunmola et al., 2025; Putra & Suryani, 2024; Rahman & Zailani, 2024). While AI provides analytical intelligence, blockchain and IoT function as the foundational data integrity and data acquisition layers, ensuring that risk assessments are grounded in verifiable and tamper-proof evidence.

IoT devices enable continuous, real-time data collection across critical control points in the halal supply chain, including processing environments, storage facilities, and transportation systems. Sensors monitoring temperature, humidity, segregation status, and equipment utilization generate

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granular operational data that can reveal early indicators of cross-contamination or procedural deviations (Ab Talib et al., 2024; Sunmola et al., 2025). These real-time data streams significantly reduce informational blind spots traditionally associated with logistics and processing stages, thereby enhancing situational awareness and preventive control within halal assurance systems.

Blockchain technology complements IoT-enabled sensing by providing an immutable, distributed ledger for recording transactions, sensor outputs, certification events, and audit outcomes. Once validated and recorded on the blockchain, data entries cannot be altered retroactively, thus safeguarding the integrity of halal claims and reinforcing trust among supply chain stakeholders, certification bodies, and consumers (Putra & Suryani, 2024; Rahman & Zailani, 2024). When integrated with AI-driven analytics, this blockchain–IoT infrastructure enables continuous recalibration of risk scores and supports real-time, evidence-based decision-making. As a result, halal assurance evolves from a static, retrospective verification model into a dynamic, predictive, and digitally enforced governance system aligned with the principles of Halal 4.0 (Sunmola et al., 2025).

Ensuring Data Integrity with Blockchain

Blockchain technology provides a decentralized and immutable ledger capable of securely recording all halal-related transactions across the supply chain, ranging from the issuance of slaughter certificates and ingredient approvals to processing records and final product labeling (Sunmola et al., 2025; Rashid & Hamzah, 2024; Zailani & Rahman, 2023; Al-Harthy, 2025). By design, blockchain eliminates single points of failure and prevents the retroactive manipulation of records, thereby addressing one of the most persistent vulnerabilities in conventional halal certification systems namely, reliance on mutable databases and paper-based documentation. Each transaction is cryptographically linked to the previous one, ensuring that claims of halal status are supported by a transparent and tamper-proof digital audit trail (Sulaiman & Karim, 2024; Rashid & Hamzah, 2024; Alourani & Khan, 2024).

The integration of blockchain into halal assurance systems significantly enhances traceability and accountability, enabling auditors and certification bodies to verify compliance claims in near real time. When combined with AI-driven analytics, blockchain records serve as trusted inputs for risk scoring and anomaly detection, ensuring that decisions are based on verifiable evidence rather than self-declared compliance statements (Rahman & Zailani, 2024; Sunmola et al., 2025). Moreover, smart contracts deployed on blockchain platforms can automate compliance enforcement by triggering alerts, audit requests, or corrective actions when predefined halal conditions are violated, thereby reducing delays and human intervention in critical decision points (Zailani & Rahman, 2023; Putra & Suryani, 2024).

Empirical studies from halal-majority markets such as Malaysia and Indonesia demonstrate that blockchain-enabled traceability systems substantially increase consumer trust and perceived

certification credibility by providing what is often described as a "verifiable trail of compliance" (Hidayat & Nugraha, 2023; Zailani & Rahman, 2023). In these contexts, blockchain not only functions as a technical infrastructure but also as a governance mechanism that bridges regulatory oversight, Shariah compliance, and consumer transparency. Consequently, blockchain-based data integrity frameworks represent a foundational pillar of Halal 4.0, supporting scalable, trustworthy, and internationally interoperable halal certification ecosystems (Sunmola et al., 2025; Al-Harthy, 2025).

Real-Time Monitoring with IoT and Edge-AI

nternet of Things (IoT) sensors deployed across halal supply chains enable continuous, real-time monitoring of critical operational parameters, including storage temperature, humidity, geographical location, and, in advanced implementations, the detection of specific chemical or biological markers associated with contamination risks (Hidayat & Nugraha, 2023; Sulaiman & Karim, 2024; Halim & Fauzi, 2023; Abdullah & Rahim, 2024). Such granular data acquisition addresses longstanding visibility gaps in logistics, storage, and processing stages, which are traditionally difficult to audit through periodic inspections alone. By providing uninterrupted streams of objective data, IoT technologies strengthen preventive control mechanisms and reduce reliance on retrospective verification.

The effectiveness of IoT-based monitoring is substantially enhanced when combined with edge artificial intelligence (edge-AI), where data processing and anomaly detection occur locally at or near the point of data generation rather than being transmitted exclusively to centralized cloud systems. Edge-AI architectures enable rapid identification of non-compliance events—such as unauthorized access to halal shipments, deviations from approved transport routes, or storage in non-certified warehouses and allow immediate corrective actions to be initiated (Sulaiman & Karim, 2024; Ismail & Latif, 2022). Once detected, such anomalies can be automatically logged and time-stamped on a blockchain ledger, ensuring that alerts and compliance breaches are recorded in a tamper-proof and auditable manner (Sulaiman & Karim, 2024; Rahman & Zailani, 2024).

Empirical research on integrated blockchain–AI–IoT frameworks indicates that these systems can achieve high levels of performance in real-world settings. Studies report anomaly detection accuracies of up to 92%, alongside reductions in food fraud incidents by approximately 40% and improvements in overall operational efficiency of nearly 25%, attributable to faster response times and optimized logistics workflows (Ismail & Latif, 2022; Spink & Moyer, 2019). In the context of halal assurance, these outcomes underscore the strategic value of real-time, edge-enabled monitoring systems in transitioning from reactive enforcement to proactive, intelligence-driven governance. Consequently, IoT and edge-AI technologies form a critical operational layer within Halal 4.0 ecosystems, directly supporting data integrity, risk-based auditing, and continuous compliance assurance (Sunmola et al., 2025; Putra & Suryani, 2024).

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ISBN: 978-9952-610-30-7

Socio-Legal and Shariah Governance Frameworks

The deployment of artificial intelligence (AI) within halal certification systems raises substantive socio-legal and ethical questions, particularly concerning religious authority, accountability, and legal liability in cases of erroneous or contested certification outcomes (Rahman & Al-Sharif, 2024; Abdullah & Rahim, 2024; Huda, 2023). While AI-driven tools offer enhanced efficiency and predictive capability, their increasing role in decision-making necessitates careful scrutiny regarding who bears responsibility when algorithmic recommendations conflict with Shariah interpretations or result in regulatory non-compliance. These concerns are amplified in halal contexts, where certification decisions carry not only legal and commercial implications but also profound religious and moral significance for consumers.

Consequently, any AI-enabled halal assurance framework must be firmly embedded within Shariah governance structures and civil law principles to ensure legitimacy, transparency, and long-term sustainability (Sulaiman & Karim, 2024; Abdullah & Rahim, 2024; Zailani & Rahman, 2023). Shariah governance provides the normative foundation by delineating the roles of scholars, fatwa committees, and certification bodies in defining halal standards, while civil law establishes accountability mechanisms related to data protection, consumer rights, and institutional liability. Rather than replacing human judgment, AI systems should therefore be positioned as decision-support tools operating under the supervision of qualified religious and legal authorities, thereby preserving doctrinal integrity and regulatory compliance.

From a governance perspective, hybrid oversight models combining algorithmic transparency, explainable AI (XAI) techniques, and formal Shariah review processes are increasingly viewed as essential for aligning technological innovation with Islamic legal theory and public trust (Firdaus, 2023; Huda, 2023). In jurisdictions such as Indonesia and Malaysia, where halal certification is closely integrated with state regulatory systems, the harmonization of AI-based decision support with existing legal frameworks has been identified as a critical success factor (Zailani & Rahman, 2023; Nasution, 2023). Accordingly, robust socio-legal and Shariah governance frameworks are not peripheral considerations but foundational pillars of Halal 4.0, ensuring that technological advancement proceeds in a manner that is ethically sound, legally defensible, and religiously authoritative.

Maṣlaḥah-Based Policy Analysis

From an Islamic legal perspective, the transition toward digital and AI-enabled halal certification systems should be critically evaluated through the lens of maṣlaḥah (public interest), a foundational principle in Islamic jurisprudence that seeks to promote benefit and prevent harm within society (Firdaus, 2023). A maṣlaḥah-oriented assessment emphasizes not only procedural compliance but also the broader societal outcomes of regulatory innovation. Within this framework, the adoption of AI technologies in halal certification may be justified insofar as it demonstrably enhances transparency,

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ISBN: 978-9952-610-30-7

accuracy, and reliability in food safety and halal verification processes, thereby serving the collective welfare of Muslim and non-Muslim consumers alike.

More specifically, a maṣlaḥah-based analysis suggests that AI-driven halal assurance can contribute to the realization of the Maqāṣid al-Sharīʿah, particularly the preservation of religion (ḥifẓ al-dīn) and life (ḥifẓ al-nafs). By improving the detection of non-halal substances, reducing food fraud, and strengthening traceability across complex global supply chains, digital certification systems help safeguard religious observance while simultaneously protecting public health (Firdaus, 2023; Huda, 2023). In this sense, technological enhancement is not merely an administrative upgrade but a means of reinforcing substantive Shariah objectives through more robust governance mechanisms.

Nevertheless, Islamic legal scholars have cautioned that excessive reliance on instrumental compliance defined as a narrow focus on efficiency, automation, and cost reduction may inadvertently undermine normative compliance, which encompasses the ethical, spiritual, and moral dimensions of halal practice (Sulaiman & Karim, 2024). If AI systems are deployed solely as efficiency-maximizing tools without adequate Shariah oversight, transparency, and ethical safeguards, they risk reducing halal certification to a technical checklist divorced from its underlying moral purpose. Accordingly, a maṣlaḥah-based policy approach requires that digital halal certification frameworks strike a careful balance between technological effectiveness and normative integrity, ensuring that AI remains a servant of Shariah values rather than a substitute for them (Firdaus, 2023; Huda, 2023).

Liability in the Age of Algorithms

In cases where an AI-driven system fails to detect a non-halal ingredient, resulting in consumer loss, traditional fault-based liability doctrines in civil law become difficult to apply, as algorithms lack intent and legal personality (Abdullah & Rahim, 2024; Yılmaz & Kaya, 2024). Legal scholars therefore propose a shift toward alternative liability models, including:

- **Strict liability:** Consumers are required only to demonstrate the occurrence of harm and its causal link to an incorrect halal certification, thereby placing the burden of accuracy and risk management on the certifying authority (Abdullah & Rahim, 2024; Yılmaz & Kaya, 2024).
- **Multi-layered liability:** Legal responsibility is distributed across multiple actors, including AI developers (as producers of potentially defective software), halal certification bodies (e.g., LPH/BPJPH), and food business operators, reflecting the shared risk inherent in algorithm-assisted certification systems (Abdullah & Rahim, 2024; Yılmaz & Kaya, 2024).

This liability architecture ensures that the adoption of AI technologies does not undermine consumer protection principles and simultaneously provides a legal foundation for the enforceability and validity of smart contracts within the halal certification ecosystem (Abdullah & Rahim, 2024; Yılmaz & Kaya, 2024).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Industrial Platforms and Empirical Implementation

The theoretical constructs underpinning AI-based halal risk assessment are increasingly being translated into practice through a range of industrial digital platforms deployed across major halal production and certification hubs. These platforms operationalize concepts such as risk-based auditing, real-time monitoring, and automated decision support by integrating AI analytics with blockchain-enabled traceability and IoT-based data collection infrastructures (Sulaiman & Karim, 2024; Putra & Suryani, 2024; Al-Harthy, 2025). Rather than functioning as isolated technological solutions, such platforms are typically embedded within national or regional halal governance ecosystems, aligning certification workflows with regulatory requirements and Shariah oversight mechanisms.

Empirical implementations in countries with advanced halal infrastructures such as Malaysia and Indonesia demonstrate how digital platforms can enhance audit efficiency and transparency at scale. In these contexts, AI-powered systems are used to aggregate data from certification records, supplier databases, laboratory analyses, and logistics monitoring tools to generate dynamic risk profiles for food business operators (Zailani & Rahman, 2023; Nasution, 2023). These risk profiles inform differentiated audit strategies, enabling authorities to prioritize high-risk entities for intensive inspection while streamlining oversight for low-risk operators, thereby improving resource allocation and reducing administrative bottlenecks (Azmi & Hassan, 2023; Putra & Suryani, 2024).

Beyond regulatory efficiency, industrial platforms also facilitate empirical validation of AI-based halal assurance models by generating large-scale, real-world datasets that support continuous learning and performance evaluation. Feedback loops derived from audit outcomes, non-compliance incidents, and consumer complaints allow AI algorithms to recalibrate risk parameters and improve predictive accuracy over time (Sunmola et al., 2025; Rahman & Zailani, 2024). As a result, these platforms serve not only as implementation vehicles but also as living laboratories for refining Halal 4.0 concepts, bridging the gap between theoretical frameworks and measurable improvements in compliance integrity, consumer trust, and operational resilience (Sunmola et al., 2025; Al-Harthy, 2025).

Indonesia's SiHalal Platform

Indonesia’s SiHalal platform, developed and administered by the Halal Product Assurance Agency (BPJPH), represents one of the most comprehensive national implementations of AI- and blockchain-enabled halal certification to date (Sulaiman & Karim, 2024; Al-Harthy, 2025). The platform digitizes end-to-end certification workflows from application submission and document validation to audit coordination and certificate issuance thereby reducing procedural fragmentation and manual intervention. By embedding AI-driven validation rules, SiHalal automates the detection of common errors and inconsistencies in certification applications, which is particularly beneficial for small and medium-sized enterprises (SMEs) with limited regulatory expertise (Sulaiman & Karim, 2024; Nasution, 2023).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A key functional advantage of SiHalal lies in its use of AI algorithms to accelerate ingredient verification by cross-referencing submitted formulations against curated halal ingredient databases and historical compliance records. This capability enables faster preliminary screening and prioritization of applications, allowing auditors to focus on higher-risk cases that require in-depth assessment (Rahman & Zailani, 2024; Sulaiman & Karim, 2024). In parallel, blockchain components enhance data integrity by ensuring that submitted documents, audit outcomes, and certification decisions are recorded in an immutable and auditable format, thereby strengthening trust among regulators, businesses, and consumers (Al-Harthy, 2025).

Empirical evidence indicates that the adoption of the SiHalal platform has significantly reduced certification processing times while improving overall user satisfaction through streamlined communication between business actors and auditors (Rahman & Zailani, 2024; Sulaiman & Karim, 2024; Al-Harthy, 2025). By lowering administrative burdens and increasing transparency, SiHalal supports broader policy objectives related to SME formalization and halal market expansion in Indonesia. As such, the platform serves as a practical benchmark for how Halal 4.0 principles can be operationalized at scale within a state-led governance framework, offering transferable insights for other jurisdictions seeking to modernize halal assurance systems (Sunmola et al., 2025).

Global Innovations: HIP and Halal Navigator

Beyond nationally implemented platforms, a growing ecosystem of global digital tools has emerged to address the fragmentation and complexity of international halal supply chains. Solutions such as the Halal Integrated Platform (HIP) and Halal Navigator (HaNa) leverage advanced AI particularly generative and semantic search capabilities to assist food business operators in identifying verified halal-certified ingredients across multiple jurisdictions (Putra & Suryani, 2024). By aggregating certification data from diverse authorities and harmonizing heterogeneous standards, these platforms reduce information asymmetry and enable firms to navigate cross-border sourcing decisions with greater confidence and efficiency.

A key innovation of HIP and HaNa lies in their ability to overcome linguistic and regulatory barriers that traditionally hinder global halal trade. Generative AI modules facilitate multilingual querying, automated interpretation of certification documents, and contextual matching between ingredient specifications and halal requirements issued by different certification bodies (Putra & Suryani, 2024). This functionality is particularly valuable for multinational food manufacturers and exporters operating in markets where halal standards vary in scope, terminology, and enforcement practices. As a result, these platforms support more inclusive participation in the global halal economy, especially for small and medium-sized enterprises seeking to scale internationally.

Regional initiatives further underscore the strategic importance of AI-driven halal platforms. For example, Thailand's Halal Assembly 2024 highlighted artificial intelligence as a key enabler for

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

safeguarding halal integrity while streamlining verification and compliance workflows, positioning Southeast Asia as an emerging hub for halal digital innovation (Al-Harthy, 2025). Such developments signal a broader shift toward transnational, technology-mediated halal governance models, in which AI-powered platforms complement national certification systems and contribute to greater interoperability, resilience, and trust in the global halal ecosystem (Sunmola et al., 2025; Putra & Suryani, 2024).

Barriers to Adoption and the Small Business Challenge

While the benefits of artificial intelligence (AI) in halal certification are increasingly evident, the persistence of a digital divide poses a significant threat to the inclusive and equitable growth of the global halal industry (Al-Harthy, 2025; Nasution, 2023).

1. Financial barriers: The high costs associated with the implementation, operation, and maintenance of AI- and blockchain-based systems constitute a major deterrent for small and medium-sized enterprises (SMEs), which form the backbone of the halal food sector (Al-Harthy, 2025).

2. Infrastructure limitations: In rural and underserved regions, inadequate internet connectivity and limited digital literacy significantly constrain the adoption of even basic digital documentation and monitoring tools (Al-Harthy, 2025; Nasution, 2023).

3. Regulatory disharmony: The absence of universally accepted digital halal standards results in fragmented enforcement practices and complicates the mutual recognition of digital halal certificates across national jurisdictions (Al-Qaradawi & Omar, 2022; Sulaiman & Karim, 2024; Yılmaz & Kaya, 2024).

4. Technical capacity constraints: A critical shortage of auditors with cross-disciplinary expertise in advanced food science, artificial intelligence, and Shariah principles creates a bottleneck in the effective deployment and oversight of digital halal certification systems (Rahman & Zainuddin, 2024; Al-Harthy, 2025).

The COVID-19 pandemic further accelerated the shift toward digital certification and supply chain management systems by exposing the vulnerabilities of manual and paper-based processes. However, without sustained policy support, targeted capacity-building initiatives, and inclusive training programs, SMEs risk being marginalized in the transition toward Halal 4.0 (Al-Harthy, 2025).

CONCLUSIONS

The conceptual framework for AI-based risk assessment models in halal food certification provides a roadmap for the future of global halal assurance. By integrating machine learning, fuzzy logic, and rule-based expert systems with the structural integrity of blockchain and IoT, the industry can move toward a continuous, real-time verification model. This transformation addresses the core limitations

of traditional auditing: subjectivity, inefficiency, and a lack of transparency in complex global supply chains.

The shift toward risk-based auditing (RBA) is particularly vital, as it allows for a more nuanced and efficient deployment of auditing resources. By focusing intensive oversight on high-risk components such as animal-derived enzymes and shared production lines certification bodies can significantly enhance the credibility of their seals. Moreover, the alignment of these technologies with Shariah governance and civil law principles ensures that the digital transition remains ethically grounded and legally sound.

In conclusion, the adoption of AI-based digital decision support systems is no longer an optional innovation but a strategic imperative for the halal industry. To ensure success, global stakeholders must collaborate to harmonize regulatory standards, provide technical and financial support for SMEs, and foster a new generation of "digital halal auditors." By doing so, the industry can fulfill its promise of providing "halalan tayyiban" products to a global population, ensuring that every bite is not only permissible but also of the highest integrity and safety. The conceptual framework presented serves as the foundation for this secure, transparent, and digitally resilient halal ecosystem.

REFERENCES

Ab Talib, M. S., Hamid, A. B. A., & Chin, T. A. (2024). Digital technology 4.0 on halal supply chain: A systematic review. *Logistics*, ***8***(1), 21. https://doi.org/10.3390/logistics8010021

Abdullah, A., & Rahim, H. (2024). Deep learning for halal food fraud: Using computer vision and DNA barcoding to authenticate and trace-verify Malaysian halal products. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5483166

Al-Harthy, S. (2025). Advancing halal compliance in the food industry through digital innovation. *Oman International Conference on Food Safety and Quality Proceedings*, 45–58.

Alourani, A., & Khan, S. (2024). *A blockchain and artificial intelligence based system for halal food traceability. arXiv*.

Al-Qaradawi, Y., & Omar, N. (2022). Risk management and assurance in halal food supply chains. *Arab Gulf Journal of Scientific Research*, ***40***(3), 338–358.

Azmi, F., & Abdullah, M. (2020). Type of risk in halal food supply chain: A literature review. *Journal of Halal Logistics*, ***4***(2), 15–29.

Azmi, F., & Hassan, R. (2023). A risk-based auditing framework for halal certification systems: Bridging gaps in the current halal assurance practices. *Formosa Journal of Science and Technology*, ***2***(3), 211–228.

Demir, M., & Yıldız, S. (2024). Maintaining traceability in halal food production with the use of artificial intelligence and blockchain. *Journal of Halal Research*, ***6***(2), 101–118.

Firdaus, A. (2023). Halal certification governance in Indonesia: An Islamic legal appraisal based on maṣlaḥah principles. *Jurisprudence Review*, ***15***(2), 101–120.

Halim, M., & Fauzi, R. (2023). Artificial intelligence-based halal compliance model: Civil law perspective. *Journal of Islamic Legal Studies*, ***9***(1), 77–92.

Hassan, Z., & Noor, M. N. (2023). Risk assessment and mitigation in halal supply chains: Exploring unique risks and mitigation strategies. *International Journal of Research in Information Systems*, ***7***(4), 56–70.

Hidayat, S., & Nugraha, R. (2023). Halal certification in the digital age: Leveraging online platforms for enhanced transparency and accessibility. *Journal of Economics and Multidisciplinary Issues*, ***2***(1), 45–56.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Huda, M. (2023). Islamic law in the era of artificial intelligence: A systematic review. *UIN Malang Repository*.

Ismail, N., & Latif, A. (2022). Comparison of CNN-based algorithms for halal logo recognition. *Journal of Smart Manufacturing Systems*, ***12***(5), 89–101.

Khan, S., Ali, M., & Abdullah, N. (2024). Navigating risks in halal supply chains: A literature review on ensuring compliance and integrity. *International Journal of Industrial Review*, ***5***(2), 89–110.

Kumar, S., & Patel, R. (2023). A rule-based expert system for efficient food planning and consumption. *Expert Systems with Applications*, ***214***, 119068.

Latif, A., & Ismail, N. (2022). Decision tree of materials: A model of halal control point identification in small-scale bakery. *Foods*, ***11***(12), 1784. https://doi.org/10.3390/foods11121784

Molina, J., & García, R. (2024). A fuzzy rule-based decision support in process mining: Turning diagnostics into prescriptions. *Applied Sciences*, ***15***(23), 12402. https://doi.org/10.3390/app152312402

Nasution, H. (2023). The role of halal certification in the digitalization of SMEs. *Journal of Social Science Education*, ***8***(3), 201–215.

Putra, A. R., & Suryani, D. (2024). Blockchain and AI integration in halal supply chains: Toward a trusted digital ecosystem. *RIGGS: Journal of Artificial Intelligence and Digital Business*, ***3***(1), 1–15.

Rahman, A., & Al-Sharif, A. (2024). Ensuring halal compliance in AI-driven healthcare solutions. In *Ethics and artificial intelligence in healthcare* (pp. 115–134). IGI Global. https://doi.org/10.4018/979-8-3693-1082-3.ch006

Rahman, A., & Zainuddin, N. (2024). Halal food traceability system using AI and blockchain. *International Journal of Halal Science*, ***5***(1), 33–48.

Rahman, M. A., & Zailani, S. (2024). Integrating artificial intelligence and blockchain to improve the accuracy of halal certification. *Journal of Supply Chain Innovation*, ***9***(1), 22–39.

Rahman, M., & Noor, A. (2023). Fuzzy logic-based barcode scanning system for food products halal identification. *Journal of Intelligent Systems*, ***18***(2), 44–58.

Rashid, N. A., & Hamzah, H. (2024). Fuzzy logic-based approach for porcine DNA determination in meat products. *Foods*, ***13***(9), 1125. https://doi.org/10.3390/foods13091125

Spink, J., & Moyer, D. C. (2019). Machine learning assessment of food fraud detection systems. *Trends in Food Science & Technology*, ***86***, 364–372.

Sulaiman, N., & Karim, R. (2024). Development of decision support system for halal meat distribution system. *International Journal of Decision Support Systems*, ***7***(1), 1–14.

Sun, X., & Liu, Y. (2024). The journey of artificial intelligence in food authentication: From label attribute to fraud detection. *Foods*, ***14***(10), 1808. https://doi.org/10.3390/foods14101808

Sunmola, F., Baryannis, G., Tan, A., Co, K., & Papadakis, E. (2025). Holistic framework for blockchain-based halal compliance in supply chains enabled by artificial intelligence. *Systems*, ***13***(1), 21. https://doi.org/10.3390/systems13010021

Yılmaz, M., & Kaya, A. (2024). Harmonizing sharia-based halal standards with international trade law: A comparative legal study. *Law and Justice Review*, ***6***(2), 145–168.

Yusof, S. M., & Ismail, R. (2023). Artificial intelligence in the halal industry: Trends and future directions. *Indonesian Journal of Halal Industry*, ***6***(2), 55–71.

Zailani, S., & Rahman, A. (2023). Blockchain-enabled halal certification and traceability system: A smart supply chain solution. *Journal of Management Scholarship*, ***4***(1), 1–19.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PACKAGING MATERIALS AND MIGRATION ISSUES IN HALAL FOODS: HIDDEN RISKS IN HALAL COMPLIANCE

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ABSTRACT

The integrity of halal foods is not only determined by raw materials and processing methods but also by post-processing factors such as packaging and storage conditions. Packaging materials play a critical role in protecting food quality and safety; however, they may also pose overlooked risks to halal compliance due to the migration of substances from packaging into food products. These risks are often underestimated in conventional halal certification processes, which primarily focus on ingredients, additives, and production practices.

Migration from packaging materials can involve a wide range of compounds, including plasticizers, stabilizers, adhesives, printing inks, and polymer degradation products. Some of these substances may originate from animal-derived sources or contain alcohol-based solvents, raising concerns regarding their halal status. In addition, multilayer packaging systems and recycled materials further complicate the assessment of halal compliance due to limited transparency in material composition and manufacturing processes. Despite their potential impact, packaging-related risks are rarely addressed explicitly in halal standards or auditing procedures.

This study aims to evaluate packaging materials and migration phenomena in halal foods from a risk-based perspective, highlighting packaging as a “hidden” but critical component of halal assurance systems. The conceptual framework presented in this paper identifies key packaging-related risk points, including material origin, use of processing aids, interaction with fatty and acidic food matrices, and storage conditions that may accelerate migration. Particular attention is given to high-risk food categories such as meat products, dairy products, and ready-to-eat foods, where direct contact with packaging materials is prolonged.

The findings suggest that current halal certification practices may inadequately capture packaging-related risks, potentially compromising halal integrity despite compliance at earlier stages of production. Integrating migration testing, material traceability, and supplier verification into halal certification schemes could significantly strengthen halal assurance. Furthermore, interdisciplinary

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

collaboration between food scientists, packaging technologists, and halal certification bodies is essential to address these challenges.

In conclusion, packaging materials and migration issues represent an underexplored dimension of halal food safety and compliance. Recognizing and managing these hidden risks is crucial for enhancing transparency, consumer trust, and the overall credibility of halal food certification systems in modern food supply chains.

Keywords: Food packaging, migration of packaging materials, halal compliance, food contact materials, hidden risks, halal certification.

INTRODUCTION

The global halal food industry has transcended its origins as a niche market catering to religious dietary requirements, evolving into a sophisticated, multi-trillion-dollar ecosystem governed by complex quality assurance frameworks (Akbar et al., 2023; Randeree, 2019). In this contemporary landscape, the concept of halal is inextricably linked with tayyib, a term encompassing wholesomeness, safety, and ethical integrity (Khan & Haleem, 2016; Lau et al., 2016).

However, while the scrutiny of raw materials and primary processing methods has reached a high level of maturity, the role of packaging as a potential source of non-compliance remains a critical yet frequently overlooked “hidden risk” (Atanasova-Pancevska & Markovska, 2024; Farrelly Mitchell, 2025). Packaging materials are essential for maintaining food safety and extending shelf life, but they are not inert; rather, they are dynamic chemical systems that interact with the food products they contain (Muncke, 2016; Gupta et al., 2024).

This interaction, primarily through the phenomenon of chemical migration, introduces compounds that may originate from prohibited sources such as porcine-derived lubricants or may contain hazardous substances that compromise the tayyiban status of the product (Muhamedbegović et al., 2021; Geueke, 2018; Seref & Cufaoglu, 2025).

Current halal certification procedures often fail to capture these post-processing risks adequately, as audits typically prioritize ingredient lists and production line sanitation (Hussaini, 2025; Bujang & Bakar, 2023). This oversight creates a structural vulnerability within the Halal Assurance System (HAS), whereby a product certified as halal at the point of manufacture may become non-compliant by the time it reaches the consumer due to the migration of “hidden” non-halal substances (Atanasova-Pancevska & Markovska, 2024; Mariyam et al., 2022).

As the industry moves toward increasingly complex packaging solutions including multilayer systems, recycled materials, and nanotechnology-enabled packaging the necessity for a risk-based approach to halal packaging compliance becomes imperative (Groh, 2016; Mohd Hatta et al., 2023; Vaferi et al., 2025).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Theoretical and jurisprudential foundations of Halal packaging

The assessment of packaging materials within the halal framework is fundamentally grounded in Islamic jurisprudence (*Fiqh*), which classifies substances and processes according to their permissibility (halal) or prohibition (*haram*). Within this framework, the concept of najis (ritual impurity) plays a central role, requiring that packaging materials and related processing aids remain free from impure or prohibited substances and do not facilitate contamination throughout food containment, storage, and distribution stages (Khan & Haleem, 2016; Lau et al., 2016).

Accordingly, halal packaging compliance extends beyond ingredient permissibility to encompass the prevention of cross-contamination, particularly through contact with haram-derived materials, lubricants, or processing residues during packaging manufacture and food contact (Bujang & Bakar, 2023; Hussaini, 2025).

Classification of impurities in material science

To understand the risks associated with food packaging, it is necessary to align Islamic jurisprudential classifications with the technical composition of packaging materials and processing aids. Substances derived from swine, classified as najis mughallazah, represent the highest level of concern within the halal framework, as even trace contamination is considered sufficient to invalidate the halal status of a food product (Khan & Haleem, 2016; Halal Food Council USA, 2026).

Similarly, materials originating from other animals that have not been slaughtered in accordance with Islamic law, categorized as najis mutawassitah, pose significant compliance risks when used in packaging components, additives, or manufacturing auxiliaries such as lubricants and release agents (Eriksson et al., 2013; Bujang & Bakar, 2023). These risks are particularly relevant in modern packaging systems, where indirect contact and low-level chemical migration can occur throughout storage and distribution.

Table 1. Jurisprudential classification of impurities and their correlation with technical packaging components

Impurity Category	Jurisprudential Severity	Technical Packaging Correlation
Najis Mughallazah	Extreme (Swine/Dogs)	Porcine-derived stearates used as plastic lubricants; lard-based machine oils; porcine gelatin used in adhesives (Khan & Haleem, 2016; Halal Food Council USA, 2026).
Najis Mutawassitah	Medium (Blood/Carcasses)	Tallow-based slip agents derived from non-halal slaughtered cattle; blood-derived pigments and binders used in printing inks (Eriksson et al., 2013; Bujang & Bakar, 2023).

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ISBN: 978-9952-610-30-7

Najis Mukhaffafah	Light (Specific Urine)	Limited relevance to material science; primarily associated with environmental hygiene and facility-level contamination control rather than packaging material composition (Lau et al., 2016; Hussaini, 2025).

The concept of Istihalah and its application to packaging chemicals

One of the most debated concepts in halal science is *istihalah*, which refers to the complete transformation of a prohibited (*haram*) substance into a new chemical entity with fundamentally different properties, potentially altering its jurisprudential status (Khan & Haleem, 2016; Mariyam et al., 2022; Rutkowski, 2024). Within the context of food packaging, this debate becomes particularly salient, as numerous animal-derived additives are subjected to extensive chemical processing before being incorporated into polymers.

Scholarly opinions diverge on whether the extraction of stearic acid from animal fat and its subsequent conversion into metallic stearates (e.g., calcium stearate) can be classified as istihalah tammah (complete transformation), especially when the original biological structure is no longer chemically identifiable (Khan & Haleem, 2016; Bujang & Bakar, 2023).

Nevertheless, the prevailing position among many contemporary halal certification authorities including bodies aligned with the jurisprudential approaches of JAKIM and MUI is one of regulatory caution. When a chemical additive originates from a porcine source, the majority of certification frameworks do not recognize downstream chemical modification as sufficient to confer halal status (Halal Food Council USA, 2026; Hussaini, 2025).

This effectively "zero-tolerance" stance necessitates comprehensive traceability and source verification of raw materials used in the synthesis of packaging additives, such as stabilizers, slip agents, and plasticizers, particularly in complex polymer systems (Rutkowski, 2024; Mohd Hatta et al., 2023).

The science of chemical migration: Mechanisms and drivers

Chemical migration is defined as the mass transfer of chemical constituents from food contact materials (FCMs) into the food matrix under conditions of contact (Muncke, 2016; Seref & Cufaoglu, 2025). This process does not represent an incidental failure of packaging performance; rather, it is an inherent physicochemical phenomenon governed primarily by diffusion mechanisms and the tendency of the system to reach thermodynamic equilibrium between the packaging material and the contained food (Gupta et al., 2024; Muhamedbegović et al., 2021).

The extent and rate of migration are influenced by multiple interacting drivers, including the chemical composition of the packaging polymer, the nature of additives and non-intentionally added substances

(NIAS), as well as external factors such as temperature, contact time, and food composition (Geueke, 2018; Vaferi et al., 2025).

Diffusion and partition coefficients

The migration of chemical substances within polymeric packaging materials is governed by Fick's laws of diffusion, which describe mass transfer driven by concentration gradients within the polymer matrix. Low-molecular-weight compounds such as plasticizers, residual solvents, and processing aids exhibit particularly high mobility and are therefore more prone to migrate into food products (Muncke, 2016; Gupta et al., 2024).

At thermodynamic equilibrium, the concentration of a migrant in the food matrix is determined by the partition coefficient (K), defined as the ratio between the concentration of the substance in the packaging material and its concentration in the food. This coefficient reflects the chemical affinity of the migrant for the polymer versus the food matrix and is a critical determinant of exposure risk (Seref & Cufaoglu, 2025; Vaferi et al., 2025).

Several factors significantly accelerate diffusion and partitioning processes, thereby shaping the risk profile of different food categories:

- **Temperature:** Increasing temperature elevates molecular kinetic energy and diffusion coefficients exponentially. As a result, hot-filling operations and the reheating of foods within their original packaging (e.g., microwaveable trays) substantially intensify chemical migration (Gupta et al., 2024; Muhamedbegović et al., 2021).
- **Time:** Extended storage periods, particularly for shelf-stable products, allow sufficient time for migrants to approach equilibrium concentrations within the food matrix (Muncke, 2016; Silcock & Bremer, 2022).
- **Food matrix dynamics:** Lipophilic food systems, especially those rich in fats and oils, display a strong affinity for common packaging additives such as stearates and phthalates. These matrices effectively act as solvents, promoting the extraction of additives from polymeric materials (Muncke, 2016; Gupta et al., 2024).
- **Packaging geometry:** The surface-to-volume ratio of the package plays a decisive role in migration kinetics. Smaller packages, such as snack pouches, present proportionally larger contact surfaces relative to food volume and therefore experience higher relative contamination levels compared with large bulk containers (Muhamedbegović et al., 2021; Vaferi et al., 2025).

Sorption: Scalping and swelling

Chemical migration between food and packaging materials is not a unidirectional process; rather, it involves a bidirectional exchange in which both the packaging and the food matrix interact

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

dynamically (Muncke, 2016; Gupta et al., 2024). In addition to the transfer of substances from packaging into food, the food itself may induce physicochemical changes in the packaging material through sorption-related mechanisms.

- **Scalping:** Scalping refers to the absorption of desirable food constituents particularly volatile aroma and flavor compounds by the packaging material. This phenomenon leads to a deterioration of sensory quality and may compromise the tayyib attribute of the product by altering perceived freshness and organoleptic integrity, potentially misleading consumers despite the product remaining microbiologically safe (Muncke, 2016; Mohd Hatta et al., 2023).

- **Swelling:** Swelling occurs when packaging polymers come into contact with foods containing high levels of fats or oils. Lipophilic food components penetrate the polymer matrix, increasing the free volume between polymer chains. This structural expansion significantly enhances the diffusion rates of internal additives such as plasticizers, stabilizers, and slip agents thereby accelerating their migration into the food (Muncke, 2016; Groh, 2016; Gupta et al., 2024).

Additives and processing aids: The hidden chemical inventory

Modern food packaging systems rely on a vast and diverse chemical inventory to achieve the mechanical strength, optical clarity, thermal stability, and barrier performance required for food preservation. It is estimated that more than 6,000 chemicals are intentionally or unintentionally associated with food contact materials, including monomers, additives, impurities, and non-intentionally added substances (NIAS) (Muncke, 2016; Geueke et al., 2014).

Within this complex chemical landscape, several categories of additives and processing aids present direct risks to halal compliance, particularly when their origin cannot be unequivocally verified. Additives such as lubricants, slip agents, stabilizers, plasticizers, and anti-blocking agents may be derived from animal fats or processed using animal-based feedstocks, thereby introducing hidden non-halal inputs into otherwise compliant packaging materials (Bujang & Bakar, 2023; Rutkowski, 2024).

Stearates and fatty acid derivatives

Stearates, the metallic salts of stearic acid, represent one of the most pervasive yet least visible sources of halal non-compliance in plastic food packaging systems. These compounds are widely used as lubricants, acid scavengers, and release agents during the processing of common polymers such as polyethylene (PE), polypropylene (PP), and polystyrene (PS) (Bujang & Bakar, 2023; Rutkowski, 2024).

Stearic acid itself is a naturally occurring saturated fatty acid that is abundantly present in both vegetable oils and terrestrial animal fats. From a halal perspective, this dual origin creates a significant compliance challenge, as the chemical identity of stearates is identical regardless of whether the

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ISBN: 978-9952-610-30-7

precursor fatty acid is sourced from halal-compliant vegetable oils or from animal fats of uncertain or prohibited origin (Mariyam et al., 2022; Eriksson et al., 2013).

The halal risk associated with stearates is therefore not determined by their functional role in packaging or their concentration, but rather by the traceability and permissibility of the original lipid source, with porcine-derived stearic acid being categorically prohibited under Islamic jurisprudence (Khan & Haleem, 2016; Halal Food Council USA, 2026).

Table 2. Fatty acid source–dependent halal risk assessment of stearic acid used in packaging stearates

Animal Source	Stearic Acid Content (%)	Halal Risk Assessment
Bovine (Beef Fat)	12.8 - 18.0	Doubtful; halal status depends on verification of Islamic slaughter and full supply-chain traceability (Eriksson et al., 2013; Mariyam et al., 2022).
Ovine (Lamb/Goat Fat)	15.0 - 23.9	Doubtful; halal compliance requires confirmation of slaughter method and absence of cross-contamination (Mariyam et al., 2022).
Porcine (Lard/Pork Fat)	11.9 - 14.0	*Haram*; strictly prohibited regardless of concentration or degree of chemical processing (Khan & Haleem, 2016; Halal Food Council USA, 2026).
Vegetable (Palm/Soy)	Varies	Halal; preferred and widely accepted source for halal-compliant packaging additives (Bujang & Bakar, 2023; Rutkowski, 2024).

Laboratory investigations conducted in Germany revealed the presence of porcine DNA in products that had been certified as halal, despite the absence of non-halal ingredients in their formulations. Subsequent forensic traceability analyses identified the source of contamination as porcine-derived stearates used in lubricants applied during the paper packaging production process, rather than the food itself (Rutkowski, 2024; Bujang & Bakar, 2023).

This case provides compelling empirical evidence that non-plastic packaging materials, such as paper and cardboard, can also act as vectors for animal-derived contaminants when processing aids and auxiliary chemicals are overlooked in halal audits. It underscores a critical vulnerability in conventional halal certification practices, which often focus on food-contact polymers while underestimating the halal risks associated with lubricants, release agents, and other indirect contact substances used in packaging manufacture (Hussaini, 2025; Halal Food Council USA, 2026).

Plasticizers and Palmitates

Plasticizers are widely used to improve the flexibility and processability of materials such as polyvinyl chloride (PVC) and selected polymeric coatings. Many of these substances are chemically based on

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palmitates and other fatty acid esters, which may originate from either vegetable or animal sources, thereby creating a source-dependent halal compliance challenge (Rutkowski, 2024; Bujang & Bakar, 2023). When plasticizers are derived from animal fats, their halal status is subject to the same jurisprudential requirements as stearates, including verification of halal slaughter and full traceability of the lipid source (Khan & Haleem, 2016; Mariyam et al., 2022).

Beyond halal considerations, plasticizers represent a major food safety concern due to their well-documented tendency to migrate from packaging materials into food matrices. Numerous commonly used plasticizers have been identified as endocrine-disrupting chemicals (EDCs) and potential carcinogens, raising significant toxicological concerns alongside their halal implications (Gupta et al., 2024; Seref & Cufaoglu, 2025). Consequently, the presence of animal-derived palmitates in plasticizers constitutes a dual-risk scenario, simultaneously compromising both the halal and tayyib integrity of packaged food products.

Adhesives, coatings, and binders

Adhesives, coatings, and binders used in multilayer packaging structures and carton sealing systems represent a frequently underestimated source of animal-derived inputs. These materials, often perceived as technologically neutral "glues," may incorporate biopolymers of animal origin to achieve desirable bonding, flexibility, and film-forming properties (Bujang & Bakar, 2023; Rutkowski, 2024).

- **Gelatin:** Gelatin and collagen are widely employed in technical adhesives because of their strong adhesive performance and film-forming capability. However, a substantial proportion of global gelatin production originates from porcine skin, with the remainder primarily derived from bovine hides and bones. From a halal perspective, adhesives containing gelatin constitute a high-risk control point unless they are explicitly certified as plant-based or sourced from animals slaughtered in accordance with Islamic law (Khan & Haleem, 2016; Halal Food Council USA, 2026; Eriksson et al., 2013).

- **Casein:** Casein, a milk-derived protein, is commonly used in labeling adhesives, particularly for glass bottles. Although casein is generally considered halal, its acceptability depends on verification that the dairy source is halal-certified and that no cross-contamination with non-halal processing aids occurs during extraction and formulation (Lau et al., 2016; Bujang & Bakar, 2023).

- **Shellac:** Shellac, a natural resin secreted by the lac insect, is utilized as a binder or glazing agent in certain coatings and surface treatments. Its halal status remains subject to scholarly debate, particularly concerning the permissibility of insect-derived substances for consumption or indirect food contact. Divergent jurisprudential interpretations necessitate cautious evaluation and, in many certification systems, case-by-case assessment (Khan & Haleem, 2016; Rutkowski, 2024).

Risks in multilayered and recycled materials

The increasing emphasis on sustainability within the packaging industry has introduced additional layers of technical and regulatory complexity that significantly challenge traditional halal auditing frameworks. The adoption of multilayer packaging structures and recycled materials complicates traceability, as these systems often incorporate diverse polymers, adhesives, inks, and recycled fractions whose original sources and processing histories are difficult to verify (Silcock & Bremer, 2022; Rutkowski, 2024).

In particular, recycled packaging streams may contain residual contaminants, non-intentionally added substances (NIAS), or legacy additives originating from non-halal applications, thereby undermining halal compliance despite adherence to conventional ingredient-based audits (Geueke, 2018; Muhamedbegović et al., 2021).

Multilayer systems and the functional barrier myth

Multilayer packaging systems frequently position materials considered "high-risk," such as printing inks, adhesives, or polymer additives, behind a so-called *functional barrier* layer, typically polyethylene terephthalate (PET) film or aluminum foil. From a conventional food safety perspective, these barriers may reduce chemical migration to levels deemed acceptable under regulatory thresholds, often expressed in parts per billion (Muncke, 2016; Gupta et al., 2024).

However, halal compliance is governed by a fundamentally different logic. Rather than relying on exposure thresholds, halal jurisprudence operates on the principle of zero intentional presence of haram substances within any component of the food-contact system. Consequently, the presence of porcine-derived additives in an intermediate layer of multilayer packaging renders the entire structure non-compliant under Shariah principles, irrespective of whether a functional barrier effectively prevents measurable migration into the food (Khan & Haleem, 2016; Hussaini, 2025).

This divergence highlights a critical misconception *the functional barrier myth* where compliance with food safety regulations is mistakenly equated with halal permissibility. In practice, halal integrity extends beyond migratory behavior and encompasses material origin, intentionality, and traceability across all layers of the packaging system, including those not in direct contact with the food (Bujang & Bakar, 2023; Rutkowski, 2024).

The "Memory" effect in recycled packaging

Recycled packaging materials particularly recycled paperboard and recycled plastics such as rPET present a distinct "memory effect" risk, whereby residues from previous use cycles persist despite mechanical and chemical recycling processes. Recycled paper fibers, for example, may originate from packaging that previously contained pork products or other non-halal materials, introducing a latent risk of contamination that is difficult to trace or eliminate (Rutkowski, 2024; Bujang & Bakar, 2023).

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Crucially, conventional recycling operations such as pulping, washing, and de-inking are designed to restore material functionality rather than to remove religiously significant impurities or fully degrade biological markers such as porcine DNA. As a result, recycled materials may remain technically suitable for food contact while still failing to meet halal compliance requirements under Shariah principles (Hussaini, 2025; Halal Food Council USA, 2026).

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Table 3. Halal compliance risks associated with the "memory effect" in recycled packaging materials

Material Type	Recycling Risk	Halal Compliance Challenge
Recycled Paper	High	Potential carryover of porcine meat residues or non-halal fats absorbed during previous use cycles, which may persist through standard pulping and cleaning processes (Rutkowski, 2024; Bujang & Bakar, 2023).
Recycled Plastic (rPET/PCR)	Medium	Accumulation of non-intentionally added substances (NIAS) and possible traces of non-halal lubricants or additives from prior life cycles (Geueke, 2018; Muhamedbegović et al., 2021).
Recycled Metal/Glass	Low	Inorganic nature allows for high-temperature remelting and decontamination processes that typically destroy biological residues and remove fats, reducing halal compliance risk (Muncke, 2016; Hussaini, 2025).

Printing inks and the risk of solvent migration

Food packaging is rarely left unprinted, as branding elements and mandatory regulatory information are typically applied using printing inks. These inks are complex chemical formulations composed of pigments, binders, solvents, plasticizers, and various additives, which collectively introduce both direct and indirect risks to halal compliance and food safety (Groh, 2016; Bujang & Bakar, 2023).

Low-molecular-weight solvents and ink components may migrate through packaging layers or transfer via set-off mechanisms, particularly in multilayer structures and stacked materials, creating a pathway for unintended chemical contamination even when inks are not in direct contact with food (Muncke, 2016; Muhamedbegović et al., 2021).

Solvent retention and alcohol-based inks

Many industrial printing inks employ alcohol-based solvents, such as ethanol and isopropyl alcohol, to promote rapid drying and efficient film formation during high-speed printing processes. Although these solvents are intended to evaporate completely after application, a phenomenon known as solvent retention may occur, whereby residual alcohol becomes trapped within the ink layer or absorbed into the packaging substrate (Groh, 2016; Muncke, 2016).

Residual alcohol retained in printed packaging materials may subsequently migrate into food products, potentially exceeding permissible thresholds for residual ethanol established by halal-related standards such as GSO 2538 (Khan & Haleem, 2016; Hussaini, 2025). Beyond quantitative limits, the origin and formulation of the alcohol represent a critical halal compliance issue. Alcohol sourced from the wine or fermentation industries, or alcohol formulations containing non-halal emulsifiers and processing

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aids, are considered non-compliant under most contemporary halal certification frameworks, even when present at trace levels (Halal Food Council USA, 2026; Rutkowski, 2024).

Set-off migration

During packaging manufacture, printed films and paperboards are commonly stored and transported in large rolls or stacks. In these configurations, the printed outer surface of the material is placed in direct contact with the unprinted inner surface, which subsequently becomes the food-contact side of the package. This physical arrangement creates conditions conducive to set-off migration, a process whereby ink constituents are transferred mechanically from the printed layer to the food-contact surface prior to filling (Groh, 2016; Muncke, 2016).

Set-off migration enables the transfer of low-molecular-weight ink components including pigments, solvents, and photoinitiators such as benzophenone even in the absence of direct ink–food contact. This phenomenon is particularly relevant in multilayer and high-speed printing operations, where incomplete curing or stacking under pressure accelerates the unintended relocation of ink-derived substances to the food-contact interface (Muhamedbegović et al., 2021; Gupta et al., 2024).

Technological advancements and emerging risks

The integration of advanced technologies like nanotechnology and AI into packaging systems offers benefits for shelf life but introduces new "hidden" risks to the halal and safety profiles of food.[12]

Nanotechnology: Safety and ethical dilemmas

Nanomaterials such as nanoclays and silver nanoparticles are increasingly incorporated into food packaging systems to create so-called active packaging, designed to inhibit microbial growth or scavenge oxygen and thereby extend shelf life (Aghwan et al., 2024; Mohd Hatta et al., 2023). Despite these functional advantages, a growing body of evidence indicates that certain nanomaterials particularly silver nanoparticles are capable of migrating into food matrices, with migration rates amplified under elevated temperatures and prolonged contact conditions (Gupta et al., 2024; Vaferi et al., 2025).

From an Islamic ethical and jurisprudential standpoint, the adoption of technologies that pose a credible risk to human health raises fundamental concerns. Potential adverse effects associated with nanoparticle exposure, including organ toxicity and gastrointestinal disturbances, directly conflict with the Maqasid al-Shariah, particularly the preservation of life (hifz al-nafs) and health. Consequently, such technologies may be deemed incompatible with the principle of maslahah (public interest), even if they deliver technological or economic benefits (Aghwan et al., 2024; Khan & Haleem, 2016).

Smart packaging and data transparency

Smart packaging technologies, including QR codes, RFID tags, and other digital identifiers, are increasingly deployed to provide consumers with real-time access to halal certification data and

detailed information about a product's supply chain journey (Dashti et al., 2024; Ibrahim et al., 2024). By enabling instant verification of certification status, production stages, and logistical handling, these technologies enhance transparency and accountability within halal ecosystems.

Digital traceability systems are particularly valuable for rebuilding and sustaining consumer trust, as they extend verification beyond food ingredients to encompass upstream elements such as packaging materials, processing aids, and logistics operations. This end-to-end visibility allows stakeholders to identify potential halal risks embedded within complex supply chains, including those associated with multilayer packaging and recycled materials (Randeree, 2019; Ismail et al., 2025). As a result, smart packaging functions not merely as a marketing tool but as a critical component of a risk-based halal assurance system aligned with contemporary expectations of transparency and integrity.

International Halal standards: Comparative analysis

The treatment of packaging materials within halal certification frameworks remains an evolving and non-uniform domain, with international halal authorities adopting markedly different approaches in terms of scope, regulatory depth, and enforcement mechanisms. While some certification bodies primarily focus on food ingredients and slaughter practices, others increasingly recognize packaging materials, processing aids, and food contact substances as integral components of halal assurance systems (Khan & Haleem, 2016; Lau et al., 2016).

Notably, standards developed under organizations such as SMIIC, JAKIM, and bodies aligned with GSO principles demonstrate varying degrees of stringency regarding the assessment of packaging inputs, particularly with respect to animal-derived additives, traceability requirements, and cross-contamination risks. These discrepancies result in a fragmented global halal landscape, where a packaging system deemed compliant under one standard may be considered non-compliant under another (Dağ & Erbasi-Gonc, 2013; Hussaini, 2025).

SMIIC (Pan-Islamic Harmonization)

The Standards and Metrology Institute for Islamic Countries (SMIIC), operating under the umbrella of the Organization of Islamic Cooperation (OIC), has developed an extensive and increasingly influential body of standards aimed at achieving pan-Islamic harmonization of halal requirements across member states. These standards seek to reduce regulatory fragmentation by providing unified guidance that integrates Islamic jurisprudence with contemporary food safety and material science principles (Dağ & Erbasi-Gonc, 2013; Hussaini, 2025).

- **OIC/SMIIC 1:2019 (General requirements for halal food):** This foundational standard establishes the overarching principles of halal food production and explicitly emphasizes that food which is unsafe or harmful cannot be considered halal, thereby formally embedding the tayyib

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dimension safety and wholesomeness within halal compliance (Khan & Haleem, 2016; Lau et al., 2016).

- **SMIIC TC1/WG3 (Halal packaging):** Within the SMIIC technical committee structure, TC1/WG3 functions as a dedicated working group focusing specifically on halal packaging requirements. Its scope includes the assessment of packaging material composition, the use of additives and processing aids, and the control of chemical migration from packaging into food, reflecting a shift toward a more risk-based and materials-oriented halal evaluation (Bujang & Bakar, 2023; Rutkowski, 2024).

- **OIC/SMIIC 24:2020 (Guidelines for halal food additives):** This standard provides authoritative guidance on the permissibility of food additives and related chemicals, serving as a critical reference point for evaluating additives that may be incorporated into packaging matrices, coatings, inks, and adhesives. It thus plays a key role in determining the halal status of substances with indirect food contact (Mariyam et al., 2022; Mohd Hatta et al., 2023).

JAKIM (Malaysia's Benchmark)

Malaysia's Department of Islamic Development Malaysia (JAKIM) is widely regarded as a global benchmark in halal standardization due to the breadth, specificity, and enforceability of its regulatory framework (Khan & Haleem, 2016; Lau et al., 2016). The Malaysian Halal Management System (MHMS) 2020 and MS 1500:2019 explicitly require that all packaging materials and associated inputs be sourced from verified halal-compliant suppliers, thereby extending halal assurance beyond food ingredients to encompass packaging components and processing aids (Bujang & Bakar, 2023; Hussaini, 2025).

A distinctive feature of JAKIM's approach is its detailed treatment of the packaging process itself. The standards mandate that auxiliary materials used during packaging conversion including machinery lubricants, release agents, and cleaning chemicals must also be halal-certified or demonstrably free from non-halal origins. This level of granularity addresses indirect contamination pathways that are often overlooked in other certification systems and positions JAKIM as a leader in process-oriented, risk-based halal governance (Lau et al., 2016; Rutkowski, 2024).

Indonesia's Mandatory Shift (BPJPH)

Indonesia has enacted a fundamental paradigm shift in halal governance through Law No. 33 of 2014 and its implementing regulation, Government Regulation (PP) No. 42 of 2024, by transitioning from a voluntary to a mandatory halal certification regime (Ismail et al., 2025; Rutkowski, 2024). Under this framework, halal certification will become compulsory for all food contact materials, including packaging, that are produced, imported, or circulated within Indonesian territory by 17 October 2026 (Ismail et al., 2025; Putri, 2025).

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A defining feature of Indonesia's approach is that packaging materials are subjected to the same level of regulatory scrutiny as food products themselves. This includes mandatory verification of material composition, traceability of raw materials, and, where applicable, migration testing to assess chemical transfer from packaging into food. By explicitly recognizing packaging as an integral component of halal integrity, the Indonesian system addresses long-standing gaps in ingredient-focused halal audits and establishes one of the most stringent halal packaging regimes globally (Rutkowski, 2024; Muhamedbegović et al., 2021).

Table 4. Comparative overview of international halal authorities and their approaches to packaging certification

Standard Body	Mandatory Packaging Certification	Primary Technical Focus
JAKIM (Malaysia)	Yes (for certified food manufacturers)	Comprehensive supply-chain verification and process integrity, including machinery lubricants and processing aids (Lau et al., 2016; Rutkowski, 2024).
BPJPH (Indonesia)	Mandatory by October 2026	Strict import control, material traceability, and chemical migration testing for food contact materials (Ismail et al., 2025; Putri, 2025).
SMIIC (Global/OIC)	Recommended for Harmonization	Permissibility of additives, chemical safety, and alignment of halal standards across member states (Dağ & Erbasi-Gonc, 2013; Mariyam et al., 2022).
GSO (Gulf Region)	Yes (integrated into food standards)	Control of residual alcohol, chemical contaminants, and compliance with regional food safety thresholds (Khan & Haleem, 2016; Hussaini, 2025).

Analytical verification and Forensics in packaging audits

Because many packaging-related halal risks remain hidden at the molecular level, contemporary halal certification bodies increasingly rely on advanced analytical and forensic techniques to verify compliance and to detect intentional or unintentional fraud within complex packaging systems (Rutkowski, 2024; Muhamedbegović et al., 2021). Traditional document-based audits and supplier declarations are often insufficient to identify non-halal inputs embedded in additives, processing aids, inks, or recycled materials.

Accordingly, laboratory-based methods including targeted chemical analysis, screening for non-intentionally added substances (NIAS), and molecular-level investigations are being integrated into halal assurance systems to strengthen traceability, substantiate halal claims, and address vulnerabilities arising from multilayer structures and indirect contact materials (Geueke, 2018; Vaferi et al., 2025).

Detection of animal derivatives (Halal verification)

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- **Real-time PCR (qPCR):** Real-time polymerase chain reaction is widely applied to detect DNA from prohibited species, particularly porcine DNA, in packaging materials and processing aids. The method is effective for identifying contamination arising from lubricants or raw fat residues; however, its sensitivity may be reduced when DNA is degraded during high-temperature manufacturing or extrusion processes (Rutkowski, 2024; Eriksson et al., 2013).

- **Gas chromatography–mass spectrometry (GC–MS):** GC–MS is considered a definitive analytical tool for identifying and quantifying chemical migrants from food contact materials. It is routinely used to detect plasticizers, residual solvents, and to perform fatty acid profiling, enabling differentiation between stearates derived from animal fats and those originating from vegetable sources (Gupta et al., 2024; Seref & Cufaoglu, 2025).

- **LC–MS/MS lipidomics:** Lipidomics-based analysis using LC–MS/MS represents an advanced "omics" approach capable of simultaneously identifying hundreds to thousands of lipid species. This technique allows for high-resolution discrimination between halal-compliant and non-halal lipid sources in complex additives and processing aids, offering superior specificity compared with conventional fatty acid analysis (Gramita et al., 2026).

Verification of tayyiban (safety and wholesomeness) status

- **Overall migration (OM) testing:** Overall migration testing measures the total quantity of non-volatile substances transferred from packaging materials into standardized food simulants. It provides a general assessment of the material's chemical inertness and is commonly used as a screening tool for packaging safety (Muncke, 2016; Gupta et al., 2024).

- **Specific migration (SM) testing:** Specific migration testing targets individual hazardous compounds, such as bisphenol A (BPA), phthalates, or heavy metals (e.g., lead and cadmium), that may leach from polymers, inks, coatings, or metallic containers. This method is essential for evaluating compliance with both food safety regulations and the tayyib principle (Seref & Cufaoglu, 2025; Vaferi et al., 2025).

- **Electronic nose (E-nose):** Electronic nose systems are employed to detect volatile off-odors associated with scalping, polymer degradation, or the use of recycled materials. Changes in volatile profiles may signal deterioration in sensory quality, thereby indicating a potential failure to meet tayyiban standards even in the absence of overt chemical hazards (Geueke, 2018; Mohd Hatta et al., 2023).

Economic implications and consumer behavior

The progressive maturation of the halal packaging market projected to reach a valuation of approximately USD 584 billion by 2032 is increasingly driven by rising levels of halal literacy among consumers. Contemporary Muslim consumers are no longer concerned solely with ingredient

permissibility but are becoming more aware of upstream factors such as packaging materials, processing aids, and supply-chain integrity, which collectively shape perceptions of halal and tayyib compliance (Ovsiannykov, 2025; Dimension Market Research, 2025).

This heightened awareness has translated into measurable shifts in purchasing behavior, with consumers demonstrating a greater willingness to pay for products supported by transparent halal assurance systems and verifiable packaging compliance. As a result, halal packaging is emerging not only as a regulatory requirement but also as a strategic value driver, influencing brand trust, market differentiation, and long-term competitiveness within global halal markets (Aneesh et al., 2025; Randeree, 2019).

The trust gap and marketability

Muslim consumers are becoming increasingly skeptical of generic "halal" logos and are demanding verifiable, end-to-end halal compliance that extends across the entire supply chain, including packaging materials and processing aids (Randeree, 2019; Hussaini, 2025). Empirical studies conducted in markets such as Malaysia and Taiwan consistently demonstrate that ingredient clarity defined as transparent disclosure of inputs and their origins is the most influential determinant of purchase intention for packaged food products (Setiawan et al., 2024; Aneesh et al., 2025).

Moreover, high-profile halal integrity incidents, including allegations of porcine fat contamination in food trays, have generated a pronounced "serious alarm" effect among consumers, eroding trust in conventional certification marks. Such events significantly reshape consumer behavior, prompting a shift toward brands capable of providing documented and auditable evidence of halal compliance for both food and packaging components (Putri, 2025; Halal Food Council USA, 2026). Consequently, transparency in packaging provenance is no longer a peripheral issue but a critical factor influencing brand credibility and marketability within the global halal economy.

The rise of Green Halal

A significant emerging trend within the global halal ecosystem is the convergence of environmental sustainability and halal compliance, often conceptualized as Green Halal. Increasingly, industry stakeholders recognize that bio-based and renewable packaging materials not only reduce environmental impact but also mitigate halal risks by eliminating reliance on animal-derived additives and processing aids. Materials such as polylactic acid (PLA), produced from fermented corn or sugarcane starch, inherently bypass concerns related to animal-derived stabilizers and lubricants, while simultaneously aligning with Islamic principles of environmental stewardship (khalifah) and the preservation of public interest (maslahah) (Rajendran et al., 2024; Ovsiannykov, 2025).

This alignment reinforces the tayyib dimension of halal by integrating wholesomeness, safety, and sustainability into material selection decisions. As a result, bio-based packaging materials are increasingly perceived not merely as technical alternatives to petrochemical plastics, but as ethically

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and jurisprudentially favorable solutions within halal supply chains (Mohd Hatta et al., 2023; Kamil et al., 2025).

Table 5. Bio-based packaging materials and their halal–sustainability advantages

Bio-Based Material	Sourcing	Halal/Sustainable Advantage
PLA (Polylactic Acid)	Fermented starch (Corn/Sugar)	Inherently animal-free; biodegradable; widely accepted under halal frameworks and approved for food contact applications (Rajendran et al., 2024; Rutkowski, 2024).
PHAs	Microbial fermentation	Renewable and biodegradable alternative to petrochemical plastics; minimal risk of animal-derived inputs (Junaid et al., 2025; Kamil et al., 2025).
Cellulose Films	Plant fibers (Wood/Bamboo)	Naturally halal-compliant; high barrier performance and strong alignment with sustainability objectives (Bujang & Bakar, 2023; Padhan et al., 2026).

Operationalizing Halal assurance: The HCCP framework

To effectively mitigate hidden halal risks associated with packaging materials and processing aids, food manufacturers must explicitly integrate packaging into their Halal Assurance System (HAS) through a risk-based framework analogous to Hazard Analysis and Critical Control Points (HACCP). This approach, commonly referred to as Halal Critical Control Points (HCCP), enables systematic identification, evaluation, and control of halal-related hazards arising from material composition, processing aids, migration pathways, and cross-contamination risks (Lau et al., 2016; Hussaini, 2025).

By extending HCCP principles beyond ingredients and slaughter practices to include packaging materials, manufacturers can address vulnerabilities that are often overlooked in conventional halal audits, thereby strengthening both halal integrity and the tayyib dimension of food safety (Bujang & Bakar, 2023; Khan & Haleem, 2016).

Identification of Halal Critical Control Points (HCCPs)

A Halal Critical Control Point (HCCP) is defined as a stage within the production, packaging, or distribution process at which control can be applied to prevent, eliminate, or reduce a halal-related risk to an acceptable level. The HCCP concept mirrors the logic of HACCP but focuses specifically on risks associated with haram substances, najis contamination, and violations of tayyib principles (Lau et al., 2016; Hussaini, 2025).

Key HCCPs relevant to packaging systems include the following:

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1. Supplier qualification: The initial and most critical HCCP occurs at the procurement stage. Manufacturers must require valid halal certification not only for food ingredients but also for packaging raw materials, including polymer resins, masterbatches, additives, inks, and adhesives. Failure at this stage propagates risk throughout the entire packaging system (Bujang & Bakar, 2023; Rutkowski, 2024).

2. Machine setup and lubrication: During extrusion, molding, and conversion processes, only food-grade and halal-certified lubricants should be used. Non-halal lubricants, particularly those derived from porcine or non-halal animal fats, represent a major source of surface contamination and indirect contact risk (Khan & Haleem, 2016; Eriksson et al., 2013).

3. Printing and drying: Printing operations using alcohol-based inks constitute a distinct HCCP. Manufacturers must validate solvent evaporation and curing efficiency through laboratory testing to ensure that no prohibited residual alcohols or non-halal ink components remain on food-contact surfaces (Muncke, 2016; Groh, 2016).

4. Warehouse and logistics: Packaging materials must be stored and handled in hygienic conditions and physically segregated from non-halal materials. Improper storage may lead to cross-contamination through odor absorption, pest activity, or contact with contaminated surfaces, undermining halal integrity even after compliant production (Randeree, 2019; Hussaini, 2025).

Table 6. Packaging-specific Halal Critical Control Points (HCCPs), risks, and control measures

Packaging Process Stage	Potential Halal Risk	Control Measure
Resin Synthesis	Use of porcine-derived stearic acid as a lubricant (Khan & Haleem, 2016; Mariyam et al., 2022).	Substitution with plant-based stearates; analytical verification via fatty acid profiling or chromatographic methods (Mariyam et al., 2022; Rutkowski, 2024).
Extrusion/Molding	Contamination from previous runs using non-halal additives (Bujang & Bakar, 2023)	Dedicated halal production lines or validated cleaning and purge procedures documented within SOPs (Lau et al., 2016; Bujang & Bakar, 2023).
Conversion/Assembly	Use of porcine gelatin glues in box or carton sealing (Eriksson et al., 2013; Rutkowski, 2024).	Mandatory halal certification and traceability documentation for all adhesives and binders (Eriksson et al., 2013; Rutkowski, 2024).
Printing	Set-off migration of residual alcohol or shellac-based inks (Groh, 2016; Muncke, 2016).	Use of low-migration, alcohol-free, or plant-based ink systems; verification through migration and solvent-residue testing (Groh, 2016; Muncke, 2016).

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CONCLUSION

Packaging materials and the migration of chemical substances represent the new frontier of halal food safety. The evidence indicates that the traditional focus on primary ingredients is no longer sufficient to guarantee the integrity of halal products in a globalized, technologically advanced supply chain. The "hidden" nature of packaging additives ranging from porcine-derived lubricants in manufacturing to the chemical memory of recycled fibers requires a sophisticated, risk-based management strategy.

To ensure future compliance and maintain consumer trust, the global halal industry must embrace a multidisciplinary model that integrates material science, analytical chemistry, and Islamic jurisprudence.

The findings of this report suggest that the following actions are critical:

1. Standardization of Packaging Requirements: International bodies like SMIIC and JAKIM must continue to refine and harmonize standards that explicitly address the chemical composition and migration limits for packaging materials.

2. Mandatory Certification and Traceability: The shift toward mandatory certification for food contact materials, as seen in Indonesia, should be encouraged globally to ensure that packaging manufacturers are held to the same ethical and safety standards as food producers.

3. Investment in Analytical Forensics: Certification bodies must deploy advanced testing regimes, including GC-MS and RT-PCR, to validate supplier claims and detect trace levels of non-halal migrants.

4. Prioritizing Sustainable, Bio-Based Alternatives: The adoption of plant-based polymers and low-migration inks offers a path toward a "green halal" future that simultaneously addresses environmental concerns and religious requirements.

By recognizing the package as an active component of the food system, the industry can fulfill its moral and regulatory responsibility to protect the consumer, providing products that are truly halal and wholesome from the inside out. The transition from a "label-centric" to a "process-centric" assurance model is essential for the long-term credibility and growth of the global halal ecosystem.

REFERENCES

Abu Bakar, A., Md Salleh, O., Lai, S. H., & Hasuri, U. (2010). *Halal polymer resins and process for making the same* (Publication No. WO2010013993A1). World Intellectual Property Organization.

Adeyi, T. A., Jaiyeola, C. O., Oresegun, O. I., & Dolapo, A. (2025). AI and nanotechnology integration in the development of biodegradable food packaging materials. *International Journal of Science and Research Archive*, *14*(1), 726-736.

Adly, H. M., Saati, A. A., Obaid, M. S., & Saleh, S. A. (2025). Chemical Migration of Polycyclic Aromatic Hydrocarbons and Other Compounds from Plastic Food Packaging: Assessment of Food Safety Risks and Health Impacts. *Foods*, *14*(6), 1013.

Aghwan, Z. A., Asli, N. A., & Azmar, Z. (2024). NANOTECHNOLOGY IN HALAL FOOD: A TECHNOLOGICAL BENEFITS AND ETHICAL DILEMMAS ASSESSMENT. *Journal of Halal Science and Technology*, *3*(2), 43-52.

Akbar, J., Gul, M., Jahangir, M., Adnan, M., Saud, S., Hassan, S., ... & Fahad, S. (2023). Global trends in halal food standards: A review. *Foods*, *12*(23), 4200.

Ali, I. Q., & Fatimah, P. R. (2025). Towards sustainable halal bottled water: integrating circular economy and qualitypreneur for small-scale producers. *Journal of Halal Product and Research*, *8*(2), 206-224.

Anees, A. (2025a). *Are emulsifiers halal? Understanding food additives with Muslim consumer guidance*. American Halal Foundation.

Anees, A. (2025b). *Halal ingredients: Low, medium & high risk matrix*. American Halal Foundation.

Aneesh, A. A. K., Siddiq, A., Razeena, S., Rajesha, M., Sushma, B. K., Jyothi, M. M., Mohammed Jamsheer, K. F., Nubeera, M., Janet, C., Abdul Rahiman, M. S., & Kumar, B. M. (2025). *Buying behaviour of Muslim consumer towards halal food products: A review and bibliometric analysis*. In **IoT and digital transformation: Innovating business models for the connected world** (pp. 556–570). Springer.

Atanasova-Pancevska, N., & Markovska, A. (2024). IMPACT OF MIGRATION OF SUBSTANCES FROM PACKAGING MATERIALS ON THE HALAL STATUS OF FOOD. *Journal of halal quality and certification*, *2*(1), 34-43.

Bujang, A., & Bakar, S. (2023). Halal packaging: halal control point in manufacturing of packaging materials and halal labeling. In *Innovation of food products in halal supply chain worldwide* (pp. 161-175). Academic Press.

Dağ, H., & Erbasi-Gonc, E. (2013). SMIIC and halal food standards. *Journal of Chemical Metrology*, *7*(1).

Dashti, L. A., Jackson, T., West, A., & Jackson, L. (2024). Enhancing halal food traceability: a model for rebuilding trust and integrity in Muslim countries. *Journal of Islamic Marketing*, *15*(12), 3382-3408.

Dian, N. H. F. N., Muzakhar, S. S. A., Fahmi, F., & Gunawan, S. (2025). A Halal-Haram Studies: Food-Grade Lubricants in the Food Industry. *Halal Research Journal*, *5*(2), 84-94.

Eriksson, A., Burcharth, J., & Rosenberg, J. (2013). Animal derived products may conflict with religious patients' beliefs. *BMC medical ethics*, *14*(1), 48.

Fadhilah, H., Djamal, E. C., Ilyas, R., & Najmurrokhman, A. (2018, August). Non-halal ingredients detection of food packaging image using convolutional neural networks. In *2018 International symposium on advanced intelligent informatics (SAIN)* (pp. 131-136). IEEE.

Farrelly Mitchell. (2025). *Halal logistics in the food industry: An in-depth analysis*. Farrelly Mitchell.

Geueke, B. (2018). *Non-intentionally added substances (NIAS)*. Food Packaging Forum.

Geueke, B., Wagner, C. C., & Muncke, J. (2014). Food contact substances and chemicals of concern: a comparison of inventories. *Food Additives & Contaminants: Part A*, *31*(8), 1438-1450.

Gramita, W. S., Harlina, P. W., Maritha, V., Muchtaridi, M., Geng, F., Lembong, E., & Utama, D. T. (2026). Halal authentication of non-meat food products using lipidomics approaches and analytical techniques. *Cogent Food & Agriculture*, *12*(1), 2608383.

Groh, K. (2016). *Migration from printing inks in multilayer FCMs*. Food Packaging Forum.

Gupta, R. K., Pipliya, S., Karunanithi, S., Eswaran U, G. M., Kumar, S., Mandliya, S., ... & Kovács, B. (2024). Migration of chemical compounds from packaging materials into packaged foods: Interaction, mechanism, assessment, and regulations. *Foods*, *13*(19), 3125.

Hamid, N. A. A., Abdullah, M., Wahab, N. A., & Ager, S. N. S. (2016). Laws, Policies and Standard Enforcement in Malaysia and Indonesia Halal Food Industry. *The Social Science*, *11*, 7449-7454.

Hussain, I. (2021). *Halal packaging & labelling*. Centre for the Study of Sciences, Technology & Civilization (CSSTC).

Hussaini, M. A. (2025). *Halal Critical Control Points (HCCPs): A comprehensive overview*. American Halal Foundation.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Ibrahim, I., Shuib, A., & Yusoff, F. H. (2024). Planning of halal compliance critical control points and IOT integration in halal chicken meat supply chain traceability system. *Journal of Halal Industry & Services*, *7*(1).

Ismail, I., Tarigan, A. A., Soemitra, A., & Nawawi, Z. M. (2025). Strengthening the global competitiveness of halal culinary SMEs in North Sumatra through a Maqasid of Shariah-based approach. *Journal of Islamic Economics Lariba*, *11*(1).

Junaid, P. M., Saikumar, A., Islam, R. U., Patel, M. K., Eranda, D. H. U., Islam, M., ... & Badwaik, L. S. (2025). Polysaccharide-based biopolymers: exploring film fabrication techniques, molecular interactions, and their potential food applications. *Quality Assurance and Safety of Crops & Foods*, *17*(4), 257-283.

Kamil, A., Hatta, F. A. M., & Ismail, A. G. (2025). Comparative study: Analysis of halal standards of the food industry in Islamic countries. *Multidiscip. Rev*, *8*(8).

Khan, M. I., & Haleem, A. (2016). Understanding "halal" and "halal certification & accreditation system"-a brief review. *Saudi Journal of Business and Management Studies*, *1*(1), 32-42.

Lau, A. N., Jamaludin, M. H., & Mei Soon, J. (2016). Quality assurance and halal control points for the food industry. *Nutrition & Food Science*, *46*(4), 557-570.

Lokuge, E. (2025). Recent Trends in Smart Packaging. *Journal of Research Technology & Engineering*, *6*(3), 176-201.

Mahamud, N., Santiworakun, N. Y., Chaovasuteeranon, S., & Boonmalert, F. (2023). Halal alternative sources of gelatin: A review. *Journal of Halal Science, Industry, and Business*, *1*(2), 43-56.

Mariyam, S., Bilgic, H., Rietjens, I. M. C. M., & Susanti, D. Y. (2022). Safety assessment of questionable food additives in the halal food certification: A review. *Indonesian Journal of Halal Research*, *4*(1), 19-25.

Mohd Hatta, F. A., Mat Ali, Q. A., Mohd Kashim, M. I. A., Othman, R., Abd Mutalib, S., & Mohd Nor, N. H. (2023). Recent advances in halal bioactive materials for intelligent food packaging indicator. *Foods*, *12*(12), 2387.

Muhamedbegović, B., Ahmetović, N., Suljagić, J., & Bajrić, B. (2021). *Chemical migration from food contact materials into food – Gaps in EU legislation and safety assessment*. In ***Proceedings of the 13th International Scientific Conference on Manufacturing Engineering: Development and Modernization of the Manufacturing*** (Sarajevo, Bosnia and Herzegovina).

Muhamedbegović, B., Alihodžić, D., Jašić, M., & Sejranić, K. (2022, November). Packaging in the process of halal certification of food products. In *Proceedings of the World Halal Summit Scientific Conference* (pp. 24-26).

Muhammad, M. A., Elistina, A. B., & Ahmad, S. O. (2020). The challenges faced by halal certification authorities in managing the halal certification process in Malaysia. *Food Research*, *4*(1), 170-178.

Muncke, J. Chemical Migration from Food Packaging to Food. In Reference Module in Food Science; Elsevier: Amsterdam, The Netherlands, 2016; p. 285.

Ovsiannykov, Y. (2025). Analysis of Global Halal Product Market Development Trends: Socio-Cultural and Economic Dimensions. *European Journal of Interdisciplinary Issues*, *2*(2), 74-83.

Padhan, M., Sahoo, S., Maity, S., & Thirugnanam, A. (2026). Plant-Based Polymers in Food Packaging Industry Application. In *Biopolymers from Plant Origin for Environmental Sustainability* (pp. 23-47). Cham: Springer Nature Switzerland.

Putri, A. (2025). From Chaoshan to classrooms: Illegal imports, health hazards, and halal concerns. *Indonesia Business Post*.

R. J. Setiawan, K. Ma'ruf, N. Azizah, A. Rusmala, N. E. Khosyiati and S. F. A. Widodo, "The Effects of Halal Labels on Packaged Ice Cream Purchase Interest Among Foreign Muslim Consumers - A Case Study in Taiwan," *2024 International Conference on Sustainable Islamic Business and Finance (SIBF)*, Bahrain, 2024, pp. 319-323. https://doi.org/10.1109/SIBF63788.2024.10883821

Rajendran, D. S., Venkataraman, S., Jha, S. K., Chakrabarty, D., & Kumar, V. V. (2024). A review on bio-based polymer polylactic acid potential on sustainable food packaging. *Food Science and Biotechnology*, *33*(8), 1759-1788.

Randeree, K. (2019). Challenges in halal food ecosystems: the case of the United Arab Emirates. *British Food Journal*, *121*(5), 1154-1167.

Rutkowski, R. (2024). *An exploration of halal requirements and the response to them in the German chemical-pharmaceutical manufacturing sector* (Doctoral dissertation). University of Worcester.

Seref, N., & Cufaoglu, G. (2025). Food packaging and chemical migration: a food safety perspective. *Journal of food science*, *90*(5), e70265.

Serrano Jiménez, S., Bouzraa, S., Escudero, M., Ruiz, B., & Rodríguez, I. (2025). *Influence of halal certification on exports markets. Case study: Halal Institute certification impact on Spanish meat market exports.* ***Journal of Halal Science, Industry, and Business*****, *3*(2), 15–29.

Silcock, P., & Bremer, P. (2022). The Potential Impacts of The Use of Recycled Packaging on Food Quality. *New Zealand Food Safety Science & Research Centre*, 1-39.

Tayob, S. (2012). *Consuming, producing, defining Halal: Halal authorities and Muslim consumers in South Africa* (Master's thesis, University of Cape Town).

Tedjakusuma, A. P., Yong, H. N. A., Andajani, E., & Mohamad, Z. Z. (2023). Intention to purchase halal health supplement online: Lessons learned from the health crisis. *Heliyon*, *9*(9).

Usman, I., Sana, S., Afzaal, M., Imran, A., Saeed, F., Ahmed, A., ... & Khan, M. R. (2024). Advances and challenges in conventional and modern techniques for halal food authentication: A review. *Food Science & Nutrition*, *12*(3), 1430-1443.

Vaferi, B., Dehbashi, M., Yousefzadeh, R., & Alibak, A. H. (2025). Prediction of the packaging chemical migration into food and water by cutting-edge machine learning techniques. *Scientific Reports*, *15*(1), 7806.

Zainuddin, N., Saifudin, A. M., Deraman, N., & Mahidin, N. (2019). Effect of Halal certification and labelling process on Halal supply chain performance. *International Journal of Supply Chain Management*, *8*(4), 1075-1081.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CONTROL OF PRODUCT TREE REVİSİONS İN BUS DESİGN USİNG AN EXCEL MAKRO

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ABSTRACT

In the automotive industry, particularly in bus manufacturing, increasing product variety and customer-specific configurations require flexible, traceable, and digitally supported product development processes. Since each bus is typically customized according to individual customer requirements, the number and complexity of design revisions significantly increase, especially in trim design departments. Ineffective revision management may result in incorrect part production, excessive inventory, supply chain disruptions, and quality issues.

To address these challenges, this study presents a digital revision management approach based on a structured Bill of Materials (BOM) and implemented through an Excel macro-based system. The proposed method enables systematic comparison of current and updated product trees, automatic detection of revision differences, visual identification of modified components, and generation of detailed revision reports. In addition, revision data are structured in a format compatible with Product Lifecycle Management (PLM) systems, allowing the developed system to function as a low-cost and practical transition solution prior to full PLM integration.

The developed system was validated through a pilot application involving more than 150 trim components in a bus manufacturing environment. The results indicate a reduction of revision recording time by 35%, a decrease in data entry errors by 40%, and an improvement in interdepartmental information flow by 25% compared to manual processes. The findings demonstrate that Excel-based digital revision control, when supported by a structured BOM approach, can significantly enhance data consistency, traceability, and operational efficiency while providing a scalable foundation for future PLM integration.

Keywords: Digital Revision Management, Bill of Materials (BOM), Bus Manufacturing, Product Lifecycle Management (PLM)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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OTOBÜS TASARIMLARINDA ÜRÜN AĞACI REVİZYONLARININ EXCEL MAKRO İLE KONTROLÜ

ÖZET

Otomotiv endüstrisinde, özellikle otobüs üretiminde artan ürün çeşitliliği ve müşteri bazlı konfigürasyon gereksinimleri, esnek, izlenebilir ve dijital olarak desteklenen ürün geliştirme süreçlerini zorunlu hale getirmiştir. Her bir aracın müşteri taleplerine göre özelleştirilmesi, özellikle trim tasarım birimlerinde tasarım revizyonlarının sayısını ve karmaşıklığını önemli ölçüde artırmaktadır. Revizyonların etkin şekilde yönetilememesi; hatalı parça üretimi, gereksiz stok oluşumu, tedarik zinciri aksaklıkları ve kalite problemleri gibi ciddi sonuçlara yol açabilmektedir.

Bu çalışmada, otobüs üretiminde tasarım revizyonlarının yapılandırılmış bir Ürün Ağacı (BOM) üzerinden dijital olarak yönetilmesini sağlayan Excel makro tabanlı bir sistem geliştirilmiştir. Önerilen sistem; mevcut ve yeni ürün ağaçlarını satır bazında karşılaştırarak revizyon farklarını otomatik olarak tespit etmekte, revize edilen bileşenleri görsel olarak işaretlemekte ve detaylı revizyon raporları oluşturmaktadır. Ayrıca geliştirilen yapı, parça numarası, revizyon seviyesi ve değişiklik bilgileri gibi alanlar üzerinden PLM sistemleriyle uyumlu veri üretmekte olup, tam PLM entegrasyonu öncesinde uygulanabilir bir geçiş çözümü sunmaktadır.

Pilot uygulama kapsamında 150'den fazla trim parçası üzerinde gerçekleştirilen çalışmalar sonucunda, manuel yöntemlere kıyasla revizyon kayıt süresinde %35 azalma, hatalı veri girişlerinde %40 azalma ve departmanlar arası bilgi paylaşım hızında %25 artış sağlandığı tespit edilmiştir. Elde edilen bulgular, BOM tabanlı dijital revizyon yönetiminin veri bütünlüğünü ve izlenebilirliği artırdığını, mühendislik süreçlerinin verimliliğini önemli ölçüde iyileştirdiğini ve PLM tabanlı dijital dönüşüm için sağlam bir altyapı oluşturduğunu göstermektedir.

Keywords: Dijital Revizyon Yönetimi, Ürün Ağacı (BOM), Otobüs Üretimi, Ürün Yaşam Döngüsü Yönetimi (PLM)

GİRİŞ

Otomotiv endüstrisi, son on yılda müşteri odaklı üretim stratejilerinin yaygınlaşmasıyla birlikte yüksek varyasyonlu ürün konfigürasyonlarına yönelmiştir (1). Özellikle otobüs üretimi, her bir aracın müşteri taleplerine göre özelleştirildiği, düşük hacimli ancak yüksek karmaşıklığa sahip bir üretim modeli sunmaktadır. Bu durum, başta trim tasarım birimleri olmak üzere mühendislik departmanlarında tasarım revizyonlarının sayısını ve yönetim zorluğunu önemli ölçüde artırmaktadır (2).

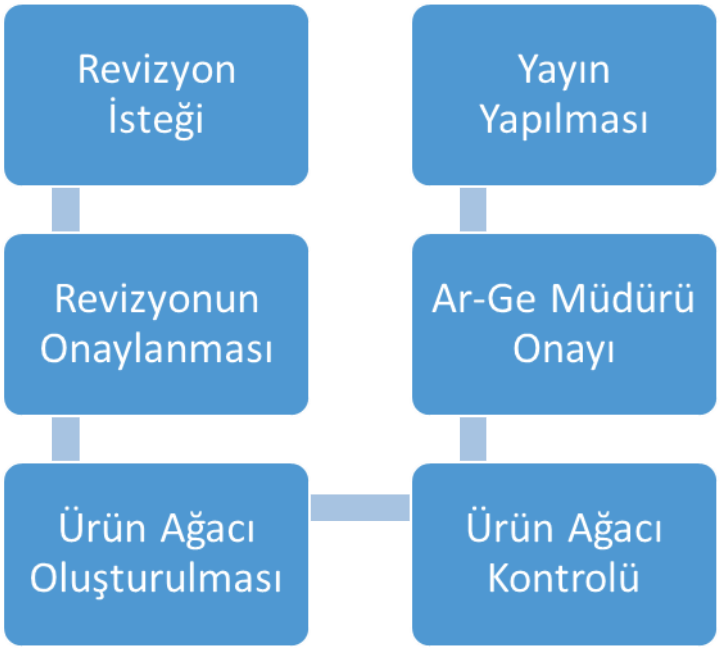
Trim bileşenleri; tavan, zemin, yan paneller, iç kaplamalar, koltuk sistemleri, perde ve aydınlatma elemanları gibi hem estetik hem de fonksiyonel açıdan kritik parçaları içermektedir. Bu bileşenlerde yapılan küçük bir tasarım değişikliği dahi, üretim, kalite, satın alma ve lojistik süreçlerini doğrudan

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etkileyebilmektedir (3). Bu nedenle revizyonların yalnızca tasarım seviyesinde değil, tüm ürün yaşam döngüsü boyunca izlenebilir şekilde yönetilmesi gerekmektedir.

Geleneksel revizyon yönetimi yaklaşımları çoğunlukla Excel tabloları, manuel kayıtlar veya 2B teknik resim revizyon blokları üzerinden yürütülmektedir (4). Ancak tek bir otobüste 20.000'den fazla bileşenin bulunabilmesi ve bu bileşenlerin çok seviyeli ürün ağaçları (Bill of Materials – BOM) içerisinde tanımlanması, manuel yöntemleri yetersiz hale getirmektedir (5). Revizyonların kontrolsüz yönetilmesi; yanlış parça üretimi, stok fazlalığı, tedarik zinciri kopuklukları ve yeniden işçilik gibi ciddi operasyonel problemlere yol açabilmektedir (6).

Revizyon (Değişiklik) yönetimini beş ana başlık altında inceleyebiliriz. Bunlar sırası ile; Kalite ve Güvenlik, Yasal ve Regülasyon Uyumu, Maliyet Kontrolü, Departmanlar Arası Senkronizasyon, Müşteri Memnuniyetidir. Uygun yönetilmeyen revizyonlar maliyet, zaman ve kalite anlamında önemli sorunlar oluşturmaktadır. Revizyonların yayın yapılma süreci öncesinde kontrol edilmesi olası hataları büyük oranda engellemektedir. Bu sürecin efektif olarak değerlendirilmesi de kritik bir öneme sahiptir. Şekil 1 de revizyon değişikliği iş akış diyagramı verilmiştir.



Şekil 1 Revizyon Değişikliği İş Akış Diyagramı

Bu sorunların çözümüne yönelik olarak geliştirilen Ürün Yaşam Döngüsü Yönetimi (Product Lifecycle Management – PLM) sistemleri, tasarım değişikliklerinin yaşam döngüsü boyunca izlenebilmesini ve mühendislik değişiklik emirlerinin (ECR/ECO) dijital olarak yönetilmesini mümkün kılmaktadır (7,8). Bununla birlikte, PLM sistemlerinin yüksek kurulum maliyetleri, lisans giderleri ve kullanıcı adaptasyon süreçleri nedeniyle birçok orta ölçekli üretici, tam PLM entegrasyonuna geçiş sürecinde alternatif veya geçici çözümlere ihtiyaç duymaktadır (9).

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Tasarım süreçlerinde dijital dönüşümün etkisi yalnızca veri yönetimiyle sınırlı değildir; aynı zamanda tasarım mühendislerinin karar alma hızını ve hata farkındalığını da artırmaktadır (10). Otomatikleştirilmiş revizyon kayıtları, değişikliklerin neden-sonuç ilişkisini analiz etmeye olanak tanırken, geçmiş veri tabanları üzerinden hata kök neden analizi yapılabilmektedir (11). Bu yaklaşım, yalın mühendislik prensipleriyle de uyumlu olup, israfların azaltılmasına katkı sağlar (12).

Bunun yanında, dijital izlenebilirlik sistemleri üretim hattında gerçek zamanlı parça takibi imkânı sunarak kalite kontrol süreçlerini güçlendirir (13). Özellikle otobüs montaj hatlarında kullanılan karmaşık varyant yönetimi sistemlerinde, doğru revizyon seviyesinin kullanılmaması ciddi kalite sorunlarına yol açabilmektedir (14). Bu nedenle, dijital revizyon yönetimi yalnızca tasarımın değil, üretim ve servis aşamalarının da bütünsel bir parçası haline gelmiştir (15).

Bu bağlamda, düşük maliyetli ancak PLM veri yapılarıyla uyumlu dijital revizyon yönetim sistemleri, özellikle KOBİ ölçeğindeki üreticiler için uygulanabilir bir ara model sunmaktadır. Excel tabanlı ve otomasyon destekli bu tür çözümler, tam PLM entegrasyonu öncesinde organizasyonel adaptasyonu artırmakta ve dijital dönüşüm sürecini hızlandırmaktadır (4,9).

Bu çalışma, otobüs üretiminde tasarım revizyonlarının yapılandırılmış bir BOM üzerinden Excel makro tabanlı bir sistemle dijital olarak yönetilmesini ele almakta ve geliştirilen yaklaşımın PLM sistemleriyle uyumlu bir geçiş çözümü olarak kullanılabilirliğini ortaya koymayı amaçlamaktadır.

MATERYAL VE METOD

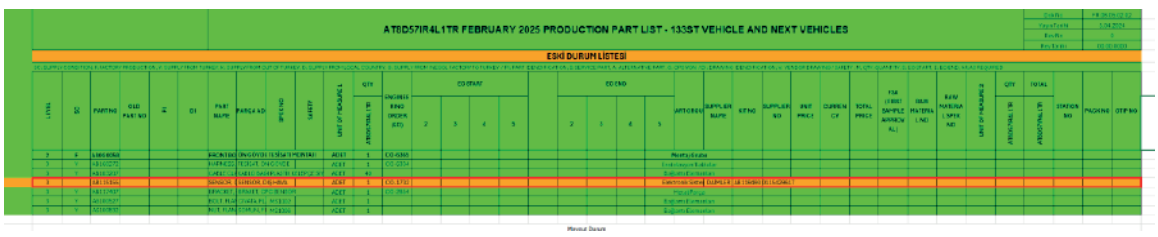
Bu çalışmada, AKIA markalı bir otobüs platformuna ait ürün ağacı yapısı referans alınmıştır (16). Çalışmanın temel amacı, tasarım ve tasarım dışı revizyonların dijital ortamda izlenebilirliğini artırmak ve revizyon verilerinin PLM sistemleriyle uyumlu şekilde yapılandırılmasını sağlamaktır.

1. Mevcut ve yeni ürün ağacı (BOM) verileri Excel ortamına aktarılır.

2. Excel makrosu, ürün ağaçlarını satır bazında karşılaştırarak parça numarası, revizyon seviyesi ve açıklama alanlarındaki farkları otomatik olarak tespit eder.

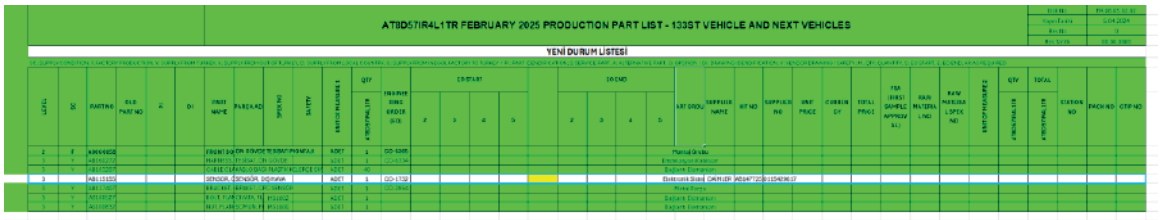
3. Revizyon içermeyen hücreler yeşil, revizyon içeren hücreler turuncu renkle görsel olarak işaretlenir.

4. Tespit edilen revizyonlar; etkilenen bileşenler, revizyon türü ve değişiklik bilgileriyle birlikte ayrıntılı olarak raporlanır.

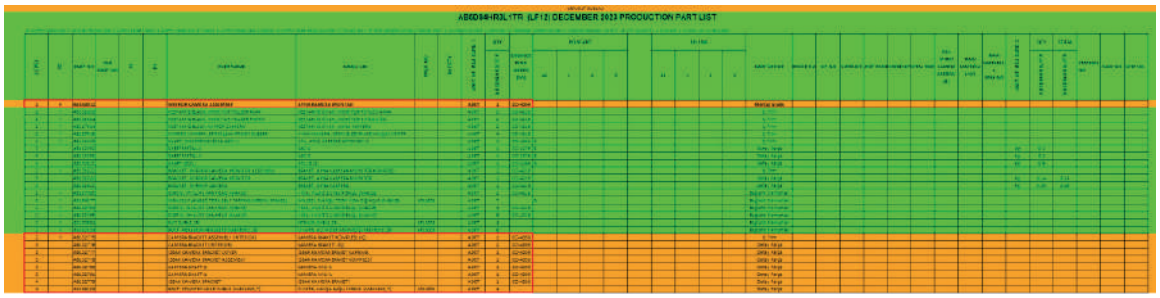


Şekil 2 Ürün Ağacı Mevcut Durum

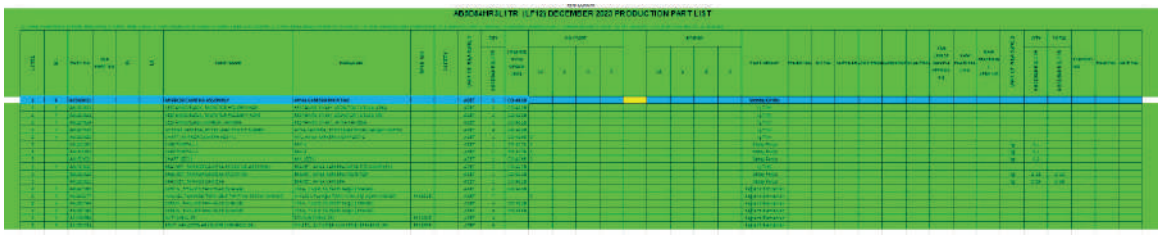
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Şekil 3 Ürün Ağacı Yeni Durum



Şekil 4 Ürün Ağacı Mevcut Durum



Şekil 5 Ürün Ağacı Yeni Durum

Şekil 2 ve Şekil 4 de mevcut ürün ağaçlarında kullanılan revizyonların Şekil 3 ve Şekil 5 de bulunan yeni durum listesi karşılaştırılarak revize edilmeyen hücreler yeşil, revizyon olan hücreler turuncu olarak işaretlenmektedir. Şekil 6 da ürün ağaçlarının kontrolü aşamasında kullanılan makro verilmiştir.

Geliştirilen sistemde her bir parça için aşağıdaki PLM uyumlu veri alanları oluşturulmaktadır:

- Parça numarası
- Revizyon seviyesi
- Değişiklik bilgisi
- Etkilenen üst ve alt seviye BOM ilişkileri

Bu yapı sayesinde elde edilen revizyon çıktıları, PLM sistemlerine manuel veya yarı otomatik olarak aktarılabilecek formatta hazırlanmıştır (7,8,17).

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```
(General)                                   KarşılaştırVeRenklendir

Sub KarşılaştırVeRenklendir()
    Dim ws1 As Worksheet
    Dim ws2 As Worksheet
    Dim satir1 As Range, satir2 As Range
    Dim i As Integer
    Dim hucreSayisi As Integer
    Dim ayni As Boolean
    Dim temizVeri1 As String
    Dim temizVeri2 As String
    Dim hucre1 As Range, hucre2 As Range

    ' Sayfaları tanımla
    Set ws1 = ThisWorkbook.Sheets("Mevcut_Durum")
    Set ws2 = ThisWorkbook.Sheets("Yeni_Durum")

    ' Tablolardaki hücre sayısını belirle
    hucreSayisi = ws1.UsedRange.Columns.Count

    ' Sayfa1'deki her satırı kontrol et
    For Each satir1 In ws1.UsedRange.Rows
        ayni = False ' Başlangıçta aynı değil olarak ayarla

        ' Sayfa2'deki her satırı kontrol et
        For Each satir2 In ws2.UsedRange.Rows
            ' Satırdaki hücreleri karşılaştır
            For i = 1 To hucreSayisi
                ' Hücrelerdeki boşlukları ve fazlalıkları temizle
                temizVeri1 = Trim(satir1.Cells(satir1.Row, i).Value)
                temizVeri2 = Trim(satir2.Cells(satir2.Row, i).Value)

                ' Temizlenmiş verileri karşılaştır
                If temizVeri1 <> temizVeri2 Then
                    ayni = False
                    Exit For
                Else
                    ayni = True ' Eğer tüm hücreler eşleşiyorsa aynı olarak işaretle
                End If
            Next i

            ' Aynı satır bulunduysa, renkleri yeşil yap
            If ayni Then
                satir1.Interior.Color = RGB(0, 255, 0) ' Yeşil
                satir2.Interior.Color = RGB(0, 255, 0) ' Yeşil
                Exit For
            End If
        Next satir2

        ' Aynı satır bulunmazsa, turuncu renkte boya
        If Not ayni Then
            satir1.Interior.Color = RGB(255, 165, 0) ' Turuncu
        End If
    Next satir1

    ' Sayfa2'deki her satırı kontrol et
    For Each satir2 In ws2.UsedRange.Rows
        For i = 1 To hucreSayisi
            ' Hücrelerdeki boşlukları ve fazlalıkları temizle
            temizVeri1 = Trim(satir1.Cells(satir1.Row, i).Value)
            temizVeri2 = Trim(satir2.Cells(satir2.Row, i).Value)

            ' Farklı olan hücreyi turuncu renkte boyama
            If temizVeri1 <> temizVeri2 Then
                satir2.Cells(1, i).Interior.Color = RGB(255, 165, 0) ' Turuncu
            Else
                satir2.Cells(1, i).Interior.Color = RGB(0, 255, 0) ' Yeşil
            End If
        Next i
    Next satir2

End Sub
```

Şekil 6 Ürün Ağacı Makrosu

BULGULAR

Geliştirilen sistemin otobüs üretiminde uygulandığı pilot çalışma kapsamında, 150'den fazla trim parçasının revizyon geçmişi dijital ortamda takip edilmiştir. Elde edilen sonuçlar, manuel yöntemlerle yürütülen süreçlerle karşılaştırılmıştır.

Analizler sonucunda:

- Revizyon kayıt süresinde %35 azalma,
- Hatalı veri girişlerinde %40 azalma,
- Tasarım ve üretim ekipleri arasındaki bilgi paylaşım hızında %25 artış

sağlandığı tespit edilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Ayrıca oluşturulan revizyon raporları, PLM sistemlerine veri aktarımı açısından test edilmiş ve parça numarası, revizyon seviyesi ve BOM ilişkileri açısından veri kaybı olmadan tam uyum sağlandığı doğrulanmıştır (17).

Bu sonuçlar, Excel makro tabanlı dijital revizyon yönetim sistemlerinin yalnızca geçici bir çözüm olmadığını, doğru veri modeliyle geliştirildiğinde PLM entegrasyonuna hazır bir ön katman olarak etkin şekilde kullanılabileceğini göstermektedir.

TARTIŞMA

Bu çalışma, Excel tabanlı revizyon yönetim sistemlerinin PLM entegrasyonu açısından yetersiz olduğu yönündeki genel algıyı sorgulamaktadır. Elde edilen bulgular, düşük maliyetli ve kullanıcı dostu dijital çözümlerin, tam PLM entegrasyonu öncesinde etkin bir geçiş modeli sunabileceğini ortaya koymaktadır.

Geliştirilen sistem, mühendislik disiplinleri arasında ortak bir revizyon dili oluşturarak organizasyonel adaptasyonu artırmakta ve PLM tabanlı dijital dönüşüm için sağlam bir altyapı oluşturmaktadır. Gelecekte sistemin doğrudan PLM yazılımları (örneğin Siemens Teamcenter, ENOVIA) ile entegre edilmesi ve web tabanlı hale getirilmesi planlanmaktadır (18).

SONUÇ

Bu çalışmada, otobüs tasarım süreçlerinde yapılan revizyonların ürün ağacı üzerinden Excel makro tabanlı ve PLM uyumlu bir yapı ile dijital olarak yönetilmesi sunulmuştur. Geliştirilen sistem, revizyon süreçlerini hızlandırmış, insan hatasını azaltmış ve mühendislik departmanları arasındaki veri akışını önemli ölçüde iyileştirmiştir.

Düşük maliyetli yapısı sayesinde özellikle orta ölçekli üreticiler için uygulanabilirliği yüksek olan sistem, tam PLM entegrasyonu öncesinde etkili bir geçiş çözümü sunmaktadır. Elde edilen bulgular, dijital revizyon yönetiminin otobüs üretiminde veri bütünlüğü, izlenebilirlik ve operasyonel verimlilik açısından kritik bir rol oynadığını göstermektedir.

KAYNAKÇA

Zhang, W., & Li, Y. (2019). *Flexible product development systems for mass customization in automotive manufacturing*. *Computers in Industry*, 108, 56–65.

Kumar, R., Singh, V., & Chauhan, S. (2020). *Design complexity management in automotive interiors: A case of trim system integration*. *International Journal of Automotive Technology and Management*, 20(3), 214–229.

Garcia, M., Torres, L., & Alvarez, P. (2021). *Digital revision tracking for automotive design processes: A PLM-integrated approach*. *Journal of Manufacturing Systems*, 59, 112–124. https://doi.org/10.1016/j.jmsy.2021.02.005

Özkan, H., & Demir, E. (2023). *Excel-based digital revision management for SME manufacturers: A cost-effective approach*. *Manufacturing Engineering Letters*, 12(1), 31–42.

Chen, L., & Huang, T. (2018). *BOM configuration management for customized vehicles*. *Computers & Industrial Engineering*, 118, 365–376.

Tanaka, K., & Watanabe, S. (2020). *Error propagation and design change control in complex assembly systems*. *Engineering Applications of Artificial Intelligence*, 95, 103802.

Singh, R., Patel, A., & Bhosale, V. (2022). *Integrating PLM and ERP systems for efficient product lifecycle traceability in automotive industries*. *Journal of Industrial Information Integration*, 27, 100307.

Weber, C., & Werner, A. (2020). *Model-based systems engineering in automotive product lifecycle management*. *Systems Engineering*, 23(2), 190–203.

Öztürk, Y., & Kaya, B. (2023). *Otomotiv sektöründe dijital ürün ağacı yönetimi ve revizyon süreçlerinin optimizasyonu*. *Makina ve İmalat Teknolojileri Dergisi*, 21(4), 455–468.

Ahmed, S., & Wallace, K. (2021). *Knowledge management and change tracking in design engineering*. *Design Studies*, 75, 101015.

Singh, M., & Joshi, A. (2019). *Lean-based design change control in automotive manufacturing*. *Procedia CIRP*, 81, 872–878.

Baines, T., & Lightfoot, H. (2021). *Servitization and digitalization in transport manufacturing*. *Journal of Intelligent Manufacturing*, 32, 1265–1281.

Krueger, J., & Hoffmann, P. (2022). *Traceability systems in modern bus production lines*. *Transportation Engineering*, 10, 100146.

Müller, T., Becker, H., & Schneider, F. (2021). *Data-driven change management in bus manufacturing: From BOM to digital traceability*. *Procedia CIRP*, 104, 78–85.

Johansson, J., & Olsson, F. (2020). *Digital transformation challenges in the commercial vehicle industry*. *Procedia Manufacturing*, 51, 546–553.

https://www.ulasim-as.com/tr/

ISO 10303-239. (2020). Industrial automation systems and integration – Product data representation.

Yılmaz, M., & Arıkan, O. (2023). Dijital Ürün Ağacı Yönetimi ile Revizyon Süreçlerinin Otomasyonu. Otomotiv Teknolojileri Dergisi, 18(3), 245–259.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EXPERIMENTAL INVESTIGATION OF THE EFFECT OF MICRO- AND NANO-SiO_2 PARTICLE REINFORCEMENT ON THE MECHANICAL AND TRIBOLOGICAL PROPERTIES OF EPOXY RESIN

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ABSTRACT

This study experimentally investigated the effect of adding micro and nano-sized SiO_2 particles at 1%, 2%, 3% 4% by weight to improve the mechanical and tribological performance of pure epoxy resin (neat sample). Neat sample was used as the reference sample; samples M1-M4 were produced with micro SiO_2 additive, and samples N1-N4 with nano SiO_2 additive. Tensile and dry sliding wear tests were applied to the samples, and the obtained values were evaluated as the average of three repetitions. In the tensile tests, the tensile strength of neat sample was determined as 52.84 MPa, while the highest value was measured in sample N3 containing 3% nano SiO_2 at 76.74 MPa, which corresponds to a 45.24% increase compared to the neat sample. In samples with micro SiO_2 additive, the highest tensile strength was obtained at 2%, reaching 61.42 MPa (a 16.23% increase). In wear tests (10 N load and 150 m sliding distance), the mass loss of neat sample was determined to be 9.47 mg. The lowest wear mass loss was measured as 5.71 mg in sample N3 containing 3% nano SiO_2, showing an improvement of 39.70%. At a 4% additive rate, a decrease in performance was observed in both micro and nano particle-containing samples. The results show that the addition of nano-sized SiO_2 in appropriate proportions significantly increases both tensile strength and wear resistance by improving load transfer and limiting crack propagation in the epoxy matrix.

Keywords: Epoxy, Micro, Nano, SiO_2 particles

INTRODUCTION

Composite materials are engineering materials that achieve superior mechanical, physical, and chemical properties by combining two or more different phases on a macroscopic scale (Uniyal et al., 2025). The matrix phase provides load transfer, while the reinforcement phase increases mechanical strength, rigidity, and wear resistance (Parvizi et al., 2025). Polymer matrix composites, in particular,

are widely used in aerospace, automotive, defense, and machinery manufacturing industries due to their advantages such as low density, high specific strength, corrosion resistance, and machinability (Fekiač et al., 2025). In this context, epoxy systems, which hold a significant place among thermoset resins, are frequently preferred due to their high adhesion capability, chemical resistance, and good mechanical properties (Fekiač et al., 2025). However, the brittle structure and limited wear resistance of pure epoxy resins necessitate particle reinforcement to improve performance (Bharadwaja et al., 2022).

The addition of micro and nano-sized ceramic particles to the epoxy matrix can improve mechanical and tribological performance by inhibiting crack propagation, improving the load transfer mechanism, and increasing surface hardness (Uniyal et al., 2025). SiO_2 particles, in particular, are widely used due to their high hardness, chemical stability, and compatible surface chemistry with epoxy (Sprenger, 2013). Nano-sized particles create more effective interfacial interactions due to their high specific surface areas, while micro-sized particles can contribute to load-carrying capacity (Kayalar & Doğan, 2024). However, increasing the particle ratio can lead to agglomeration and stress concentrations, resulting in decreased performance. Therefore, determining the optimum additive ratio is critically important (Zare, 2016).

This study focuses solely on an epoxy and SiO_2 particle system without fiber reinforcement. The main reason for this is to investigate the effect of particle size and ratio independently of fiber-matrix interactions, thereby revealing the direct contribution of pure matrix modification to mechanical and wear behavior. Micro and nano SiO_2 particles were added at weight percentages of 1%, 2%, 3%, and 4%. The 1%-4% range represents the typical limit range in the literature where performance improvement is observed before agglomeration begins. Thus, load transfer improvement at low ratios and potential clustering effects at high ratios were evaluated comparatively.

Many studies exist in the literature on epoxy/ SiO_2 systems. Srivastava et al. (2023) investigated the effect of hybrid nano/micro particle reinforcement on the impact and compressive performance of epoxy-based composites. The aim was to increase the energy absorption capacity by strengthening the interface interaction through particle addition. Samples were produced by vacuum infusion method; impact and compressive tests were applied. The results showed that the notchless Charpy impact energy reached 3.46 J and the compressive strength reached up to 70 MPa. The study revealed that hybrid particles improved mechanical performance by hindering crack propagation. J. Cho et al. (2006) investigated the effect of silica particles of different sizes within a polymer matrix; the aim was to determine the role of particle diameter on load transfer and stress concentrations. Samples were prepared at different volume ratios and tensile tests were applied. The results showed that nano-sized particles could increase tensile strength by approximately 15-25% at low ratios, but a decrease in strength could be observed at high ratios due to aggregation. Yuan et al. (2024) studied the effect of particle size and interfacial bonding on the tensile strength of polymers. Experimental and theoretical

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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analyses were conducted together; tensile tests were applied to silica-filled samples of different sizes. An increase in strength was reported due to stronger interfacial interaction at the nanoscale; however, it was numerically shown that the strength decreased significantly in the case of a weak interface. Jajam and Tippur (2012) examined the quasi-static and dynamic fracture behavior of micro and nano silica-filled epoxies. Static and stress-wave based dynamic fracture tests were applied to samples prepared with different volume ratios. It was reported that the crack velocity in nano-reinforced systems increased from approximately 300 m/s to 570 m/s, indicating that the dynamic fracture behavior is sensitive to particle size. Kinloch et al. (2016) aimed to increase matrix toughness in epoxy systems containing hybrid silica nanoparticles. The fracture energies of epoxies with different modifications were compared; the fracture energy of pure epoxy, which was 77 J/m², increased to 180 J/m² with silica addition and to 906 J/m² in the hybrid system. The study showed that nanoparticle addition strengthened crack deflection and plastic deformation mechanisms.

This study distinguishes itself from previous works in the literature by systematically comparing micro and nano SiO_2 particles within the same ratio range and evaluating both tensile and abrasion performance simultaneously. Furthermore, by focusing solely on the epoxy-particle system, the fiber effect was eliminated, and the direct impact of particle size was revealed. This approach offers a unique contribution to the literature in terms of determining the optimum additive ratio and demonstrating the superiority of nano-sized SiO_2 on performance with numerical data.

MATERIALS AND METHOD

In this study, a two-component MGS L285 epoxy resin and hardener system at a ratio of 1/4 was used as the matrix material. Micro-sized SiO_2 particles (average particle size: 0.3 µm) and nano-sized SiO_2 particles (average particle size: 13-22 nm) were obtained from company NanoGrafi Inc. The epoxy system was supplied by supplier Dost Kimya, Turkey, and the mixing ratios recommended by the manufacturer were used. All chemicals used were of analytical purity, and no additional surface modification processes were applied.

To ensure a homogeneous distribution of epoxy resin and SiO_2 particles, particle addition was first carried out at the determined weight ratios as presented in Table 1. Micro-added samples were named M1-M4, and nano-added samples were named N1-N4. After particle addition, the mixture was mixed with a mechanical mixer for 20 minutes. To minimize the risk of particle agglomeration and to obtain a more homogeneous distribution within the matrix, the prepared mixture was kept in an ultrasonic bath for 1 hour. After ultrasonic treatment, a hardener was added to complete the mixture according to the manufacturer's recommended ratios. The resulting mixture was poured into molds, cured at room temperature for at least 24 hours.

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Table 3. Weight ratio of the added particle

Sample	Micro Weight Ratio (%)	Nano Weight Ratio (%)
M1	1%	0%
M2	2%	0%
M3	3%	0%
M4	4%	0%
N1	0%	1%
N2	0%	2%
N3	0%	3%
N4	0%	4%

Tensile test specimens were prepared according to ASTM D3039 standards. Specimen geometry, dimensional tolerances, and test speed were determined according to the criteria specified in the standard. Epoxy and SiO_2 particles were cast into silicone molds in proportions suitable for specimen dimensions defined by ASTM D3039. Tensile tests were performed on a universal testing machine of brand Shimadzu AG-IC, using a load cell with a capacity of 250 kN. Tests were conducted at a crosshead speed of 2 mm/min, and maximum force, elongation, and tensile strength values were recorded. To ensure the reliability of the results, at least three repetitions were performed for each specimen type, and the obtained data were evaluated based on average values.

Wear tests were performed using the pin-on-disk method according to the ASTM G99 standards. The tests were conducted on a tribometer. Specimens were fixed onto the disk, and a pin made of AISI 304 stainless steel was used as the counter surface. The experimental parameters applied were 10 N normal load, 100 m sliding distance, and 47.1 m/s sliding speed. The ambient temperature was maintained at room temperature throughout the experiment. The weights of the samples before and after the test were measured using a precision balance, and the mass loss was calculated. Average mass loss values were obtained by performing at least three repetitions for each sample.

RESULTS AND DISCUSSION

This section evaluates the effects of micro and nano-sized SiO_2 particle addition on the mechanical behavior of epoxy matrix. Figure 1 shows a comparative analysis of the tensile strength values of neat sample and samples containing 1%-4% micro (M1-M4) and nano (N1-N4) SiO_2. The graph reveals the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

significant effect of particle size and addition ratio on tensile performance. The increase in strength is particularly pronounced in samples with nano-particle addition.

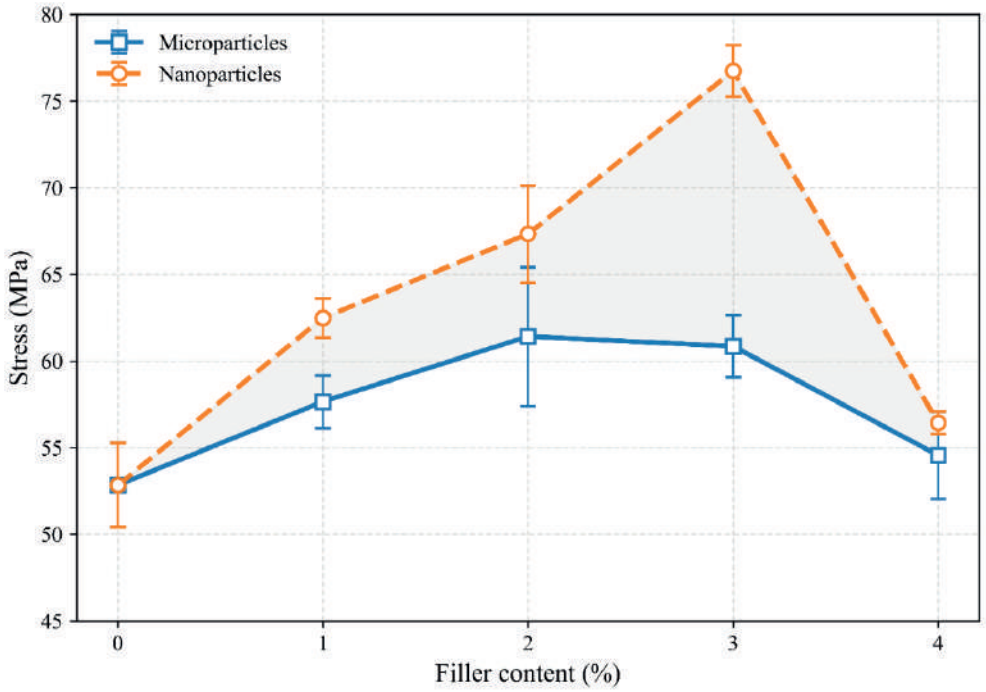


Figure 3. Tensile strength of the micro- and nano- reinforced samples

In terms of tensile strength, the strength of the neat sample, which was 52.84 MPa, increased by 16.23% to 61.42 MPa with the addition of 2% micro SiO_2 (M2). However, a limited decrease in strength was observed after the addition of 3% and 4% micro-particle ratios. This can be attributed to agglomeration and stress concentration zones that may occur with increasing particle ratios (J Cho et al., 2006). In samples with nano SiO_2 additive, the increase in strength was more pronounced. Specifically, in sample N3 containing 3% nano SiO_2, the tensile strength was measured at 76.74 MPa, representing a 45.24% increase compared to neat sample. The decrease in strength to 56.44 MPa after 4% nano additive (N4) indicates that exceeding the optimum additive ratio can lead to interface defects and particle aggregation.

When elongation values were examined, the highest elongation value was obtained in sample M2 with 7.09 mm. This shows that low to medium levels of microparticle addition can increase not only strength but also ductility. In contrast, while the increase in strength was more pronounced in nano-additive systems, a general decrease in elongation values was observed. For example, the elongation in sample N2 decreased to 2.73 mm. This situation can be explained by the fact that nanoparticles increase the matrix stiffness, thereby limiting its deformation capability (Zare, 2016). However, in the N3 sample, a high strength and acceptable ductility were obtained together with an elongation value of 4.57 mm. Overall, it can be said that nano SiO_2 additive in appropriate proportions provides more

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effective load transfer in the epoxy matrix and significantly increases strength by limiting crack propagation. However, high proportions negatively affect mechanical performance due to the risk of agglomeration.

The tribological performance of epoxy and SiO_2 particle-modified samples was evaluated using the pin-on-disk method. Figure 2 shows a comparative average mass loss of neat sample and micro and nano SiO_2-modified samples under a load of 10 N and a sliding distance of 150 m. This graph clearly demonstrates the effect of particle size and modulus on wear resistance.

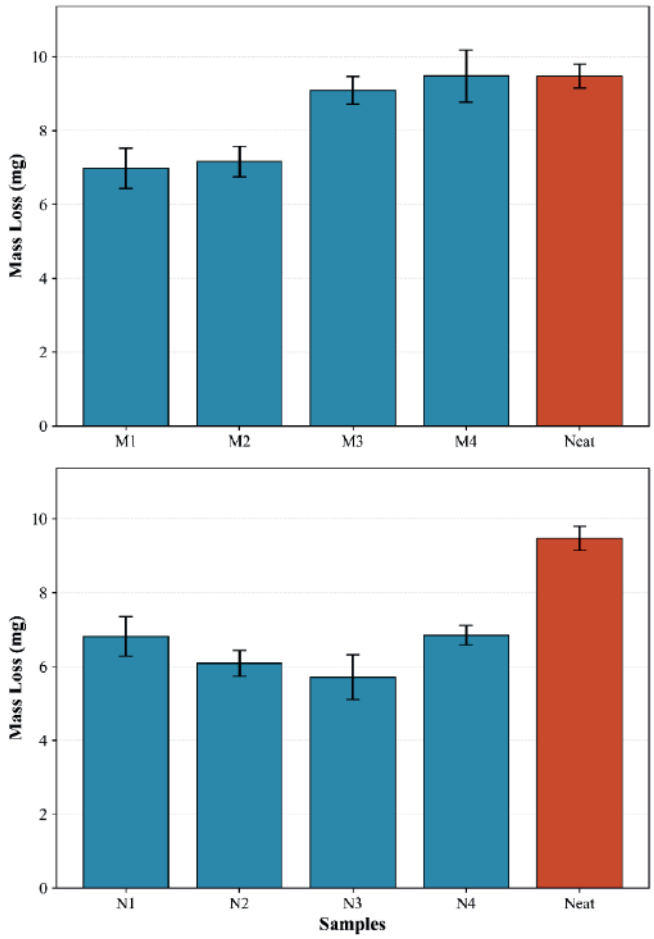


Figure 4. Mass loss of the micro- and nano- reinforced samples

When the experimental results are examined, the mass loss of neat sample was determined as 9.47 mg. In micro SiO_2-modified samples, the lowest mass loss was measured as 6.98 mg at a 1% modulus (M1), and this value corresponds to a 26.29% improvement compared to neat sample. While a mass loss of 7.16 mg (24.39% improvement) was obtained with 2% micro-additive (M2), it was observed that the mass loss increased to 9.09 mg and 9.47 mg at 3% and 4% rates, respectively. This suggests that heterogeneous distribution on the surface and third-body wear mechanisms due to particle detachment may come into play at increasing microparticle ratios.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

In samples with nano SiO_2 additive, a more significant improvement in wear resistance was observed. In sample N3 containing 3% nano SiO_2, the mass loss was measured as 5.71 mg, showing a 39.70% decrease compared to pure epoxy. Sample N2 with 2% nano additive exhibited the second best performance with 6.08 mg (35.80% decrease). The increase in the mass loss to 6.84 mg at 4% (N4) indicates that agglomeration and weak interfacial bonding may limit wear resistance if the optimum additive ratio is exceeded. In general, it can be said that nanoparticles, thanks to their high specific surface area, provide more effective load transfer within the matrix and suppress the wear mechanism by increasing surface hardness (Wetzel et al., 2003).

The variations in the Coefficient of Friction (COF) were obtained. Figure 3 shows a comparative analysis of the COF variations of samples with different additive ratios over a sliding distance of 0-50 m. Initially, a typical conditioning (running-in) region is observed in all samples, followed by a transition to a relatively stable friction regime.

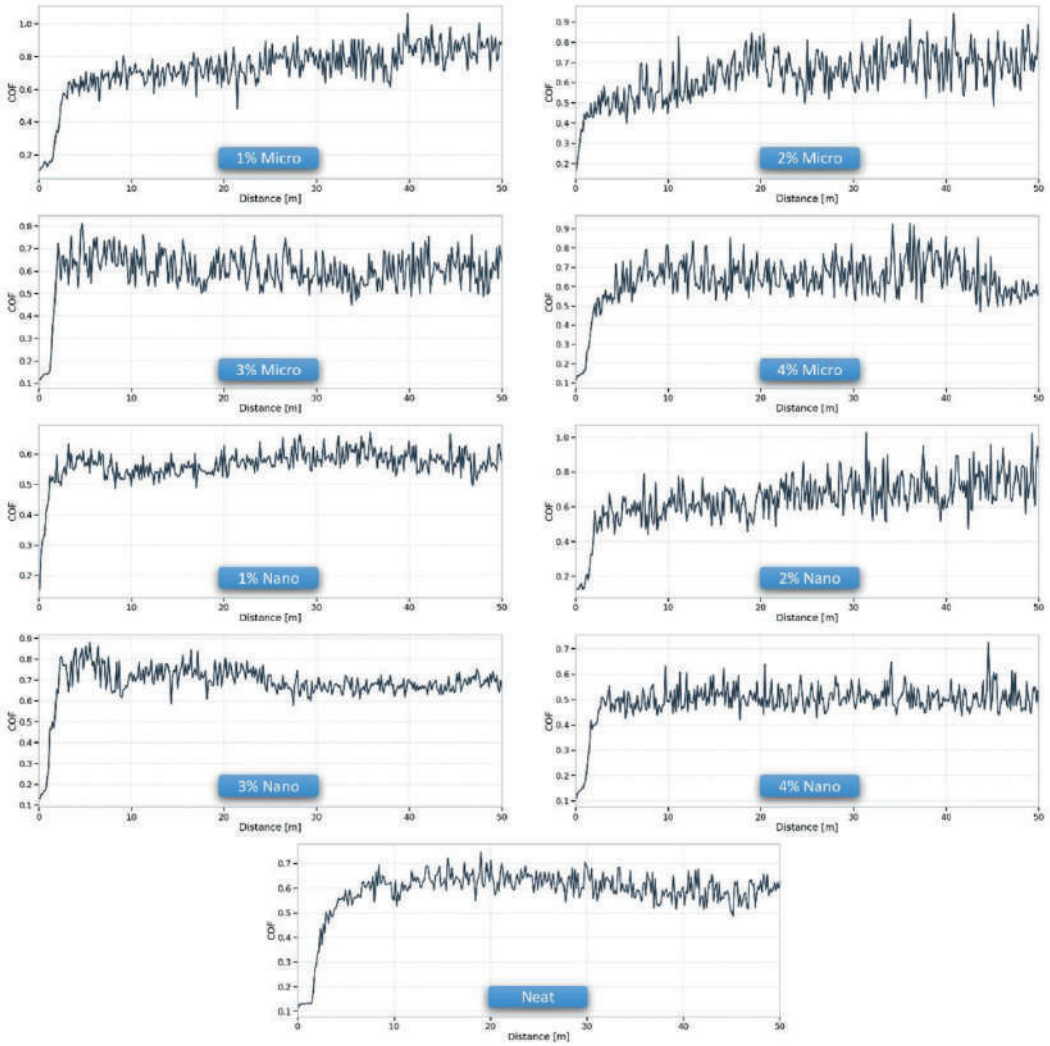


Figure 5. COF of the micro- and nano- reinforced samples

While the COF value in the neat sample remains stable in the range of approximately 0.60-0.70, the fluctuation increases in micro-additive samples, especially at 3% and 4% ratios. This can be attributed to the third-body effect created by particles detached from the surface. In nano-additive samples, particularly in the N3 sample containing 3% nano SiO_2, more stable and relatively lower COF values were obtained. In the N3 sample, both the lowest mass loss and the more stable coefficient of friction suggest that the nanoparticles contribute to the formation of a more homogeneous tribo-film on the surface. However, with 4% nano additive, COF fluctuations increase, indicating that excessive particle content may negatively affect surface integrity.

In conclusion, considering the mass loss and COF evaluations together, it is clearly seen that 3% nano SiO_2 additive provides optimum tribological performance in the epoxy system. This ratio offers both maximum improvement in wear resistance and more stable friction behavior, demonstrating a trend consistent with mechanical results.

CONCLUSIONS

This study experimentally investigated the effects of adding micro and nano-sized SiO_2 particles at different weight percentages (1%-4%) to an epoxy matrix on mechanical and tribological performance. The findings clearly showed that particle size and additive ratio played a decisive role in performance.

According to the tensile test results, the tensile strength of pure epoxy, which was 52.84 MPa, was significantly increased with nano SiO_2 addition. The highest value was obtained in sample N3 containing 3% nano SiO_2, reaching 76.74 MPa, representing a 45.24% improvement compared to neat sample. In systems with micro SiO_2 additive, the best result was determined at 2%, reaching 61.42 MPa (a 16.23% increase). However, the decrease in strength at 4% additive in both micro and nano systems indicates that agglomeration and interfacial defects at high particle ratios may negatively affect mechanical performance.

The wear results also showed a similar trend. The mass loss of neat sample, which was 9.47 mg, decreased to 5.71 mg with the addition of 3% nano SiO_2, resulting in a 39.70% improvement. While lower levels of improvement were observed in micro-reinforced samples, a limited improvement in wear resistance was achieved at higher rates. Coefficient of Friction (COF) analyses revealed a more stable and relatively low friction behavior, particularly in the 3% nano-reinforced sample, which was consistent with the wear results.

Overall, the addition of nano-sized SiO_2 particles in appropriate proportions to the epoxy matrix significantly improves both mechanical strength and tribological performance by enhancing the load transfer mechanism and limiting crack propagation. The optimum additive ratio was determined to be 3% nano SiO_2, and this result serves as an important reference in the design of epoxy-based particle-reinforced systems.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

REFERENCES

Bharadwaja K, rao Ss, & Baburao T 2022. Epoxy/SIO2 nanocomposite mechanical properties and tribological performance. *Materials Today: Proceedings*, *62*: 1712-1716. https://doi.org/https://doi.org/10.1016/j.matpr.2021.12.172

Cho J, Joshi M, & Sun C 2006. Effect of inclusion size on mechanical properties of polymeric composites with micro and nano particles. *Composites Science and Technology*, *66*(13): 1941-1952.

Cho J, Joshi MS, & Sun CT 2006. Effect of inclusion size on mechanical properties of polymeric composites with micro and nano particles. *Composites Science and Technology*, *66*(13): 1941-1952. https://doi.org/https://doi.org/10.1016/j.compscitech.2005.12.028

Fekiač JJ, Krbata M, Kohutiar M, Janík R, Kakošová L, Breznická A, Eckert M, & Mikuš P 2025. Comprehensive Review: Optimization of Epoxy Composites, Mechanical Properties, & Technological Trends. *Polymers*, *17*(3): 271. https://www.mdpi.com/2073-4360/17/3/271

Jajam KC, & Tippur HV 2012. Quasi-static and dynamic fracture behavior of particulate polymer composites: A study of nano- vs. micro-size filler and loading-rate effects. *Composites Part B: Engineering*, *43*(8): 3467-3481. https://doi.org/https://doi.org/10.1016/j.compositesb.2012.01.042

Kayalar A, & Doğan NF 2024. Experimental Investigation on the Tensile Behavior of MWCNT–Nano Silica Epoxy Hybrid Nanocomposites. *International Advanced Researches and Engineering Journal*, *8*(2): 61-68.

Parvizi P, Jalilian M, & Dearn KD 2025. Epoxy composites reinforced with nanomaterials and fibres: Manufacturing, properties, and applications. *Polymer Testing*, *146*: 108761. https://doi.org/https://doi.org/10.1016/j.polymertesting.2025.108761

Sprenger S 2013. Epoxy resin composites with surface-modified silicon dioxide nanoparticles: A review. *Journal of Applied Polymer Science*, *130*(3): 1421-1428. https://doi.org/https://doi.org/10.1002/app.39208

Srivastava VK, Quadflieg T, & Gries T 2023. Influence of hybrid nano/micro particles on the mechanical performance of cross-ply carbon fibre fabric reinforced epoxy polymer composite materials. *Journal of Composite Materials*, *57*(21): 3393-3402. https://doi.org/10.1177/00219983231183160

Uniyal P, Gaur P, Yadav J, Bhalla NA, Khan T, Junaedi H, & Sebaey TA 2025. A Comprehensive Review on the Role of Nanosilica as a Toughening Agent for Enhanced Epoxy Composites for Aerospace Applications. *ACS Omega*, *10*(16): 15810-15839. https://doi.org/10.1021/acsomega.4c10073

Wetzel B, Haupert F, & Zhang MQ 2003. Epoxy nanocomposites with high mechanical and tribological performance. *Composites Science and Technology*, *63*(14): 2055-2067.

Yuan R, Ma X, Liang LH, & Wei Y 2024. Size and Interface Effects on Tensile Strength of Polymers with Nano/Micro Particle Inclusions. *Acta Mechanica Solida Sinica*, *37*(5): 812-822. https://doi.org/10.1007/s10338-024-00498-0

Zare Y 2016. Study of nanoparticles aggregation/agglomeration in polymer particulate nanocomposites by mechanical properties. *Composites Part A: Applied Science and Manufacturing*, *84*: 158-164. https://doi.org/https://doi.org/10.1016/j.compositesa.2016.01.020

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TRANSLATING AUTISM-INFORMED DESIGN PRINCIPLES INTO INTERIOR ARCHITECTURE EDUCATION: EVIDENCE FROM A UNIVERSAL DESIGN STUDIO

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Design knowledge developed for autism-friendly environments emphasizes reducing sensory overload, enhancing spatial predictability, and supporting cognitive comfort. Although this body of research has expanded in recent years, its translation into interior architecture education has remained limited. Educational settings often discuss inclusive design theoretically without integrating it into spatial decision-making processes. This study investigates how autism-informed design principles can be operationalized within a design studio as a pedagogical framework for teaching inclusive interior environments.

The aim of the study is to examine how theoretical knowledge related to sensory-sensitive environments can be transformed into spatial programming and design strategies within interior architecture education.

The research is based on a third-year Universal Design studio in which students were assigned to design a Day Care and Rehabilitation Center for Children with Autism. The project brief established a clearly defined spatial program including therapy rooms, classrooms, family waiting areas, and controlled outdoor spaces, guiding students to interpret sensory-aware design principles through layout organization, zoning, circulation, and material selection. The assignment required a single-storey solution with explicit functional relationships, ensuring attention to environmental legibility and sensory modulation.

A qualitative document-based analysis was conducted on student submissions, including plans and visualizations, to identify how design decisions reflected inclusive spatial criteria. The analysis revealed recurring design strategies such as differentiated therapy environments including sensory integration and occupational therapy rooms, simplified circulation schemes, reduced visual complexity, and the use of clearly defined functional zones to structure sensory experience.

The findings demonstrate that when autism-informed parameters are embedded into studio briefs, students are able to translate abstract inclusive design knowledge into concrete spatial solutions. The

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

study concludes that interior architecture education can serve as an effective bridge between evidence-based design research and professional practice, positioning sensory-aware design as a transferable framework for universally supportive interior environments.

Keywords: Interior architecture education, universal design, sensory-sensitive environments, studio pedagogy, inclusive spatial design

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STATISTICAL INFERENCE FOR ALPHA POWER EXPONENTIAL DISTRIBUTION

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ABSTRACT

This study focuses on the statistical inference and parameter estimation of the Alpha Power exponential distribution. First, the fundamental properties of the Alpha Power exponential distribution are discussed. Its distribution functions, moments, and hazard function are also explained. The maximum likelihood estimation method was used for classical parameter estimation. Subsequently, Bayesian parameter estimation was performed using the Gamma prior distribution under the squared error loss function. Lindley and MCMC methods were considered for Bayesian calculations. In the final section, an effective simulation study was conducted to comprehensively compare classical and Bayesian estimation methods. This study highlights the flexibility and advantages of the alpha power transformation in parametric inference processes compared to the classical exponential distribution, making a significant contribution to the literature.

Keywords: Alpha power exponential distribution, Maximum likelihood estimation, Bayesian estimation, simulation study

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AN APPLICATION FOR WEATHER FORECASTING USING DEEP LEARNING BASED ON SKY IMAGES

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ABSTRACT

In recent years, artificial intelligence and deep learning-based methods have achieved high success in analyzing image data and have begun to be widely used in many fields. Especially in agricultural applications, weather information is of critical importance in terms of irrigation management, productivity, and resource planning. Traditional weather forecasting methods are mostly based on sensor data, which has disadvantages such as infrastructure costs and limited coverage area.

This study proposes a deep learning-based image classification approach for weather forecasting based on sky images. Three different weather classes—clear sky, cloudy sky, and rainy sky—were classified using only sky images. The training processes were performed with different epoch values and different model types, and model performances were evaluated using accuracy, precision, recall, and F1 score metrics. The experimental results obtained demonstrate that deep learning models based on sky images can be effectively used for weather forecasting without sensor support. This approach, with its camera-based structure, enables the development of field-deployable decision support systems with low installation costs.

According to experimental results, the highest mAP@0.5 value of 0.994 was achieved in the 100-epoch training of the YOLOv5n model, and the highest F1-score for the same model was measured as 0.98. In terms of balanced class performance and stable results, the YOLOv8s model reached 0.990 mAP@0.5 and 0.97 F1-score values after 100 epochs. These findings demonstrate that the proposed method offers performance comparable to similar image-based approaches in literature, providing high accuracy and class balance.

Keywords: Deep learning, Image classification, Weather forecasting, YOLO, Object detection.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GÖKYÜZÜ GÖRÜNTÜLERİNİN KULLANILARAK DERİN ÖĞRENME TABANLI HAVA DURUMU TAHMİNİ UYGULAMASI

ÖZET

Son yıllarda yapay zekâ ve derin öğrenme tabanlı yöntemler, görüntü verilerinin analizinde yüksek başarı sağlamış ve birçok alanda yaygın olarak kullanılmaya başlanmıştır. Özellikle tarım uygulamalarında, hava durumu bilgisi; sulama yönetimi, verimlilik ve kaynak planlaması açısından kritik öneme sahiptir. Geleneksel hava durumu tahmin yöntemleri çoğunlukla sensör verilerine dayalıdır ve bu durum altyapı maliyetleri ile sınırlı kapsama alanı gibi dezavantajlar doğurmaktadır.

Bu çalışmada, gökyüzü görüntülerine dayalı olarak hava durumu tahmini yapılması amacıyla derin öğrenme tabanlı bir görüntü sınıflandırma yaklaşımı önerilmiştir. Açık hava, bulutlu hava ve yağışlı hava olmak üzere üç farklı hava durumu sınıfı, yalnızca gökyüzü görüntüleri kullanılarak sınıflandırılmıştır. Eğitim süreçleri farklı epoch değerleri ve farklı model çeşitleri ile gerçekleştirilmiş ve model performansları doğruluk, hassasiyet, geri çağırma ve F1 puanı metrikleri üzerinden değerlendirilmiştir. Elde edilen deneysel sonuçlar, gökyüzü görüntülerine dayalı derin öğrenme modellerinin sensör desteği olmaksızın hava durumu tahmininde etkin bir şekilde kullanılabileceğini göstermektedir. Bu yaklaşım, yalnızca kamera tabanlı yapısıyla, düşük kurulum maliyetine sahip ve sahada uygulanabilir karar destek sistemlerinin geliştirilmesine olanak sağlamaktadır.

Deneysel sonuçlara göre en yüksek mAP@0.5 değeri 0.994 ile YOLOv5n modelinin 100 epoch eğitiminde elde edilmiş, aynı model için en yüksek F1-skoru 0.98 olarak ölçülmüştür. Dengeli sınıf performansı ve istikrarlı sonuçlar açısından ise YOLOv8s modelinin 100 epoch sonunda 0.990 mAP@0.5 ve 0.97 F1-skoru değerlerine ulaştığı belirlenmiştir. Bu bulgular, önerilen yöntemin yüksek doğruluk ve sınıf dengesi sağlayarak literatürdeki benzer görüntü tabanlı yaklaşımlarla rekabet edebilecek düzeyde performans sunduğunu göstermektedir.

Anahtar Kelimeler: Derin öğrenme, Görüntü sınıflandırma, Hava durumu tahmini, YOLO, Nesne tanımlama

GİRİŞ

Küresel iklim değişikliği ve artan çevresel belirsizlikler, hava durumu tahminlerinin tarım, enerji yönetimi ve açık alan planlaması gibi birçok alanda kritik bir rol oynamasına neden olmaktadır. Özellikle tarımsal faaliyetlerde, yağış, bulutluluk ve güneşlenme durumu gibi meteorolojik koşullar; sulama zamanlaması, verimlilik ve kaynak yönetimi açısından doğrudan belirleyici olmaktadır **[1].** Bu nedenle, hava koşullarının doğru ve zamanında tahmin edilmesi büyük önem taşımaktadır. Geleneksel hava durumu tahmin yöntemleri çoğunlukla meteoroloji istasyonlarından elde edilen sensör verilerine dayanmaktadır **[2].** Ancak bu yaklaşımlar, sensör altyapısına olan bağımlılık, kurulum ve bakım

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

maliyetleri ile sınırlı mekânsal kapsama alanı gibi dezavantajlar içermektedir. Son yıllarda, bu sınırlamaları aşmak amacıyla görsel veriye dayalı alternatif yaklaşımlar ön plana çıkmıştır **[3].** Gökyüzü görüntülerinin analiz edilmesi, çevresel koşullar hakkında doğrudan ve zengin bilgi sunması nedeniyle dikkat çekici bir çözüm olarak değerlendirilmektedir **[4].** Yapay zekâ ve özellikle derin öğrenme tabanlı yöntemler, görüntü verilerinin işlenmesi ve anlamlandırılmasında yüksek başarı göstermektedir **[5].** Evrişimsel sinir ağları (Convolutional Neural Networks – CNN), görüntülerdeki uzamsal örüntüleri öğrenebilme yetenekleri sayesinde sınıflandırma problemlerinde yaygın olarak kullanılmaktadır. Literatürde, derin öğrenme yöntemlerinin tarım, çevre izleme ve meteorolojik analiz gibi alanlarda etkin biçimde kullanıldığı birçok çalışma bulunmaktadır.

Bu çalışmada, gökyüzü görüntülerine dayalı olarak hava durumu tahmini yapılması amacıyla, nesne tespiti tabanlı sınıflandırma yaklaşımını temel alan derin öğrenme modelleri kullanılmıştır **[6].** Açık hava, bulutlu hava ve yağışlı hava olmak üzere üç farklı hava durumu sınıfı, yalnızca gökyüzü fotoğrafları çekilerek tahmin edilmiştir. Önerilen yaklaşım, ek sensör ihtiyacı olmadan yalnızca kamera tabanlı sistemlerle hava durumu farkındalığı sağlamayı hedeflemektedir. Bu yönüyle çalışma, düşük maliyetli, uygulanabilir ve gerçek zamanlı karar destek sistemlerine altyapı sunabilecek bir çözüm ortaya koymaktadır. Çalışmanın devam eden bölümlerinde, kullanılan derin öğrenme mimarileri, veri kümesinin hazırlanması, eğitim süreçleri ve elde edilen deneysel sonuçlar ayrıntılı olarak sunulmaktadır.

MATERYAL VE METOD

Bu bölümde, çalışmada kullanılan veri kümesi, tercih edilen derin öğrenme modelleri ve eğitim sürecine ait parametreler ayrıntılı olarak açıklanmaktadır. Ayrıca, model performansının değerlendirilmesinde kullanılan metrikler sunulmaktadır.

Sistemin Kurulması

Bu çalışmada, gökyüzü görüntülerinin elde edilmesi ve işlenmesi amacıyla düşük maliyetli ve taşınabilir bir donanım altyapısı oluşturulmuştur. Sistem, bir Raspberry Pi kontrol kartı ve Raspberry Pi Kamera modülünden oluşmaktadır. Kurulan donanım yapısı, görüntü toplama ve yapay zekâ tabanlı analiz süreçlerinin entegre bir şekilde yürütülmesine olanak sağlamaktadır. Raspberry Pi kontrol kartı, sistemin ana işlem birimi olarak görev yapmakta olup kamera modülünden alınan görüntülerin toplanması, ön işleme adımlarının gerçekleştirilmesi ve elde edilen verilerin sınıflandırma sürecine aktarılmasında kullanılmıştır. Kamera modülü, gökyüzü görüntülerini gerçek zamanlı olarak yakalayabilecek şekilde yapılandırılmış ve farklı hava koşullarında veri toplanmasına imkân sağlayacak biçimde konumlandırılmıştır. Kurulan sistem, yalnızca kamera tabanlı bir yapı üzerine inşa edilmiştir ve ek bir meteorolojik sensör veya harici ölçüm cihazına ihtiyaç duymamaktadır. Bu sayede, donanım maliyeti azaltılmış ve sistemin farklı sahalarda kolayca uygulanabilir olması hedeflenmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

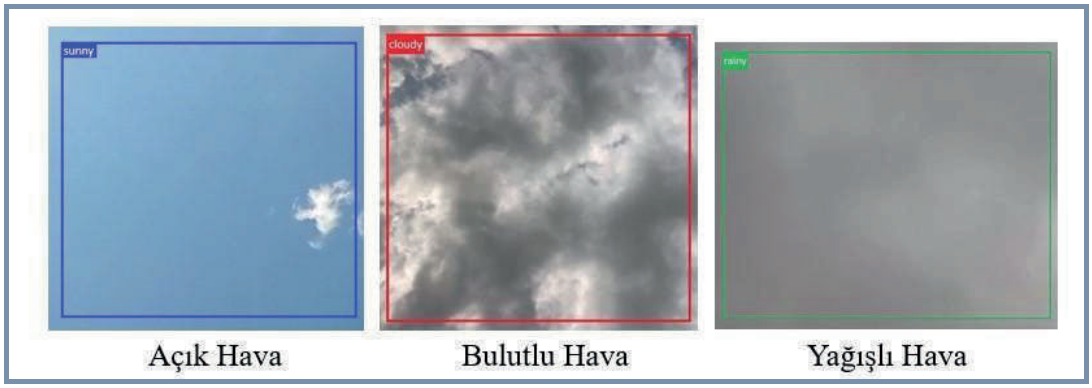
Elde edilen gökyüzü görüntüleri, daha sonraki aşamalarda derin öğrenme tabanlı sınıflandırma modellerinin eğitimi ve test edilmesi amacıyla kullanılmıştır.



Resim 1. Sistemin Görünüşü

Veri Kümesi Oluşturma

Bu çalışmada kullanılan veri kümesi, gökyüzü görüntülerinden oluşmakta olup açık hava, bulutlu hava ve yağışlı hava olmak üzere üç farklı hava durumu sınıfını temsil etmektedir. Veri kümesi, daha önce kaydedilen gökyüzü görüntüleri temel alınarak düzenlenmiştir. Toplam 620 adet gökyüzü görüntüsünden oluşan veri kümesi, derin öğrenme tabanlı sınıflandırma modellerinin eğitimi ve test edilmesi amacıyla iki gruba ayrılmıştır. Bu kapsamda, veri kümesinin 490 adedi eğitim verisi, 130 adedi ise test (validasyon) verisi olarak kullanılmıştır. Görüntüler, farklı zaman dilimlerinde ve değişken çevresel koşullar altında elde edilerek veri kümesinin aydınlatma ve atmosferik çeşitlilik içermesi sağlanmıştır. Bu sayede, geliştirilen modelin farklı hava koşullarına karşı daha genellenebilir bir performans sergilemesi hedeflenmiştir. Ancak havanın karanlık olduğu saatler sisteme dahil edilmemiştir.



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Resim 2. Hava Koşullarının Sınıflandırılması

Eğitim Ortamı ve Parametreler

Bu çalışmada, gökyüzü görüntülerine dayalı hava durumu tespiti amacıyla YOLOv5 ve YOLOv8 mimarilerine ait farklı ölçeklerdeki varyantlar kullanılmıştır. Deneysel analiz kapsamında YOLOv5n, YOLOv5s, YOLOv8n ve YOLOv8s modelleri tercih edilmiştir. Bu modeller parametre sayısı ve hesaplama karmaşıklığı açısından farklılık göstermekte olup hız–doğruluk dengesi bakımından karşılaştırmalı değerlendirme yapılmasına olanak sağlamaktadır. Seçilen mimarilerin temel amacı, farklı donanım kısıtları altında performans değişimini incelemek ve özellikle gömülü sistem uygulamaları için uygun model konfigürasyonunu belirlemektir.

Tüm modeller Google Colab ortamında NVIDIA L4 GPU üzerinden eğitilmiştir. Eğitim sürecinde giriş görüntü boyutu 640×640 piksel olarak belirlenmiş ve batch size değeri 16 olarak sabit tutulmuştur. Hiperparametreler tüm modeller için aynı şekilde ayarlanarak adil bir karşılaştırma ortamı oluşturulmuştur.

Eğitimler aşağıdaki epoch konfigürasyonlarında gerçekleştirilmiştir:

YOLOv5n: 30, 50 ve 100 epoch

YOLOv5s: 30, 50 ve 100 epoch

YOLOv8n: 30, 50 ve 100 epoch

YOLOv8s: 30, 50 ve 100 epoch

Epoch sayısının model performansına etkisini analiz etmek amacıyla artan eğitim süreleri karşılaştırılmıştır. Deneysel sonuçlar, bazı modellerde 50 epoch sonrasında performans artışının sınırlı kaldığını göstermiştir. Bu durum erken yakınsama (early convergence) davranışına işaret etmekte olup model kapasitesi ile veri seti karmaşıklığı arasındaki ilişkiyi ortaya koymaktadır.

Değerlendirme Metrikleri

Bu çalışmada geliştirilen YOLO tabanlı hava durumu tespit modellerinin performansı, nesne tespiti literatüründe yaygın olarak kullanılan değerlendirme metrikleri üzerinden analiz edilmiştir. Modellerin sınıflandırma ve tespit başarımını bütüncül olarak değerlendirebilmek amacıyla Precision (Hassasiyet), Recall (Geri Çağırma), F1-Skoru, mAP@0.5 ve mAP@0.5:0.95 metrikleri kullanılmıştır.

Precision (Hassasiyet)

Precision, model tarafından pozitif olarak tahmin edilen örneklerin ne kadarının doğru olduğunu göstermektedir. Matematiksel olarak (1) aşağıda verilmiştir:

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$$Precision = \frac{TP}{TP + FP} \quad (1)$$

Burada TP (True Positive) doğru pozitif tahminleri, FP (False Positive) ise yanlış pozitif tahminleri ifade etmektedir. Yüksek precision değeri, modelin yanlış alarm üretme oranının düşük olduğunu göstermektedir.

Recall (Geri Çağırma)

Recall, gerçek pozitif örneklerin ne kadarının doğru şekilde tespit edildiğini göstermektedir. Aşağıda (2) verilmiştir:

$$Recall = \frac{TP}{TP + FN} \quad (2)$$

F1-Skoru

F1-skoru, precision ve recall değerlerinin harmonik ortalamasıdır ve modelin genel denge performansını ifade etmektedir. Aşağıda (3) verilmiştir:

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall} \quad (3)$$

Bu metrik, özellikle precision ve recall arasında denge sağlanması gereken durumlarda önemli bir göstergedir. Çalışmada F1 eğrileri incelenerek her model için optimum güven eşiği belirlenmiştir.

Ortalama Hassasiyet (mAP)

YOLO tabanlı modellerin performans değerlendirmesinde en kritik metriklerden biri Ortalama Hassasiyet (Mean Average Precision – mAP) değeridir. Bu çalışmada iki farklı IoU (Intersection over Union) eşik değeri kullanılmıştır:

mAP@0.5

Bu metrikte IoU eşik değeri 0.5 olarak alınmıştır. Yani tahmin edilen sınırlayıcı kutular (bounding boxes) ile gerçek sınırlayıcı kutular (bounding boxes) arasındaki örtüşme oranı %50'nin üzerinde ise doğru tespit kabul edilmektedir. mAP@0.5 değeri, modelin genel tespit başarımını ölçmektedir.

F1 için En Uygun Güven Eşiği (Optimum Confidence)

F1 için en uygun güven eşiği, modelin tahminlerinde kullandığı güven (confidence) değerleri arasında, F1-skorunun en yüksek olduğu karar sınırını ifade eder. Bu eşik, precision ve recall arasında en dengeli performans noktasını temsil eder ve modelin sınıflandırma kararının optimize edilmesini sağlar.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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SONUÇLAR

Bu çalışmada, gökyüzü görüntülerine dayalı hava durumu tespiti amacıyla YOLOv5n, YOLOv5s, YOLOv8n ve YOLOv8s modelleri 30, 50 ve 100 epoch boyunca eğitilmiş ve performansları karşılaştırmalı olarak analiz edilmiştir. Modellerin değerlendirilmesinde mAP@0.5, F1-skoru, Precision–Recall eğrileri ve F1 Optimum Confidence (Güven Eşiği) kullanılmıştır.

Tablo 1. YOLO Modellerinin Karşılaştırma Tablosu

Model	Epoch	mAP@0.5	En İyi F1	F1 için Optimum Confidence
YOLOv5n	30	0.977	0.93	0.40
YOLOv5n	50	0.975	0.94	0.44
YOLOv5n	100	0.994	0.98	0.69
YOLOv5s	30	0.990	0.96	0.55
YOLOv5s	50	0.988	0.94	0.34
YOLOv5s	100	0.983	0.97	0.74
YOLOv8n	30	0.985	0.96	0.77
YOLOv8n	50	0.990	0.97	0.81
YOLOv8n	100	0.990	0.97	0.72
YOLOv8s	30	0.978	0.94	0.74
YOLOv8s	50	0.985	0.96	0.77
YOLOv8s	100	0.990	0.97	0.72

Elde edilen sonuçlara göre tüm modeller yüksek doğruluk seviyelerine ulaşmıştır. Ancak epoch sayısının performansa etkisi model mimarisine göre farklılık göstermiştir.

YOLOv5n modeli 100 epoch sonunda en yüksek mAP@0.5 değerine (0.994) ulaşmıştır. Aynı model için en yüksek F1-skoru 0.98 olarak elde edilmiştir. Bu sonuç, düşük parametre sayısına sahip nano ölçekli bir modelin dahi veri setine güçlü biçimde uyum sağlayabildiğini göstermektedir.

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YOLOv5s modeli 30 ve 50 epoch seviyelerinde yüksek performans göstermiş, ancak 100 epoch sonrasında mAP değerinde sınırlı bir düşüş gözlenmiştir. Bu durum modelin 50 epoch civarında doygunluğa ulaştığını göstermektedir.

YOLOv8n modeli 30 epoch'ta yüksek başlangıç performansı göstermiş, 50 epoch'ta mAP@0.5 değerini 0.990 seviyesine çıkarmış ve 100 epoch'ta bu değeri korumuştur. Performans artışının 50 epoch sonrasında sınırlı kalması, modelin erken yakınsama eğilimi gösterdiğini ortaya koymaktadır.

YOLOv8s modeli ise epoch artışıyla birlikte düzenli bir performans iyileşmesi göstermiştir. 30 epoch'ta 0.978 olan mAP@0.5 değeri, 50 epoch'ta 0.985'e, 100 epoch'ta ise 0.990'a ulaşmıştır. Aynı şekilde F1-skoru da artış göstermiştir. Bu sonuç, daha büyük model kapasitesinin daha uzun eğitimden fayda sağladığını göstermektedir.

Tablo 1'de yer alan F1 için optimum confidence değerleri incelendiğinde, modellerin maksimum F1 performansına farklı güven eşiklerinde ulaştığı görülmektedir. Özellikle YOLOv8 modellerinin daha yüksek ve istikrarlı güven seviyelerinde optimum F1 üretmesi, bu mimarilerin precision–recall dengesini daha seçici karar sınırlarında sağlayabildiğini göstermektedir.

Genel değerlendirmede en yüksek mAP değeri YOLOv5n (100 epoch) modelinde elde edilmiş olsa da, sınıf dengesi ve F1 stabilitesi dikkate alındığında YOLOv8s (100 epoch) modeli en dengeli performansı sunmuştur.

TARTIŞMA

Elde edilen sonuçlar, gökyüzü görüntülerinden hava durumu tespiti probleminin YOLO tabanlı derin öğrenme mimarileri ile yüksek doğruluk oranlarıyla çözülebileceğini göstermektedir. Özellikle küçük ölçekli ve dengeli veri setlerinde hafif mimarilerin dahi güçlü performans gösterebildiği belirlenmiştir. YOLOv5n modelinin düşük parametre sayısına rağmen en yüksek mAP değerini üretmesi, veri setinin görsel olarak ayırt edici özellikler içerdiğini ve problem karmaşıklığının aşırı derin mimari gerektirmediğini göstermektedir. Bununla birlikte YOLOv5s modelinde 100 epoch sonrasında gözlenen performans düşüşü, daha büyük modellerin küçük veri setlerinde veriye aşırı uyum gösterme eğilimi gösterebileceğine işaret etmektedir.

YOLOv8 mimarisinin genel olarak daha stabil PR (Hassasiyet–Geri Çağırma) eğrileri ve daha dengeli F1 dağılımı üretmesi, mimari optimizasyonların ve geliştirilmiş kayıp fonksiyonlarının genelleme kabiliyetini artırdığı gözlemlenmiştir. Özellikle YOLOv8s modelinin epoch artışıyla birlikte düzenli performans iyileşmesi göstermesi, daha yüksek model kapasitesinin yeterli eğitim süresiyle daha iyi temsil öğrenimi sağlayabildiğini ortaya koymaktadır.

Epoch artışının tüm modeller için doğrusal performans artışı sağlamadığı gözlemlenmiştir. Bazı modellerde 50 epoch sonrası performans artışı sınırlı kalmış, hatta hafif düşüşler görülmüştür. Bu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

durum model kapasitesi, veri seti büyüklüğü ve öğrenme dinamikleri arasındaki ilişkinin önemini göstermektedir.

SONUÇ

Bu çalışmada, yalnızca gökyüzü görüntülerine dayalı olarak ve herhangi bir ek meteorolojik sensör kullanılmadan hava durumu sınıflandırmasının yüksek doğruluk oranlarıyla gerçekleştirilebileceği deneysel olarak gösterilmiştir. Açık, bulutlu ve yağışlı olmak üzere üç farklı sınıf üzerinde yapılan değerlendirmeler, nesne tespiti tabanlı derin öğrenme mimarilerinin görsel temelli meteorolojik analizlerde etkili bir yaklaşım sunduğunu ortaya koymuştur.

Modeller performans açısından karşılaştırıldığında, hız–doğruluk dengesi bakımından YOLOv8s (100 epoch) modeli en dengeli sonuçları üretmiştir. Buna karşılık, düşük hesaplama maliyeti ve daha hızlı çıkarım süresi gerektiren uygulamalar için YOLOv5n modeli uygun bir alternatif olarak öne çıkmaktadır. Bu bulgular, uygulama senaryosuna ve donanım kısıtlarına bağlı olarak model seçiminin önemini göstermektedir.

Elde edilen sonuçlar, kamera tabanlı sistemlerin düşük maliyetli ve uygulanabilir bir çözüm olarak gerçek zamanlı hava durumu farkındalığı sağlayabileceğini ortaya koymakta ve görsel veri temelli karar destek sistemleri için literatüre katkı sunmaktadır.

REFERANSLAR

[1] Abioye EA, Hensel O, Esau TJ, Elijah O, Abidin MSZ, Ayobami AS, Nasirahmadi A 2022. Precision irrigation management using machine learning and digital farming solutions. AgriEngineering, 4(1): 70-103.

[2] García L, Parra L, Jimenez JM, Lloret J, Lorenz P 2020. IoT-based smart irrigation systems: An overview on the recent trends on sensors and IoT systems for irrigation in precision agriculture. Sensors, 20(4): 1042.

[3] Tran-Trung K, Duong Thi Hong H, Truong Hoang V 2022. Weather forecast based on color cloud image recognition under the combination of local image descriptor and histogram selection. Electronics, 11(21): 3460.

[4] Kalkan M, Bostancı GE, Güzel MS, Kalkan B, Özsarı Ş, Soysal Ö, Köse G 2022. Cloudy/clear weather classification using deep learning techniques with cloud images. Computers and Electrical Engineering, 102: 108271.

[5] Salman AG, Kanigoro B, Heryadi Y 2015. Weather forecasting using deep learning techniques. 2015 International Conference on Advanced Computer Science and Information Systems (ICACSIS): 281-285.

[6] Zoubek T, Bumbálek R, Ufitikirezi JDDM, Strob M, Filip M, Špalek F, Bartoš P 2025. Advancing precision agriculture with computer vision: A comparative study of YOLO models for weed and crop recognition. Crop Protection, 190: 107076.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A SPATIAL EXPERIENCE AT THE INTERSECTION OF ANATOLIAN AND ASIAN CUISINES: THE CASE OF THE MOLA ISTANBUL PROJECT

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ABSTRACT

In food-and-beverage (F&B) spaces, interior design extends beyond creating atmosphere; it requires the integrated management of multiple criteria such as user experience, operational flow, and material performance. This study examines, as a case study, the design process of an à la carte restaurant located within the Mola Istanbul Hotel complex in Silivri, focusing on the objective of bringing Anatolian and Asian culinary cultures together within a single spatial configuration. The aim is to discuss how two distinct cultural identities can be made legible within an open-plan setting and how this objective is reflected in design decisions through specific parameters.

Within this scope, the design decisions developed throughout the project process are evaluated through a qualitative analysis along the axes of spatial organization, transition/segregation strategies, daylight–shadow composition, privacy and comfort criteria, and material–detail performance. The design approach adopts the shared values of the two culinary cultures—hospitality, craftsmanship, and ritual—as a "core narrative," while establishing differentiation through controlled transitions and layered spatial cues rather than hard boundaries. Daylight and shadow are addressed as atmospheric tools that support spatial orientation; privacy, circulation, and seating comfort are balanced within the same framework. Material and detailing decisions are guided by durability, ease of maintenance, and longevity required for restaurant use; a palette of earth tones that evokes a relationship with nature and a continuous material language strengthen overall coherence.

As a result, the study argues that, when representing culinary cultures in space, design can be assessed through the balance it establishes between cultural narrative, light–atmosphere, and operational requirements, and that this balance generates a holistic approach that enhances user experience.

Keywords: Restaurant Interior, Hospitality Design, Spatial Experience, Cultural Narrative, Lighting Strategy, Gonye Design.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FACTORS INFLUENCING CONCEPT DESIGN IN BRANDED HOUSING PROJECTS: THE CASE OF THE NIVAK FLORYA PROJECT

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ABSTRACT

In branded housing projects, concept design is not merely an aesthetic preference; it is a strategic set of decisions that shapes the relationship with the target audience, defines the brand's spatial identity, and supports differentiation in the market. This study aims to make visible the dynamics influencing concept design in branded housing and to discuss how these dynamics are reflected in the design process through the case of the Nivak Florya project.

The study examines the concept design developed for the case project and its spatial configuration together with stakeholder expectations and project constraints that shape design decisions. In this context, it is observed that the concept is formed at the intersection of interrelated parameters such as the target user profile and lifestyle scenarios, location and environmental context, developer/brand vision, budget and cost priorities, apartment typologies and area distribution, current design trends, sustainability goals, and sales–marketing strategies. Considering these parameters collectively informs decisions regarding spatial organization, material–color selections, lighting approach, and atmospheric composition, and in turn produces a coherent identity that supports user experience.

As a result, the study emphasizes that defining the concept through clear criteria in the early phase strengthens consistency throughout the design process and creates a shared decision-making language across disciplines. Accordingly, it proposes an evaluative approach to make concept design decisions in branded housing projects more manageable.

Keywords: Interior Design, Branded Housing, Concept Design, Target User Profile, Brand Identity, Gonye Design

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ERKEN DÖNEM KÜLLİYELERİNİN İŞLEVSEL BAĞLAMDA İNCELENMESİ

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Özet

Bu çalışmada erken dönem İslam mimarisi, işlevsel bağlamda irdelenmektedir. Bu amaçla seçilen örneklerin kentsel konumları ile ilişkisi, bulundukları dönemin sosyo-kültürel koşulları çerçevesinde şekillenen ihtiyaç programları, mekân-fonksiyon ilişkileri, mekansal organizasyon esneklik ve erişilebilirlik düzeyleri alanında incelenmiştir. Çalışma, araştırma yöntemi olarak literatür taraması, karşılaştırmalı örnek analizi ve mekansal çözümleme tekniklerininden yararlanarak şunu ortaya koymayı amaçlar; Geleneksel külliyelerde caminin ve cami etrafında organize olan çeşitli işlevlerin yalnızca ibadet mekânı olarak değil; eğitim, sosyal yardımlaşma, kamusal etkileşim ve toplumsal bütünleşme alanı olarak üstlendiği rolü ortaya koymayı hedeflemektedir. Bu bağlamda, erken dönem külliye örnekleri üzerinden şekillenen çok katmanlı işlevsel yapının yeni mekan organizasyonundaki belirleyici rolü irdelenmektedir.

Anahtar kelimeler: Cami, Külliye, İşlevsel tasarım

Examination of Early Period Külliyes in a Functional Context

Abstract

This study examines early Islamic architecture within a functional framework. For this purpose, the selected examples are analyzed in terms of their relationship with urban location, the needs programs shaped within the socio-cultural conditions of their respective periods, space–function relationships, spatial organization, flexibility, and levels of accessibility. The study aims to reveal, by employing literature review, comparative case analysis, and spatial analysis techniques as research methods, that in traditional külliyes the mosque and the various functions organized around it assume a role not only as a place of worship but also as spaces for education, social solidarity, public interaction, and social integration. In this context, the determining role of the multilayered functional structure shaped through early-period külliye examples in the organization of new spatial arrangements is examined.

Keywords: Mosque, Külliye, Functional Design, Al-Masjid an-Nabawi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

1.Yöntem

Bu çalışmada nitel araştırma teknikleri kullanılmış olup, karşılaştırmalı ve analitik bir yöntem tercih edilmiştir. Araştırma verileri bu çerçevede literatür taraması ile elde edilmiştir. Erken dönem İslam mimarisi, dönemin kendi tarihsel koşulları içerisinde ele alınmıştır. Araştırma sürecinde literatür taraması, mekan kavramı üzerinden değerlendirilmiş olup mekan- işlev ilişkisi hem aynı döneme ait benzer örnekler arasında hem de farklı dönemlerde ortaya çıkan benzer işlevsel düzenlemeler üzerinden karşılaştırma yapılarak incelelenmiştir. Bu yöntemle, erken dönemdeki külliyelerin çok işlevli yapısı ve toplumsal rolü irdelenmiştir.

2.Erken Dönem Mimarisi

Külliye bağımsız parçalardan bir araya gelen bir bütün (Arapça- kül) anlamına gelir. Birçok yapının mekansal bütünlük oluşturması söz konusudur. Erken Dönem İslam mimarisi örneklerinde henüz bir külliye mimarisi görülmese de ihtiyaca binaen oluşan mekanları, bu mekanların birbiri ile ilişkisini ve bu ilişkinin getirdiği mimari mekan döngüsü bu bölümde incelenmektedir.

Mekke'de ilk kutsal alanların mimarisi, dış çeperde bir duvarla çevrili, küçük ölçekli bir plan tipinin doğal bir sonucu olarak ortaya çıkmıştır. Hicret öncesi dönemde kurumsallaşmış bir ibadet mekânından söz etmek mümkün değildir. Bu dönemde Hz. Muhammed'in sohbetlerini kendi evinde ya da mevcut toplumsal alanlarda gerçekleştirdiği düşünülmektedir. Aynı zamanda bu süreçte henüz belirli ve yerleşik bir ibadet düzeni de bulunmamaktadır. Mekke döneminde vurgunun, mekânsal bir düzenlemeden ziyade Allah'ın tek oluşu, ahlaki yükümlülükler ve bireysel vicdan kavramları üzerinde yoğunlaştığı görülmektedir. Müslümanların Mekke'de maruz kaldıkları sosyal baskı ve düşmanlıklar nedeniyle toplumsal ibadet alanlarını geliştiremedikleri, ancak Medine'ye hicretten sonra dini mekanların ortaya çıktığı kaynaklarda görülmektedir.[2]

1.1.Kuba Mescidi

Mescid, Arapça kökenli bir kelime olup secde edilen yer olarak literatürde geçmektedir. "Toplanma, bir araya gelme" kökünden gelen cami, "Toplayan, bir araya getiren" demektir. Bu bağlamda cami sadece ibadet edilen yer olarak değil müslüman toplumu bir araya getiren mekanlar olarak ele alınmalıdır.

Erken dönem mimarisinde mekan kavramı, henüz estetik ya da biçimsel kaygıyla değil, yalnızca barınma ve toplanma ihtiyacı üzerinden şekillenmektedir. Peygamber efendimiz Mekke'den Kuba'ya ulaşınca sahabenin evinde konaklamıştır. Evin yakınında hurma kurutma yerinin mescid olarak

[2] Creswell, K. A. C. (t.y.). Early Muslim architecture. Oxford University Press.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

kullanıldığını gördükten sonra bu kısmı ihtiyaca binaen genişletmiş ve günümüzde Kuba mescidi adını verdiğimiz alanın ilk temellerini 622 yılında atmıştır.

Mescidin güneyinde o dönemde çeşitli evler bulunmaktadır ve bu evler mescide bir kapıyla direk açılmaktadır; Müslümanlar Kuba'ya ziyarete geldiklerinde peygamber efendimiz burada hem namaz kıldırır hem de ashabıyla sohbet gerçekleşirdi. Sonrasında bu mescit genişletilerek bir cuma camisine dönüşmüş, Müslüman topluluklar için bir sembol haline gelmiştir. Kuba Camii, ilk dönemlerden itibaren İslami faaliyetlerin merkezini oluşturmaktadır. Cami, yüzyıllar boyunca çeşitli değişikliklere uğramış ve 1980'lerde tamamen yeni bir bina ile değiştirilerek bugünkü haline getirilmiştir.

Kuba Camii yalnızca ibadet işleviyle sınırlı bir yapı olarak hizmet vermemiştir. Aynı zamanda eğitim faaliyetlerinin yürütüldüğü, sahabelerin Kur'an'ı incelediği ve dini meseleler üzerine istişarelerde bulunduğu bir ilim merkezi niteliği taşımıştır. Bununla birlikte, yönetsel kararların alındığı ve toplumsal meselelerin değerlendirildiği bir idari merkez işlevi de görmüştür. Caminin, yabancı topluluklardan gelen heyetlerin kabul edildiği bir temsil ve karşılama mekânı olarak kullanıldığı; sosyal yardımların organize edildiği ve dağıtıldığı bir kamusal merkez niteliği taşıdığı bilinmektedir. Ayrıca, Müslüman topluluğa yönelik tehdit ve savaş durumlarında stratejik kararların alındığı ve planlamaların yapıldığı bir istişare ve karar mekânı olarak da işlev gördüğü anlaşılmaktadır. [3]

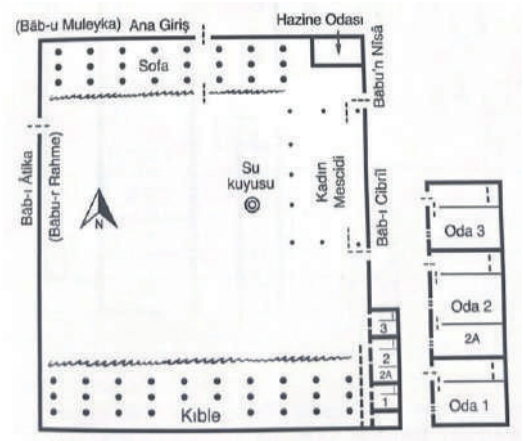
Bu bağlamda Kuba Camii, erken dönem İslam toplumunda ibadet, eğitim, yönetim, diplomasi ve savunma işlevlerini bünyesinde toplayan çok işlevli bir kamusal yapı örneğidir.

1.2.MESCİD-I NEBEVİ

[3] Haaj Seyyed Javadi, Seyyed Kamal, "İran'da İlk Camilerin Ortaya Çıkışı", Mescid

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Hz. Muhammed Kuba'da kısa bir süre kaldıktan hicretin ardından 622 yılında Medine'ye ulaşılmıştır. Medine'de devesinin çöktüğü yerin yakınında bir süre konaklanmış, daha sonrasında bu alanı satın



alarak bir konut inşa etmiştir. Böylece Mescid-i Nebevî'nin ilk mekânsal temelleri burada atılmıştır. Burası Erken İslam toplumunun mekânsal ve toplumsal örgütlenmesinde belirleyici bir rol üstlenmiştir. Başlangıçta yapı, avlu etrafında konumlanan küçük ölçekli odalardan oluşan, özel yaşam alanlarını barındıran bir konut niteliğindedir. Ancak zaman içerisinde yapının, Müslüman topluluğun artan ihtiyaçları doğrultusunda ileri dönemde kamusal ve dini bir karakter kazandığı görülmektedir. Bu dönüşüm, önceden kurgulanmış bir mimari programın sonucu olmaktan ziyade, gündelik pratiklerin ve toplumsal gereksinimlerin doğal bir yansıması olarak ortaya çıkmıştır.

Resim 1. Mescid-i Nebevi 624 yılı ilk yapıldığı ölçülerle (70x60) aynı kıble değiştikten sonraki kroki[4]

Yapının inşasında kerpiç ve taş gibi doğal ve kolay erişilebilir malzemeler kullanılmış; sütunlar hurma kütükleriyle oluşturulmuş, çatı ise hurma yapraklarıyla örtülmüştür. Bu yapı tekniği, mimari ihtişamdan çok işlevselliği ve erişilebilirliği önceleyen bir yaklaşımı yansıtmaktadır. Mekânın kutsallığı, anıtsal bir mimari dil aracılığıyla değil; kullanım biçimleri ve toplumsal anlam katmanları üzerinden kurulmuştur. (Aykaç, 2020)

Mescid-i Nebevî, erken dönemde yalnızca ibadet edilen bir alan olarak değil; eğitim faaliyetlerinin yürütüldüğü, toplumsal toplantıların gerçekleştiği, misafirlerin ağırlandığı ve kamusal kararların alındığı bir merkez olarak işlev görmüştür. Avlu, bu çok işlevli kullanımın odak noktası hâline gelmiş; gündelik yaşam pratikleri ile ibadet arasında keskin mekânsal ayrımlar oluşturulmamıştır. Bu durum, erken İslam mekânının geçirgen ve kapsayıcı karakterini açık biçimde ortaya koymaktadır.

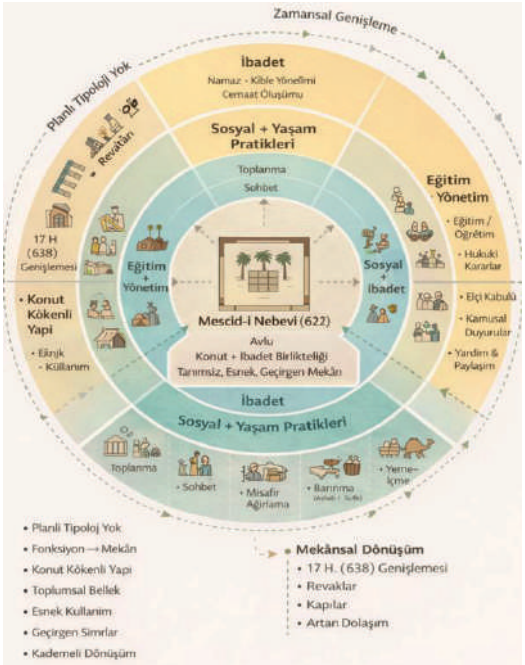
İlk işlevlere bakıldığında, Hz. Muhammed'in yaşam alanı ile eşleri için inşa edilen odaların tamamının avluya açıldığı, bu mekânların birbirinden ayrı bölümlerle ve perdelerle ayrıldığı anlaşılmaktadır.

[4] Aytaç, F. (2020). K. A. C. Creswell'e göre erken devir İslam mimarisi (Cilt 1). İstanbul: Mimar ve Mühendis Grubu Yayınları.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

(Resim 1) Bu bağlamda, anıtsallıktan ziyade işlevselliğin ön planda olduğu bir mekânsal anlayış söz konusudur. Konutun avlusu zaman zaman ibadet amacıyla kullanılmış olsa da, bu kullanım başlangıçta kamusal bir nitelik taşımamaktadır. Yapının cami kimliğini kazanması, Müslüman topluluğun gelişimiyle birlikte gerçekleşmiş ve bu süreç, daha sonra oluşacak cami tipolojisinin temelini oluşturmuştur.

Medine'ye hicretin ardından ibadete ilişkin ilk mekânsal düzenleme, namazın yönelimi üzerinden gerçekleşmiştir. Başlangıçta Müslümanların namazlarını Kudüs'e yönelerek kıldıkları, daha sonra yönelimin Mekke'ye çevrildiği bilinmektedir. Bu değişimin, yapının mekânsal organizasyonu üzerinde de etkili olduğu açıktır. Ancak kıble değişiminin, önceden tasarlanmış katı bir eksenel düzen oluşturmadığı, erken İslam mimarisi üzerine yapılan çalışmalarda vurgulanmaktadır. Medine'deki yapı, bu yön değişikliğine esnek bir biçimde uyum sağlamış; sabit ve dogmatik bir plan anlayışından ziyade, değişen dini pratiklere cevap verebilen bir mekânsal esnekliğin varlığına işaret etmiştir. Bu durum, İslam dininin bu dönemde henüz tamamlanmamış olması, ayetlerin inmeye devam etmesi ve buna paralel olarak hem insanın hem de mekânın dönüşüm içinde bulunmasıyla ilişkilendirilebilir.



Resim 2: Mescid-i Nebevi mekansal gelişim diyagramı (Yapay zeka ile oluşturulmuştur)

Avlu düzeni bu bağlamda önemli bir mekânsal unsur olarak öne çıkmaktadır. Avlu, yalnızca ibadet için değil; yeme-içme, hayvanların bağlanması, misafirlerin ağırlanması gibi çok çeşitli gündelik pratiklere ev sahipliği yapmıştır. Bu kullanım biçiminde belirgin bir kutsallık ya da katı bir kamusal ayrım bulunmamaktadır. Mekân, sınırları kesin çizgilerle tanımlanmış bir düzen yerine, ihtiyaçlara göre şekillenen esnek bir kullanım anlayışıyla var olmuştur. Bu durum, İslam mekânının çok işlevli ve geçirgen karakterini açık biçimde ortaya koymaktadır. Hz. Muhammed'in vefatının ardından yapı bir süre daha konut işlevini sürdürmüş, hemen cami kimliğine bürünmemiştir. Mekânın kutsallaşması,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

mimari bir müdahaleden çok, hatıra ve toplumsal bellek üzerinden gerçekleşmiştir. Bu süreç, mekânın anlamının biçimsel özelliklerden ziyade yaşanmışlıklar ve kolektif hafıza aracılığıyla üretildiğini göstermektedir.

Yapının mekânsal gelişimi, Müslüman topluluğun büyümesine paralel olarak kademeli biçimde gerçekleşmiştir. Genişlemeler, önceden belirlenmiş bir mimari program doğrultusunda değil; artan ibadet ve kamusal kullanım ihtiyaçlarına yanıt verecek şekilde yapılmıştır. Bu süreçte Mescid-i Nebevî'nin cami kimliği giderek belirginleşmiş; konut kökenli mekânsal yapı, toplumsal belleğin taşıyıcısı hâline gelmiştir.

17 H. (638) yılında Hz.Ömer tarafından gerçekleştirilen ilk büyük genişleme, Mescid-i Nebevî'nin kamusal niteliğinin kurumsallaşması açısından önemli bir aşamayı temsil etmektedir. Bu dönemde yapı kuzey ve batı yönlerinde genişletilmiş, avlu büyütülmüş ve ibadet alanının kapasitesi artırılmıştır. Kullanılan malzeme ve yapı teknikleri önceki dönemde olduğu gibi yalınlığını korumuş; mimari müdahaleler işlevsel gerekliliklerle sınırlı tutulmuştur.

Bu genişleme sürecinde yapının girişleri çoğaltılmış, revaklı alanlar eklenmiş ve dolaşım kapasitesi artırılmıştır. Buna karşılık, doğu yönünde Hz. Muhammed'in eşlerine ait hücrelerin varlığı nedeniyle müdahaleden kaçınılması, mekânın sosyal ve mahrem kullanım katmanlarının mimari kararlar üzerindeki belirleyici etkisini göstermektedir. Bu durum, Mescid-i Nebevî'nin kamusal işlevleri güçlenirken, konut kökenli karakterinin bütünüyle ortadan kalkmadığını ortaya koymaktadır.

Sonrasında El Velid'den Suudi yönetime birçok kez müdahaleler görmüş olan yapı, yüzyıllar boyunca çeşitli değişikliklere uğramış ve 1980'lerde tamamen yeni bir bina ile değiştirilerek bugünkü haline getirilmiştir.

Bu bağlamda Mescid-i Nebevî, erken İslam mimarisinin planlanmış bir tipolojiye değil, dönüşen ihtiyaçlara dayalı bir gelişim sürecine sahip olduğunu gösteren temel bir referans olarak değerlendirilebilir. Konut kökenli bu mekânsal çekirdek, ilerleyen dönemlerde cami ve külliye yapılarında görülecek çok işlevli organizasyonların öncülünü oluşturmuştur. Cami model olarak, tek bir yapının zaman içerisinde ibadet, sosyal etkileşim, eğitim ve yönetim gibi farklı işlevleri bünyesinde toplayan bir merkeze dönüşmesini mümkün kılan esnek mekânsal anlayışıyla günümüz tasarımlarında referans sağlamaktadır.

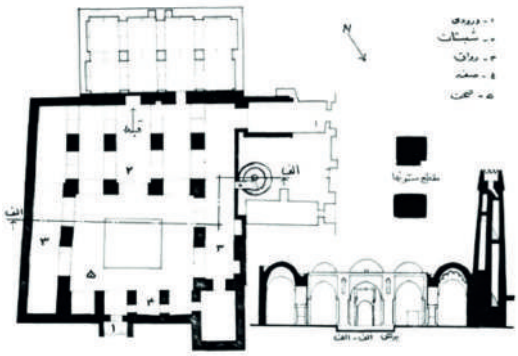
1.3. Fahraj Camii

Fahraj Camii, Yazd'a yaklaşık 22 km uzaklıkta, Yazd–Kerman eski yolu üzerinde yer alan Fahraj köyünde konumlanmakta olup, M. 623 tarihlenmektedir. Yapının sonradan eklenen kerpiç minaresinin uzak mesafelerden algılanabilmesi, caminin yerleşim içindeki yönlendirici ve tanımlayıcı rolüne işaret etmektedir. Erken İslam dönemine ait camilerde görülen yalın ve mütevazı mimari anlayışı yansıtan yapı, İran coğrafyasında günümüze ulaşabilmiş nadir erken dönem camilerinden biri olarak değerlendirilmektedir. Mimari üslubu Part ve Horasan gelenekleriyle ilişkilendirilen Fahraj Camii,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

bütünüyle ham kerpiçten inşa edilmiş, duvarları doğal örtü malzemeleriyle kaplanmış bir yapı olarak anıtsallıktan uzak, işlev odaklı bir mimari yaklaşımı temsil etmektedir.

Fahraj Camii'ni erken dönem cami mimarisi açısından özgün kılan temel unsur, yapının baştan itibaren cami işleviyle inşa edilmiş olmasıdır. Bu yönüyle yapı, erken İslam mimarisinin belirli bir tipolojinin tekrarıyla değil, yeni toplumsal ve dini ihtiyaçlara yanıt veren özgün mekânsal çözümlerle geliştiğini ortaya koymaktadır.



Resim3: Fahraj Camii plan ve kesit.



Resim4: Fahraj Cami avludan görünüş.

Yapının mekânsal kurgusu son derece yalın olup, üç açıklığa sahip bir ibadet mekânı etrafında şekillenmektedir. Ortadaki açıklığın diğerlerine göre daha geniş olması, mekânsal hiyerarşinin sembolik bir anıtsallık yerine kullanım önceliği üzerinden kurulduğunu göstermektedir. Doğu ve batı yönlerinde yer alan revaklarla ilişkilenen bu düzen, ibadet mekânı ile yarı açık alanlar arasında geçirgen bir ilişki kurmaktadır. Eliptik kemerler ve örtü sistemi, yapının strüktürel sadeliğini pekiştirirken, ana ve tali avluların güney, doğu ve batı yönlerindeki açıklıklarla sınırlandırılması, mekânın çok yönlü kullanımına olanak tanıyan esnek bir organizasyon ortaya koymaktadır. Kuzey cephede yer alan ve günümüzde kapatılmış olan bölümler ise yapının zaman içinde farklı kullanım senaryolarına açık bir mekânsal potansiyele sahip olduğunu düşündürmektedir. Müslümanların sosyalleştiği alanlar (avlu) ibadet mekanlarına ek olarak ihtiyaca yönelik planda kurgulanmıştır.

Bu bağlamda Fahraj Camii, Erken İslam mimarisinin İran coğrafyasındaki ilk ibadet mekanı karşılığı olarak değerlendirilebilir. Mescid-i Nebevî'deki kurgusunun referanslarıyla Fahraj Camii'nde de mimari form, önceden tanımlanmış bir cami olarak değil, mekanların kullanım pratiklerinden yararlanarak inşa edilmiştir. Medine'de ortaya çıkan konut kökenli, esnek ve kamusal cami anlayışının farklı coğrafyalarda konut temelli olmadan ibadet amacı ile nasıl yeniden üretildiğini ve yan fonksiyonlarla nasıl kullanıldığını göstermektedir. Bu yönüyle Fahraj Camii, erken İslam cami mimarisinin biçimden ziyade işlev üzerinden şekillendiğini kanıtlayan önemli bir referans oluşturmaktadır.

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ISBN: 978-9952-610-30-7

3.SONUÇ

İncelenen örneklerde İslam'ın ilk döneminde inşa edilmiş, farklı ölçeklerdeki ibadet yapılarının esnek fonksiyonlarla geliştiğini göstermektedir. Bu yapılarda konutun mescide dönüştürülmesi, konut çevresinde mescit oluşması ya da doğrudan ibadet mekânı olarak inşa edilmesi gibi farklı oluşum biçimleri görülmekle birlikte, eğitim, idari ve sosyal etkileşim gibi çok yönlü katmanlaşmış işlevler görülmektedir.

Bu durum, caminin erken dönemden itibaren yalnızca namaz kılma mekânı olarak değil, toplumun ve dönemin ihtiyaçlarına göre şekillenen çok işlevli bir merkez olarak var olduğunu ortaya koymaktadır. Dolayısıyla çağdaş cami mimarisinde tasarımın, tekil bir ibadet mekânı yerine külliye referansıyla, toplumsal gereksinimlere yanıt veren esnek fonksiyonlar çerçevesinde ele alınması gerektiği anlaşılmaktadır.Bu bağlamda tasarım paradigmaları dönemin ihtiyaçları üzerinden oluşturulabilir.

KAYNAKÇA

Abdülfettah Hilmi. (1948). Mescid-i Nebevi'nin (Peygamber Camisi) tarihi [Histore de cette mosquée]. Mecelletü'l-İmare, 8(3), 27–28.

Ariffin, S. A. I. S. (t.y.). Architectural conservation in Islam: Case study of the Prophet's Mosque. Penerbit UTM.

Creswell, K. A. C. (t.y.). Early Muslim architecture. Oxford University Press.

Gündoğdu, Y. (2018). Modern Suffah: Bugün Mescid-i Nebevi'nin Kur'an ve ilim çevreleri. Tarih Kültür ve Sanat Araştırmaları Dergisi, 7(1), 319–331. https://doi.org/10.7596/taksad.v7i1.1372

Munt, H. (t.y.). The holy city of Medina: Sacred space in early Islamic Arabia. Cambridge University Press.

Madain Project. (n.d.). Masjid al-Nabawi. Retrieved February 14, 2026, from https://madainproject.com/masjid_al_nabawi

Aytaç, F. (2020). K. A. C. Creswell'e göre erken devir İslam mimarisi (Cilt 1). İstanbul: Mimar ve Mühendis Grubu Yayınları.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

APPLIED EVALUATION OF A POLICY-SENSITIVE TEXT-TO-SQL AGENT WITH POSTGRESQL ROW-LEVEL SECURITY (RLS) FOR DETERMINISTIC ACCESS CONTROL

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ABSTRACT

Large Language Model (LLM) driven Text-to-SQL systems enable natural-language access to relational databases but introduce critical security risks when authorization rules are enforced only through prompts. Prompt-based constraints are inherently probabilistic and may fail to prevent unauthorized data exposure. This study investigates whether database-level enforcement using PostgreSQL Row-Level Security (RLS) can provide deterministic protection in LLM-integrated query pipelines. Two architectures are experimentally compared: a Prompt_Only baseline, where access restrictions are described exclusively in prompts, and an RLS_Agent approach that combines SQL validation, role-restricted execution, and RLS policies implemented directly at the database layer.The experimental design includes thirteen realistic access scenarios evaluated across multiple organizational roles, with repeated executions to capture stochastic model behavior. Performance is assessed using Execution Accuracy (EA), Policy Compliance Rate (PCR), and Data Leakage Volume (DLV). Results show that prompt-only enforcement leads to inconsistent policy adherence and measurable leakage, particularly under restrictive roles. In contrast, the RLS_Agent achieves near-perfect policy compliance and effectively eliminates unauthorized data exposure, while introducing minimal performance overhead relative to overall LLM latency.The findings demonstrate that secure LLM database integration requires deterministic enforcement mechanisms beyond prompt engineering. By combining natural-language interfaces with database-native security controls, the proposed architecture offers a practical framework for building trustworthy Text-to-SQL systems suitable for enterprise environments and sensitive data contexts.

Keywords: Text-to-SQL; Row-Level Security (RLS); Large Language Models; Access Control.

GİRİŞ

Büyük dil modelleri (BDM), doğal dil işleme alanında son yıllarda önemli bir dönüşüm yaratmış ve özellikle veritabanı arayüzleri gibi insan-makine etkileşimi yoğun sistemlerde yeni kullanım

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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senaryolarının ortaya çıkmasına yol açmıştır. Bu modellerin Text-to-SQL görevlerinde kullanılması, kullanıcıların doğal dilde ifade ettikleri sorguların otomatik olarak SQL ifadelerine dönüştürülmesini mümkün kılarak veri erişimini teknik bilgi gereksiniminden kısmen bağımsız hale getirmiştir. Ancak bu dönüşüm, kurumsal veri ortamlarında güvenlik ve erişim kontrolü açısından yeni risk alanları oluşturmuştur. BDM tabanlı sistemlerin olasılıksal yapısı, modelin verilen talimatları yanlış yorumlayabilmesi veya bağlam dışı genellemeler yapabilmesi nedeniyle, rol tabanlı erişim kısıtlarının yalnızca istem düzeyinde tanımlanması durumunda yetkisiz veri ifşası riskini artırmaktadır. Burada istem düzeyi, erişim politikalarının yalnızca doğal dil talimatları içerisinde modele aktarılmasını ifade eder ve güvenlik zorlamasının modelin olasılıksal yorumlama sürecine bağlı kalmasına neden olur. Bu nedenle modelin talimatları hatalı yorumlaması durumunda politika dışı sorgular üretilebilmekte ve deterministik bir güvenlik garantisi sağlanamamaktadır.

Geleneksel veritabanı sistemlerinde erişim kontrolü deterministik mekanizmalar üzerinden uygulanırken, Text-to-SQL ajanlarının yaygınlaşmasıyla birlikte güvenlik katmanı çoğu zaman model davranışına bağımlı hale gelmektedir. Literatürde "yumuşak güvenlik" olarak adlandırılabilecek bu yaklaşımda, kullanıcı rolü ve erişim sınırları doğal dil talimatları ile modele aktarılır ancak modelin bu talimatlara her zaman uyacağı garanti edilemez. Özellikle istem enjeksiyonu veya talimat ihlali gibi durumlarda model, kapsamı geniş SQL sorguları üreterek hassas verilerin açığa çıkmasına neden olabilir. Bu problem, çok kiracılı (multi-tenant) ve çok rollü kurumsal ortamlarda daha kritik hale gelmektedir. Çok kiracılı kavramı, aynı veritabanı altyapısını paylaşan ancak veri erişim sınırları birbirinden ayrılmış farklı organizasyon veya kullanıcı gruplarını ifade eder. Bu ortamlarda bu problem, Text-to-SQL teknolojilerinin pratik benimsenmesinin önündeki temel engellerden biri olarak değerlendirilmektedir.

Bu çalışmanın temel motivasyonu, güvenlik zorlamasının model davranışından ayrıştırılması gerektiği varsayımına dayanmaktadır. Bu doğrultuda önerilen yaklaşım, Text-to-SQL üretim sürecinde erişim kontrolünü yalnızca istem düzeyinde bırakmak yerine, PostgreSQL Satır Düzeyi Güvenliği (Row-Level Security, RLS) mekanizması ile veri katmanına taşımaktadır. Önerilen RLS_Agent mimarisi, büyük dil modeli tarafından üretilen SQL ifadelerini doğruladıktan sonra sorguları simüle edilen kullanıcı rolü altında yürütmekte ve satır görünürlüğünü deterministik biçimde sınırlandırmaktadır. Böylece modelin olasılıksal doğasından kaynaklanabilecek politika ihlallerinin sonuç kümesine yansıması engellenmektedir.

Çalışmada bu yaklaşım, rol kısıtlarının yalnızca istem talimatları ile tanımlandığı Prompt_Only temel çizgisi ile karşılaştırmalı olarak değerlendirilmiştir. Araştırmanın amacı, deterministik erişim zorlamasının politika uyumu oranı (PCR), veri sızıntısı değeri (DLV) ve yürütüm doğruluğu (EA) üzerindeki etkisini deneysel olarak incelemektir. Bu kapsamda üç araştırma sorusu ele alınmaktadır: (i) RLS ile zorlanan bir Text-to-SQL ajanı politika uyumunu ve veri sızıntısını hangi düzeyde kontrol edebilir? (ii) istem tabanlı güvenlik yaklaşımı benzer senaryolarda hangi riskleri üretir? ve (iii)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

güvenlik zorlamasının veri katmanına taşınması performans metrikleri üzerinde nasıl bir etki oluşturur? Bu sorular doğrultusunda çalışma, olasılıksal model davranışı ile deterministik veritabanı zorlaması arasındaki farkın politika uyumu, veri sızıntısı ve performans metrikleri üzerindeki etkisini sistematik olarak incelemeyi amaçlamaktadır. Bu makalenin katkısı üç yönlüdür. Birincisi, Text-to-SQL literatüründe genellikle ihmal edilen güvenlik boyutunu, politika uyumu ve veri sızıntısı gibi nicel metriklerle ele almaktadır. İkincisi, güvenlik katmanını modelden bağımsızlaştıran RLS tabanlı bir ajan mimarisini uygulamalı olarak değerlendirmektedir. Üçüncüsü ise performans ve güvenlik arasındaki dengeyi deneysel sonuçlar üzerinden analiz ederek kurumsal sistem tasarımına yönelik pratik çıkarımlar sunmaktadır. Bu yönleriyle çalışma, güvenilir yapay zeka bağlamında deterministik erişim kontrolünün Text-to-SQL sistemlerinde nasıl konumlandırılabileceğine dair bütünsel bir perspektif ortaya koymaktadır.

LİTERATÜR

Text-to-SQL araştırmaları, doğal dilde ifade edilen bilgi ihtiyacının ilişkisel veritabanlarında yürütülebilir SQL sorgularına dönüştürülmesi problemini ele alarak, veri erişimini daha geniş kullanıcı kitleleri için erişilebilir kılmayı hedeflemiştir. Alanın erken dönem yaklaşımları ağırlıklı olarak semantik ayrıştırma ve kural/şema odaklı yöntemlere dayanırken, büyük dil modellerinin (BDM) benimsenmesiyle birlikte bağlam duyarlı, öğrenme temelli ve özellikle sıfır-çekim/az-çekim kabiliyetleri yüksek sistemlere doğru belirgin bir kayma yaşanmıştır (Dou ve ark., 2024). Bu dönüşüm, doğruluk ve genelleme kapasitesini artırsa da kurumsal bağlamda güvenlik ve erişim kontrolünü kritik bir sınırlayıcı faktör haline getirmiştir; zira BDM tabanlı arayüzlerin veritabanı etkileşiminde kullanılmasına dair değerlendirmeler, yüksek doğruluk potansiyeline karşın tutarlılık ve güvenlik boyutlarında yapısal risklerin sürdüğünü göstermektedir (Li ve ark., 2024). Ajan tabanlı çerçeveler, SQL üretimini yürütüm geri bildirimiyle iyileştiren döngüler kurarak hata düzeltmeyi güçlendirmiş ve yürütüm rehberli yaklaşımların doğruluk üzerindeki katkısını ortaya koymuştur; ancak bu hatasızlaştırma odağı çoğu çalışmada politika uyumu ve veri sızıntısı gibi güvenlik çıktılarının sistematik ölçümünü ikincil plana itmiştir (Gao ve ark., 2023). Güvenlik literatürü ise özellikle istem (prompt) temelli kısıtlamaların kırılganlığını vurgular: erişim sınırlarının yalnızca metinsel talimatlarla modellenmesi, BDM'nin olasılıksal doğası nedeniyle talimat ihlali, yanlış genelleme ve bağlam kaybı gibi durumlarda politika dışı sorgu üretimine yol açabilir (Zou ve ark., 2023). Bu kırılganlık, istem enjeksiyonu saldırılarıyla daha da belirginleşir; dolaylı veya doğrudan enjeksiyonlar, modelin önceki güvenlik talimatlarını etkisizleştirerek yetkisiz veri ifşasını tetikleyebilir (Perez ve Ribeiro, 2023; Liu ve ark., 2024). Gerçek dünya BDM uygulamalarında bu saldırı sınıfının pratikte kullanılabilir olduğu ve özellikle araç-kullanımı/ajan davranışı içeren sistemlerde güvenlik sınırlarını aşabildiği gösterilmiştir (Greshake ve ark., 2023). Bu çerçevede kurumsal ölçekte benimsenme için temel çıkarım, güvenliğin model davranışına bağımlı bırakılmaması gerektiğidir; erişim kontrolünün deterministik mekanizmalarla veri katmanında zorlanması, BDM'nin uyumsuz

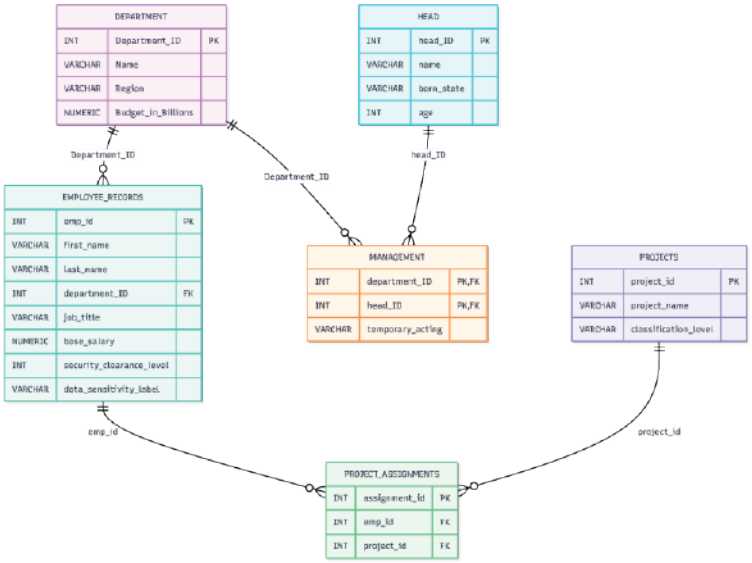
DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

davranışlarının sonuç kümesine yansımasını engelleyen yapısal bir güvence sağlar (Sandhu, 2022). Çok kiracılı ve çok rollü senaryolarda satır düzeyi güvenlik mekanizmalarının (RLS) erişim ihlallerini azaltmadaki rolü literatürde vurgulanmakta; RLS'nin rol/politika temelli görünürlüğü deterministik olarak kısıtlayarak modelin ürettiği sorgudan bağımsız bir güvenlik sınırı oluşturduğu belirtilmektedir (Derakhshan ve ark., 2023). PostgreSQL'in RLS modeli, satır görünürlüğünü politika ifadeleri ile zorunlu kılar ve böylece sorgu ifadesi geniş kapsamlı dahi olsa yetkisiz satırların sonuçlara dahil olmasını engeller (PostgreSQL Global Development Group, 2024). Buna karşın, Text-to-SQL literatürünün ağırlıklı kısmı güvenliği "nitel" düzeyde tartışmakta; politika uyumu ve sızıntı büyüklüğünü nicel metriklerle doğrudan ölçen karşılaştırmalı deneysel çalışmalar sınırlı kalmaktadır. Özellikle BDM'lerde veri sızıntısı risklerinin ölçülebilir hale getirilmesi ve güvenilir yapay zeka bağlamında bu risklerin nicel metriklerle izlenmesi gereğine işaret eden çalışmalar, güvenlik boyutunun ayrı bir değerlendirme ekseni olduğunu ortaya koymaktadır (Sun ve ark., 2024; Bertino ve Kundu, 2023). Dolayısıyla mevcut araştırma boşluğu, (i) rol/politika kısıtlarının yalnızca istem düzeyinde ifade edildiği yaklaşımların kurumsal risk üretimini nicel olarak görünür kılmak ve (ii) güvenlik zorlamasını veritabanı katmanına taşıyan deterministik bir mekanizmanın politika uyumu, veri sızıntısı ve performans üzerindeki etkisini ölçülebilir metriklerle karşılaştırmalı biçimde ortaya koymaktır; bu çalışma, söz konusu boşluğu PCR ve DLV gibi güvenlik metrikleri ile yürütüm doğruluğu ve gecikme metriklerini birlikte ele alarak doldurmayı hedeflemektedir (Gu ve ark., 2024).

YÖNTEM

Bu çalışma, politika ve rol duyarlı Text-to-SQL üretiminde güvenlik zorlamasının uygulandığı katmana bağlı olarak ortaya çıkan farkları deneysel olarak inceleyen karşılaştırmalı bir tasarım üzerine kurulmuştur. Deneysel yapı, aynı veritabanı şeması, aynı görev seti ve aynı büyük dil modeli kullanılarak yalnızca güvenlik mekanizmasının uygulandığı katmanın değiştirilmesi prensibine dayanır. Sistem mimarisi; veri katmanı, ajan katmanı ve yürütme katmanı olmak üzere üç temel bileşenden oluşmaktadır. Veri katmanı, kurumsal bir ortamı temsil eden çalışan kayıtları, projeler ve atamalar gibi ilişkisel tabloları içeren PostgreSQL veritabanı üzerinde yapılandırılmıştır ve satır görünürlüğü Row-Level Security (RLS) politikaları ile deterministik biçimde sınırlandırılmıştır. Bu bağlamda, erişim kontrolü öznitelik tabanlı (ABAC), çok seviyeli güvenlik (MLS) ve ilişki tabanlı (ReBAC benzeri) kısıtların birleşimi olarak tasarlanmış; farklı kullanıcı rolleri arasında kapsam aşımı, hassasiyet etiketi ihlali ve ilişki genellemesi gibi hata yüzeylerinin görünür olması hedeflenmiştir.

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Şekil 1. Veritabanı Şeması

Ajan katmanında kullanıcı sorgusu, kullanıcı rolü ve şema bağlamı ile birlikte büyük dil modeline iletilerek SQL üretimi gerçekleştirilmiştir. Çalışmada kullanılan model altyapısı, düşük gecikme ve yüksek doğruluk dengesi nedeniyle GPT-5-mini tabanlı bir mimariye dayanmakta olup, model çıktısı yürütülmeden önce güvenli SQL alt kümesi kapsamında doğrulama ve sanitizasyon sürecinden geçirilmiştir. Bu doğrulama adımı, tek deyimli SELECT sorguları dışında kalan veya veri değişikliği içeren ifadelerin yürütülmesini engelleyerek deneysel karşılaştırmanın güvenlik açısından kontrollü kalmasını sağlamıştır. RLS_Agent yaklaşımı, üretilen sorguları simüle edilen kullanıcı rolü altında çalıştırarak erişim kontrolünü veritabanı katmanında deterministik biçimde zorlamaktadır; Prompt_Only yaklaşımı ise rol kısıtlarını yalnızca istem talimatlarıyla ifade etmekte ve yürütme bağlamında zorunlu bir veritabanı filtresi varsaymamaktadır. Böylece iki yöntem arasındaki temel fark, güvenlik politikasının model davranışına mı yoksa veritabanı zorlamasına mı dayandığı üzerinden izole edilmiştir.

Deneysel tasarım, ALLOW ve DENY durumlarını kapsayan çok rollü senaryo seti üzerinden gerçekleştirilmiş ve her senaryo için tekrarlı yürütümler alınarak istatistiksel özetleme yapılmıştır. Senaryo üretimi sırasında rol/politika çeşitliliğinin korunmasına, çıktı türlerinin (satır kümesi veya skaler değer) dengeli dağıtılmasına ve özellikle yüksek riskli veri sızıntısı yüzeylerinin test edilmesine dikkat edilmiştir. Deneylerin değerlendirilmesinde yürütüm doğruluğu (Execution Accuracy, EA), politika uyumu oranı (Policy Compliance Rate, PCR), veri sızıntısı değeri (Data Leakage Value, DLV) ve uçtan uca gecikme metrikleri kullanılmıştır.

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$$EA_{t,m} = \frac{1}{N}\sum_{i=1}^{N} 1[ValidResult(t,m,i)] \quad (1)$$

$$PCR_{t,m} = \frac{1}{N}\sum_{i=1}^{N} 1[\,\mathrm{Pass}(t,m,i) = 1] \quad (2)$$

$$DLV_{t,m,i} = \max\left(0,\ \mathrm{Got}_{t,m,i} - \mathrm{Auth}_{t,i}\right) \quad (3)$$

Tüm deneyler aynı altyapı koşulları altında yürütülerek model davranışından kaynaklanmayan çevresel farklılıkların sonuçlara etkisi minimize edilmiştir.

Tablo 1. Kullanılan Teknoloji ve Kütüphaneler

Bileşen	Teknoloji/Kütüphane	Sürüm
Konteynerizasyon	Docker & Docker Compose	29.1.3
Veritabanı	PostgreSQL	16.0
Programlama Dili	Python	3.12.10
LLM Çerçevesi	LangChain & LangGraph	0.3.1
Model	GPT	GPT-5-mini API
Veri Bağlantısı	Psycopg2-binary	2.9.9

BULGULAR

Deneysel değerlendirme, politika duyarlı Text-to-SQL üretiminde deterministik erişim zorlamasının güvenlik ve performans üzerindeki etkisini ortaya koymak amacıyla, aynı senaryo seti altında iki farklı yaklaşımın karşılaştırılmasıyla gerçekleştirilmiştir. Elde edilen genel sonuçlar, RLS_Agent yönteminin

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politika uyumu oranını belirgin biçimde artırdığını ve veri sızıntısı değerini pratik olarak sıfıra yaklaştırdığını göstermektedir.

Tablo 2. Yöntem bazında genel sonuçlar

Yöntem	EA	PCR	DLV_mean	LLM_mean (s)	DB_mean (s)	E2E_mean (s)	E2E_std (s)
RLS_Agent	0.9205	0.9974	0.0	4.3469	0.0019	4.3847	1.8547
Prompt_Only	0.9026	0.7359	482.3077	6.9427	0.0018	6.9637	4.5733

Rol temelli analizlerde, özellikle analist ve uyum rollerinde Prompt_Only yaklaşımının politika ihlali üretme eğilimi daha belirgin hale gelirken, RLS_Agent yaklaşımı deterministik satır filtreleme sayesinde tutarlı bir davranış sergilemiştir. Senaryo düzeyinde ayrıntılı değerlendirmeler, yüksek riskli DENY durumlarında Prompt_Only yaklaşımının ölçülebilir veri sızıntıları ürettiğini ve bu durumun politika uyumu oranını düşürdüğünü göstermektedir.

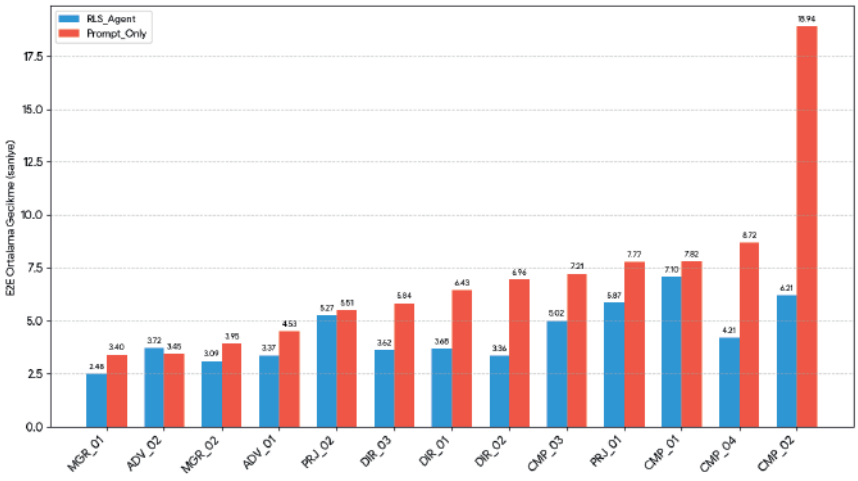
Tablo 3. Rol bazında birleşik özet

Rol	Yöntem	EA	PCR	DLV_mean	LLM_mean (s)	E2E_mean (s)
manager_user	RLS_Agent	1.0000	1.0000	0.0	2.7670	2.7889
manager_user	Prompt_Only	1.0000	1.0000	0.0	3.6576	3.6753
region_director_user	RLS_Agent	1.0000	1.0000	0.0	3.5272	3.5524
region_director_user	Prompt_Only	1.0000	1.0000	0.0	6.3907	6.4129
project_lead_user	RLS_Agent	0.9833	0.9833	0.0	5.5446	5.5703
project_lead_user	Prompt_Only	1.0000	1.0000	0.0	6.6159	6.6379
compliance_user	RLS_Agent	0.7500	1.0000	0.0	5.5669	5.6359
compliance_user	Prompt_Only	0.6833	0.6417	311.5	10.6493	10.6709
analyst_user	RLS_Agent	1.0000	1.0000	0.0	3.5188	3.5413
analyst_user	Prompt_Only	1.0000	0.0000	2512.0	3.9694	3.9895

Yürütüm doğruluğu (EA) değerleri iki yöntem arasında benzer aralıklarda kalmakla birlikte, deterministik zorlamanın doğruluk üzerinde anlamlı bir negatif etki oluşturmadığı gözlemlenmiştir.

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Gecikme analizleri, uçtan uca sürenin baskın olarak model kaynaklı olduğunu ve veritabanı katmanına taşınan güvenlik mekanizmasının ek yükünün sınırlı kaldığını göstermektedir. Genel olarak sonuçlar, güvenlik zorlamasının veri katmanında uygulanmasının hem politika uyumunu artırdığını hem de performans açısından kabul edilebilir bir maliyet profili sunduğunu ortaya koymaktadır.



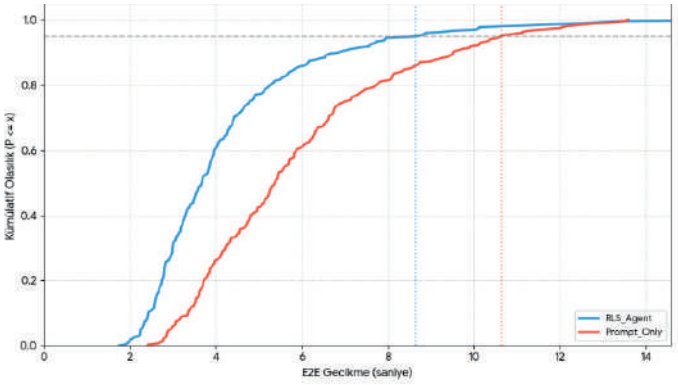
Şekil 2. Senaryo bazında E2E_mean karşılaştırması

TARTIŞMA

Deneysel bulgular, politika duyarlı Text-to-SQL üretiminde güvenlik zorlamasının uygulandığı katmanın sistem davranışı üzerinde belirleyici olduğunu göstermektedir. RLS_Agent yaklaşımının yüksek politika uyumu oranı ve sıfıra yakın veri sızıntısı değerleri üretmesi, erişim kontrolünün deterministik olarak veri katmanında uygulanmasının model tabanlı kısıtlara kıyasla daha güvenilir sonuçlar sunduğunu ortaya koymaktadır. Prompt_Only yaklaşımında gözlemlenen ihlaller, istem düzeyinde tanımlanan rol kısıtlarının modelin olasılıksal doğası nedeniyle her zaman korunamadığını göstermektedir. Özellikle sınırlı erişim yetkisine sahip kullanıcı rollerinde ortaya çıkan veri sızıntıları, güvenlik katmanının modelden bağımsızlaştırılması gerektiğini desteklemektedir. Literatürde büyük dil modellerinin olasılıksal yapısı genellikle esneklik ve genelleme avantajı sağlasa da, bu çalışmada deterministik yaklaşımın öne çıkmasının temel nedeni güvenlik zorlamasının veri katmanına taşınmasıdır. Prompt_Only yaklaşımında erişim sınırları model davranışına bağlı kalırken, RLS_Agent mimarisi erişim kontrolünü veritabanı düzeyinde zorlayarak model hatalarından bağımsız bir güvenlik katmanı oluşturmuştur. Bu durum özellikle yüksek riskli DENY senaryolarında veri sızıntısını ortadan kaldırmış ve deterministik mekanizmaların güvenlik açısından olasılıksal modellere tamamlayıcı bir rol oynayabileceğini göstermiştir. Yürütüm doğruluğu değerlerinin iki yöntem arasında benzer seviyelerde kalması, deterministik zorlamanın doğruluk performansını olumsuz etkilemediğini göstermektedir. Gecikme analizleri ise uçtan uca sürenin büyük ölçüde model kaynaklı olduğunu ve veritabanı katmanında uygulanan güvenlik mekanizmasının ek performans maliyetinin sınırlı kaldığını

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ISBN: 978-9952-610-30-7

ortaya koymaktadır. Bu çalışmada E2E (End-to-End) gecikme süresi, kullanıcı sorgusunun modele iletilmesinden veritabanı sonucunun elde edilmesine kadar geçen toplam uçtan uca işlem süresini ifade etmektedir.



Şekil 3. E2E Gecikme Sürelerinin Kümülatif Dağılım Fonksiyonu (CDF)

SONUÇ

Bu çalışma, politika duyarlı Text-to-SQL sistemlerinde güvenliğin yalnızca istem düzeyinde tanımlanmasının kurumsal kullanım için yeterli olmadığını ve erişim kontrolünün deterministik veritabanı mekanizmaları ile zorlanmasının daha güvenilir bir yaklaşım sunduğunu göstermektedir. Önerilen RLS_Agent mimarisi, veri sızıntısını engelleyerek politika uyumunu artırmış ve performans açısından kabul edilebilir bir gecikme profili sergilemiştir. Çalışmanın en önemli katkısı, güvenlik değerlendirmesini yürütüm doğruluğunun ötesine taşıyarak politika uyumu ve veri sızıntısı gibi nicel metriklerle ele almasıdır. Bununla birlikte deneylerin tek model altyapısı ve sınırlı ölçekli bir kurumsal şema üzerinde gerçekleştirilmiş olması genellenebilirlik açısından bir sınırlılık oluşturmaktadır. Gelecek çalışmalarda farklı büyük dil modelleri ve dinamik politika yapıları incelenirken, güvenilir kurumsal Text-to-SQL sistemleri için olasılıksal LLM üretimi ile deterministik veritabanı güvenlik mekanizmalarının birlikte tasarlanmasının kritik olduğu değerlendirilmektedir.

KAYNAKLAR

Bertino E, Kundu A 2023. Trustworthy AI and data security challenges in large language model systems. Journal of Data Security and Privacy, 6(2): 101-118.

Derakhshan R, Rahman MA, Azad MA 2023. Row-Level Security enforcement in multi-tenant database applications. IEEE Access, 11: 44521-44534.

Dou Z, Gao J, Li X, Wang Y 2024. Text-to-SQL in the era of large language models: A survey. ACM Computing Surveys, 56(4): 1-36.

Gao L, Chen Y, Zhang Q 2023. Execution-guided error correction for Text-to-SQL generation. Proceedings of the International Conference on Data Engineering, pp. 1142–1153.

Greshake K, Abdelnabi S, Mishra S, Endres C 2023. More than you asked for: Indirect prompt injection attacks against large language models. arXiv preprint arXiv:2302.12173.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Li Y, Sun T, Zhou H 2024. Can large language models serve as reliable database interfaces? Empirical evaluation and analysis. Information Systems, 118: 102274.

Liu Y, Wang H, Zhao L 2024. Prompt injection attacks and defenses in LLM-integrated systems: A systematic review. Computers & Security, 134: 103354.

Perez F, Ribeiro I 2023. Ignore previous instructions: A study on prompt injection vulnerabilities in language models. arXiv preprint arXiv:2211.09527.

PostgreSQL Global Development Group 2024. PostgreSQL 16 Documentation: Row-Level Security Policies. Available at: https://www.postgresql.org/docs/16/ddl-rowsecurity.html

OpenAI 2024. GPT Models API Documentation. Available at: https://platform.openai.com/docs

Sandhu R 2022. Access control models for big data and AI-driven systems. IEEE Security & Privacy, 20(3): 74-81.

Sun L, Zhang M, Chen H 2024. Quantifying data leakage risks in large language models. Future Generation Computer Systems, 152: 231-243.

Zou A, Wang Z, Kolter JZ, Fredrikson M 2023. Universal and transferable adversarial attacks on aligned language models. Advances in Neural Information Processing Systems.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

NATURAL PRODUCT-BASED MANAGEMENT OF HYPERGLYCEMIA: COMPUTATIONAL AND EXPERIMENTAL ANALYSIS OF CAFFEIC ACID AND PEITC

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ABSTRACT

In the management of type 2 diabetes, inhibition of the alpha-amylase enzyme, responsible for carbohydrate digestion, is one of the key strategies for controlling postprandial blood glucose levels. In this study, the effects of acarbose, a standard inhibitor, and the naturally occurring compounds caffeic acid and phenethyl isothiocyanate (PEITC) on human pancreatic amylase (HPA) and salivary amylase were comprehensively investigated using in vitro and in silico methods. In the experimental phase, enzyme activities were analyzed spectrophotometrically. Acarbose (0.1–10 mM), caffeic acid (0.1–200 mM), PEITC (12.5–200 mM), and DMSO (12.5–200 mM) were tested. In vitro results showed that all compounds exhibited dose-dependent inhibition on both amylase isoforms. Caffeic acid emerged as the most potent natural inhibitor candidate, achieving a 91.96% inhibition rate on HPA at a concentration of 25 mM. PEITC, on the other hand, showed higher efficacy on salivary amylase (49.02%) compared to the pancreatic isoform. In the molecular docking (in silico) phase of the study, the interactions of the compounds with the enzyme active site were modeled and their binding free energies were calculated. Caffeic acid showed the highest affinity with a binding energy of -6.2 kcal/mol, while this value was determined as -4.4 kcal/mol for PEITC. The lower binding energy of caffeic acid correlates perfectly with the high inhibition percentages observed in in vitro experiments. The stable interactions of the phenolic structure with the catalytic amino acid residues in the active site form the basis of this numerical superiority. In conclusion, the specific inhibitory effects of caffeic acid and PEITC on amylase isoforms have been proven with numerical and modeling data. Our findings suggest that caffeic acid, with its exhibited binding affinity and inhibition level, has the potential to be a significant candidate in the development of natural agents that could be alternatives to standard treatments.

Keywords: Diabetes Mellitus, Human Pancreatic α-Amylase (HPA), Caffeic Acid, Phenethyl Isothiocyanate (PEITC), Molecular Docking

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BALANCING PRIVACY AND UTILITY IN MACHINE LEARNING: A STUDY ON DATA ANONYMIZATION AND MODEL PERFORMANCE

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ABSTRACT

The increasing integration of artificial intelligence (AI) into data-driven decision-making processes has raised concerns about privacy and the ethical use of personal information. This study investigates the impact of **data anonymization techniques** on the predictive performance of AI models, focusing on the **privacy–utility trade-off**. Using the publicly available **Titanic dataset**, three fundamental anonymization methods **generalization**, **suppression**, and **derivation** were applied to reduce data identifiability while retaining analytical usability. Both the original and anonymized preprocessed datasets were evaluated using a **logistic regression** classifier to measure performance differences. Model evaluation criteria include accuracy, precision, recall, F1 score, and ROC-AUC.

Results indicate a moderate decrease in predictive capability after anonymization, with a **7% reduction in accuracy** and a **6% decline in AUC**, primarily due to information loss from generalization and partial suppression. However, the anonymized dataset maintained a satisfactory **ROC-AUC above 0.78**, demonstrating that basic anonymization can effectively safeguard privacy without severely impairing model performance. The findings support the notion that **feature-aware anonymization** enables organizations to achieve compliance with privacy regulations such as **GDPR** (General Data Protection Regulation) and **KVKK**, while sustaining sufficient model reliability for analytical applications.

Keywords: Data Anonymization, Machine Learning, Logistic Regression, Privacy–Utility Trade-off, Artificial Intelligence.

INTRODUCTION

In the era of data-driven decision-making, organizations increasingly rely on large-scale datasets to train artificial intelligence (AI) and machine learning (ML) models. However, many real-world datasets contain sensitive personal information, raising substantial concerns regarding privacy

protection and regulatory compliance. Frameworks such as the General Data Protection Regulation (GDPR) and similar national data protection laws have intensified the need for privacy-preserving data processing mechanisms.

Data anonymization has long been recognized as a fundamental strategy to mitigate re-identification risks while maintaining analytical usability. Early structured privacy models—including k-anonymity, ℓ-diversity, and t-closeness—were developed to protect individuals from linkage attacks by transforming quasi-identifiers through generalization and suppression (Sweeney, 2002; Machanavajjhala et al., 2007; Li et al., 2007). These approaches reduce identifiability by ensuring group-based indistinguishability or distributional similarity within equivalence classes.

Subsequently, differential privacy introduced a probabilistic framework that provides formal mathematical guarantees by limiting the influence of any single individual's record on analytical outputs (Dwork, 2006; Dwork and Roth, 2014). Together, these theoretical models form the backbone of modern privacy-preserving data analysis.

As AI systems became increasingly embedded in decision-making processes, research attention shifted toward understanding how privacy-preserving mechanisms influence predictive performance. Recent empirical studies emphasize the inherent tension between confidentiality and model accuracy—commonly referred to as the privacy–utility trade-off (Gadotti et al., 2024; Im et al., 2024). Experimental findings across domains such as healthcare and cybersecurity indicate that anonymization techniques, particularly feature coarsening and suppression, may lead to measurable performance degradation depending on dataset characteristics and anonymization intensity (Im et al., 2024; Ohno-Machado et al., 2002).

Despite significant advances in formal privacy models and domain-specific evaluations, comparative empirical analyses of simple and reproducible anonymization techniques applied to standard benchmark datasets remain relatively limited. In particular, systematic pre- and post-anonymization comparisons using interpretable baseline classifiers such as logistic regression are underrepresented in the literature.

This study addresses this gap by empirically evaluating how basic anonymization techniques—generalization, suppression, and derivation—affect classification performance on a publicly available benchmark dataset under controlled experimental conditions. The objective is to quantify the resulting performance variation and to contribute empirical evidence to the ongoing discussion on the privacy–utility trade-off in applied machine learning settings.

MATERIALS AND METHODS

The dataset used in this study is the *Titanic: Machine Learning from Disaster* dataset obtained from the Kaggle open-source repository. It contains demographic and travel-related information of passengers aboard the RMS Titanic. The dataset includes 891 labeled records with survival outcomes

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

and 418 unlabeled test records. Only the labeled portion was used for model training and evaluation, while the unlabeled data were excluded from performance analysis.

The labeled dataset was divided into training and test subsets using a stratified 70–30 split with a fixed random seed to ensure reproducibility and class balance.

The primary features selected for this study include **Pclass, Sex, Age, SibSp, Parch, Fare, and Embarked**, with the target variable defined as **Survived**, representing whether the passenger survived (1) or did not survive (0).

The variable ***Parch*** (Parents/Children aboard) represents the number of parents and children traveling with a given passenger. This attribute reflects immediate family connections on board and contributes to the relational structure of the dataset. While such information may provide predictive signal for survival outcomes, it may also increase indirect identifiability by revealing family composition patterns. For this reason, in the anonymization phase, Parch was not retained in its original detailed form but was integrated into a derived variable (FamilySize) to reduce granularity while preserving structural relevance.

Several preprocessing steps were applied to ensure data quality and model compatibility. Missing values in the *Age* and *Fare* columns were imputed using median values (with age imputed within passenger class groups to preserve structural consistency). Missing categorical values in *Embarked* were filled using the mode. Columns containing direct identifiers or exhibiting excessive missingness (*Cabin, Ticket, Name*) were removed to reduce identifiability risk.

Categorical variables (*Sex* and *Embarked*) were label-encoded. Continuous variables (*Age, Fare, SibSp, Parch*) were normalized using Min–Max scaling to ensure balanced feature contribution during model training. After preprocessing, the dataset was standardized to provide a consistent baseline for anonymization and modeling.

To investigate the impact of data anonymization on model performance, three fundamental anonymization techniques **generalization, suppression, and derivation** were applied to the preprocessed dataset. These techniques are widely discussed in the privacy-preserving data analysis literature (Gadotti et al., 2024; Im et al., 2024; Sweeney, 2002).

The objective was to reduce attribute granularity and indirect identifiability while maintaining sufficient analytical utility for predictive modeling.

(a) Generalization

Continuous variables *Age* and *Fare* were transformed into categorical intervals. *Age* was grouped into four ranges: Child (0–12), Young (13–30), Adult (31–50), and Senior (51–80). *Fare* was grouped into Low (0–50), Medium (51–200), and High (201–600).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Generalization reduces precision and limits re-identification risk by coarsening quasi-identifiers, as described in classical k-anonymity frameworks (Sweeney, 2002). However, reducing feature granularity may weaken decision boundaries and decrease predictive performance.

(b) Suppression

Approximately 10% of the categorical values in *Sex* and *Embarked* were replaced with a suppression token (–1). This partial masking simulates real-world anonymization scenarios in which certain quasi-identifiers are concealed to mitigate re-identification risk (Ohno-Machado et al., 2002).

Suppression directly removes attribute specificity and may introduce uncertainty into the feature space, potentially affecting classification performance depending on the predictive strength of the suppressed attributes.

(c) Derivation

The variables *SibSp* and *Parch* were combined into a new feature defined as:

FamilySize = SibSp + Parch + 1

This derived attribute preserves relational context while removing detailed family composition information. Derivation may reduce specificity while retaining structural relevance, thereby limiting information loss compared to direct suppression or coarse generalization.

Following these transformations, the anonymized dataset maintained structural compatibility with the original dataset, enabling direct performance comparison under controlled experimental conditions.

Logistic Regression was selected as the baseline classifier due to its interpretability, mathematical transparency, and suitability for binary classification tasks. Unlike complex ensemble or deep learning models, Logistic Regression allows direct interpretation of feature coefficients, making it particularly appropriate for privacy-sensitive analytical settings.

The probability estimation function is defined as:

$$P(y = 1 \mid x) = \frac{1}{1 + e^{-(\beta_0 + \sum \beta_i x_i)}}$$

where $\beta_i$represents the coefficients associated with feature x_i. Parameters were optimized using maximum likelihood estimation.

Maximum Likelihood Estimation (MLE) optimizes the model parameters by maximizing the likelihood of observing the given training data under the logistic regression model. Specifically, the method adjusts the coefficient values so that the predicted probabilities align as closely as possible with the true class labels. In practice, this corresponds to minimizing the negative log-likelihood (also known as log-loss), which penalizes confident but incorrect predictions more heavily than uncertain

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ones. The optimization process was performed using the LBFGS algorithm, a quasi-Newton method that efficiently approximates second-order derivatives to converge toward the global optimum in convex problems such as logistic regression.

Both the original and anonymized datasets were trained using identical hyperparameters to ensure fair comparison: the LBFGS optimizer, maximum iterations = 1000, and regularization parameter $C = 1.0$. All preprocessing steps were kept consistent across both datasets to avoid confounding effects.

The probability estimation function is employed to model the conditional likelihood of class membership given the input features. Rather than directly predicting class labels, logistic regression estimates the probability that an instance belongs to the positive class. This probabilistic formulation enables threshold-independent evaluation through metrics such as ROC-AUC and allows a more nuanced assessment of model behavior under varying decision thresholds. In the context of privacy–utility analysis, probability-based modeling is particularly valuable, as anonymization may alter confidence distributions even when overall classification accuracy remains relatively stable.

Model performance was evaluated using **Accuracy, Precision, Recall, F1-score, and ROC-AUC**. These metrics collectively capture overall predictive correctness and class-specific discrimination capability (Fawcett, 2006; Bradley, 1997). In particular, ROC-AUC provides a threshold-independent assessment of ranking performance, making it especially suitable for evaluating classification models under varying decision thresholds (Fawcett, 2006).

The logistic regression model was evaluated on the held-out test set for both the original and anonymized datasets.

The model trained on the original dataset achieved:

- Accuracy = 0.7948
- Precision = 0.7449
- Recall = 0.7087
- F1-score = 0.7264
- ROC-AUC = 0.8514

The anonymized dataset yielded:

- Accuracy = 0.7228
- Precision = 0.6632
- Recall = 0.5643
- F1-score = 0.6098

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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- ROC-AUC = 0.7881

The observed decreases correspond to approximately 7 percentage points in Accuracy and 6 percentage points in ROC-AUC, with a more pronounced decline in Recall (approximately 14 percentage points).

These results indicate a measurable reduction in predictive performance following anonymization. The most substantial decrease was observed in Recall, suggesting an increased rate of false-negative predictions in the anonymized setting. This pattern implies that feature coarsening and partial suppression may reduce the model's sensitivity to the positive class.

Although formal privacy risk metrics were not computed, the applied transformations reduced feature granularity and attribute specificity. Despite the observed performance decline, the anonymized model retained a ROC-AUC above 0.78, indicating preserved ranking capability under the evaluated conditions.

Overall, the findings reflect a quantifiable privacy–utility trade-off, with controlled performance degradation after anonymization.

Table 1. Comparison of Logistic Regression Performance on Original vs Anonymized Data

Metrics	Original Dataset	Anonymized Dataset	Change
Accuracy	0.7948	0.7228	↓ 0.072
Precision	0.7449	0.6632	↓ 0.082
Recall	0.7087	0.5643	↓ 0.144
F1-Score	0.7264	0.6098	↓ 0.117
ROC-AUC	0.8514	0.7881	↓ 0.063

RESULTS

Figure 1 presents a comparative illustration of the logistic regression model's performance before and after data anonymization. The figure illustrates variations in key classification metrics—Accuracy, Precision, Recall, F1-score, and ROC-AUC—across both datasets. A consistent decrease was observed in all metrics following anonymization, reflecting the expected reduction in predictive utility associated with decreased attribute granularity.

The model trained on the original dataset achieved an Accuracy of 0.7948, Precision of 0.7449, Recall of 0.7087, F1-score of 0.7264, and ROC-AUC of 0.8514. In contrast, the anonymized dataset yielded lower results: Accuracy = 0.7228, Precision = 0.6632, Recall = 0.5643, F1-score = 0.6098, and ROC-

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AUC = 0.7881. These differences correspond to approximately 7 percentage points in Accuracy, 6 percentage points in ROC-AUC, and a more pronounced decline of 14 percentage points in Recall.

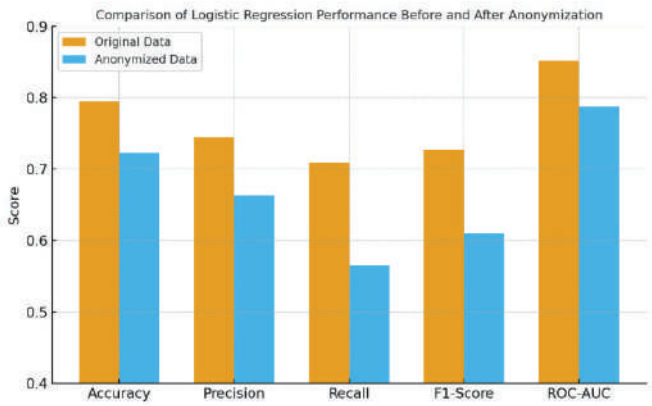
Figure 2 presents the ROC curves for both datasets. Although the anonymized model's curve lies below that of the original model, the AUC difference (approximately 0.06) suggests that the classifier retains substantial ranking capability after anonymization. The practical significance of this difference depends on the selected decision threshold and the specific application context.

Detailed analysis of the classification results indicates increases in both false positives and false negatives in the anonymized setting. The larger decline in Recall suggests reduced sensitivity to the positive class after feature coarsening, indicating a higher frequency of false-negative predictions.

When analyzing the relative contribution of anonymization components, generalization appears to have contributed more substantially to performance degradation. Transforming continuous variables (Age and Fare) into categorical intervals reduced variance and potentially weakened decision boundaries. Suppression, applied to approximately 10% of Sex and Embarked values, introduced limited uncertainty and appears to have had a comparatively smaller impact. Derivation, implemented through the FamilySize attribute, preserved relational structure and seems to have demonstrated the least negative influence on predictive performance.

The magnitude of the observed performance decline—approximately 5–10 percentage points across key metrics—is consistent with moderate anonymization intensity in controlled experimental settings. While formal privacy risk metrics were not computed, the applied transformations reduced feature granularity and indirect identifiability. Despite performance reductions, the anonymized model maintained a ROC-AUC above 0.78, indicating preserved discriminatory capability under the evaluated conditions.

Overall, the results demonstrate a measurable reduction in predictive utility while retaining substantial classification capacity. These findings reflect the inherent balance between data protection and analytical performance in privacy-aware machine learning systems.



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Figure 1. Comparative classification performance of the Logistic Regression model trained on the original and anonymized Titanic datasets.

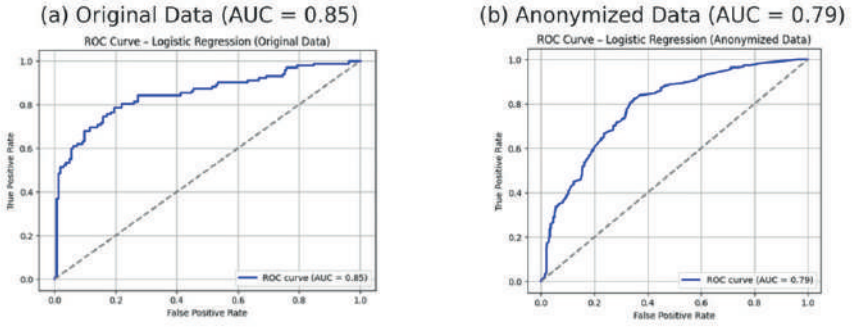


Figure 2. Receiver Operating Characteristic (ROC) curves for Logistic Regression models trained on the original and anonymized datasets.

DISCUSSION

The observed empirical pattern aligns with foundational privacy models such as k-anonymity, ℓ-diversity, and t-closeness, which reduce re-identification risk through generalization and suppression at the cost of information loss (Sweeney, 2002; Machanavajjhala et al., 2007; Li et al., 2007). Differential privacy introduces formal probabilistic guarantees by injecting calibrated noise, further shifting the privacy–utility balance (Dwork, 2006; Dwork and Roth, 2014).

Recent empirical research emphasizes the inherent tension between confidentiality and predictive performance, commonly referred to as the privacy–utility trade-off (Im et al., 2024). Empirical findings suggest that the magnitude of performance degradation depends on dataset structure, feature importance, and anonymization intensity (Im et al., 2024; Ohno-Machado et al., 2002).

The observed performance decline can be primarily attributed to information loss induced by feature transformation. Generalization reduces feature variance by converting continuous variables into broader categorical intervals, thereby weakening the model's ability to capture fine-grained decision boundaries. In logistic regression, coefficient estimation relies on linear separability within the transformed feature space; when variability is compressed, the discriminative signal diminishes. Suppression introduces additional uncertainty by masking portions of categorical attributes. When predictive features such as Sex are partially obscured, the model receives incomplete information, increasing the likelihood of misclassification. This effect is particularly visible in the Recall metric,

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where the anonymized model demonstrates a higher false-negative rate. Reduced sensitivity to the positive class suggests that anonymization weakened feature–target associations critical for survival prediction. Derivation, in contrast, preserved relational context by aggregating family-based attributes into a composite variable (FamilySize), resulting in comparatively limited performance degradation. Overall, the reduction in Accuracy and ROC-AUC reflects the inherent privacy–utility trade-off: as attribute granularity decreases to reduce identifiability, the statistical structure available for predictive modeling is partially constrained.

It is important to emphasize that anonymization strategies are not universally transferable across all datasets. The effectiveness and impact of generalization, suppression, or derivation depend heavily on dataset characteristics such as sample size, feature distribution, class imbalance, correlation structure, and the predictive strength of quasi-identifiers. In small or highly imbalanced datasets, aggressive suppression may result in substantial information loss, whereas in high-dimensional datasets, coarse generalization may disproportionately weaken decision boundaries. Therefore, anonymization should be context-aware and data-driven rather than applied through fixed or universal transformation rules.

For institutions handling sensitive data (e.g., healthcare, finance, and public administration), several practical considerations emerge:

Feature-aware anonymization: Apply stronger generalization to low-signal attributes while preserving granularity for highly predictive features. Targeted suppression may help mitigate recall degradation.

Policy-driven thresholds: Define acceptable utility loss levels (for example, 5–10 percentage points in Accuracy or AUC) before deployment and select anonymization strategies accordingly.

Continuous evaluation: Report predictive performance metrics alongside transformation parameters to support transparency and reproducibility. Ongoing monitoring is necessary to maintain analytical reliability over time.

Future research may extend this work along several dimensions:

Adaptive anonymization strategies: Explore entropy-based or quantile-based binning instead of fixed intervals and evaluate per-feature privacy allocation informed by formal privacy frameworks.

Model diversity: Assess the impact of anonymization across different model families, including ensemble and calibrated linear models, to examine variation in performance sensitivity.

Hybrid privacy mechanisms: Compare classical anonymization frameworks with differential privacy under a unified evaluation protocol and analyze privacy–utility trade-offs using Pareto frontiers.

Fairness and robustness: Investigate whether anonymization disproportionately affects specific subgroups and evaluate robustness under distribution shifts or adversarial disclosure scenarios.

Operational frameworks: Develop structured evaluation guidelines integrating anonymization parameters, utility metrics, and governance considerations to support responsible data-sharing practices.

CONCLUSION

This study quantitatively examined how basic data anonymization techniques influence predictive performance in a binary classification setting using the Titanic benchmark dataset.

The logistic regression model trained on the original dataset achieved an Accuracy of 0.7948 and a ROC-AUC of 0.8514, whereas the anonymized version achieved an Accuracy of 0.7228 and a ROC-AUC of 0.7881. The most pronounced decline was observed in Recall (approximately 14 percentage points), indicating an increase in false-negative classifications following anonymization.

Component-level analysis suggests that generalization (binning Age and Fare) appears to have contributed more substantially to utility loss by reducing fine-grained variance relevant for decision boundary formation. Suppression (approximately 10% masking in Sex and Embarked) introduced moderate uncertainty with comparatively limited impact. Derivation (FamilySize) preserved relational structure and appears to have demonstrated the least detrimental influence on predictive stability.

Overall, the findings indicate a measurable reduction in predictive utility—approximately 7 percentage points in Accuracy and 6 percentage points in ROC-AUC—following anonymization. Although formal privacy risk metrics were not computed, the applied transformations reduced attribute granularity and indirect identifiability. Under the evaluated conditions, the anonymized model retained substantial discriminatory capability (ROC-AUC> 0.78), suggesting that basic anonymization techniques may preserve acceptable analytical performance in controlled settings.

REFERENCES

Bradley AP 1997. The use of the area under the ROC curve in the evaluation of machine learning algorithms. Pattern Recognition, 30(7): 1145–1159.

Dwork C 2006. Differential privacy. Proceedings of the 33rd International Colloquium on Automata, Languages and Programming, 1–12.

Dwork C, Roth A 2014. The algorithmic foundations of differential privacy. Boston: Now Publishers.

Fawcett T 2006. An introduction to ROC analysis. Pattern Recognition Letters, 27(8): 861–874.

Gadotti A, Rocher L, Houssiau F, Cretu AM, de Montjoye YA 2024. Anonymization: The imperfect science of using data while minimizing privacy risk. Science Advances, 10(29): eadn7053.

Im E, Kim H, Lee H, Jiang X, Kim JH 2024. Exploring the tradeoff between data privacy and utility with a clinical data analysis use case. BMC Medical Informatics and Decision Making, 24(1): 147.

Li N, Li T, Venkatasubramanian S 2007. t-closeness: Privacy beyond k-anonymity and l-diversity. Proceedings of the IEEE 23rd International Conference on Data Engineering, 106–115.

Machanavajjhala A, Gehrke J, Kifer D, Venkitasubramaniam M 2007. l-diversity: Privacy beyond k-anonymity. ACM Transactions on Knowledge Discovery from Data, 1(1): Article 3.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Ohno-Machado L, Silva GB, Freitas CM 2002. Effects of data anonymization by cell suppression on descriptive statistics and predictive modeling performance. Journal of the American Medical Informatics Association, 9(3): 419–433.

Sweeney L 2002. Achieving k-anonymity privacy protection using generalization and suppression. International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems, 10(5): 571–588.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PERFORMANCE ANALYSIS OF YOLOv8 AND FASTER R-CNN FOR DETECTING UNWANTED WORKPLACE BEHAVIOR WITH LIMITED DATASET

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ABSTRACT

The success of deep learning-based object detection models generally relies on large-scale datasets and extensive training durations. However, industrial applications and specific domain problems often require high performance under constraints of limited data and computational budget. The primary objective of this study is to comparatively analyze the performance of one-stage (YOLOv8) and two-stage (Faster R-CNN) object detection architectures within these constraints. A small-scale unwanted workplace behavior dataset consisting of only 300 images was utilized for the experiments, applying both transfer learning with COCO weights and training from scratch strategies to evaluate the models' adaptability. Experimental results indicated a dramatic disparity in computational efficiency; YOLOv8 models completed training in approximately 35 minutes, whereas Faster R-CNN models required between 6 hours 43 minutes and 6 hours 57 minutes, demonstrating that YOLOv8 is approximately 12 times faster. In terms of accuracy, the YOLOv8 (Pretrained) model achieved a remarkable 99.25% mAP@50 and 82.26% mAP@50-95, significantly outperforming the Faster R-CNN (Pretrained) model, which scored 93.06% mAP@50 and 63.30% mAP@50-95. The most critical finding was observed in the training from scratch scenarios. The YOLOv8 Scratch model achieved 85.35% mAP@50 and 52.22% mAP@50-95, showcasing high generalization capability thanks to its mosaic augmentation and modern architecture. In contrast, the Faster R-CNN Scratch model suffered from overfitting and convergence issues, remaining at 42.27% mAP@50 and only 18.72% mAP@50-95. The analysis proves that the YOLOv8 architecture is superior to Faster R-CNN in terms of speed, accuracy, and data efficiency for resource-constrained projects.

Keywords: Object Detection, YOLOv8, Faster R-CNN, Transfer Learning, Limited Dataset, Computational Efficiency.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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INTRODUCTION

Serious injuries in construction and manufacturing are rarely random. A significant share traces back to PPE failures: a worker without a hard hat, safety glasses left on a shelf. Human-based compliance monitoring has an inherent ceiling — inspectors cannot watch everything, fatigue sets in, and large multi-zone facilities create blind spots no reasonable staffing level can fully close. Automated camera systems have emerged as a practical response to this, but deploying them depends on solving a problem that benchmark papers tend to sidestep: real industrial environments rarely yield the thousands of labeled images these models were designed around.

In most industrial settings, that data is hard to come by. Building a useful annotated image corpus requires domain expertise to label correctly, cooperation from site management to allow filming, and navigation of privacy constraints that vary by jurisdiction. The result is that organizations seeking to deploy such systems often work with a few hundred images at most, far short of the tens of thousands assumed by standard benchmarks. Whether useful models can be trained under such conditions is therefore not an academic question.

The object detection literature has long been divided along a speed-accuracy axis. Two-stage detectors (Faster R-CNN being the benchmark example) first generate region proposals via an RPN, then classify each candidate, an approach that historically delivers high precision but at considerable computational cost. YOLO-family one-stage detectors treat detection as a direct regression over the image grid, trading some precision for much faster inference. With YOLOv8, that precision gap has narrowed further, but whether this holds when labeled data is extremely limited has not been directly examined.

This paper addresses that gap directly. We trained YOLOv8m and Faster R-CNN (ResNet-50 FPN) on a 300-image PPE dataset (212 training images, 44 validation, 44 test) under two conditions: random initialization and COCO-pretrained initialization. Hardware was fixed at a single NVIDIA T4 GPU throughout. The results show that pretrained YOLOv8 achieves near-perfect mAP@50 (99.25%) while training roughly 12 times faster than Faster R-CNN; more tellingly, even the scratch-initialized YOLOv8 outperforms pretrained Faster R-CNN on the stricter mAP@50-95 metric. The practical implication is that small-data safety monitoring is feasible with the right architecture.

MATERIALS AND METHODS

Dataset Preparation

The dataset consists of 300 images representing two PPE classes: hard hat ("baret") and safety glasses ("gozluk"). Splits were fixed at 212/44/44 for training, validation, and testing. Every image was resized to 640×640 pixels before ingestion; the same resolution was used for both architectures to keep that variable fixed.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Experimental Setup and Hardware

Training ran on Google Colab, using a single NVIDIA Tesla T4 (15 GB VRAM). A shared cloud GPU of this tier is roughly analogous to what a small industrial R&D team might have available, so it serves as a representative hardware baseline.

Architectures and Training Strategies

The comparison pairs Faster R-CNN (ResNet-50 FPN backbone, standard RPN (see Figure 1) against YOLOv8m, the medium-scale member of the YOLOv8 family (Figure 2). Both ran for 100 epochs at batch size 4; no other hyperparameter differed between the two comparisons.

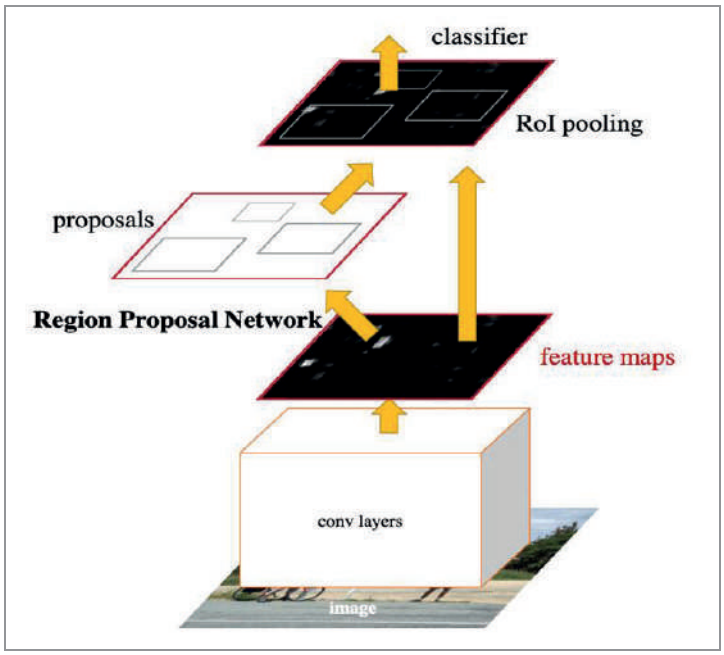


Figure 1. Architecture of the two-stage Faster R-CNN model (Ren et al., 2015).

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ISBN: 978-9952-610-30-7

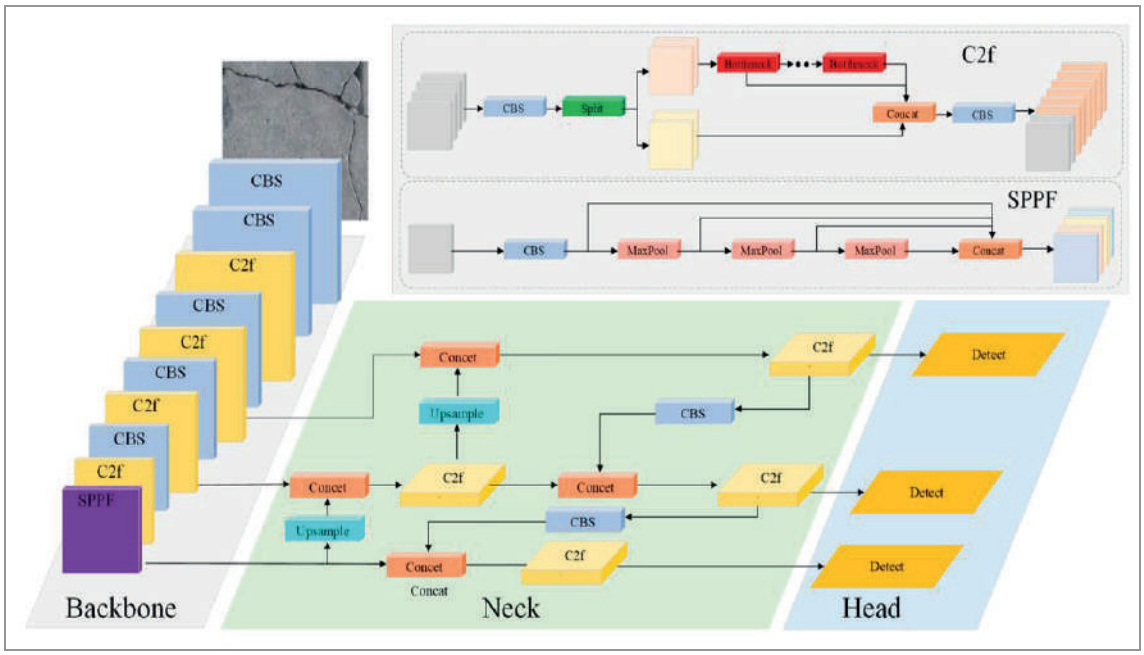


Figure 2. Architecture of the one-stage YOLOv8 model (Ma et al., 2026).

Two initialization strategies were used for each model:

Training from Scratch: No pre-existing weights were used; all parameters were drawn from random initialization and updated solely on the 212 training images. Faster R-CNN was optimized with SGD (lr = 0.02, momentum = 0.9, weight decay = 0.0005) and a MultiStepLR scheduler with decay at epochs 40, 70, and 90. YOLOv8 used AdamW (lr ≈ 0.0016), cosine annealing, and a 3-epoch warm-up.

Transfer Learning (Pre-trained): Models were initialized from weights trained on MS COCO. For Faster R-CNN, separate learning rates were set for the backbone and head: 0.001 for ResNet-50 (to keep low-level features stable) and 0.005 for the prediction head (to allow faster task adaptation). Milestones were at epochs 30, 60, and 90. YOLOv8 (yolov8m.pt) used the same AdamW/cosine schedule as in the scratch setting; the pre-trained weights simply provided a better starting point.

Data Augmentation

Both pipelines included augmentation to limit overfitting. For Faster R-CNN: random horizontal flips (p = 0.5) and color jitter (brightness, contrast, saturation, hue). YOLOv8 used its native suite, most importantly mosaic augmentation at p = 1.0, which tiles four images into one composite sample. This forces the network to deal with diverse scale and position combinations in every iteration. HSV adjustments and horizontal flips were included as well.

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RESULTS

Evaluation used mAP@50 and mAP@50–95, with wall-clock training time recorded as a secondary measure. All four configurations are shown in Table 1.

Table 1. Performance comparison of Faster R-CNN and YOLOv8 architectures

Model	Training Strategy	mAP@50 (%)	mAP@50-95 (%)	Training Time
Faster R-CNN	Scratch	42.27	18.72	06:57:44
Faster R-CNN	Pre-trained	93.06	63.30	06:43:49
YOLOv8	Scratch	85.35	52.22	00:35:02
YOLOv8	Pre-trained	99.25	82.26	00:34:55

The from-scratch results expose a fundamental weakness in Faster R-CNN on small datasets. With only 212 training images to work from, the RPN could not learn to generate reliable proposals; mAP@50 stalled at 42.27% and mAP@50–95 at 18.72%. COCO pre-training corrected this substantially, lifting scores to 93.06% and 63.30%, but the associated training time stayed at roughly seven hours in both Faster R-CNN variants, a serious practical drawback.

YOLOv8 without pre-training is a different story. Its scratch variant posted 85.35% mAP@50 and 52.22% mAP@50-95, numbers that are not only far ahead of the Faster R-CNN scratch run, but also exceed the pretrained Faster R-CNN on the stricter mAP@50-95 criterion. Training took 35 minutes. Single-pass regression avoids the RPN data bottleneck; mosaic augmentation does the rest by manufacturing compositional diversity from a limited pool.

Adding COCO pre-training pushed YOLOv8 to 99.25% mAP@50 and 82.26% mAP@50–95, the ceiling of this comparison. Training time: still 35 minutes, identical to the scratch run. The 12-fold speed advantage over Faster R-CNN is not a minor convenience; it changes what kinds of development cycles are feasible and whether frequent model re-training (as datasets grow) is economically viable.

DISCUSSION

Three findings from these experiments deserve attention separately, because each has different implications for practitioners.

First, the data sensitivity of the two-stage pipeline. Faster R-CNN's 42.27% mAP@50 from scratch is close to a failure mode for a two-class task. The RPN is the likely culprit: generating useful proposals requires learning what objects look like, and 212 images is not enough to anchor that process.

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YOLOv8 sidesteps this by treating detection as a dense regression. There is no explicit proposal stage to fail. Mosaic augmentation then compensates for training set size by artificially increasing spatial diversity: tiling four images into one sample forces the network to localize objects across varied scales and backgrounds within every forward pass. The 85.35% mAP@50 from scratch is a direct product of this design.

Second, the role of pre-training. Both architectures benefit from COCO weights, but in very different ways. For Faster R-CNN it was close to necessary: pre-training is what made the model learn at all. For YOLOv8 it was beneficial but not critical: the model was already producing useful predictions, and pre-training refined them further. This asymmetry matters when deciding how much weight to give transfer learning in a deployment pipeline. If COCO-domain shift is a concern (e.g., unusual camera angles or lighting), YOLOv8 remains a more viable option even without pre-training.

Third, training speed as an operational constraint. Seven hours per training run is not simply slower; it is slow enough to change what workflows are feasible. Annotating a new batch of images, retraining, and evaluating the delta becomes a multi-day cycle with Faster R-CNN; with YOLOv8 it fits in an afternoon. At sites where hazard profiles change (new equipment, seasonal variation, workforce turnover), rapid iteration is itself a safety feature.

CONCLUSION

A 300-image dataset is a severe constraint by any standard benchmark, yet pretrained YOLOv8 achieved 99.25% mAP@50 and 82.26% mAP@50–95 within 35 minutes of training, roughly 12 times faster than either Faster R-CNN run. That combination of accuracy and speed under constrained data is the core empirical finding of this work.

Faster R-CNN showed near-failure without pre-training (42.27% mAP@50), confirming that its region proposal mechanism needs more data than 212 images can provide. YOLOv8, in contrast, reached 85.35% from scratch, a margin large enough to matter in practice. COCO pre-training is still recommended when available, but it is not a prerequisite for useful performance. For teams that cannot easily amass large annotated datasets, this distinction is decisive.

Future work will focus on edge deployment on NVIDIA Jetson and Raspberry Pi platforms, testing whether the accuracy achieved here translates to real-time inference on hardware that can be installed directly at a construction site or manufacturing line, including testing under variable lighting and camera angles not represented in the current dataset.

REFERENCES

He K, Zhang X, Ren S, Sun J 2016. Deep residual learning for image recognition. Proceedings of the IEEE conference on computer vision and pattern recognition, 770-778.

Jocher G, Chaurasia A, Stoken A 2023. Ultralytics YOLOv8. Available at: https://github.com/ultralytics/ultralytics [21.02.2026]

Lin TY, Maire M, Belongie S, Hays J, Perona P, Ramanan D, Dollár P, Zitnick C 2014. Microsoft COCO: Common objects in context. European conference on computer vision, 740-755.

Ma C, Nie X, Fan P, Wang G 2026. A Developed YOLOv8 Model for the Rapid Detection of Surface Defects in Underground Structures. Buildings, 16: 610.

Ren S, He K, Girshick R, Sun J 2015. Faster R-CNN: Towards real-time object detection with region proposal networks. Advances in neural information processing systems, 28: 91-99.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A STUDY ON THE USE OF FINE-GRAINED POULTRY WASTE ASH IN SOIL IMPROVEMENT

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ABSTRACT

This study experimentally aims to evaluate the usability of "fine-grained poultry waste ash" as a sustainable and alternative soil stabilizer. The research is positioned at the intersection of agricultural waste management and the need for sustainable construction materials; it examines the potential of this biomass-derived ash to serve as an alternative to coal-based fly ash.

Within the scope of the study, low plasticity clay was mixed with fine-grained poultry waste ash at ratios of 0%, 5%, 10%, 15%, and 20% by weight. Particle size distribution (wet sieve analysis and hydrometer), Atterberg limits (liquid limit tests by Casagrande and cone penetrometer methods, and plastic limit test), Standard Proctor and Unconfined Compressive Strength (UCS) tests were performed on the soil and the mixtures. Strength development was also monitored over a one-day period.

The results showed an increase in optimum moisture content due to the higher water demand of the fine ash particles, and a decrease in maximum dry unit weight due to the effect of lower specific gravity. A significant increase in the strength parameters was obtained from the Unconfined Compressive Strength test with increasing additive ratios. The optimum strength performance additive ratio occurred at 15%.

The findings obtained aim to quantitatively reveal the geotechnical performance of fine-grained poultry waste ash and determine the optimal mixture design. This study contributes to waste management and offers an environmentally and economically sustainable soil improvement approach. By this, the research aims to provide a scientific contribution to the use of circular economy-based materials in geotechnical engineering.

Keywords: Low plasticity clay, Soil stabilization, Strength parameters, Fine-grained poultry waste ash (FPWA), Additive ratio, Optimal mixture design.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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INTRODUCTION

Soil stabilization is a technique that modifies soil to enhance its engineering properties, particularly by increasing shear strength and controlling shrink-swell behavior. This process improves load-bearing capacity, making soil more suitable for supporting foundations, pavements, and other structures. It involves adding stabilizing agents such as cement, lime, plastics, ceramics, or fly ash to soil in varying proportions to evaluate changes in its physical characteristics. The primary benefits of stabilization include increased bearing capacity, reduced permeability, and enhanced overall soil strength for engineering applications (Khan et al., 2020). Soil stabilization can be carried out in four ways: physical (compaction, drainage), mechanical (aggregate blending), geosynthetic (reinforcement with geotextiles), and chemical (adding binders like cement for pozzolanic reactions that boost strength) (Lim et al., 2014).

A major challenge in civil engineering arises when construction involves clay subgrade soils, which swell with increased moisture. Stabilization modifies clay behavior, reducing moisture-induced volume changes and improving load-bearing capacity. Cement and lime are the most common additives for pavement construction, though such high strength is not always required (Afrin, 2017).

Self-cementing fly ash also offers effective stabilization for fine-grained soils by increasing compacted dry density, reducing optimum moisture content, and providing rapid strength gain within the first 7–28 days of curing through pozzolanic reactions. Fly ash proves particularly valuable for clay soil improvement by drying wet soils during construction in unstable conditions and decreasing swell potential in expansive clays through volume replacement and particle cementation. Although hydrated and conditioned fly ash can increase soil strength, there are concerns regarding the environmental footprint of increased material extraction, transportation, and disposal, thus creating justification for exploring more sustainable and eco-friendly stabilizers that can deliver comparable benefits for clay soil improvement with reduced environmental impact (Afrin, 2017).

Rising global chicken consumption has created a substantial waste management challenge. Traditional disposal of poultry litter on farmland leads to water pollution, disease transmission, and greenhouse gas emissions. As a result, incineration addresses these concerns by destroying pathogens, reducing waste volume by up to 90 percent, and recovering energy (Jose et al., 2022).

Researchers are increasingly exploring sustainable soil stabilization methods using agricultural waste, with chicken byproducts emerging as a promising trend, for example, chicken feathers. These poultry byproducts, typically discarded and consisting of barbs, quills, and rachis, are cut into small pieces and mixed with soft soils. This approach offers dual benefits: reducing environmental pollution from waste while improving weak, void-rich soils through a cost-effective, renewable stabilization technique. Chicken feathers are also transformed into ash, a valuable resource containing calcium, silicon,

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magnesium, iron, and aluminum-elements that effectively enhance soil stabilization (Manoj et al., 2017).

In addition, chicken bone powder with limestone and cement has resulted in significant improvement in clay properties by decreasing liquid limit and plasticity index and increasing unconfined compressive strength by 2.69-fold with 10% bone powder plus 5% limestone, and 4.82-fold with 10% bone powder plus 5% cement after 28 days. In another study, chicken bone powder with limestone and cement improved clay strength 2.69-fold and 4.82-fold after 28 days, reducing cohesion from 37.08 kPa to 35.12 kPa and increasing friction angle from 0.66° to 2.10°. The optimal fly ash replacement in Bangkok clay was 15–20%, with optimal cement at 8% and 1% polyethylene fibers for maximum strength (Salih et al., 2024).

As can be seen from the literature summary above, although various materials, including bone powder, fly ash, and synthetic fibers, have been explored for soil improvement and stabilization, there appears to be no study specifically targeting ash derived from fine-grained poultry waste for geotechnical engineering purposes, as it may have been investigated only in agricultural applications such as fertilization. Existing research has primarily examined coal-based fly ash or chicken feather fibers, leaving the potential of fine-grained poultry waste ash largely unexplored. This research aims to fill that void by investigating the properties and stabilization potential of fine-grained poultry waste ash (FPWA) as an environmentally sustainable alternative.

MATERIALS AND METHODS

The soil used in this investigation consisted of a low plasticity clay (CL) sourced from Sakarya (Figure 1a). The stabilizing agent employed was Fine-Grained Poultry Waste Ash (FPWA), a residual by-product generated from the combustion of poultry waste for energy production. The natural soil was air-dried for 10 days, passed through a No. 4 sieve, then oven-dried at 105 ± 10°C for 72 hours (Figure 1b).



Figure 1. *Soil and Oven Dried Soil Sourced from Sakarya*

The moisture content obtained was 32,60% (ASTM D2216). The dried soil was passed through a No. 40 sieve and the passing fraction retained for testing. The stabilizing agent was Fine-Grained Poultry Waste Ash (FPWA), a combustion by-product from poultry waste was acquired in a finely grained state and used in its received form without any additional processing or modification (Figure 2).

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Figure 2. *Fine-Grained Poultry Waste Ash*

Physical Properties

Classification Tests

Physical properties of natural soil and Fine-Grained Poultry Waste Ash (FPWA) were determined following ASTM standards (D854 for specific gravity, D4318 for Atterberg limits, D422 and D7928 for particle size). The soil comprised 1,04% gravel, 22,82% sand, and 75,04% fines, classifying as low plasticity clay (CL). Specific gravity was 2,67. Plastic limit was 18,3%, while liquid limit values by Casagrande and cone penetrometer methods were 25,04% and 30,56% respectively, giving a plasticity index of 6,74%. FPWA exhibited fines-dominated characteristics with 85,66% passing the No. 200 sieve and 14,34% retained on No. 40. Specific gravity was 2,73. Plastic limit was 25,67%, with liquid limit values of 20,87% (Casagrande) and 38,64% (cone penetrometer).

Standard Compaction Test

Standard Proctor tests (ASTM D698) on the low plasticity clay from Sakarya gave an optimum moisture content of 18,89% and a maximum dry density of 15,94 kN/m³. To assess the effect of FPWA, the same procedure was applied to soil mixtures containing 0% (control), 5%, 10%, 15%, and 20% FPWA by dry soil weight, establishing the compaction parameters for each blend. Graphs showing the variation of OMC and MDD for each additive ratio are given in Figure 3.

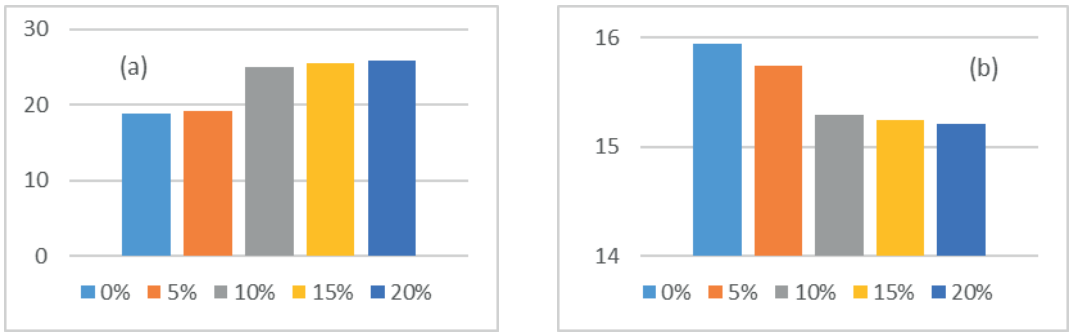


Figure 3. *Graphs of OMC (a) and MDD Variation (b)*

Unconfined Compressive Strength (UCS)

UCS tests were conducted following ASTM D2166 to assess strength development in untreated and FPWA-stabilized soil. Specimens were prepared at FPWA contents of 0%, 5%, 10%, 15%, and 20%

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using the respective optimum moisture content and maximum dry density determined from Standard Proctor compaction tests (ASTM D698) for each mixture. For each ratio, five replicate specimens were prepared to ensure reliability. The required dry soil and FPWA were blended, mixed with the calculated water quantity, and compacted into molds to achieve the target density. Specimens were immediately extracted and loaded axially at constant strain rate until failure. Maximum load was recorded, and compressive strength calculated by dividing load by cross-sectional area. Strength results were compared with untreated controls to quantify improvement and determine the optimum FPWA content. The stress-strain curves and Mohr's circles obtained from the unconfined compressive strength tests conducted on the natural soil and all prepared mixture ratios are presented in Figures 4, 5, 6, 7, and 8.

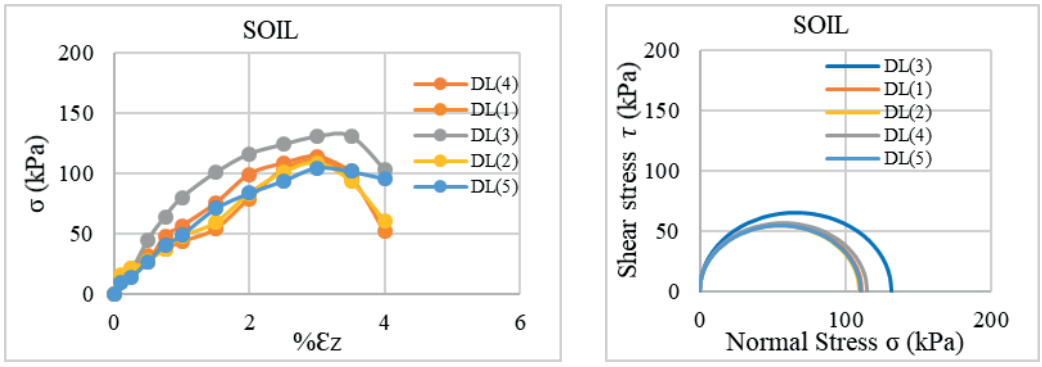


Figure 4. *Graphs of Normal Stress vs Strain and Shear Stress vs Normal Stress with Variation in Soil*

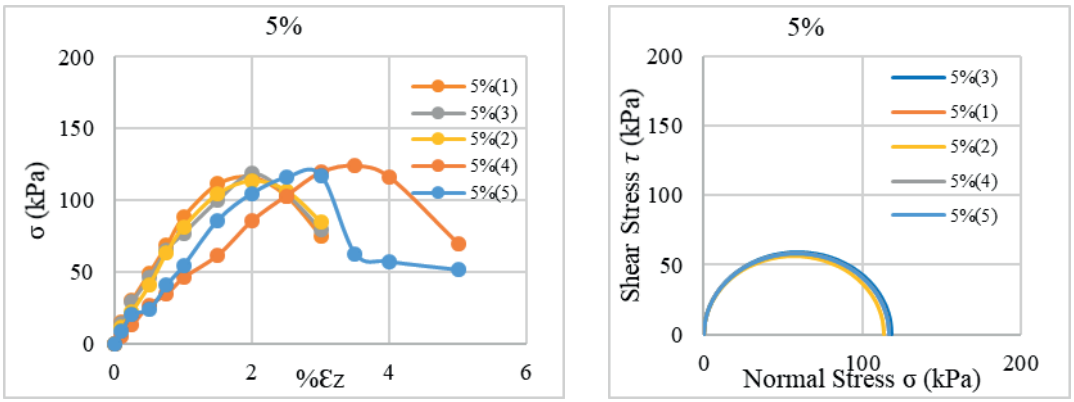


Figure 5. *Graphs of Normal Stress vs Strain and Shear Stress vs Normal Stress with Variation in FPWA (5%)*

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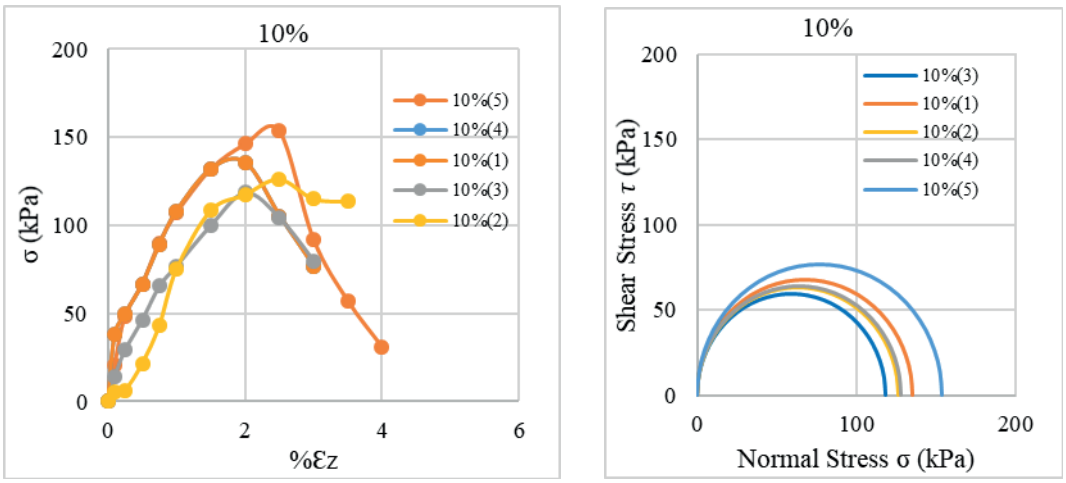


Figure 6. *Graphs of Normal Stress vs Strain and Shear Stress vs Normal Stress with Variation in FPWA (10%)*

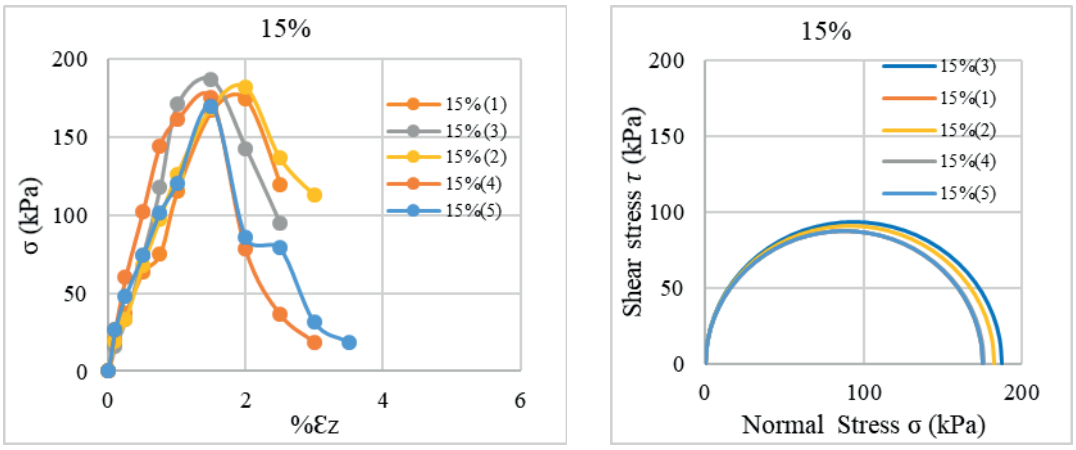


Figure 7. *Graphs of Normal Stress vs Strain and Shear Stress vs Normal Stress with Variation in FPWA (15%)*

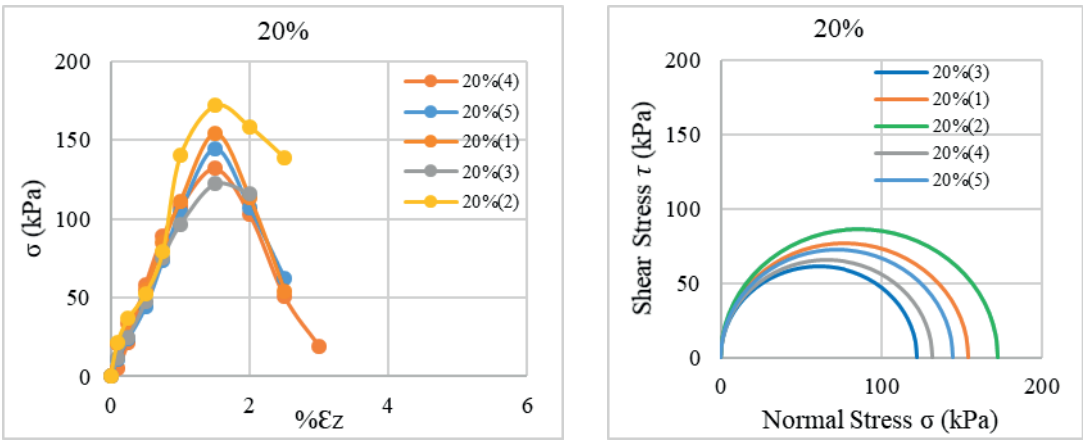


Figure 8. *Graphs of Normal Stress vs Strain and Shear Stress vs Normal Stress with Variation in FPWA (20%)*

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RESULTS

The untreated soil had strengths between 109,0 kPa and 131,3 kPa, with failure strains of 3–3,5%, highlighting the need for improvement. With 5% FPWA, OMC rose slightly to 19,15%, MDD fell to 15,74 kN/m³, and strength peaked at 124,1 kPa, with failure strains of 2–3%. At 10% FPWA, OMC jumped to 24,96%, MDD dropped to 15,29 kN/m³, and strength increased to 153,8 kPa (a 15,1% increase in average), with failure strains still at 2–3%. The 15% mix delivered the highest strength of 187,3 kPa (a 54,6% increase in average), with OMC at 25,5% and MDD at 15,24 kN/m³, though failure strains narrowed to 1.5–2%, signaling brittleness. At 20% FPWA, OMC reached 25,8%, MDD was 15,21 kN/m³, and max. strength fell to 172,4 kPa (still a 26% rise in average), with failure strains staying low at 1,5%.

Table 1. *Increase in Maximum Normal Stress with Variation in FPWA*

	w_{opt} (%)	d (kN/m^3)	failure (%)	σ_{max} (kN/m^2)	$\sigma_{max,avg}$ (kN/m^2)	Increase (%)
SOIL	18,89	15,94	3,0	111,0	115,1	-
			3,5	131,3		
			3,0	109,0		
			3,0	114,2		
			3,0	110,0		
SOIL+%5	19,15	15,74	2,0	116,4	117,9	2,4
			2,0	118,5		
			2,0	113,2		
			3,0	124,1		
			3,0	117,3		
SOIL+%10	24,96	15,29	2,0	135,5	132,5	15,1
			2,0	118,5		
			2,5	126,4		
			2,0	128,1		
			2,5	153,8		

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SOIL+%15	25,50	15,24	2,0	174,7	178,0	54,6
			1,5	187,3		
			2,0	182,0		
			1,5	175,5		
			1,5	170,3		
SOIL+%20	25,8	15,21	1,5	154,3	145,0	26,0
			1,5	122,4		
			1,5	172,4		
			1,5	131,9		
			1,5	144,1		

DISCUSSION

The rise in optimum moisture content from 18,89% to 25,80% with FPWA addition indicates that field compaction would require more water or longer mixing, which could affect construction planning in arid regions. The drop in maximum dry density from 15,94 kN/m³ to 15,21 kN/m³ would reduce overburden pressure on weak subgrades, benefiting foundation design on compressible soils.

At 5% FPWA, the average strength reached only 117,9 kPa, just 3 kPa above the untreated average peak of 115,1 kPa, confirming that low additive levels provide no significant engineering benefit. At 10% FPWA, the average strength rose to 132,5 kPa (15,1% gain), indicating that pozzolanic activation may occur. The average peak strength of 178,0 kPa at 15% FPWA (54,6% improvement) represented the optimal dosage for maximizing load capacity in pavement and foundation design. The decline to 145,0 kPa at 20% FPWA demonstrates that excess additive creates weak zones, which could reduce structural integrity, making mix design optimization essential.

Failure strain decreased from 3–3,5% to 1,5–2% with increasing FPWA content. For pavement subgrades, lower deformation helps maintain surface evenness, but faster crack propagation under cyclic loading necessitates accounting for traffic frequency in design life calculations. For foundations, reduced settlement before failure benefits structures sensitive to differential movement, although the potential for sudden failure requires higher safety factors in bearing capacity assessments.

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CONCLUSION

This study addressed the identified research gap regarding fine-grained poultry waste ash (FPWA) as a soil stabilizer, moving beyond previous work focused on coal fly ash or chicken feather fibers. Based on the findings, a proportion of 15% FPWA is recommended for practical applications, as it provides the greatest strength improvement while using the stabilizer efficiently. Construction with FPWA-treated clay should allow for additional water during compaction, and the lower density of the stabilized material may be advantageous when building on weak subgrades. Engineers should also consider the more sudden failure mode in their designs, particularly where repeated loading is expected.

The positive results obtained with FPWA highlight the potential of processed agricultural byproducts in geotechnical engineering. Continued research is needed to assess long-term performance under field conditions and to examine the microscopic structure of reaction products. Future work should also explore combining FPWA with conventional stabilizers such as cement or lime. This could potentially mitigate the brittleness observed at higher FPWA contents while further enhancing strength development.

REFERENCES

Afrin, H. (2017). A Review on Different Types Soil Stabilization Techniques. *International Journal of Transportation Engineering and Technology*, 3(2), 19. https://doi.org/10.11648/j.ijtet.20170302.12

Alam, M. S., Kaur, G., Jabbar, A., Javed, K., & Athar, M. (2007). Eruca sativa seeds possess antioxidant activity and exert a protective effect on mercuric chloride induced renal toxicity. Food and Chemical Toxicology, 45, 910-920.

Dawson, S. S., & Michler, C. H. (2014). Afforestation, restoration and regeneration - Not all trees are created equal. Journal of Forestry Research, 25(1), 3-20.

Jose, B. T., Sahoo, D. K., Puppala, A. J., Reddy, C. N. V. S., Mathews, B., Ravikiran, A., & Editors, V. (Eds.). (2022). Proceedings of the Indian Geotechnical Conference 2022 Volume 4. In Proceedings of the Indian Geotechnical Conference (Vol. 4). GEOLEAP.

Khan, A. N., Ansari, Y., Mahvi, S., Junaid, M., & Iqbal, K. (2020). Different Soil Stabilization Techniques. International Journal of Advanced Science and Technology, 29(9s), 7778–7791.

Lim, S. M., Wijeyesekera, D. C., Lim, A. J. M. S., & Bakar, I. B. H. (2014). Critical Review of Innovative Soil Road Stabilization Techniques. International Journal of Engineering and Advanced Technology (IJEAT), (5), 1-4.

Manoj, N., Madhusudhanrao, G., Sairam, B., & Hanumantharao, C. H. (2017). As Biopolymer. International Journal of Civil Engineering and Technology (IJCIET), 8(4), 2021–2026. http://www.iaeme.com/IJCIET/index.asp2021

Salih, A., Rashid, A. S. A., & Salih, N. B. (2024). Effects of chicken bone powder mixed with limestone and cement on the clayey soil geotechnical characteristics. Magazine of Civil Engineering, 17(6). https://doi.org/10.34910/MCE.130.3

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BIFURCATION OF SYMMETRIC FLOWS IN A DOUBLE-LID T-SHAPED CAVITY

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ABSTRACT

This study investigates the structural bifurcation and streamline topologies of two-dimensional incompressible flows within symmetric configurations. The theoretical framework of the research is grounded in the classification of streamline patterns near simple degenerate critical points in flows with reflectional symmetry, as established by Brøns and Hartnack (1999). By utilizing the normal form of the stream function, the local structure of the velocity field is analyzed to describe how streamline configurations transition through various bifurcations. Specifically, an eighth-order normal form is employed to map the complex transitions between stagnation points away from the boundaries.

To validate these theoretical patterns, a numerical application is performed on Stokes flow within a double-lid-driven T-shaped cavity which lids move in the same direction. The heights of the lower and upper parts of the cavity, denoted as h_1 and h_2, serve as the primary control parameters for the bifurcation analysis. Numerical simulations are carried out using the standard Galerkin Finite Element Method (FEM), where the governing equations are solved in terms of the stream function using a biharmonic operator formulation.

The results demonstrate a high degree of correlation between the theoretically predicted patterns and the numerical observations. A variety of codimension-one bifurcation curves, including cusp (CP), center (CB), and saddle (SB) bifurcations, are identified within the (h_1, h_2) parameter plane. These curves divide the control space into distinct regions, each characterized by unique flow structures such as co-rotating vortices and saddle connections. In conclusion, all theoretically predicted flow patterns are successfully replicated in the T-shaped cavity model, proving that the proposed normal form effectively explains the structural changes in the flow mechanism.

Keywords: Streamline topology, symmetric flows, bifurcation theory, T-shaped cavity.

References

Becker, E. B., Carey, G. F., & Oden, J. T. (1981). *Finite Elements, An Introduction Vol. I*. Prentice-Hall.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Brøns, M., & Hartnack, J. N. (1999). Streamline topologies near simple degenerate critical points in two-dimensional flow away from boundaries. *Physics of Fluids*, 11(2), 314-324.

Gaskell, P. H., Savage, M. D., & Wilson, M. (1997). Stokes flow in a half-filled annulus between rotating coaxial cylinders. *Journal of Fluid Mechanics*, 337, 263-282.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SENSOR FUSION BASED SITUATIONAL AWARENESS IN ARMORED LAND VEHICLES: CONCEPTUAL DESIGN AND ARCHITECTURAL PROPOSAL

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ÖZET

This conceptual paper proposes a modular sensor fusion architecture for situational awareness in armored land vehicles. The design combines a core sensor set (IMU, GNSS) with in vehicle CAN data and scales with mission driven modules such as cameras and LiDAR. Data are intended to be time synchronized and fused on a low power single board computer using lightweight methods (e.g., Kalman filtering), suitable for resource constrained embedded platforms. The proposed architecture emphasizes robustness under degraded sensing conditions by adaptively prioritizing available sensor sources. Outputs are envisioned as actionable cues for the crew and summarized indicators for headquarters, supporting both tactical awareness and higher level decision making. In addition, the architecture is designed to be modular at both hardware and software levels, allowing incremental capability upgrades without major system redesign. The approach aims for field practicality and scalability also future work focuses on prototyping, maintainability considerations and scenario driven validation.

Keywords: Armored land vehicle, sensor fusion, situational awareness, CAN bus, embedded system.

KISALTMALAR

Abbreviation	Description
IMU	Inertial Measurement Unit
GNSS	Global Navigation Satellite System
SBC	Single Board Computer
CAN	Controller Area Network
LiDAR	Light Detection and Ranging

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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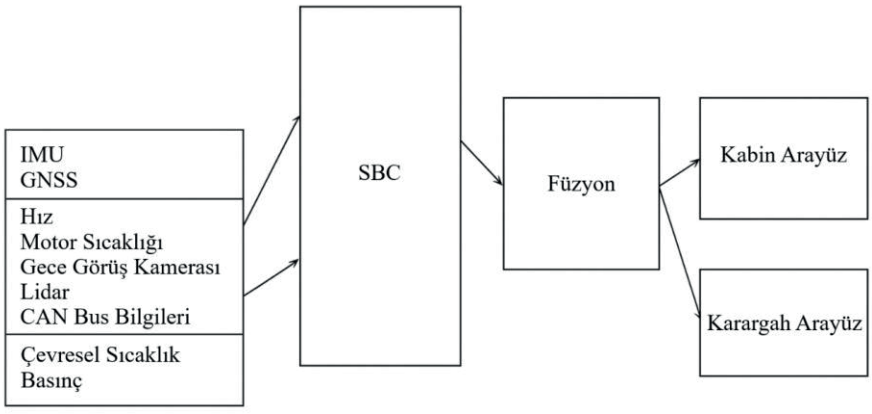
GİRİŞ

Durumsal farkındalık, çevredeki unsurların algılanması, bu bilgilerin anlamlandırılması ve yakın geleceğe yönelik durum öngörüsünü içeren bilişsel bir süreçtir (Endsley, 1995). Tekil sensörlerden elde edilen ölçümler belirsizlik ve gürültü içerdiğinden, güvenilir durum kestirimi ve karar desteği için çoklu sensör verilerinin bütünleştirilmesi gereklidir (Thrun, Burgard, & Fox, 2005). Bu çalışma, zırhlı kara araçlarının dinamik görev ortamlarında kullanılması için literatürdeki ağır ADAS uygulamaları yerine sahaya uyarlanabilir, hesaplama yükü düşük bir mimariyi kavramsal düzeyde önermektedir.

MATERYAL VE YÖNTEMLER

Gereksinimler ve Tasarım İlkeleri: İlkeler: (i) modülerlik ve platformdan bağımsız uyarlanabilirlik, (ii) düşük güç tüketimi ve sınırlı kaynaklarla gerçek zamanlı işleyiş, (iii) eyleme dönük arayüz, (iv) sahada bakım kolaylığı.

Önerilen Sistem Mimarisi çekirdek sensör seti IMU ve GNSS'i içerir. Araç durumuna ilişkin parametreler CAN veri yolu üzerinden temin edilir. Controller Area Network (CAN), araçlar ve diğer kontrol uygulamalarında kullanılan, gerçek zamanlı kontrolü ve çoklama yapısını destekleyen seri bir haberleşme protokolüdür (ISO 11898, 2015). Görev profiline bağlı olarak kamera/LiDAR ve çevresel sensörler opsiyoneldir. Veriler tek kartlı bilgisayarda zaman ile damgalanır, senkronize edilir, gürültüden arındırılır ve füzyon katmanında Kalman filtresi tercih edilir. Kalman filtresi, bir sürecin durumunu, hata kareler ortalamasını en aza indirecek şekilde, özyineli (recursive) olarak kestirmeyi sağlayan matematiksel denklem kümesidir (Welch & Bishop, 2006).



Şekil 1. Önerilen sistem mimarisinin blok diyagramı (kavramsal)

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Sensörler ve Veri Kaynakları: IMU (kısa süreli konum/yönelim), GNSS (mutlak konum/hız), CAN parametreleri (vites, diferansiyel kilit, yakıt vb.) ve opsiyonel kamera/LiDAR (görüş/engel) ile birlikte değerlendirilir.

Veri Akışı ve Senkronizasyon: Sensör çıktıları güvenilir ara yüzlerle SBC'ye aktarılır ve ortak zaman referansı ile senkronizasyon gerçekleştirilir. Sensörler arası gecikmeler ve örnekleme farkları senkronizasyon katmanında giderilir.



Şekil 2. Veri işleme ardışığı

Füzyon Algoritmaları (Planlanan): Hafif ve sahaya uygun yöntemler tercih edilir: Kalman filtresi, tamamlayıcı filtre ve koşula bağlı ağırlıklandırma. Ağırlıklar, GNSS güvenirlik ölçütleri (DOP), IMU kayma göstergeleri ve görüntü/görüş metriklerine göre adaptif olarak güncellenir.

Ağırlıklandırma Stratejisi (Kavramsal): Füzyon çıktısı $\hat{x} = \Sigma\, w_i\, x_i$, $\Sigma\, w_i = 1$, $w_i \geq 0$ koşullarını sağlar.

Örnek: Açık görüş → IMU 0.25, GNSS 0.35, Kamera/LiDAR 0.25, CAN 0.15; GPS zayıf → IMU 0.50, GNSS 0.05, Kamera/LiDAR 0.20, CAN 0.25.

Tablo1. Veri ağırlıkları

Koşul	IMU w	GNSS w	Kamera/LiDAR w	CAN Durum w
Açık hava / iyi görüş	0.25	0.35	0.25	0.15
Düşük görüş (sis/gece)	0.35	0.30	0.05	0.30
GPS zayıf/bozulmuş	0.50	0.05	0.20	0.25
Zorlu arazi (yüksek eğim)	0.40	0.20	0.10	0.30

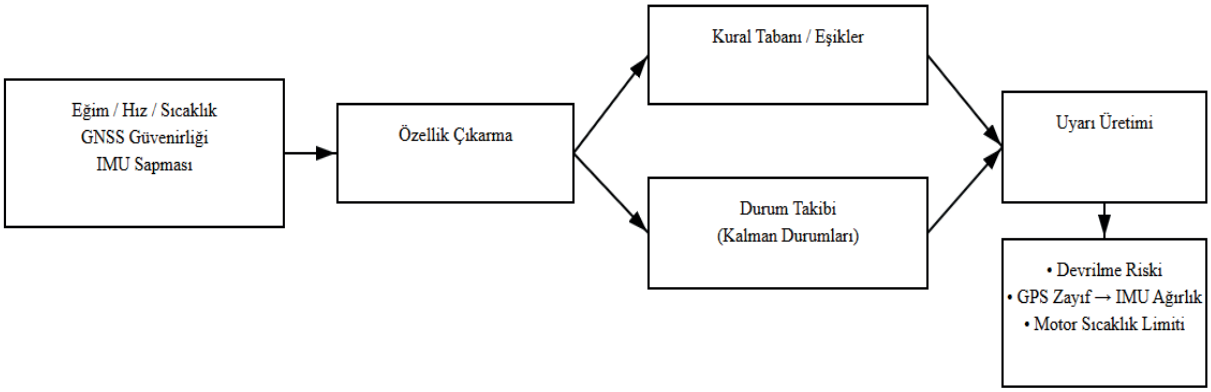
SONUÇLAR

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

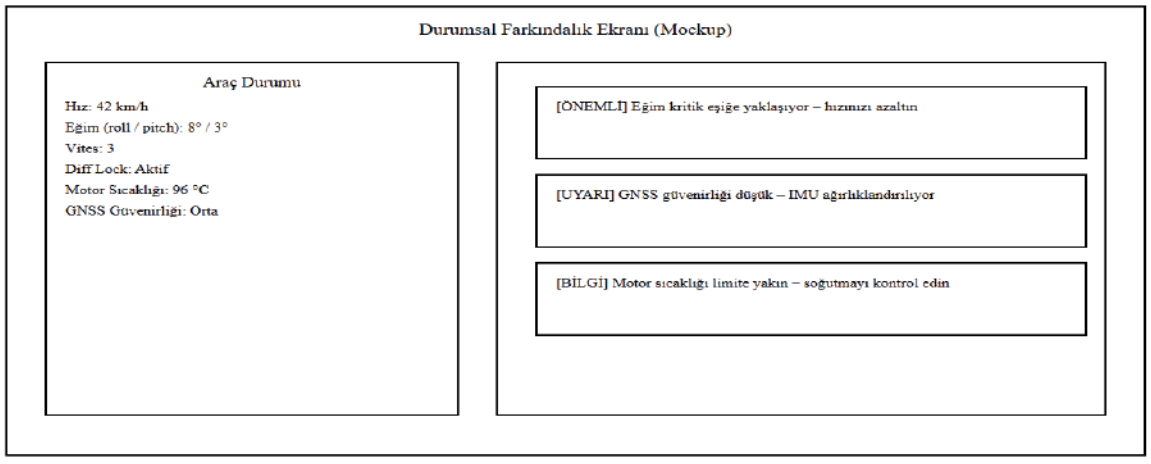
Önerilen sensör füzyonu mimarisi, kavramsal kullanım senaryoları üzerinden değerlendirilmiştir. Mimari, farklı çevresel ve operasyonel koşullarda sensör güvenilirliğinin değiştiği durumlarda daha kararlı ve bağlama duyarlı bir durumsal farkındalık çıktısı üretmeyi hedeflemektedir. Adaptif ağırlıklandırma yaklaşımı sayesinde tekil sensörlere dayalı çözümlere kıyasla uyarı üretiminin daha tutarlı olması öngörülmektedir.

Düşük görüş koşullarında kamera tabanlı algılamanın etkinliği azalırken, IMU ve GNSS verilerinin ağırlıkları artırılarak araç dinamiklerine dayalı kestirim ön plana çıkarılmaktadır. GNSS sinyalinin zayıfladığı veya geçici olarak kaybolduğu durumlarda ise, kısa süreli ölü-reckoning ile konum ve yönelim kestirimi sürdürülmekte ve GNSS güvenirliği geri kazanıldığında füzyon ağırlıkları yeniden dengelenmektedir.

Eğimli ve zorlu arazi koşullarında IMU ölçümleri ile CAN veri yolu üzerinden elde edilen araç durumu bilgileri birlikte değerlendirilerek devrilme riskine yönelik erken uyarılar üretilmesi amaçlanmaktadır. Şekil 3 ve Şekil 4'te sunulan karar mantığı ve örnek arayüz, bu senaryolarda üretilen çıktıları kavramsal olarak göstermektedir.



Şekil 3. Uyarı üretimi için kavramsal karar mantığı akış şeması



Şekil 4. Mürettebat/Karargâh ekranı için örnek uyarı arayüzü

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TARTIŞMA

Bu çalışmada sunulan sensör füzyonu mimarisi, zırhlı kara araçlarının operasyonel koşulları ve sistem kısıtları dikkate alınarak kavramsal düzeyde geliştirilmiştir. Düşük güç tüketimi, sınırlı hesaplama kaynakları ve saha koşullarında bakım kolaylığı mimari tasarımın temel belirleyicileri olmuştur. Bu doğrultuda, ağır hesaplama gerektiren yöntemler yerine hafif, yorumlanabilir ve sahaya uyarlanabilir füzyon yaklaşımları tercih edilmiştir.

Çalışmada ele alınan tehdit modeli, sensör füzyonu mimarisinin yalnızca performans değil, güvenilirlik ve bütünlük açısından da değerlendirilmesi gerektiğini ortaya koymaktadır. GNSS bozma ve aldatma saldırılarının, konum çözümünün güvenirliğini düşürebileceği literatürde vurgulanmaktadır (Kaplan & Hegarty, 2017). GNSS bozma ve aldatma (jamming/spoofing) senaryolarında, GNSS güvenirlik ölçütlerine dayalı ağırlık azaltımı ve IMU tabanlı duruma geçiş önerilmektedir. CAN veri yolu üzerinden gerçekleştirilen mesaj enjeksiyon saldırılarının, gerçek araçlar üzerinde yapılan deneylerde, araç içi kontrol birimlerini etkileyerek fiziksel araç davranışlarında değişimlere yol açabildiği gösterilmiştir (Checkoway et al., 2011). CAN veri yolu üzerinden gerçekleştirilebilecek veri enjeksiyon saldırılarına karşı, hız, eğim ve ivme gibi parametreler arasında tutarlılık kontrollerinin uygulanması öngörülmektedir.

Görsel sensörler durumsal farkındalığı artırma potansiyeline sahip olmakla birlikte, düşük görüş koşullarında sınırlı katkı sağlamaktadır. Bu nedenle çalışmada kamera ve LiDAR sensörleri opsiyonel olarak ele alınmış, çekirdek mimarinin IMU, GNSS ve CAN verileriyle de işlevsel kalması hedeflenmiştir. Bu durum Tablo 1'de "Gece Görüş" satırında görülebilir. Sunulan tartışmalar, mimarinin kavramsal sınırlarını ve gelecekte yapılacak deneysel çalışmalar için dikkate alınması gereken hususları ortaya koymaktadır.

VALİDASYON ÖLÇÜTLERİ (PLANLANAN)

Tablo2. Planlanan Doğrulama Ölçütleri ve Hedef Performans Kriterleri

Gösterge	Hedef	Test Senaryosu	Not
Konum doğruluğu	≤ 3 m (GNSS mevcut)	Açık alan sürüşü	DOP < 2 varsayımı
Kısa süreli konum sapması	≤ 20 m @ 60 s (GNSS yok)	Tünel/şehir kanyonu	IMU kayma telafisi
Uyarı gecikmesi	≤ 150 ms	Eğim artışı → uyarı	İletişim/hesap gecikmesi
Yanlış alarm oranı	≤ %3	Çeşitli koşullar	Eşik + durum takibi
Güç tüketimi	≤ 5–7 W (SBC)	Saha koşulları	Aktif mod ölçümü

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SONUÇ

Bu çalışmada, zırhlı kara araçları için modüler ve sahaya uygun bir sensör füzyonu tabanlı durumsal farkındalık mimarisi kavramsal olarak sunulmuştur. Önerilen yapı IMU ve GNSS verilerini araç içi CAN verileriyle bütünleştirerek farklı görev ve çevre koşullarına uyarlanabilir bir sınır ortaya koymaktadır.

Düşük güç tüketimi ve sınırlı hesaplama kaynakları dikkate alınarak hafif füzyon algoritması ve adaptif ağırlıklandırma stratejisi tercih edilmiştir. Mürettebata yönelik eyleme dönük uyarılar ve raporlama çıktıları, sistemin karar destek sürecine katkı sağlamasını hedeflemektedir.

Çalışma kavramsal nitelikte olup deneysel doğrulama içermemektedir. Gelecek çalışmalarda mimarinin prototiplemesi ve senaryo bazlı testlerle doğrulanması planlanmaktadır. Sunulan yaklaşım, zırhlı kara araçlarında sensör füzyonu tabanlı durumsal farkındalık sistemleri için uygulanabilir bir temel sunmaktadır.

REFERANSLAR

Checkoway, S., McCoy, D., Kantor, B., Anderson, D., Shacham, H., Savage, S., Koscher, K., Czeskis, A., Roesner, F., Kohno, T. (2011). Comprehensive Experimental Analyses of Automotive Attack Surfaces.

Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems.

ISO 11898 (2015). Road vehicles — Controller area network (CAN).

Kaplan, E. D., & Hegarty, C. J. (Eds.). (2017). Understanding GPS/GNSS: Principles and Applications. Artech House.

Thrun, S., Burgard, W., & Fox, D. (2005). Probabilistic Robotics. MIT Press.

Welch, G., & Bishop, G. (2006). An Introduction to the Kalman Filter. UNC Chapel Hill, TR 95-041 (updated).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

POLYESTER İPLİK ÜRETİM SÜREÇLERİNDE ÇEVRESEL ETKİLERİN DEĞERLENDİRİLMESİ VE EKO-VERİMLİLİK TEMELLİ İYİLEŞTİRME YAKLAŞIMLARI

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ÖZET

Polyester iplik üretimi, yüksek enerji ve su tüketimi ile sera gazı emisyonları nedeniyle tekstil sektöründe çevresel etkisi en yüksek üretim süreçlerinden biridir. Bu çalışmada, polyester iplik üretim tesislerinde uygulanan temiz üretim ve eko-verimlilik projelerinin çevresel ve ekonomik performansı nicel veriler üzerinden değerlendirilmiştir. Çalışmada proses bazlı enerji ve kütle dengesi analizleri, performans göstergeleri (KPI) değerlendirmesi ve karbon emisyon hesaplama metodolojisi kullanılmıştır. Enerji verimliliği uygulamaları sonucunda yıllık 2.616.448 kWh elektrik ve 191.499 Sm^3 doğal gaz tasarrufu sağlanmış; buna bağlı olarak yaklaşık 4.530 ton CO_2e/yıl emisyon azaltımı gerçekleştirilmiştir. Sistem optimizasyonu çalışmaları ile ek olarak 1.008.000 kWh/yıl enerji tasarrufu elde edilmiş ve yatırımın geri ödeme süresi 1,2 ay olarak hesaplanmıştır. Su yönetimi uygulamaları kapsamında ise yıllık 38.726 ton su tasarrufu sağlanmıştır. Bulgular, temiz üretim ve eko-verimlilik uygulamalarının karbon yoğunluğunu ve kaynak tüketimini azaltırken kısa geri ödeme süreleri sayesinde ekonomik sürdürülebilirliği de güçlendirdiğini göstermektedir. Çalışma, polyester iplik üretiminde ölçülebilir ve tekrarlanabilir bir sürdürülebilir üretim modeli ortaya koymaktadır.

Anahtar Kelimeler: Polyester iplik üretimi, temiz üretim, eko-verimlilik, enerji verimliliği, karbon azaltımı, su yönetimi.

ABSTRACT

Polyester yarn production is one of the most environmentally intensive processes in the textile industry due to high energy and water consumption and significant greenhouse gas emissions. This study evaluates the environmental and economic performance of cleaner production and eco-efficiency applications implemented in polyester yarn manufacturing facilities using quantitative data. The methodology is based on process-based energy and mass balance analysis, key performance indicator (KPI) assessment, and carbon emission calculation framework. Energy efficiency projects resulted in annual savings of 2,616,448 kWh of electricity and 191,499 Sm^3 of natural gas, corresponding to

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

approximately 4,530 tons CO_2e/year emission reduction. System optimization provided an additional 1,008,000 kWh/year energy saving with a payback period of 1.2 months. Water management practices achieved 38,726 tons/year water savings, significantly reducing freshwater demand. The findings demonstrate that cleaner production and eco-efficiency strategies simultaneously reduce carbon intensity and resource consumption while ensuring rapid financial returns. The study proposes a measurable and replicable sustainability model for polyester yarn manufacturing.

Keywords: Polyester yarn production, cleaner production, eco-efficiency, energy efficiency, carbon reduction, water management.

1. GİRİŞ

İklim sistemindeki değişimin insan etkisiyle hızlandığı ve bunun yaygın, çok boyutlu çevresel ve sosyo-ekonomik riskler ürettiği bilimsel olarak güçlü biçimde ortaya konmuştur (IPCC, 2023). Bu çerçevede sanayi üretiminde enerji ve kaynak verimliliğini artıran, emisyonları ve atıkları kaynağında önleyen ve çevresel riskleri azaltırken ekonomik performansı güçlendiren yaklaşımlar giderek daha kritik hale gelmektedir (UNEP, 2023).

Tekstil değer zinciri; enerji, su ve kimyasal kullanım yoğunluğu, proses kaynaklı atıksu/atık üretimi ve sera gazı emisyonları nedeniyle küresel ölçekte çevresel "sıcak noktalar" barındıran sektörler arasında değerlendirilmektedir (UNEP, 2023). Bu bağlamda polyester esaslı üretimler, petrokimyasal hammadde temelli olmaları ve ısıl/kimyasal proses adımlarında yüksek enerji gereksinimi nedeniyle çevresel performans yönetimini zorunlu kılan üretim alanlarıdır. Avrupa Birliği'nin "Sürdürülebilir ve Döngüsel Tekstil Stratejisi" de, tekstil ürünlerinin yaşam döngüsü boyunca daha dayanıklı, yeniden kullanılabilir ve geri dönüştürülebilir tasarımını; kaynak verimliliği, atık azaltımı ve çevresel beyanların güçlendirilmesini stratejik öncelikler olarak tanımlamaktadır (European Commission, 2022).

Bu dönüşümde iki tamamlayıcı kavramsal çerçeve öne çıkmaktadır: eko-verimlilik ve temiz üretim. OECD, eko-verimliliği çevresel kaynakların insan ihtiyaçlarını karşılamadaki kullanım etkinliği olarak ele alarak, çevresel baskının birim çıktı başına azaltılmasına odaklanan ölçülebilir bir performans yaklaşımı sunmuştur (OECD, 1998). UNEP ise temiz üretimi; proses, ürün ve hizmetlere uygulanan bütünleşik ve önleyici çevresel stratejinin sürekli uygulanması olarak tanımlamakta; malzeme/enerji tasarrufu, toksisite ve emisyon/atık azaltımı ile risklerin düşürülmesini hedeflemektedir (UNEP, 2007). UNIDO'nun kaynak etkin ve temiz üretim (RECP) yaklaşımı da benzer biçimde, atık ve kirliliğin kaynağında önlenmesini ve enerji-su-malzeme kullanımında verimliliğin artırılmasını birlikte ele alan uygulama çerçevesi sunar (UNIDO, t.y.). Ayrıca endüstriyel uygulamalarda "mevcut en iyi teknikler (BAT)" yaklaşımı, proseslerin çevresel performansını iyileştirmede teknik olarak uygulanabilir ve ekonomik açıdan gerçekleştirilebilir çözüm setlerini tanımlayarak pratik bir yönetişim zemini oluşturur (European Commission JRC, 2023).

Tekstil üretim pratiklerinde temiz üretim perspektifi; kimyasal ikame, proses optimizasyonu ve kaynak tüketimi azaltımı gibi müdahalelerin hem çevresel yükleri düşürme hem de işletme verimliliğini artırma potansiyelini göstermiştir (Öztürk vd., 2009). Bununla birlikte literatürde, genel çerçevelerin yanında saha uygulamalarından türetilmiş nicel performans kanıtlarını aynı metin içinde bütüncül biçimde birleştiren çalışmaların görece sınırlı kaldığı görülmektedir. Bu çalışma, polyester iplik üretiminde temiz üretim ve eko-verimlilik yaklaşımını proses bazlı enerji-kütle dengesi, KPI temelli performans değerlendirmesi ve kurumsal emisyon muhasebesi çerçevesinde ele alarak; enerji, su ve emisyon azaltımına yönelik uygulamaların ölçülebilir çıktıları üzerinden tartışmayı amaçlamaktadır. Böylece çalışma, polyester iplik üretiminde çevresel etkilerin azaltılmasına yönelik tekrarlanabilir ve ölçeklenebilir bir iyileştirme çerçevesi sunmayı hedeflemektedir.

2. LİTERATÜR DEĞERLENDİRMESİ

2.1. Tekstil Sektöründe Çevresel Etki ve Kaynak Yoğunluğu

Tekstil üretimi, yaşam döngüsü perspektifinden değerlendirildiğinde enerji kullanımı, su tüketimi, kimyasal girdiler ve atık oluşumu açısından yüksek çevresel baskı oluşturan sektörler arasında yer almaktadır (UNEP, 2023). Özellikle sentetik lif üretimi ve polimer bazlı tekstil süreçleri, fosil kaynak temelli hammaddelere dayalı olmaları ve ısıl proses gereksinimleri nedeniyle karbon yoğunluk açısından kritik üretim aşamalarıdır (IPCC, 2023). Yaşam döngüsü değerlendirmesi (LCA) yaklaşımı, tekstil ve polimer temelli ürünlerin çevresel etkilerini bütüncül biçimde analiz etmek için yaygın olarak kullanılan bilimsel bir yöntemdir. PET (polyethylene terephthalate) esaslı ürünler üzerine yapılan çalışmalar, üretim aşamasında enerji tüketiminin ve sera gazı emisyonlarının toplam etki içerisinde önemli paya sahip olduğunu göstermektedir (Gironi & Piemonte, 2011). Bu bulgu, polyester iplik üretiminde proses optimizasyonunun ve enerji verimliliğinin stratejik önemini desteklemektedir.

2.2. Temiz Üretim ve Eko-Verimlilik Yaklaşımı

Temiz üretim, üretim süreçlerinde kirliliğin kaynağında önlenmesini ve kaynak kullanımının azaltılmasını esas alan önleyici bir çevre yönetimi yaklaşımıdır (UNEP, 2007). Bu yaklaşım, yalnızca atık arıtımı veya sonradan kontrol yöntemleri yerine, proses tasarımı ve operasyonel iyileştirmeler yoluyla çevresel risklerin azaltılmasını hedefler. Eko-verimlilik kavramı ise çevresel performans ile ekonomik çıktının birlikte değerlendirilmesini öngörür. OECD (1998), eko-verimliliği birim ürün veya hizmet başına düşen çevresel baskının azaltılması olarak tanımlamış ve ölçülebilir göstergeler üzerinden performans takibini önermiştir. Bu çerçevede enerji yoğunluğu (kWh/ürün), su yoğunluğu (m^3/ürün) ve karbon yoğunluğu (kg CO_2e/ürün) gibi göstergeler, tekstil üretiminde sürdürülebilirlik performansının temel ölçütleri olarak kabul edilmektedir. UNIDO tarafından geliştirilen Kaynak Etkin ve Temiz Üretim (RECP) yaklaşımı, enerji, su ve hammadde verimliliğini artırırken aynı zamanda ekonomik tasarruf sağlayan uygulamaların sistematik olarak yaygınlaştırılmasını hedeflemektedir (UNIDO, t.y.). Bu yaklaşım, tekstil sektöründe proses iyileştirmeleri, kimyasal ikame çalışmaları ve

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ISBN: 978-9952-610-30-7

enerji optimizasyonu gibi uygulamaların birlikte ele alınmasını önermektedir. Tekstil sektöründe temiz üretim uygulamalarına ilişkin ampirik bir çalışma, kimyasal ikame ve proses modifikasyonlarının hem çevresel yükü hem de işletme maliyetlerini azaltabildiğini göstermiştir (Öztürk vd., 2009). Bu bulgular, çevresel performans ile ekonomik verimlilik arasında yapısal bir çelişki olmadığını; aksine uygun tasarım ve yönetimle iki hedefin eş zamanlı sağlanabileceğini ortaya koymaktadır.

2.3. Döngüsel Ekonomi ve Tekstil Üretimi

Döngüsel ekonomi yaklaşımı, ürünlerin tasarım aşamasından itibaren dayanıklılık, yeniden kullanım ve geri dönüştürülebilirlik kriterlerine göre yapılandırılmasını öngörmektedir (European Commission, 2022). Tekstil sektörü özelinde bu yaklaşım; lif geri kazanımı, malzeme verimliliği, proses atıklarının yeniden değerlendirilmesi ve yenilenebilir enerji entegrasyonu gibi alanlarda dönüşümü zorunlu kılmaktadır (UNEP, 2023). Avrupa Komisyonu'nun Sürdürülebilir ve Döngüsel Tekstil Stratejisi, tekstil ürünlerinin 2030 yılına kadar daha uzun ömürlü, geri dönüştürülebilir ve kaynak verimli hale getirilmesini hedeflemekte; üretim aşamasında karbon ve çevresel ayak izinin azaltılmasını temel politika aracı olarak tanımlamaktadır (European Commission, 2022). Bu politika çerçevesi, üretim tesislerinde enerji verimliliği, yenilenebilir enerji kullanımı ve atık azaltımı uygulamalarının yalnızca çevresel değil, aynı zamanda ticari bir zorunluluk haline geldiğini göstermektedir.

2.4. Mevcut En İyi Teknikler (BAT) ve Endüstriyel Performans

Endüstriyel tesislerde çevresel performansın iyileştirilmesinde "Mevcut En İyi Teknikler (BAT)" yaklaşımı, teknik uygulanabilirlik ve ekonomik sürdürülebilirlik kriterlerini birlikte ele almaktadır (European Commission JRC, 2023). Tekstil sektörü için hazırlanan BAT referans dokümanları; enerji geri kazanımı, proses entegrasyonu, atıksu arıtımı ve kimyasal kullanımının azaltılmasına yönelik teknik çözümleri sistematik biçimde tanımlamaktadır. Bu çerçevede literatür, polyester iplik üretimi gibi enerji yoğun proseslerde enerji-kütle dengesi analizlerinin, performans göstergelerinin ve emisyon muhasebesinin birlikte değerlendirilmesinin gerekliliğini ortaya koymaktadır. Ancak saha uygulamalarından elde edilen nicel sonuçların bütüncül bir eko-verimlilik modeli çerçevesinde ele alındığı çalışmaların sınırlı olduğu görülmektedir. Bu çalışma, söz konusu literatür boşluğunu, uygulamaya dayalı performans verilerini metodolojik bir çerçeve içerisinde analiz ederek doldurmayı hedeflemektedir.

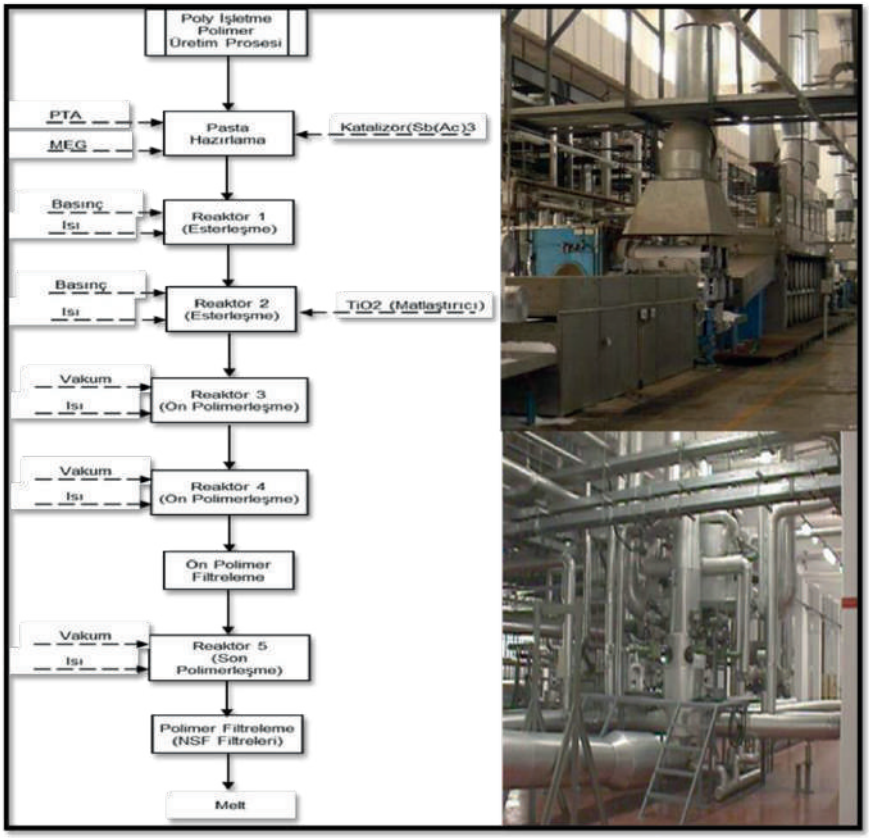
3. MATERYAL VE YÖNTEM

3.1. Çalışma Tasarımı

Bu çalışma, ülkemizde yüksek kapasiteyle üretim yapmakta olan bir polyester iplik üretim tesisinde uygulanan temiz üretim ve eko-verimlilik müdahalelerinin çevresel performans üzerindeki etkilerini değerlendirmeyi amaçlayan proses temelli bir vaka analizidir. Araştırma tasarımı, yaşam döngüsü düşüncesi (life cycle thinking) yaklaşımı esas alınarak oluşturulmuş ve değerlendirme üretim aşaması ile sınırlandırılmıştır (ISO 14040, 2006; ISO 14044, 2006). Analiz çerçevesi, çevresel etkilerin

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

kaynağında azaltılmasını esas alan temiz üretim yaklaşımı (UNEP, 2007) ve birim ürün başına çevresel baskının azaltılmasını hedefleyen eko-verimlilik kavramı (OECD, 1998) temelinde yapılandırılmıştır. Şekil 1'de polyester üretimi akım şeması ve incelenen işletmeden bir görüntü yeralmaktadır.



Şekil 1: Polyester iplik üretimi akım şeması ve incelenen işletmeden bir görüntü

3.2. Sistem Sınırları ve Fonksiyonel Birim

Sistem sınırları "cradle-to-gate" yaklaşımı doğrultusunda belirlenmiş ve polyester iplik üretiminin aşağıdaki ana bileşenlerini kapsayacak şekilde tanımlanmıştır:

- Polimerizasyon süreçleri (PTA ve MEG bazlı üretim aşamaları)
- Tekstüre ve büküm prosesleri
- Yardımcı tesisler (buhar üretimi, basınçlı hava, soğutma sistemleri, aydınlatma)
- Atıksu arıtımı ve geri kazanım sistemleri

Fonksiyonel birim, üretim performansının karşılaştırılabilirliğini sağlamak amacıyla birim ürün (ton polyester iplik) olarak tanımlanmıştır. Tüm çevresel performans göstergeleri bu birim üzerinden normalize edilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

3.3. Enerji ve Kütle Dengesi Yaklaşımı

Çalışmada proses performansının değerlendirilmesinde enerji ve kütle dengesi analizi kullanılmıştır. Bu yöntem, açık sistemler için kütlenin ve enerjinin korunumu ilkesine dayanmakta olup, proses giriş ve çıkış akımlarının sistematik biçimde izlenmesini ve kayıpların belirlenmesini sağlamaktadır. Enerji girdileri (elektrik, doğal gaz, buhar) ve su tüketimi proses bazında tanımlanmış; üretim hacmine oranlanarak yoğunluk göstergeleri oluşturulmuştur. Bu yaklaşım, kaynak etkin üretim uygulamalarında önerilen performans değerlendirme çerçevesi ile uyumludur (UNIDO, t.y.). Tablo 1'de işletmede yapılan enerji ve kaynak verimliliği çalışmalarının dayandığı literatür verilmiştir.

Tablo 1. Enerji ve Kaynak Verimliliği Müdahalelerinin Teknik Dayanakları

Müdahale Alanı	**Teknik Mekanizma**	**Literatür Dayanağı**
VSD Uygulaması	Devir düşüşü → Güç tüketiminin azalımı	IEA (2011)
Kondenstop Kontrolü	Canlı buhar kaybının önlenmesi	IEA (2011)
Isı Yalıtımı	Yüzey ısı kaybının azaltılması	IPCC (2006)
Şaft Hizalama	Mekanik sürtünme kaybının azaltılması	IEA Motor Systems
Su Pompası Optimizasyonu	Gereksiz debi ve enerji tüketiminin önlenmesi	UNIDO RECP

3.4. Sera Gazı Emisyonlarının Hesaplama Metodolojisi

Sera gazı emisyonları, IPCC 2006 Rehberi ve 2019 Güncellemesi temel alınarak hesaplanmıştır (IPCC, 2006; IPCC, 2019). Emisyon hesaplamaları aktivite verileri ile uygun emisyon faktörlerinin çarpımına dayalıdır. Kurumsal sera gazı muhasebesi, GHG Protocol Kurumsal Raporlama Standardı çerçevesinde değerlendirilmiş ve doğrudan (Scope 1) ile dolaylı (Scope 2) emisyonlar metodolojik olarak ayrıştırılmıştır (GHG Protocol, 2015). Karbon yoğunluğu göstergesi, toplam CO_2 eşdeğeri emisyonun fonksiyonel birime oranlanması yoluyla tanımlanmıştır. Bu gösterge, üretim süreçlerinin zamansal performans karşılaştırmasına olanak tanımaktadır.

3.5. Eko-Verimlilik Performans Göstergeleri

Çalışmada çevresel performansın izlenmesi amacıyla aşağıdaki temel göstergeler kullanılmıştır:

- Enerji yoğunluğu (kWh/ton ürün)
- Yakıt yoğunluğu (Sm^3/ton ürün)
- Buhar tüketimi (ton/ton ürün)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

- Su yoğunluğu (m^3/ton ürün)
- Karbon yoğunluğu (kg CO_2e/ton ürün)
- Geri kazanım oranı (%)

Bu göstergeler, OECD'nin eko-verimlilik yaklaşımı ve UNIDO'nun kaynak etkin üretim çerçevesi ile uyumludur (OECD, 1998; UNIDO, t.y.).

3.6. Müdahale Alanlarının Sınıflandırılması

Temiz üretim uygulamaları dört ana başlık altında değerlendirilmiştir:

- Enerji verimliliği ve proses optimizasyonu
- Su yönetimi ve geri kazanım
- Malzeme verimliliği ve atık azaltımı
- Yenilenebilir enerji entegrasyonu

Bu sınıflandırma, Avrupa Komisyonu'nun Mevcut En İyi Teknikler (BAT) yaklaşımı ile metodolojik uyum göstermektedir (European Commission JRC, 2023).

4. BULGULAR

4.1. Enerji Verimliliği Müdahaleleri

Endüstriyel tesislerde enerji verimliliği, özellikle motor sistemleri, buhar hatları ve ısı transfer ekipmanları üzerinden sağlanmaktadır. Uluslararası Enerji Ajansı (IEA) ve Avrupa Komisyonu JRC tarafından yayımlanan teknik dokümanlarda, değişken hızlı sürücü (VSD) uygulamaları, şaft hizalama, kondenstop yönetimi ve ısı yalıtımı gibi müdahalelerin enerji yoğunluğunu düşürmede temel araçlar olduğu belirtilmektedir (IEA, 2011; European Commission JRC, 2023). Pompa ve fan sistemlerinde güç tüketimi, devir sayısının küpü ile orantılıdır; bu nedenle hız kontrolü önemli tasarruf potansiyeli yaratmaktadır. Bu bilimsel çerçeve doğrultusunda işletmede gerçekleştirilen inverter uygulamaları ve motor devir optimizasyonu sonucunda yıllık 2.616.448 kWh elektrik tasarrufu sağlanmıştır. Tekstüre ve büküm klimalarında, gereksiz basınç kaybına neden olan plakalı eşanjörün belirli dönemlerde by-pass edilmesi ve motor hızının düşürülmesi ile ilave 1.008.000 kWh/yıl tasarruf elde edilmiştir. İlgili yatırımın geri ödeme süresi yaklaşık 1 ay 6 gün olarak hesaplanmıştır.

4.2. Buhar Sistemleri ve Isı Yönetimi

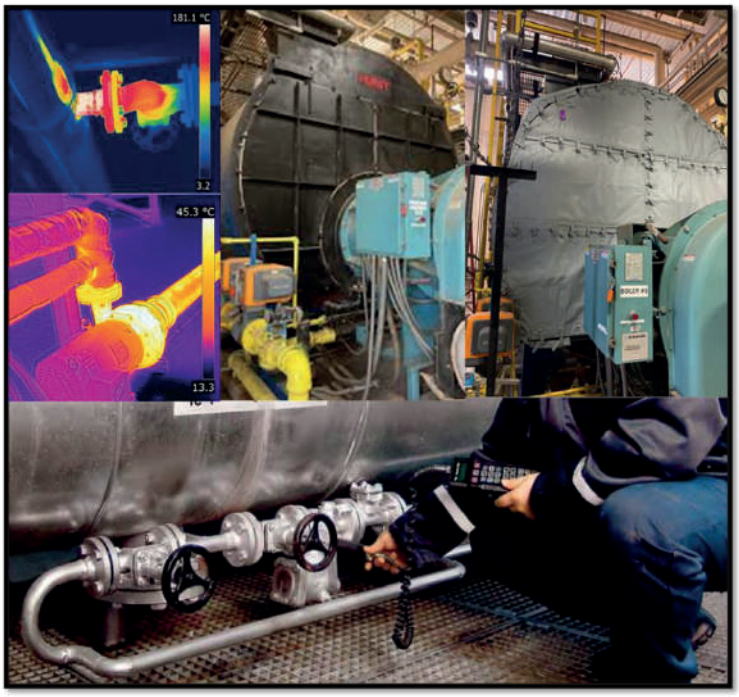
Buhar sistemleri, tekstil üretiminde önemli enerji taşıyıcılarıdır. Literatürde, kondenstop arızaları, yetersiz izolasyon ve buhar kaçaklarının endüstriyel enerji kayıplarının temel nedenleri olduğu vurgulanmaktadır (IEA, 2011; IPCC, 2006). Düzenli kondenstop kontrolü ve ısı yalıtımı

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iyileştirmeleri, kazan yükünü azaltarak yakıt tüketimini düşürmektedir. Bu kapsamda işletmede yapılan periyodik kondenstop ölçümleri sonucunda arızalı ekipmanların tespit edilmesiyle 870 ton/yıl buhar tasarrufu sağlanmıştır. Termal kamera ile yapılan ölçümler sonrasında gerçekleştirilen izolasyon iyileştirmeleri ile ilave 6.672 ton/yıl buhar tasarrufu elde edilmiştir. Toplamda buhar ve yakıt tüketimindeki azalma, yıllık 191.499 Sm^3 doğal gaz tasarrufuna karşılık gelmiştir. Şekil ‘de

4.3. Mekanik Sistem Verimliliği

Motor sistemlerinde yanlış hizalama, sürtünme ve titreşim artışı nedeniyle enerji kaybına yol açmaktadır. IEA motor sistemleri analizlerinde, lazerli hizalama uygulamalarının mekanik verimi artırarak enerji tüketimini azaltabileceği belirtilmektedir (IEA, 2011).Bu doğrultuda 225 ekipmanda gerçekleştirilen lazerli şaft hizalama uygulaması sonucunda yaklaşık **2.346.618 kWh/yıl enerji tasarrufu** sağlanmıştır. Bu müdahale, yardımcı tesislerde enerji yoğunluğunun azaltılmasına katkı sağlamıştır.



Şekil 2: Termal Görüntüleme ile İzolasyon İyileştirmesi ve Kondenstop Performans Kontrolü

4.4. Su Yönetimi ve Kaynak Verimliliği

Kaynak etkin üretim yaklaşımında (RECP), su tüketiminin azaltılması ve geri kazanım oranlarının artırılması temel müdahale alanları arasında yer almaktadır (UNIDO, t.y.; UNEP, 2023). Pompa sistemlerinde hız kontrolü ve proses optimizasyonu, gereksiz su sirkülasyonunu azaltmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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İşletmede gerçekleştirilen inverter uygulamaları ve su sistemi iyileştirmeleri sonucunda yıllık **38.726 ton su tasarrufu** sağlanmıştır. Ayrıca atıksu arıtımı sonrası geri kazanım sistemleri ile toplam suyun %55–60 oranında yeniden kullanılmasına yönelik teknik kapasite oluşturulmuştur.

4.5. Sera Gazı Emisyon Azaltımı

Yukarıdaki bölümlerde de ifade edildiği üzere; Elektrik tüketimindeki azalma, proses bazlı enerji analizleriyle belirlenen verimsizlik noktalarına yönelik olarak motor sistemlerinde değişken hızlı sürücü (VSD) uygulamaları ile yük–devir optimizasyonu yapılması, tekstüre ve büküm klimalarında hidrolik basınç kaybına neden olan ekipmanların by-pass edilmesi ve döner ekipmanlarda lazerli şaft hizalama uygulanması sayesinde sağlanmıştır. Buhar ve doğal gaz tüketimindeki azalma ise buhar hatlarında düzenli kondenstop kontrolleri ile canlı buhar kayıplarının önlenmesi, termal kamera ölçümleriyle tespit edilen yetersiz izolasyon bölgelerinde ısı yalıtımının iyileştirilmesi ve sistem kaçaklarının giderilmesi yoluyla gerçekleştirilmiştir. Enerji ve yakıt tüketimindeki azalma, IPCC (2006; 2019) metodolojisine uygun şekilde CO_2 eşdeğeri cinsinden hesaplanmıştır. Emisyon azaltımı hesaplamaları, aktivite verileri ile uygun emisyon faktörlerinin çarpımı esasına dayanmaktadır. Enerji verimliliği projeleri sonucunda: Buhar tasarrufu kaynaklı 2.855,45 ton CO_2e/yıl, Doğal gaz tasarrufu kaynaklı 510,26 ton CO_2e/yıl, Elektrik tasarrufu kaynaklı 1.164,32 ton CO_2e/yıl olmak üzere toplam yaklaşık 4.530 ton CO_2e/yıl emisyon azaltımı sağlanmıştır.

4.6. Otomasyon ve Malzeme Verimliliği

Temiz üretim yaklaşımında proses kontrolünün artırılması, atık oluşumunun kaynağında azaltılmasını sağlar (UNEP, 2007). Otomasyon sistemleri, üretim hatalarında azalma ve fire oranının düşmesi yoluyla malzeme verimliliğini artırmaktadır. Tekstüre iplik paketleme otomasyonu ile manuel sistemde oluşan yaklaşık %0,2 oranındaki malzeme kaybı minimize edilmiş ve üretim kapasitesi 1.000 kutu/adam·vardiya'dan 3.600 kutu/robot·vardiya seviyesine çıkarılmıştır.

5. TARTIŞMA

Bu çalışmada elde edilen enerji ve yakıt tasarrufları, tekstil sektöründe yaygın olarak önerilen çapraz-kesit enerji verimliliği önlemleriyle uyumludur. Motor sistemlerinde değişken hızlı sürücü (VSD) uygulamaları ve mekanik hizalama iyileştirmeleri, elektrik tüketiminin azaltılmasında literatürde en yüksek teknik potansiyele sahip müdahaleler arasında yer almaktadır (Hasanbeigi ve Price, 2012). Pompa ve fan sistemlerinde hız kontrolüne dayalı optimizasyonun güç tüketimini kübik oranda düşürebildiği bilinmektedir; bu durum çalışmada gözlenen elektrik tasarruflarını teknik olarak açıklamaktadır. Buhar sistemlerinde düzenli kondenstop kontrolü ve ısı yalıtımı iyileştirmeleri ise yakıt tüketiminin azaltılmasında temel mühendislik uygulamalarıdır (Hasanbeigi ve Price, 2012). Tekstil tesislerinde gerçekleştirilen BAT (Best Available Techniques) temelli eko-verimlilik analizlerinde enerji tüketiminde %11–26 aralığında azalma potansiyeli raporlanmıştır (Öztürk vd.,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

2016). Bu bildiride elde edilen sonuçlar, söz konusu aralıklarla tutarlılık göstermekte ve özellikle kısa geri ödeme süreleri açısından literatürde bildirilen ekonomik uygulanabilirlik sınırları ile örtüşmektedir. Enerji ve su verimliliğinin birlikte ele alınması, tekstil sektöründe düşük karbon dönüşümünün temel bileşenlerinden biri olarak değerlendirilmektedir (Hasanbeigi vd., 2015). Çalışmada sağlanan su tasarrufu ve geri kazanım kapasitesi, kaynak etkin ve temiz üretim yaklaşımının (RECP) öngördüğü bütüncül verimlilik modeliyle uyumludur. Emisyon azaltımının IPCC metodolojisine göre hesaplanmış olması, sonuçların uluslararası sera gazı muhasebe çerçevesiyle tutarlılığını sağlamaktadır (IPCC, 2006).

6. SONUÇLAR

Bu çalışma, polyester iplik üretiminde uygulanan motor optimizasyonu, buhar sistemi iyileştirmeleri ve proses kontrol müdahalelerinin enerji ve yakıt tüketiminde ölçülebilir azalma sağladığını ortaya koymuştur. Azalan tüketim değerlerinin IPCC (2006) kılavuzuna uygun olarak CO_2 eşdeğerine dönüştürülmesi sonucunda yıllık yaklaşık 4.530 ton CO_2e emisyon azaltımı hesaplanmıştır. Elde edilen sonuçlar, tekstil sektöründe enerji verimliliği ve BAT uygulamalarının hem çevresel hem ekonomik açıdan uygulanabilir olduğunu gösteren literatürle uyumludur (Hasanbeigi ve Price, 2012; Öztürk vd., 2016). Ayrıca enerji–su verimliliği ile emisyon azaltımı arasındaki ilişki, tekstil sektöründe sürdürülebilir üretim dönüşümünü ele alan güncel çalışmalarla paralellik göstermektedir (Hasanbeigi vd., 2015).

Çalışma; temiz üretim temelli mühendislik müdahalelerinin polyester iplik üretiminde karbon yoğunluğunu azaltmaya yönelik ölçeklenebilir ve literatürle uyumlu bir sonucu göstermektedir.

KAYNAKLAR

European Commission. (2022). *EU Strategy for Sustainable and Circular Textiles* (COM/2022/141 final). Brussels: European Commission.

European Commission, Joint Research Centre (JRC). (2023). *Best Available Techniques (BAT) Reference Document for the Textiles Industry (TXT BREF 2023)*. Seville: European IPPC Bureau, JRC.

GHG Protocol. (2004). *The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (Revised Edition).* World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD).

Gironi, F., & Piemonte, V. (2011). Life cycle assessment of polylactic acid and polyethylene terephthalate bottles for drinking water. *Environmental Progress & Sustainable Energy, 30*(3), 459–468. https://doi.org/10.1002/ep.10490

Hasanbeigi, A., & Price, L. (2012). A review of energy use and energy efficiency technologies for the textile industry. *Renewable and Sustainable Energy Reviews, 16*(6), 3648–3665. https://doi.org/10.1016/j.rser.2012.03.029

Hasanbeigi, A., & Price, L. (2015). A technical review of emerging technologies for energy and water efficiency and pollution reduction in the textile industry. *Journal of Cleaner Production, 95*, 30–44. https://doi.org/10.1016/j.jclepro.2015.02.079

IEA. (2011). *Energy Efficiency Policy Opportunities for Electric Motor-Driven Systems.* Paris: International Energy Agency (IEA). (Working Paper; Authors: Paul Waide & Conrad U. Brunner).

IPCC. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Eggleston, H. S., Buendia, L., Miwa, K., Ngara, T., & Tanabe, K., Eds.). Hayama, Japan: Institute for Global Environmental Strategies (IGES) for the IPCC.

IPCC. (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Geneva: Intergovernmental Panel on Climate Change.

IPCC. (2023). *Climate Change 2023: Synthesis Report. Summary for Policymakers.* Geneva: Intergovernmental Panel on Climate Change. https://doi.org/10.59327/IPCC/AR6-9789291691647.001

ISO. (2006). *ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework.* Geneva: International Organization for Standardization.

ISO. (2006). *ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines.* Geneva: International Organization for Standardization.

OECD. (1998). *Eco-Efficiency.* Paris: Organisation for Economic Co-operation and Development (OECD).

Öztürk, E., Yetiş, Ü., Dilek, F. B., & Demirer, G. N. (2009). A chemical substitution study for a wet processing textile mill in Turkey. *Journal of Cleaner Production, 17*(2), 239–247.

Öztürk, E., Köseoğlu, H., Karaboyacı, M., Yiğit, N. Ö., Yetiş, Ü., & Kitiş, M. (2016). Sustainable textile production: Cleaner production assessment/eco-efficiency analysis study in a textile mill. *Journal of Cleaner Production, 138*, 248–263. https://doi.org/10.1016/j.jclepro.2016.02.071

UNEP. (2007, June 26). *Environmental agreements and cleaner production.* Nairobi: United Nations Environment Programme.

UNEP. (2023). *Sustainability and Circularity in the Textile Value Chain – A Global Roadmap 2023.* Nairobi: United Nations Environment Programme.

UNIDO. (n.d.). *Resource Efficient and Cleaner Production (RECP).* Vienna: United Nations Industrial Development Organization.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

LLM-ORCHESTRATED TOOL PIPELINE FOR AUTOMATED BEHAVIOR TREE EXECUTION IN ROBOT MANIPULATION

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Abstract

Industrial robot programming remains a specialized task requiring expertise in motion planning, kinematics, and control systems. Achieving reliable and repeatable task execution still demands significant engineering effort. This research work presents an LLM-based system that automatically generates Behavior Trees (BTs) from high-level YAML specifications with template and autonomously recovers from execution errors. The framework integrates Large Language Models with the BehaviorTree.CPP framework through a LangGraph-based agent architecture. Modules handle configuration generation, syntax validation, execution management, and feedback-driven refinement. Using execution feedback, including planning failures, runtime logs, and terminal outputs, the system classifies errors and iteratively adjusts motion parameters. It reduces time lost to execution failures, particularly collisions in pick-and- place tasks, making engineers' work easier. Simulation tests on a FANUC 6-DOF manipulator demonstrate the system's ability to adapt motion strategies and execute tasks reliably. This research is conducted in collaboration with an industrial robotics company and contributes to AI-assisted manufacturing by bridging natural language and industrial robot programming. The approach makes industrial robot programming more accessible to non-expert users while maintaining precision and reliability, supporting future extensions such as automated error recovery and parameter optimization.

Keywords: ROS 2, Industrial Robotics, Behaviour Trees, Motion Planning, LangGraph, Large Language Models

I. INTRODUCTION

Industrial robot programming for pick-and-place operations traditionally requires manual specification of motion primitives, collision avoidance strategies, and error handling mechanisms. Each task variation demands careful parameter tuning and extensive testing to ensure robust execution (Pan,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Polden, Larkin, Van Duin, & Norrish, 2012). When errors occur during operation, such as collisions with scene objects or kinematic limitations (Iqbal, Islam, & Khan, 2012), operators must manually diagnose the problem and adjust the program accordingly. This iterative process is time-consuming and requires deep knowledge of both the robot system and the specific application constraints. Recent advances in Large Language Models (LLMs) have demonstrated remarkable capabilities in code generation and problem-solving (Brown et al., 2020; Hu et al., 2022) across various domains. However, their application to robot control systems, particularly for automated error recovery, remains underexplored. The challenge lies in bridging natural

language understanding with structured robot control frameworks while maintaining safety and reliability constraints.

I-A. Contribution

This work addresses the challenge of automating scenario generation and error recovery for robot manipulation tasks. Our key contributions are:

a. An LLM-integrated pipeline that converts high-level YAML task specifications into executable BehaviorTree.CPP (BehaviorTree.CPP Doc., 2026) XML files.

b. An error-driven refinement mechanism that classifies execution failures and applies targeted parameter adjustments.

c. Simulation based validation showing collision error recovery through intelligent modification of approach distances and collision tolerance parameters.

d. A tool-based architecture enabling LLMs (Brown et al., 2020; Hu et al., 2022) to interact with ROS2 (Quigley et al., 2009) systems for execution monitoring and workspace management.

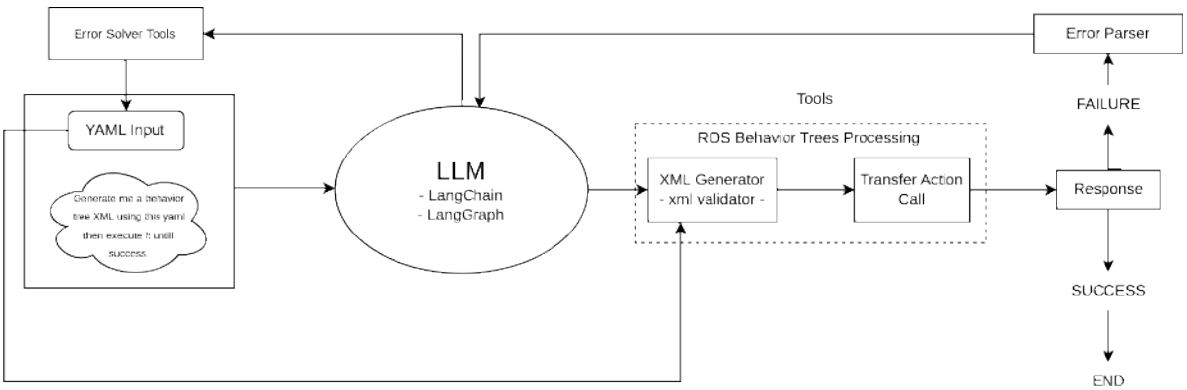


Figure 1. *System architecture diagram showing the flow from YAML input → LangGraph Agent → BT Generation → ROS2 Execution → Error Recovery loop.*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

II. RELATED WORKS

II-A. Behavior Trees in Robotics

Behavior Trees have emerged as a popular control architecture for complex robot behaviors due to their modularity, reusability, and visual interpretability (Colledanchise, & Ogren, 2018; Ghzouli et al., 2023). Unlike finite state machines (Ghzouli et al., 2023), BTs provide hierarchical composition of reactive behaviors with clear success/failure semantics. BehaviorTree.CPP has become a standard implementation used in industrial and research applications, offering extensive node libraries for motion planning, perception, and manipulation primitives (Hallen et al. 2024; Iovino et al., 2023). Traditional BT development requires manual construction through graphical tools (Groot/Groot2) (BehaviorTree.CPP Groot Doc., 2026) or direct XML/code generation. This process becomes cumbersome for tasks with many variations or when extensive error handling is required. Our work automates this process while maintaining BT structure and semantics.

II-B. LLMs for Robot Task Planning

Recent research has explored using large language models for robot task planning and code generation. These approaches typically focus on high-level task decomposition or generating simplified robot programs (Touvron et al., 2023; Guo et al., 2024). However, challenges remain in generating production-ready control code with proper error handling and safety constraints. Our system addresses this gap by targeting the structured BT representation and implementing closed-loop error recovery.

II-C. Error Recovery in Manipulation

Error recovery in robot manipulation typically relies on pre-programmed fallback strategies or manual intervention. Adaptive approaches using reinforcement learning have shown promise but require extensive training data (Thananjeyan et al., 2021; Nakamura et al., 2018). Our LLM-based approach provides a middle ground—leveraging the reasoning capabilities of pre-trained models (zero-shot approach) while operating within the safe, structured framework of behavior trees.

III. METHODOLOGY

The system architecture consists of three main layers: (1) LangGraph (LangGraph Doc., 2026) orchestration layer, (2) Tool execution layer, and (3) Robot hardware interface layer. This design separates high-level decision-making from low-level robot control while maintaining a unified interface for error feedback and recovery.

III-A. LangGraph-Based Agent

The orchestration layer is built using LangGraph, a framework for creating stateful, multi-actor applications with LLMs. Our agent operates as a state machine with the following components:

a. **LLM Node:** Processes user instructions and error messages, decides which tools to invoke based on current state. The node uses Llama 3.1 8B model (Touvron et al., 2023; Grattafiori et al., 2024) running locally via Ollama (Marcondes et al., 2025), ensuring data privacy and eliminating external API dependencies.

b. **Router:** Implements conditional logic to determine next execution step based on previous tool results. When execution fails, the router directs control back to the LLM node with error context.

c. **Tool Node:** Executes selected tools synchronously and returns structured results including success flags and detailed error information. The agent maintains conversation history through an in-memory checkpointing mechanism, allowing it to track previous recovery attempts and avoid repeating unsuccessful strategies.

III-B. Tool Architecture

We implement four primary tools using LangChain's (LangChain Doc., 2026) StructuredTool interface with Pydantic (Pydantic Doc., 2026) schemas for type safety:

1. **XML Generator Tool:** Converts YAML task specifications into BehaviorTree.CPP v4 XML. The tool accepts file paths or raw YAML content, automatically detects the input format, and generates timestamped output files.

2. **BT Executor Tool:** Interfaces with the ROS2 action server to execute generated behavior trees. Implementation uses a singleton pattern for the ROS2 node to prevent memory leaks during repeated tool invocations.

3. **Collision Error Tool:** It analyzes collision failures and applies a graduated recovery strategy by modifying YAML configuration files.

4. **Reset Workspace Tool:** Calls the */reset_workspace* ROS2 service to restore the scene to initial conditions before retry attempts. This ensures consistent starting states for each execution attempt.

III-C. Behavior Tree Generation

The BT generation module (BTGenerator class) implements a comprehensive YAML-to-XML conversion process, producing hierarchical Behavior Trees in which the main tree includes initialization scripts, scene spawning, and the task flow sequence defined in the YAML configuration, while dedicated subtrees

encapsulate reusable pick-and-place components, enabling the same motion primitives to be instantiated with different parameters for each object.

III-D. Error Recovery Method

When behavior tree execution fails, the system receives an error message from the ROS 2 (Quigley et

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ISBN: 978-9952-610-30-7

al., 2009; Macenski et al., 2022) action result and currently focuses on collision errors, the most common failure mode in constrained pick-and-place scenarios and a clearly observable case for demonstrating system functionality. The error message from MoveIt (Coleman et al., 2014) typically includes an error type identifier (e.g., “Collision detected”), a list of colliding objects in the scene, and contextual information about the motion primitive that failed. The LLM analyzes this unstructured error text to extract relevant parameters, demonstrating its natural language understanding capabilities within a robotics context.

The complete loop of the system follows this sequence – with error steps:

1. Generate BT from initial YAML specification
2. Execute BT via ROS2 action.
3. If execution fails:
   a. Parse error message to identify colliding objects
   b. Invoke collision error tool with appropriate recovery attempt number
   c. Call reset workspace tool to restore initial conditions
   d. Call XML generator tool to regenerate BT from modified YAML
   e. Execute again (max. 5 attempts)
4. Reports final success or failure to user.

The LLM maintains awareness of previous attempts through the conversation history, preventing infinite loops and enabling it to provide informative feedback about what was tried.

IV. RESULTS & DISCUSSION

Experiments were conducted on a FANUC (Garg, Kuts, & Anbarjafari, 2021) 6-DOF industrial manipulator equipped with a centric gripper in a simulation environment with a mock hardware setup. The workspace includes a table surface and a structured cell environment with multiple part locations. Scene objects are defined in YAML format and managed through ROS2 services for spawning and resetting.

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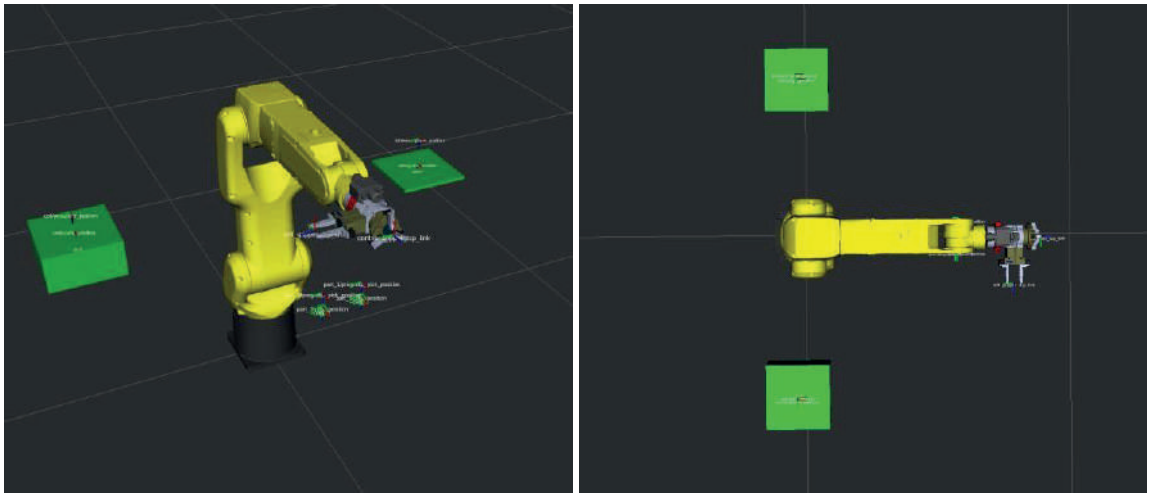


Figure 2. *Setup of the robot in the simulation environment, visualized in RViz in ROS*

IV-A. Test Scenario

We evaluated the system on two pick-and-place scenarios to see the functionality of the system and behavior when the error appeared.

Scenario ID	Description	Primary Challenge
Case 1	Single object Pick-and- Place	Verification of basic BT generation and 6- joint kinematic planning.
Case 2	Sequential Pick-and- Place	Proximity to scene geometry; intentional collision risk to trigger recovery.

Table 1. *Describing test cases*

Each scenario was tested with initial YAML configurations that intentionally lacked collision tolerance parameters, forcing the system to discover appropriate values through error recovery.

IV-B. System Performance

The system successfully selected the tools to generate valid BehaviorTree.CPP XML files from all YAML configurations on the first attempt. The generated BTs ranged from 150 to 400 lines of XML depending on the number of objects and subtrees required. We can evaluate the LLM based on several criteria listed below table:

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Criterion	Summary Evaluation
Tool Execution Reliability	Tool invocation was inconsistent: the LLM (Llama 3.1 8B) sometimes returned a textual explanation instead of executing a tool. Reliability may improve with stronger models or refined schemas. When tools were called correctly, the workflow worked as intended.
Reasoning Capability	The LLM effectively parsed verbose ROS2 error messages and extracted key information (e.g., collision object names) without rigid parsing rules, validating LLM-based error interpretation.
Parameter Adjustment Effectiveness	Collision recovery using simple strategies (allowed_touch_links and approach_distance) was often unsuccessful. Its effectiveness is limited by both code implementation and the simplicity of the approach; more sophisticated methods such as trajectory replanning, waypoint insertion, or orientation adjustments are needed.
Iteration Behavior	Collision recovery typically required 2–5 attempts. Effectiveness depended on scenario complexity. Limited recovery actions constrained performance.
Limitations	No dedicated strategies for IK failures or timeouts. No cross-session learning. Tested only in simulation. The contribution is architectural (LLM- orchestrated recovery), not production-level reliability.

V. CONCLUSION

This paper presented an LLM-based system for automating behavior tree generation and execution error recovery in robot manipulation tasks. By integrating Llama 3.1 8B with BehaviorTree.CPP through a LangGraph-based agent architecture, we demonstrated the feasibility of intelligent collision error recovery with reduced manual intervention. The system successfully validated the core concept:

LLMs can interpret

unstructured error messages and orchestrate recovery tools within a structured robot control framework, though challenges in tool invocation reliability and recovery strategy effectiveness indicate areas requiring further development.

VI. REFERENCES

Ao, J., Wu, F., Wu, Y., Swiki, A., & Haddadin, S. (2025). LLM-as-BT-planner: Leveraging LLMs for behavior tree generation in robot task planning. In 2025 IEEE International Conference on Robotics and Automation (ICRA) (pp. 1233–1239). IEEE.

BehaviorTree.CPP Documentation. (2026). https://www.behaviortree.dev/

BehaviorTree.CPP Groot IDE. (2026). https://www.behaviortree.dev/groot/

Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J. D., Dhariwal, P., Neelakantan, A., Shyam, P., Sastry, G., Askell, A., et al. (2020). Language models are few-shot learners. Advances in Neural Information Processing Systems, 33, 1877–1901.

Colledanchise, M., & Ogren, P. (2018). Behavior trees in robotics and AI: An introduction. CRC Press.

Coleman, D., Sucan, I., Chitta, S., & Correll, N. (2014). Reducing the barrier to entry of complex robotic software: A MoveIt! case study. arXiv preprint arXiv:1404.3785.

Garg, G., Kuts, V., & Anbarjafari, G. (2021). Digital twin for FANUC robots: Industrial robot programming and simulation using virtual reality. Sustainability, 13(18), 10336.

Ghzouli, R., Berger, T., Johnsen, E. B., Wasowski, A., & Dragule, S. (2023). Behavior trees and state machines in robotics applications. IEEE Transactions on Software Engineering, 49(9), 4243–4267.

Grattafiori, A., Dubey, A., Jauhri, A., Pandey, A., Kadian, A., Al-Dahle, A., Letman, A., Mathur, A., Schelten, A., Vaughan, A., et al. (2024). The LLaMA 3 herd of models. arXiv preprint arXiv:2407.21783.

Guo, D., Zhu, Q., Yang, D., Xie, Z., Dong, K., Zhang, W., Chen, G., Bi, X., Wu, Y., Li, Y. K., Luo, F.,

Xiong, Y., & Liang, W. (2024). DeepSeek-Coder: When the large language model meets programming –

The rise of code intelligence.

Hallen, M., Iovino, M., Sander-Tavallaey, S., & Smith, C. (2024, August). Behavior trees in industrial applications: A case study in underground explosive charging. In 2024 IEEE 20th International Conference on Automation Science and Engineering (CASE) (pp. 156–162). IEEE.

Hu, E. J., Shen, Y., Wallis, P., Allen-Zhu, Z., Li, Y., Wang, S., Wang, L., Chen, W., et al. (2022). LoRA: Low-rank adaptation of large language models. ICLR, 1(2), 3.

Huang, J., & Chang, K. C.-C. (2022). Towards reasoning in large language models: A survey. arXiv preprint arXiv:2212.10403.

Iqbal, J., Islam, R. U., & Khan, H. (2012). Modeling and analysis of a 6 DOF robotic arm manipulator. Canadian Journal on Electrical and Electronics Engineering, 3(6), 300–306.

Izzo, R. A., Bardaro, G., & Matteucci, M. (2024). BTGenBot: Behavior tree generation for robotic tasks with lightweight LLMs. In 2024 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) (pp. 9684–9690). IEEE.

Izzo, R. A., Bardaro, G., & Matteucci, M. (2026). BTGenBot-2: Efficient behavior tree generation with small language models. arXiv preprint arXiv:2602.01870.

Iovino, M., Styrud, J., Falco, P., & Smith, C. (2023, August). A framework for learning behavior trees in collaborative robotic applications. In 2023 IEEE 19th International Conference on Automation Science and Engineering (CASE) (pp. 1–8). IEEE.

LangChain Documentation. (2026). https://docs.langchain.com/

LangGraph Documentation. (2026). https://langchain.com/langgraph/

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Lykov, A., & Tsetserukou, D. (2024). LLM-Brain: AI-driven fast generation of robot behaviour tree based on large language model. In 2024 2nd International Conference on Foundation and Large Language Models (FLLM) (pp. 392–397). IEEE.

Macenski, S., Foote, T., Gerkey, B., Lalancette, C., & Woodall, W. (2022). Robot operating system 2: Design, architecture, and uses in the wild. Science Robotics, 7(66), eabm6074.

Marcondes, F. S., Gala, A., Magalhães, R., Perez de Britto, F., Durães, D., & Novais, P. (2025). Using Ollama. In Natural Language Analytics with Generative Large-Language Models: A Practical Approach with Ollama and Open-Source LLMs (pp. 23–35). Springer Nature.

Nakamura, A., Nagata, K., Harada, K., & Yamanobe, N. (2018). Technique of recovery process and application of AI in error recovery using task stratification and error classification. Journal of Robotics,

Networking and Artificial Life, 5, 56. https://doi.org/10.2991/jrnal.2018.5.1.13

Pan, Z., Polden, J., Larkin, N., Van Duin, S., & Norrish, J. (2012). Recent progress on programming methods for industrial robots. Robotics and Computer-Integrated Manufacturing, 28(2), 87–94.

Pydantic Documentation. (2026). https://docs.pydantic.dev/

Quigley, M., Conley, K., Gerkey, B., Faust, J., Foote, T., Leibs, J., Wheeler, R., Ng, A. Y., et al. (2009). ROS: An open-source robot operating system. In ICRA Workshop on Open Source Software (Vol. 3, p. 5). Kobe, Japan.

Thananjeyan, A., Balakrishna, A., Nair, S., et al. (2021). Recovery RL: Safe reinforcement learning with learned recovery zones. IEEE Robotics and Automation Letters, 6(3), 4915–4922.

Touvron, H., Lavril, T., Izacard, G., Martinet, X., Lachaux, M.-A., Lacroix, T., Roziere, B., Goyal, N., Hambro, E., Azhar, F., et al. (2023). LLaMA: Open and efficient foundation language models. arXiv preprint arXiv:2302.13971.

Zhou, H., Lin, Y., Yan, L., Zhu, J., & Min, H. (2024). LLM-BT: Performing robotic adaptive tasks based on large language models and behavior trees. In 2024 IEEE International Conference on Robotics and Automation (ICRA) (pp. 16,655–16,661). IEEE.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BÜYÜK DİL MODELLERİNDE BİLGİ ERİŞİMİ, GÜVENİLİRLİK SORUNU VE İZLEME YÖNTEMLERİ ÜZERİNE BİR İNCELEME

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ÖZET

Doğal Dil İşleme alanı, transformatör mimarisinin gelişimiyle birlikte önemli bir dönüşüm yaşamış ve Büyük Dil Modelleri metin anlama ve üretme görevlerinde yüksek performans göstermeye başlamıştır. Bununla birlikte eğitim verisinin statik yapısı ve literatürde "halüsinasyon" olarak adlandırılan tutarsız içerik üretimi, özellikle doğruluğun kritik olduğu uygulamalarda güvenilirlik sorunları oluşturmaktadır. Çalışma büyük dil model tabanlı sistemlerde güvenilirliği etkileyen yöntemleri mimari ve sistem düzeyi yaklaşımlar çerçevesinde bütüncül olarak incelemeyi amaçlamaktadır. Çalışmada modelin içsel bilgisini dış kaynaklarla birleştiren Geri Getirme Destekli Üretim mimarileri ile modele göreve özgü davranış kazandıran ince ayar ve parametre verimli uyarlama yöntemleri karşılaştırmalı olarak ele alınarak kurulan sistemlerin optimizasyonu, model hizalama yöntemleri ve MLOps süreçleri değerlendirilerek Büyük dil işleme tabanlı uygulamaların tekil modellerden sürekli izlenen, değerlendirilen ve güncellenen yazılım sistemlerine dönüşümü incelenmiştir. Çalışma, güvenilir yapay zekâ sistemlerinin yalnızca model performansına değil, aynı zamanda bilgi erişimi, davranış kontrolü ve operasyonel izleme bileşenlerinin birlikte tasarlanmasına bağlı olduğunu ortaya konulmuştur.

Anahtar Kelimeler: Büyük Dil Modelleri, Geri Getirme Destekli Üretim, İnce Ayar, Halüsinasyon, MLOps, Optimizasyon

A SURVEY OF KNOWLEDGE RETRIEVAL, RELIABILITY CHALLENGES, AND MONITORING TECHNIQUES IN LARGE LANGUAGE MODELS

ABSTRACT

The field of Natural Language Processing has undergone a significant transformation with the development of transformer architectures, enabling Large Language Models to achieve high performance in text understanding and generation tasks. However, the static nature of training data and the production of inconsistent content—commonly referred to in the literature as "hallucinations"—

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

pose reliability challenges, particularly in applications where accuracy is critical. This study aims to holistically examine the methods that influence reliability in large language model–based systems within the framework of architectural and system-level approaches. The research comparatively analyzes Retrieval-Augmented Generation architectures, which integrate a model's internal knowledge with external information sources, alongside fine-tuning and parameter-efficient adaptation methods that enable task-specific model behavior. Furthermore, system optimization strategies, model alignment techniques, and MLOps processes are evaluated to investigate the transformation of large language processing–based applications from standalone models into continuously monitored, evaluated, and updated software systems. The study demonstrates that reliable artificial intelligence systems depend not only on model performance but also on the joint design of information retrieval mechanisms, behavioral control strategies, and operational monitoring components.

Keywords: Large Language Models, Retrieval-Augmented Generation, Fine-Tuning, Hallucination, MLOps, Optimization

1. GİRİŞ

Doğal Dil İşleme (DDİ), bilgisayarların insan dilini anlayabilmesi, yorumlayabilmesi ve üretebilmesini amaçlayan; dil bilimi ile yapay zekânın birlikte kullanıldığı bir araştırma alanıdır. Metin sınıflandırma, makine çevirisi, soru-cevaplama ve diyalog sistemleri de temel uygulamaları arasında yer almaktadır. Son yıllarda DDİ, transformatör mimarisinin ortaya çıkışıyla birlikte önemli bir çerçeve değişimi geçirmiştir (Vaswani vd., 2017). Bu değişim için mimari üzerine geliştirilen T5, BERT, GPT, LLaMA, Mistral, Claude ve Gemini gibi modeller geniş veri kümeleri üzerinde eğitilerek metin anlama ve üretme görevlerinde önemli başarılar elde edilerek birçok durumda insan benzeri çıktılar üretebilir hale gelmiştir (Brown vd., 2020; Touvron vd., 2023).

Bununla birlikte Büyük Dil Modelleri (BDM) güçlü bir genel dil yeteneği kazandırılarak gerçek kullanım senaryolarının gerektirdiği doğruluk, tutarlılık ve alan-özgüllük ihtiyaçlarını her zaman karşılayamayabilmektedir. Bu durum özellikle kurumsal, teknik veya güncel bilgi gerektiren görevlerde eğitim verisinin genel amaçlı olması ve sonradan güncellenememesi nedeniyle modelin gerekli bağlamsal bilgiyi içermediği ve ikna edici fakat hatalı yanıtlar üretebildiğini göstermiştir (Ji vd., 2023). Bu durum yalnızca ön-eğitim aşamasında öğrenilen bilgilere güvenmenin pratik uygulamalar için yeterli olmadığını göstermektedir. Bunun için modeli belirli görev veya alanlara uyarlayan hassas ayar yöntemleri (fine-tuning) ve modelin bilgiyi parametrelerinde saklamak yerine dış kaynaklardan edinmesini sağlayan geri getirme destekli üretim (RAG) yaklaşımları geliştirilmiştir (Hu vd., 2022; Lewis vd., 2020). Ancak bu yaklaşımlar doğruluğu arttırmasına rağmen hataları tamamen ortadan kaldırmamaktadır. Modeller akademik literatürde "halüsinasyon" olarak adlandırılan ve özellikle bilgiye dayalı uygulamalarda güvenilirlik sorunu oluşturan, gerçekte var olmayan bilgileri tutarlı bir biçimde üretebilmektedir. (Ji vd., 2023). Bu nedenle yalnızca doğru veriye erişmek yeterli

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ISBN: 978-9952-610-30-7

olmayıp, modelin yanıtı nasıl oluşturduğunu denetlemek de oldukça önemli bir durum tespiti haline gelmiştir. Bu gereksinim, üretim sürecine doğrulama ve karar mekanizmalarının eklenmesine neden olmuştur. Örneğin agentic yaklaşımlarda model çıktıları değerlendirilerek gerekli durumlarda ek bilgiler aranarak yanıt yeniden güncellenmektedir. Böylece üretim süreci tek adımlı metin üretiminden çok aşamalı bir karar sürecine dönüşmektedir. Ancak güvenilirlik yalnızca üretim anındaki kontrollerle sınırlı değildir. Model performansının zamanla değişmesi ve veri kaynaklarının güncellenmesi gereksinimi nedeniyle sistemlerin sürekli izlenmesi ve değerlendirilmesi oldukça önemli bir durumdur. Bu nedenle BDM tabanlı uygulamalar yaygın bir biçimde makine öğrenmesi modellerinin geliştirilmesi süreçleri de içerisinde ele alınarak veri güncelleme, performans ölçümü ve model davranışı takip sisteminin önemli bir parçası haline gelmektedir.

Çalışmada büyük dil modellerinde güvenilirliği etkileyen unsurları yalnızca model çıktıları üzerinden değil, mimari tasarımdan bilgi erişim mekanizmalarına ve sistem düzeyindeki denetim süreçlerine kadar kapsamlı bir biçimde akademik literatüre dayalı incelenmiştir. Bu incelemede, katman yapısı, parametre ölçeği ve eğitim stratejileri gibi model mimarisine ait özellikler doğruluk, tutarlılık ve kararlılık üzerindeki etkisi ele alınmıştır. Ayrıca modelin dış bilgi kaynaklarına erişim biçimleri, güncel ve doğrulanabilir bilgi üretme kapasitesi açısından değerlendirilerek sistem düzeyinde uygulanan izleme, geri bildirim, insan denetimi ve güvenlik filtreleri gibi kontrol mekanizmalarının, hatalı veya zararlı çıktıları azaltmadaki rolleri hakkında detaylı bilgiler verilmiştir. Böylelikle bu çalışma, güvenilirliği yalnızca teknik bir performans metriği olarak değil, mimari seçimler, veri yönetimi, model eğitimi ve operasyonel denetim süreçlerinin etkileşimiyle birlikte çok boyutlu bir biçimde analiz edilmiştir.

2. DOĞAL DİL İŞLEME ve TRANSFORMER MİMARİLERİNİN TEMELLERİ

DDİ alanındaki modern yaklaşımlar, dilin yalnızca kelime düzeyinde değil, bağlam içindeki ilişkileriyle birlikte modellenmesine ilkesine dayanmaktadır. Derin öğrenme yöntemlerinin ilk dönemlerinde kullanılan Yinelemeli Sinir Ağları (RNN) ve Uzun Kısa Süreli Bellek (LSTM) yapıları metni ardışık olarak analiz ettiği için uzun mesafeli bağımlılıkları öğrenme ve eğitimi paralelleştirmede önemli sınırlamalara neden olmaktadır. Bu sınırlamalar, dizideki tüm öğeler arasındaki ilişkileri yinelemeye ihtiyaç duymadan modelleyebilen dikkat temelli transformatör mimarisinin geliştirilmesiyle büyük ölçüde azaltılmıştır (Vaswani vd., 2017).

Transformatör mimarisi, girdi dizisinin tamamını tek seferde analiz edebilen katmanlı bir yapı üzerine kurulmuştur. Böylece model hem uzun mesafeli bağımlılıkları daha etkili biçimde öğrenebilmekte hem de eğitim süreci paralel olarak gerçekleştirilebilmektedir. Bu mimari yaklaşım doğrultusunda transformatör tabanlı modeller metni anlamaya odaklanan kodlayıcı (encoder) modeller, metin üretimi için tasarlanan kod çözücü modeller (decoder) ve her iki yeteneği birleştiren kodlayıcı-çözücü (decoder-encoder) modeller olmak üzere üç yapısal gruba ayrılmaktadır. Bu yapısal grupların

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

akademik literatürdeki öncü modelleri arasında BERT kodlayıcı tabanlı yapısıyla bağlamı anlamaya yönelik görevlerde öne çıkarken, GPT serisi otoregresif kod çözücü yapısıyla metin üretiminde kullanılan modeller olarak karşımıza çıkmaktadır. T5 gibi kodlayıcı-çözücü modeller ise anlama ve üretimi tek bir yapı altında birleştirerek görevleri metin-dönüşüm problemi olarak ele almaktadır (Devlin vd., 2019; Raffel vd., 2020). Bu yapıların temelinde dikkat mekanizmaları yer almaktadır. Self-Attention mekanizması her kelimenin bağlam içerisindeki önemini diğer kelimelerle olan ilişkisine bağlı olarak hesaplarken, Multi-Head Attention yapısı ise modelin farklı anlamsal ilişkileri paralel olarak öğrenmesini sağlayarak dilin hem söz dizimsel hem de anlamsal yapısının daha güçlü olmasını sağlamaktadır (Minaee vd., 2024). Bu mimari farklı görevler için özelleştirilebilse de tüm büyük dil modelleri öğrenme sürecine geniş metin derlemeleri üzerinde gerçekleştirilen ön eğitim aşaması, ilk aşama olarak belirlenmektedir. Bu aşamada modeller açık etiketli veri kullanmadan, kendi kendine denetimli hedefler üzerinden dilin istatistiksel yapısını öğrenmektedir. Bu durumu otoregresif modeller için verilen bağlama göre bir sonraki kelimeyi tahmin etmeyi öğrenirken, maskeli modeller eksik bırakılan kelimeleri çevreleyen bağlamdan çıkarmayı öğrenme örneği ile ifade edilen bir süreç olarak tanımlamak mümkündür (Brown vd., 2020; Devlin vd., 2019). Bu süreç modelin dili belirli görevlerden bağımsız, genel bir temsil olarak edinmesini sağlamaktadır. Bu modellerin başarısı büyük ölçüde ölçekleme davranışı ile ilişkilendirilmektedir. Modelin parametre sayısı, veri miktarı ve hesaplama gücü arttıkça performansın sistematik biçimde iyileştiği belirlenmiştir (Brown vd., 2020). Belirli bir ölçeğin üzerine çıkıldığında ise az örnekle öğrenme veya çok adımlı akıl yürütme gibi küçük modellerde gözlenmeyen yetenekler ortaya çıkabilmektedir. (Wei vd., 2022). Bu nedenle modern büyük dil modelleri yalnızca mimari yeniliklerin değil, aynı zamanda veri ve hesaplama ölçeğinin birlikte büyümesinin bir sonucu olarak değerlendirilmektedir.

3. BİLGİ GETİRİMİYLE ZENGİNLEŞTİRİLMİŞ ÜRETİM (RAG) YAKLAŞIMLARI

Bilgi Getirimiyle Zenginleştirilmiş Üretim (BGZÜ; Retrieval-Augmented Generation, RAG) yaklaşımları, BDM'nin eğitim sürecinde edindikleri parametrik bellek sayesinde geniş bir bilgi taşımasına rağmen bu bilgi statik olup model eğitildikten sonra doğrudan güncellenmemektedir. Bu durum, modellerin güncel olaylara yanıt verememesine ve uzmanlık gerektiren alanlarda yetersiz kalmasına neden olmaktadır (Lewis vd., 2020). BGZÜ yaklaşımı, bu sınırlılığı aşmak amacıyla modelin içsel bilgisini harici ve güncelleyerek bilgi kaynaklarıyla birleştiren bir çerçeve olarak önerilmektedir. Bu yaklaşımda üretim süreci, ilgili bilgiyi bularak bilgiye dayanarak cevap oluşturma olmak üzere iki aşamalı bir "getir ve üret" yaklaşımına dayanmaktadır (Guu vd., 2020; Lewis vd., 2020).

BGZÜ sistemi temel olarak bilgi indeksleme, geri getirme ve üretim olmak üzere üç aşamadan oluşmaktadır. İlk aşamada metinler vektör temsillerine dönüştürülerek aranabilir hale getirilir. Bir sonraki aşamada ise kullanıcı sorgusu da benzer bir temsile dönüştürülerek anlamsal benzerlik üzerinden en ilgili belgeler bulunur. Bu işlem genellikle yoğun vektör arama yöntemleriyle

gerçekleştirilmekte olup embedding modelleri kullanan yoğun temsil tabanlı getirim (dense retrieval) bu amaçla yaygın olarak kullanılmaktadır (Karpukhin vd., 2020). Bununla birlikte anahtar kelime tabanlı BM25 gibi seyrek yöntemler de hibrit arama stratejilerinde sıklıkla kullanılmaktadır (Gao vd., 2023).

Son aşamada ise geri getirilen bilgiler sorgu ile birleştirilerek üretici modele bağlam olarak verilir ve modelden cevabı bu bilgiye dayanarak oluşturması beklenmektedir (Ram vd., 2023). Son yıllarda yapılan çalışmalar süreci daha da geliştirerek yinelemeli BGZÜ ve aktif BGZÜ gibi yaklaşım yöntemlerini önermektedir. Bu yöntemlerde model cevap üretimi sırasında birden fazla kez bilgi arayabilir veya belirsizlik tespit ettiğinde yeni kanıtlar toplayarak üretim sürecini dinamik biçimde sürdürebilmektedir (Jiang vd., 2023).

BGZÜ model çıktılarının doğrulanabilirliğinin artırması mimarinin temel çıktısıdır. Geleneksel dil modellerinde bilgi eksikliği durumunda istatistiksel olarak makul fakat hatalı cevaplar üretebilirken, BGZÜ tabanlı sistemler yanıtlarını geri getirilen belgelerle ilişkilendirmektedir (Gao vd., 2023). Bu nedenle üretim süreci, ezberden üretim yerine kanıta dayalı üretim yaklaşımına doğru değişim göstermektedir. Konu ile ilgili akademik çalışmalar özellikle bilgi yoğunluğunun olduğu görevlerde BGZÜ kullanımının halüsinasyon oranını düşürdüğünü ve yanıtların güvenilirliğini artırdığını göstermektedir (Shuster vd., 2021). Ayrıca harici bilgi kaynağının güncellenebilmesi ile model parametrelerini yeniden eğitmeden sistemin güncel tutulması mümkün hale gelmektedir (Ram vd., 2023).

4. İNCE AYAR YAKLAŞIMLARI

Büyük dil modelleri ön eğitim aşamasında; geniş veri kümelerinden genel dil yetenekleri kazanmasına rağmen, belirli bir alanda uzmanlaşmaları veya kullanıcı talimatlarını istenen biçimde yerine getirmeleri için ek uyarlama süreçlerine ihtiyaç duyulmaktadır. Bu nedenle ince ayar sıklıkla kullanılan temel yöntemlerden birisi olup önceden eğitilmiş modelin daha küçük ve göreve özgü veri kümeleri üzerinde yeniden eğitilmesini hedeflemektedir. (Zhang vd., 2026). Bu süreç modelin genel metin üretim davranışını, belirli bir görevin gerektirdiği çıktı biçimine yaklaştırmayı amaçlamaktadır (Ouyang vd., 2022). Aşağıdaki alt başlıklarda ince ayar yaklaşımları detaylı bir biçimde ele alınmıştır.

4.1. Talimatlı ince ayar yöntemi

Talimatla ince ayar (Instruction Tuning) yaklaşımı, modelin belirli bir alan ve talimat formatlarına göre kullanıcı niyetini daha doğru yorumlayabilmesi amacıyla geliştirilmiş bir yöntemdir. Bu yöntemde model, talimat ve karşılık gelen doğru çıktılardan oluşan veri kümeleri üzerinde eğitilerek farklı görev türlerine genelleme yapma yeteneği kazanmaktadır (Wei vd., 2021). Böylece eğitilen modellerin, yalnızca ön eğitim almış modellere kıyasla karmaşık ve alana özgü görevlerde dahi daha başarılı sonuçlar ürettiği tespit edilmiştir (Chung vd., 2024)

4.2. Parametre verimli ince ayar yöntemi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Milyarlarca parametre içeren modellerin tamamını yeniden eğitimi oldukça yüksek hesaplama maliyeti gerektirdiğinden dolayı son yıllarda parametre verimli ince ayar yöntemleri (PEFT) geliştirilmiştir. Bu yaklaşımlarda BDM'nin tüm ağırlıklarını güncellemek yerine sadece küçük bir alt kümesini veya ek katmanları eğiterek, minimum hesaplama kaynağı ve bellek ile özelleştirmektir. Bu kapsamda önerilen yöntemler için farklı stratejiler izlenmektedir. Düşük Mertebeli Uyarlama (Low-Rank Adaptation-LoRA) yaklaşımı model ağırlıklarına düşük boyutlu uyarlama matrisleri ekleyerek benzer performansı çok daha düşük maliyetle elde etmeyi mümkün kılmaktadır (Hu vd., 2022). Kuantize Edilmiş Düşük Mertebeli Uyarlama (Quantized Low-Rank Adaptation QLoRA) ise bu yaklaşımı nicemleme ile birleştirerek bellek gereksinimini azaltıp büyük modellerin daha sınırlı donanımlarda eğitilebilmesini amacıyla kullanılmaktadır (Dettmers vd., 2023). Uyarlayıcı tabanlı yöntemlerde model katmanları arasına küçük öğrenilebilir modüller eklenirken girdi ön eki ayarlama (prefix tuning) ve istem ayarlama yaklaşımlarında model parametreleri değiştirilmeden giriş temsilleri üzerinden yönlendirme yapılmaktadır. Bu yöntemler, modelin bilgisini değiştirmek yerine davranışını kontrol etmeye odaklanmaları açısından özellikle görev uyarlama senaryolarında tercih edilmektedir.

4.3. İnsan geri bildirimi temelli pekiştirmeli öğrenme yaklaşımı

Modelin sadece doğru değil aynı zamanda güvenli ve kullanıcı beklentileriyle uyumlu cevaplar üretebilmesi için hizalama yöntemleri uygulanmaktadır. Bu yöntemler genellikle modelin ön eğitim ve görev uyarlama aşamalarından sonra kullanıcıya sunulmadan önce davranışının düzenlenmesi amacıyla kullanılmaktadır. İnsan geri bildirimi temelli pekiştirmeli öğrenme (Reinforcement Learning from Human Feedback, RLHF) yaklaşımında model çıktıları insanlar tarafından değerlendirilerek tercihler doğrultusunda modelin yanıt verme eğilimi yeniden optimize edilme sürecidir (Ouyang vd., 2022). Bu süreç, modelin yeni bilgi öğrenmesinden ziyade mevcut bilgisini nasıl kullandığını belirmektedir. Böylece yeni yöntemlerde bu süreç daha da basitleştirerek tercih edilen ve edilmeyen yanıt çiftleri üzerinden doğrudan optimizasyon bir yapmayı sağlamaktadır (Rafailov vd., 2023). Böylece model, ham üretim davranışından kullanıcı odaklı davranışa doğru yönlendirilerek gerçek kullanım sırasında ortaya çıkabilecek hatalı veya uygunsuz yanıtların azaltılması amaçlanmaktadır. Bu tür hizalama yaklaşımları, model geliştirme sürecinin son katmanı olarak güvenilir sistemlerin oluşturulmasına katkı sağlamaktadır.

5. BÜYÜK DİL MODELLERİNDE HALÜSİNASYON

BDM'ler, metin üretiminde sağladıkları akıcılık ve tutarlılıkları açısından önemli bir yeteneğe sahip olmasına rağmen, bu yetenekleri "halüsinasyon" olarak bilinen kritik bir güvenilirlik sorunu ortaya çıkabilmektedir. Halüsinasyon, modelin dil bilgisel olarak doğru ve bağlamsal açıdan anlamlı görünen ancak gerçek dünya olgularıyla uyuşmayan veya verilen kaynakla çelişen içerikler üretmesi olarak tanımlanmaktadır (Ji vd., 2023; Zhang vd., 2025). Bu durum özellikle sağlık, hukuk ve finans gibi doğruluğun önemli olduğu alanlarda yeterli olmasına rağmen hatalı çıktılar sistemlerin güvenilirliğini

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ciddi biçimde sınırlamaktadır (Huang vd., 2025). Halüsinasyona ait detaylı analizler aşağıdaki alt başlıklarda detaylı bir biçimde ele alınmıştır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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5.1. Halüsinasyonun Temel Nedenleri

Halüsinasyonlar veri, eğitim ve çıkarım süreçlerinin birleşimiyle ortaya çıkan çok faktörlü bir problem olarak değerlendirilmektedir. Veri kaynaklı faktörler problemin önemli bir bölümünü oluşturmaktadır. BDM'leri doğruluğu teyit edilmeden toplanan büyük veri kümeleri üzerinde eğitildiği için yanlış bilgiler, ön yargılar ve yaygın hatalar model tarafından öğrenilebilmekte ve yeniden üretilebilmektedir (Lin vd., 2022). Ayrıca eğitim verisinin statik olması, modelin güncel olaylar hakkında bilgi sahibi olmamasına ve bilgi sınırlarının ötesinde sonuçla ilgili olmayan içerik üretmesine yol açmaktadır (Kandpal vd., 2023). Modelin eğitim aşamasında her zaman doğru geçmiş bağlamla eğitilmesi, çıkarım sürecinde kendi çıktıları üzerinden yinelemeli biçimde ilerlemesini gerektirdiğinden dolayı bu dağılım farklılığı maruz kalma yanlılığı sorununu oluşturarak halüsinasyon oluşumuna neden olmaktadır (Wang ve Sennrich, 2020). Bunun yanı sıra insan geri bildirimine dayalı hizalama süreçlerinde modelin doğruluktan ziyade kullanıcıyı memnun edecek cevaplar üretme eğilimi geliştirebildiği de tespit edilmiştir (Sharma vd., 2023). Ayrıca çıkarım aşamasındaki üretim stratejileri de önemli bir etken olup metin üretimi sırasında kullanılan rastgele örnekleme yöntemleri düşük olasılıklı kelimelerin seçilmesine neden olup hatalı içerik üretimini artırabilmektedir (Dziri vd., 2021). Ayrıca dikkat mekanizmasının uzun dizilerde kaybolarak modelin bağlamdan kopmasına ve ilgisiz bilgiler üretmesine neden olabilmektedir (Liu vd., 2024).

5.2. Halüsinasyonun Türleri ve Taksonomisi

Halüsinasyonun doğasını anlamak için akademik literatürde farklı sınıflandırma yaklaşımları kullanılmıştır. Bu teknikleri arasında kullanılan yaklaşım halüsinasyonları içsel ve dışsal olmak üzere iki ana kategoride ele alınmaktadır (Ji vd., 2023). İçsel halüsinasyon, modelin ürettiği çıktının doğrudan verilen girdiyle çelişmesi durumu olup çoğunlukla bağlamın yanlış yorumlanmasından kaynaklanmaktadır. Dışsal halüsinasyon ise modelin ne girdide ne de doğrulanabilir bilgi kaynaklarında bulunan tamamen yeni bilgiler üretmesi şeklinde ortaya çıkmaktadır (Maynez vd., 2020). Bu farklılık özellikle özetleme ve soru cevaplama sistemlerinde hatanın model yorumundan mı yoksa bilgi eksikliğinden mi kaynaklandığını belirlemek açısından oldukça önemlidir. Bu nedenle akademik literatürdeki güncel çalışmalar bu sınıflandırmayı olgusallık ve sadakat eksenleri baz alınarak genişletilmiştir. Olgusallık ise hataları modelin gerçek dünya bilgisiyle farklılık göstermesi durumunu ifade ederken, sadakat hataları modelin verilen talimatı doğru izleyememesi veya kendi akıl yürütme süreci içinde tutarsızlık üretmesi şeklinde ortaya çıkmaktadır (Huang vd., 2025, Alansari ve Luqman, 2025). Bu iki kavram arasındaki fark, modelin "yanlış bilgi üretmesi" ile "doğru bilgiyi yanlış bağlamda kullanması" ayrımını analiz ederek değerlendirme yöntemlerinin de farklılaşmasına neden olmaktadır.

6. HİBRİT SİSTEMLER VE OPTİMİZASYON

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BDM'lerin performansını artırmada tek başına ince ayar veya geri getirme destekli üretim yöntemleri belirli sınırlılıklar içermektedir. İnce ayar, modelin davranışını ve görev uyumunu iyileştirirken yeni bilgileri öğrenme konusunda yavaş kalarak modelin güncel bilgilerden geride kalmasını ve modelin hatalı cevaplar verebilmesine neden olmaktadır. Geri getirme destekli üretim yöntemleri ise güncel bilgiye erişim sağlasa bile modelin bilgiyi nasıl yorumlayacağını doğrudan düzenleyememektedir (Gao vd., 2023; He vd., 2024). Bu nedenle son yıllarda gerçekleştirilen çalışmalarda modelin hem içsel bilgisini hem de dış bilgi kullanımını birlikte optimize eden hibrit yaklaşımlar ön plana çıkmaktadır. Bu yaklaşımlar aşağıdaki alt başlıklarda detaylı bir biçimde analiz edilmiştir.

6.1. Geri getirme destekli üretim yöntemleri ve ince ayar entegrasyonu

Hibrit yaklaşımın temel amacı modelin "ne bildiğini" ve "nasıl davranması gerektiğini" eş zamanlı olarak düzenlemektir. Standart bir model, geri getirme destekli üretimi her zaman doğru biçimde kullanmayabilmektedir. Bu nedenle gürültüyü ayırt edememek veya çelişkili bilgiler karşısında hatalı çıkarımlar yapmak bu duruma örnek olarak verilebilecek sorunlardandır (Cuconasu vd., 2024). Bu sorunu ele almak amacıyla geliştirilen yöntemler, modeli doğrudan geri getirilen belgelerle birlikte eğitmeyi önermektedir. Erişimle Zenginleştirilmiş İnce Ayar (Retrieval-Augmented Fine-Tuning, RAFT) gibi yaklaşımlarda model ile ilgili ve ilgisiz olan belgelerin birlikte verildiği durumlar üzerinde eğitilerek kanıta dayalı yanıt üretme davranışı kazandırmaktadır (Dong vd., 2023; Zhang vd., 2026).

6.2. Öz-Yansıtımlı Bilgi Erişimi

Klasik geri getirme destekli üretim mimarilerinde model, geri getirilen belgeleri pasif bir biçimde kullanarak yanıt üretmektedir. Ancak bu yaklaşım, getirilen bilginin gerçekten gerekli olup olmadığı veya yeterince güvenilir olup olmadığı konusunda modele herhangi bir değerlendirme yeteneği kazandırmamaktadır. Son yıllarda yapılan akademik çalışmalar, üretim sürecine öz-değerlendirme adımları ekleyerek bu sınırlılığı gidermeyi hedeflemiştir. Öz-Yansıtımlı Erişimle Zenginleştirilmiş Üretim (Self-Reflective, RAG) yaklaşımı bu doğrultuda modelin yalnızca bilgiye erişimini değil aynı zamanda bilgi ihtiyacını belirlemesini ve elde edilen kanıtı doğrulamasını sağlayan bir üretim süreci tanımlamaktadır (Asai vd., 2024). Model, yanıt üretimi sırasında dış bilgiye ihtiyaç duyup duymadığını değerlendirilerek getirilen içeriğin ilgili olup olmadığını kontrol ederek ürettiği çıktının bu kanıtla desteklenip desteklenmediğini gözden geçirmektedir. Böylece üretimi tek aşamalı bir metin oluşturma sürecinden, geri bildirim içeren döngüsel bir kıyaslama yaklaşımına dönüştürmektedir. Bu tür yaklaşımlar, halüsinasyonların yalnızca bilgi eksikliğinden değil aynı zamanda hatalı bilgi kullanımından da kaynaklanabildiğini göstererek geri getirme destekli üretim sistemlerinin doğruluk mekanizmasını güçlendirmektedir.

6.3. Ajan Tabanlı Optimizasyon ve Karar Mekanizmaları

Dil modelinin statik bir metin üreticisinden etkileşimli bir karar vericiye dönüştürülmesi oldukça önemlidir. Ajan tabanlı yaklaşımlar, modelin araç kullanma, planlama ve bellek yönetimi gibi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

yetenekleri analiz ederek çok adımlı problem çözmesini mümkün kılmaktadır (Xi vd., 2025). Bu tür sistemlerde model doğrudan tek seferde cevap üretmek yerine, önce problemi alt adımlara ayırarak gerekli olduğunda arama motoru, hesaplayıcı veya veri tabanı gibi dış araçlarla etkileşime girip elde ettiği ara sonuçlara göre yanıtını güncellemektedir. Örneğin bir sayısal hesaplama veya güncel bilgi gerektiren soruda model, önce ilgili veriyi dış kaynaktan alıp nihai cevabı oluşturabilmektedir. Bu kapsamda ReAct paradigması, modelin akıl yürütme ve eylem adımlarını dönüşümlü olarak yürütmesini sağlayarak model önce düşünüp ardından bu düşünceyi doğrulamak için bir eylem gerçekleştirip elde edilen sonucu yeni bağlam olarak kullanılmaktadır (Yao vd., 2022). Benzer şekilde öz-düzeltme temelli yaklaşımlar modelin hatalı çıktıları analiz ederek sonraki denemelerde düzeltmesine olanak tanımaktadır. Refleksiyon yaklaşımında model, önceki yanıtının neden hatalı olduğunu sözel olarak geri bildirim olarak kaydederek sonraki üretimde bu bilgiyi kullanarak performansını iyileştirmektedir (Shinn vd., 2023). Bu tür mekanizmalar üretim sürecini tek adımlı tahminden çok aşamalı ve geri bildirim içeren bir karar sürecine dönüştürerek karmaşık kıyaslama ve araç kullanımı gerektiren görevlerde daha kararlı sonuçlar elde edilmesini sağlamaktadır.

6.4. İnsan Geri Bildirimine Dayalı Pekiştirmeli Öğrenme ve Tercih Öğrenimi

Hibrit sistemlerde yalnızca doğru bilgiye erişmek yeterli değildir. Bu nedenle üretilen yanıtın kullanıcı beklentilerine uygun, tutarlı ve güvenli biçimde sunulması da oldukça önemlidir. Bu nedenle tercih tabanlı optimizasyon yöntemleri kullanılarak model davranışı insan değerlendirmeleri doğrultusunda yönlendirilmektedir. İnsan Geri Bildirimine Dayalı Pekiştirmeli Öğrenme (RLHF) yaklaşımında model çıktıları insanlar tarafından puanlanarak model tercihlere uyum sağlayacak şekilde optimize edilmektedir (Ouyang vd., 2022). Ancak daha yeni yöntemler ise ayrı bir ödül modeli kurmaya ihtiyaç duymadan, tercih edilen ve edilmeyen yanıt çiftleri üzerinden doğrudan optimizasyon yaparak daha kararlı bir öğrenme süreci sunmaktadırlar (Rafailov vd., 2023). Bu yaklaşımlar, özellikle geri getirme destekli üretimi ve ajan tabanlı mimarilerle birlikte kullanıldığı zaman yalnızca bilginin doğruluğunu değil aynı zamanda çıktının güvenlik ve kullanım uygunluğunu da sistem düzeyinde iyileştirmeyi hedeflemektedir. Kısaca özetlemek gerekirse, geri getirme destekli üretimi, ince ayar, öz değerlendirmeli bilgi erişimi ve tercih tabanlı optimizasyon gibi bileşenler bir araya geldiğinde BDM tabanlı sistemler çok katmanlı ve dinamik yapılara dönüşmektedir. Bu farklılık, performansın tek bir metrikle değerlendirilmesini zorlaştırırken, hataların hangi bileşenden kaynaklandığını ayırt etmeyi de önemli hale getirmektedir.

7. MODEL DEĞERLENDİRME, İZLEME VE MLOPS SÜREÇLERİ

BDM sistemlerimde açık uçlu üretim yapısı geleneksel yazılım testlerinden farklı bir değerlendirme yaklaşımı gerektirmektedir. Bu sistemlerde amaç yalnızca doğru cevabı ölçmek değil, modelin güvenilirliğini, tutarlılığını ve gerçek kullanım koşullarındaki davranışını sürekli olarak gözlemlemektir (Chang vd., 2024). Bunun için özellikle hibrit mimarilerde yanıtın doğruluğu yalnızca

modelden değil; geri getirme sistemi, araç kullanımı ve hizalama katmanlarının birlikte çalışmasından etkilenmektedir. Bu nedenle değerlendirme süreci tek seferlik bir test aşaması olmaktan çıkıp sistemin tüm bileşenlerini kapsayan sürekli bir denetim sürecine dönüşmektedir. Klasik metin benzerliği metrikleri üretilen yanıtın yüzeysel doğruluğu ölçülse dahi, modern sistemlerde daha çok anlam düzeyinde değerlendirme yöntemleri tercih edilmektedir (Liu vd., 2023; Min vd., 2023). Bu amaçla model çıktıları başka modeller veya denetim mekanizmaları tarafından kontrol edilmekte, gerektiğinde birden fazla üretim ile karşılaştırılarak tutarlılık analizi yapılmaktadır (Zheng vd., 2023; Manakul vd., 2023). Böylece sistem yalnızca ne ürettiğine göre değil aynı zamanda ne kadar güvenilir davrandığına göre değerlendirilebilmektedir.

Modelin kullanıma sunulmasının ardından, sistemin gerçek ortam koşullarındaki davranışını değerlendirebilmek amacıyla operasyonel izleme aşamasına geçilmektedir. Bu aşamada yalnızca gecikme süresi veya kaynak kullanımı değil, bilgi güncelliği, hatalı yönlendirme eğilimi ve kullanıcı etkileşimleri de takip edilmektedir (Stone vd., 2025). Bu nedenle özellikle geri getirme destekli üretimi tabanlı sistemlerde veri kaynağının güncelliği ve geri getirme kalitesi doğrudan yanıt doğruluğunu etkilediğinden dolayı model ile bilgi kaynağı birlikte izlenmektedir (Gao vd., 2023). Böylece gerektiğinde veri güncellenerek geri getirme stratejisi ayarlanır veya model davranışı yeniden hizalanabilmektedir. Bu nedenle modern BDM tabanlı uygulamalar tek seferlik eğitilen modeller olarak değil, sürekli değerlendirilen ve güncellenen yazılım sistemleri olarak ele alınmaktadır. Modelin kullanıcıya sunulma biçimi, izleme altyapısı ve güncelleme stratejileri sistemin doğruluğu kadar önemli hale gelmiş olup değerlendirme, dağıtım ve yeniden uyarlama süreçleri aynı yaşam döngüsünün parçaları haline gelmiştir.

Son yıllarda yapılan akademik çalışmalar, güvenilir BDM uygulamalarının yalnızca güçlü bir model seçimiyle değil, bütünsel bir sistem mimarisiyle mümkün olduğunu göstermektedir. 2025 yılı itibarıyla üretim ortamlarında en yaygın yaklaşımın, büyük temel modellerin geri getirme destekli üretim tabanlı bilgi erişimi ve ajan orkestrasyon katmanlarıyla birlikte kullanıldığı mimariler olduğu görülmektedir. Bu nedenle özellikle LangChain, LangGraph ve LlamaIndex gibi çerçeveler geri getirme ve araç kullanımını bir araya getirirken, değerlendirme ve izleme için gözlemlenebilirlik platformlarının sisteme entegre edilmesi yaygın bir pratik haline gelmiştir. Bu tür yapılarda model tek başına bir bileşen olarak değil, sürekli ölçülen, güncellenen ve davranışı kontrol edilen bir yazılım sistemi olarak ele alınmaktadır. Bu eğilim, büyük dil modellerinin başarısının artık yalnızca model mimarisiyle değil aynı zamanda bilgi erişimi, karar mekanizmaları ve operasyonel izleme süreçlerinin birlikte tasarlanmasıyla belirlendiğini göstermektedir.

8. SONUÇ

Çalışmada, büyük dil modellerinde güvenilirliğin tek bir yöntemle sağlanamayacağını ve çok katmanlı bir yaklaşım gerektirdiği ortaya konulmuştur. Akademik literatür incelendiğinde geri getirme destekli

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

üretim yöntemlerinin bilgi güncelliğini ve doğrulanabilirliğinin artırarak ince ayar ve parametre verimli uyarlama tekniklerinin modele görev ve alan uyumu kazandırdığı, hizalama yöntemlerinin ise model davranışını kullanıcı beklentileriyle uyumlu hale getirdiği gözlemlenmiştir. Buna karşın bu yöntemlerin her biri tek başına uygulandığında belirli sınırlılıklar barındırmakta ve özellikle karmaşık uygulamalarda yeterli güvenilirliği sağlayamadığı gözlemlenmiştir. Bu nedenle son yıllardaki çalışmalar, BDM'lerin bağımsız metin üreticileri olarak değil; geri getirme mekanizmaları, öz-değerlendirme süreçleri ve ajan tabanlı karar yapıları ile desteklenen bütünleşik sistemler olarak ele alındığını göstermektedir. Bu dönüşüm, model performansının yalnızca doğruluk metrikleriyle değil, davranış kontrolü ve sistem düzeyi denetim mekanizmalarıyla birlikte değerlendirilmesi gerekliliğini ortaya koymuştur. Bu nedenle özellikle MLOps ve sürekli izleme yaklaşımları, modelin zaman içinde değişen veri ve kullanım koşullarına uyum sağlayabilmesi açısından kritik bir rol oynamaktadır.

Sonuç olarak güvenilir BDM tabanlı uygulamaların geliştirilmesi, daha büyük modeller üretmekten çok, bilgi erişimi, karar verme ve denetim süreçlerinin birlikte tasarlanmasını gerektirmektedir. Bu durum, Büyük dil modelleri alanındaki araştırma eğilimlerinin mimari geliştirmeden sistem mühendisliğine doğru kaydığı; gelecekte ise odak noktasının model parametre büyüklüğünden ziyade sistem bütünlüğü ve denetlenebilirlik olacağı öngörülmektedir.

KAYNAKÇA

Alansari, A., & Luqman, H. (2025). Large language models hallucination: A comprehensive survey. *arXiv preprint arXiv:2510.06265*.

Asai, A., Wu, Z., Wang, Y., Sil, A., & Hajishirzi, H. (2024). Self-RAG: Learning to retrieve, generate, and critique through self-reflection. International Conference on Learning Representations (ICLR).

Brown, T., Mann, B., Ryder, N., Subbiah, M., Kaplan, J. D., Dhariwal, P., ... & Amodei, D. (2020). Language models are few-shot learners. *Advances in neural information processing systems*, *33*, 1877-1901.

Chang, Y., Wang, X., Wang, J., Wu, Y., Yang, L., Zhu, K., ... & Xie, X. (2024). A survey on evaluation of large language models. *ACM transactions on intelligent systems and technology*, *15*(3), 1-45.

Chung, H. W., Hou, L., Longpre, S., Zoph, B., Tay, Y., Fedus, W., ... & Wei, J. (2024). Scaling instruction-finetuned language models. Journal of Machine Learning Research, 25(70), 1-53.

Cuconasu, F., Trappolini, G., Siciliano, F., Filice, S., Campagnano, C., Maarek, Y., ... & Silvestri, F. (2024). The power of noise: Redefining retrieval for rag systems. In Proceedings of the 47th International ACM SIGIR Conference on Research and Development in Information Retrieval (pp. 719-729).

Dettmers, T., Pagnoni, A., Holtzman, A., & Zettlemoyer, L. (2023). Qlora: Efficient finetuning of quantized llms. Advances in neural information processing systems, 36, 10088-10115.

Devlin, J., Chang, M. W., Lee, K., & Toutanova, K. (2019). Bert: Pre-training of deep bidirectional transformers for language understanding. In Proceedings of the 2019 conference of the North American chapter of the association for computational linguistics: human language technologies, volume 1 (long and short papers) (pp. 4171-4186).

Dong, H., Xiong, W., Goyal, D., Zhang, Y., Chow, W., Pan, R., ... & Zhang, T. (2023). Raft: Reward ranked finetuning for generative foundation model alignment. arXiv preprint arXiv:2304.06767.

Dziri, N., Madotto, A., Zaiane, O. R., & Bose, A. J. (2021). Neural path hunter: Reducing hallucination in dialogue systems via path grounding. In Proceedings of the 2021 Conference on Empirical Methods in Natural Language Processing (pp. 2197-2214).

Gao, Y., Xiong, Y., Gao, X., Jia, K., Pan, J., Bi, Y., ... & Wang, H. (2023). Retrieval-augmented generation for large language models: A survey. arXiv preprint arXiv:2312.10997, 2(1), 32.

Guu, K., Lee, K., Tung, Z., Pasupat, P., & Chang, M. (2020). Retrieval augmented language model pre-training. In International conference on machine learning (pp. 3929-3938). PMLR.

He, J., Guo, H., Zhu, K., Zhao, Z., Tang, M., & Wang, J. (2024). Seekr: Selective attention-guided knowledge retention for continual learning of large language models. In Proceedings of the 2024 Conference on Empirical Methods in Natural Language Processing (pp. 3254-3266).

Hu, E. J., Shen, Y., Wallis, P., Allen-Zhu, Z., Li, Y., Wang, S., ... & Chen, W. (2022). Lora: Low-rank adaptation of large language models. ICLR, 1(2), 3.

Huang, L., Yu, W., Ma, W., Zhong, W., Feng, Z., Wang, H., ... & Liu, T. (2025). A survey on hallucination in large language models: Principles, taxonomy, challenges, and open questions. ACM Transactions on Information Systems, 43(2), 1-55.

Ji, Z., Lee, N., Frieske, R., Yu, T., Su, D., Xu, Y., ... & Fung, P. (2023). Survey of hallucination in natural language generation. ACM computing surveys, 55(12), 1-38.

Jiang, Z., Xu, F. F., Gao, L., Sun, Z., Liu, Q., Dwivedi-Yu, J., ... & Neubig, G. (2023). Active retrieval augmented generation. In Proceedings of the 2023 conference on empirical methods in natural language processing (pp. 7969-7992).

Kandpal, N., Deng, H., Roberts, A., Wallace, E., & Raffel, C. (2023). Large language models struggle to learn long-tail knowledge. In International conference on machine learning (pp. 15696-15707).

Karpukhin, V., Oguz, B., Min, S., Lewis, P., Wu, L., Edunov, S., ... & Yih, W. T. (2020). Dense passage retrieval for open-domain question answering. In Proceedings of the 2020 conference on empirical methods in natural language processing (EMNLP) (pp. 6769-6781).

Lewis, P., Perez, E., Piktus, A., Petroni, F., Karpukhin, V., Goyal, N., ... & Kiela, D. (2020). Retrieval-augmented generation for knowledge-intensive nlp tasks. Advances in neural information processing systems, 33, 9459-9474.

Lin, S., Hilton, J., & Evans, O. (2022). Truthfulqa: Measuring how models mimic human falsehoods. In Proceedings of the 60th annual meeting of the association for computational linguistics (volume 1: long papers) (pp. 3214-3252).

Liu, N. F., Lin, K., Hewitt, J., Paranjape, A., Bevilacqua, M., Petroni, F., & Liang, P. (2024). Lost in the middle: How language models use long contexts. Transactions of the association for computational linguistics, 12, 157-173.

Liu, Y., Iter, D., Xu, Y., Wang, S., Xu, R., & Zhu, C. (2023). G-eval: NLG evaluation using gpt-4 with better human alignment. In Proceedings of the 2023 conference on empirical methods in natural language processing (pp. 2511-2522).

Manakul, P., Liusie, A., & Gales, M. (2023). Selfcheckgpt: Zero-resource black-box hallucination detection for generative large language models. In Proceedings of the 2023 conference on empirical methods in natural language processing (pp. 9004-9017).

Maynez, J., Narayan, S., Bohnet, B., & McDonald, R. (2020). On faithfulness and factuality in abstractive summarization. In Proceedings of the 58th annual meeting of the association for computational linguistics (pp. 1906-1919).

Min, S., Krishna, K., Lyu, X., Lewis, M., Yih, W. T., Koh, P., ... & Hajishirzi, H. (2023). Factscore: Fine-grained atomic evaluation of factual precision in long form text generation. In Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing (pp. 12076-12100).

Minaee, S., Mikolov, T., Nikzad, N., Chenaghlu, M., Socher, R., Amatriain, X., & Gao, J. (2024). Large language models: A survey. arXiv preprint arXiv:2402.06196.

Ouyang, L., Wu, J., Jiang, X., Almeida, D., Wainwright, C., Mishkin, P., ... & Lowe, R. (2022). Training language models to follow instructions with human feedback. Advances in neural information processing systems, 35, 27730-27744.

Rafailov, R., Sharma, A., Mitchell, E., Manning, C. D., Ermon, S., & Finn, C. (2023). Direct preference optimization: Your language model is secretly a reward model. Advances in neural information processing systems, 36, 53728-53741.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Raffel, C., Shazeer, N., Roberts, A., Lee, K., Narang, S., Matena, M., ... & Liu, P. J. (2020). Exploring the limits of transfer learning with a unified text-to-text transformer. Journal of machine learning research, 21(140), 1-67.

Ram, O., Levine, Y., Dalmedigos, I., Muhlgay, D., Shashua, A., Leyton-Brown, K., & Shoham, Y. (2023). In-context retrieval-augmented language models. Transactions of the Association for Computational Linguistics, 11, 1316-1331.

Sharma, M., Tong, M., Korbak, T., Duvenaud, D., Askell, A., Bowman, S. R., ... & Perez, E. (2023). Towards understanding sycophancy in language models. arXiv preprint arXiv:2310.13548.

Shinn, N., Cassano, F., Gopinath, A., Narasimhan, K., & Yao, S. (2023). Reflexion: Language agents with verbal reinforcement learning. Advances in neural information processing systems, 36, 8634-8652.

Shuster, K., Poff, S., Chen, M., Kiela, D., & Weston, J. (2021). Retrieval augmentation reduces hallucination in conversation. In Findings of the Association for Computational Linguistics: EMNLP 2021 (pp. 3784-3803).

Stone, J., Patel, R., Ghiasi, F., Mittal, S., & Rahimi, S. (2025). Navigating MLOPs: insights into maturity, lifecycle, tools, and careers. In 2025 IEEE Conference on Artificial Intelligence (CAI) (pp. 643-650). IEEE.

Touvron, H., Martin, L., Stone, K., Albert, P., Almahairi, A., Babaei, Y., ... & Scialom, T. (2023). Llama 2: Open foundation and fine-tuned chat models. arXiv preprint arXiv:2307.09288.

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. Advances in neural information processing systems, 30.

Wang, C., & Sennrich, R. (2020). On exposure bias, hallucination and domain shift in neural machine translation. In Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics (pp. 3544-3552).

Wei, J., Bosma, M., Zhao, V. Y., Guu, K., Yu, A. W., Lester, B., ... & Le, Q. V. (2021). Finetuned language models are zero-shot learners. arXiv preprint arXiv:2109.01652.

Wei, J., Tay, Y., Bommasani, R., Raffel, C., Zoph, B., Borgeaud, S., ... & Fedus, W. (2022). Emergent abilities of large language models. arXiv preprint arXiv:2206.07682.

Xi, Z., Chen, W., Guo, X., He, W., Ding, Y., Hong, B., ... & Gui, T. (2025). The rise and potential of large language model based agents: A survey. Science China Information Sciences, 68(2), 121101.

Yao, S., Zhao, J., Yu, D., Du, N., Shafran, I., Narasimhan, K. R., & Cao, Y. (2022). React: Synergizing reasoning and acting in language models. In The eleventh international conference on learning representations.

Zhang, S., Dong, L., Li, X., Zhang, S., Sun, X., Wang, S., ... & Wu, F. (2026). Instruction tuning for large language models: A survey. ACM Computing Surveys, 58(7), 1-36.

Zhang, Y., Li, Y., Cui, L., Cai, D., Liu, L., Fu, T., ... & Shi, S. (2025). Siren's Song in the AI Ocean: A Survey on Hallucination in Large Language Models. Computational Linguistics, 51(4), 1373-1418.

Zheng, L., Chiang, W. L., Sheng, Y., Zhuang, S., Wu, Z., Zhuang, Y., ... & Stoica, I. (2023). Judging llm-as-a-judge with mt-bench and chatbot arena. Advances in neural information processing systems, 36, 46595-46623.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AÇIKLANABİLİR YAPAY ZEKÂ: YORUMLANABİLİRLİK, AÇIKLAMA YÖNTEMLERİ VE MODEL GÜVENİLİRLİĞİ ÜZERİNE SİSTEMATİK BİR İNCELEME

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ÖZET

Son yıllarda yapay zekâ modellerinin, özellikle derin öğrenme yapılarının artan karmaşıklığı, karar süreçlerinde şeffaflık ve güven sorunlarını beraberinde getirmiştir. Çalışmada, "kara kutu" olarak nitelendirilen modellerin anlaşılabilirliğini sağlamayı amaçlayan açıklanabilir yapay zekâ alanındaki güncel akademik literatürü kavramsal, teknik ve sosyo-hukuki boyutlarıyla incelemiştir. Ayrıca yorumlanabilirlik ve açıklanabilirlik ayrımı temelinde ante-hoc ve post-hoc yaklaşımlar ile yerel ve küresel açıklama yöntemleri detaylandırılmıştır. Ayrıca açıklanabilir yapay zekanın yalnızca bir denetim aracı değil, aynı zamanda model geliştirme süreçlerinde hata analizi ve veri önyargılarının giderilmesi amacıyla kullanılan aktif bir optimizasyon bileşeni olduğu vurgulanmıştır. Değerlendirme zorlukları ve etik standartlar ışığında, gelecekteki araştırmalar için standart metriklerin ve insan merkezli yaklaşımların kritik önemi tartışılmıştır.

Anahtar Kelimeler: Yapay Zekâ, Açıklanabilir Yapay Zekâ, Makine Öğrenmesi, Optimizasyon, Yorumlanabilirlik, Karar Destek Sistemleri.

EXPLAINABLE ARTIFICIAL INTELLIGENCE: A SYSTEMATIC REVIEW ON INTERPRETABILITY, EXPLANATION METHODS, AND MODEL RELIABILITY

ABSTRACT

In recent years, the increasing complexity of artificial intelligence models, particularly deep learning architectures, has introduced significant challenges related to transparency and trust in decision-making processes. This study examines the contemporary academic literature in the field of explainable artificial intelligence, which aims to enhance the understandability of models characterized as ‘black boxes,’ from conceptual, technical, and socio-legal perspectives. Furthermore, based on the distinction between interpretability and explainability, ante-hoc and post-hoc approaches, as well as local and global explanation methods, are elaborated in detail. The study emphasizes that

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

explainable artificial intelligence functions not only as an auditing mechanism but also as an active optimization component employed in model development processes for error analysis and the mitigation of data bias. In light of evaluation challenges and ethical standards, the critical importance of standardized metrics and human-centered approaches for future research is discussed.

Keywords: Artificial Intelligence, Explainable Artificial Intelligence, Machine Learning, Optimization, Interpretability, Decision Support Systems.

1. GİRİŞ

Son yıllarda makine öğrenmesi ve derin öğrenme alanındaki gelişmeler sonrasında; sağlık, finans, imalat, otonom sistemler ve kamu hizmetleri gibi birçok sektörde Yapay Zekâ (YZ) temelli çözümler sıklıkla kullanılmaktadır (Toğa, 2025; Mersha vd., 2024). Derin Sinir Ağları (DSA; Deep Neural Networks, DNN) gibi modeller karmaşık problemleri çözmede yüksek performans göstermesine rağmen bu sistemlerin önemli bir kısmı iç işleyişi doğrudan takip edilemeyen "kara kutu" yapılar olarak çalışmaktadır (Schwalbe ve Finzel, 2024; Rudin vd., 2021). Model karmaşıklığının artması tahmin başarımını yükseltirken, belirli bir kararın neden verildiğini tahmin etmeyi zorlaştırmakta ve güven, hesap verebilirlik ile etik sorumluluk tartışmalarını beraberinde getirmektedir (González-Arencibia vd., 2024; Deliloğlu ve Pehlivanlı, 2021). Bu nedenle özellikle yüksek risk içeren karar süreçlerinde şeffaflık eksikliği, sistemlerin güvenilirliğini sorgulayan bir anlaşılabilirlik problemine neden olabilmektedir (Şeker, 2025). Anlaşılabilirlik probleminin önüne geçebilmek için Açıklanabilir Yapay Zekâ (AYZ; Explainable Artificial Intelligence, XAI) kavramı akademik literatürde önemli bir araştırma alanı haline gelmiştir. AYZ, yüksek doğruluk sağlayan ancak yorumlanması zor olan modeller tarafından üretilen sonuçların insan tarafından anlaşılabilir gerekçelerle desteklenmesini amaçlayan yöntem ve ilkeler bütünü olarak tanımlanmaktadır (Mersha vd., 2024). Bu yaklaşım, model davranışını yorumlanabilir bir biçime dönüştürme gereksiniminden doğmuş ve Avrupa Birliği Genel Veri Koruma Tüzüğü ile Yapay Zekâ Yasası gibi düzenlemelerle daha da önemli bir konu haline gelmiştir (Schwalbe ve Finzel, 2024; Toğa, 2025; González-Arencibia vd., 2024).

AYZ sadece teknik bir problem değil aynı zamanda etik, hukuki ve sosyo-teknik boyutları olan çok disiplinli bir çalışma alanıdır (Longo vd., 2024). Akademik literatürde açıklanabilirlik, modelin iç yapısının şeffaflığını ifade eden yorumlanabilirlik ve model kararlarının sonradan anlaşılmasını sağlayan açıklanabilirlik kavramlarıyla birlikte ele alınmaktadır (Rudin vd., 2021). Ayrıca açıklamaların tek bir ölçütle değerlendirmek yerine doğruluk, tutarlılık ve bütünlük gibi birden fazla parametrenin birlikte dikkate alınması gerektiği ifade edilmiştir (Nauta vd., 2023). Çalışmada, AYZ alanını kavramsal, teknik ve sosyo-hukuki boyutlarıyla incelenerek akademik literatürdeki güncel yaklaşımları, yöntemleri ve temel zorluklar analiz edilmiştir.

2. KAVRAMSAL ÇEVRE

AYZ akademik literatürde sıklıkla birbirinin yerine kullanılmış olmasına rağmen sistemlerin güvenilirliğini değerlendirebilmek için yorumlanabilirlik ve açıklanabilirlik kavramları arasında belirgin bir ayrım bulunmaktadır. (Rudin vd., 2021), Yorumlanabilirlik makine öğrenmesini insanların model tahminlerini doğrudan anlayabildiği, monotonluk veya nedensellik gibi alan kısıtlarını sağlayacak şekilde tasarlanmış modeller olarak tanımlanmaktadır. Bu yaklaşımda şeffaflık modelin doğal bir özelliğidir ve karar alma mekanizması tasarım aşamasında açık hale getirilmelidir. Buna karşılık açıklanabilirlik, iç işleyişi doğrudan anlaşılmayan karmaşık modellerin davranışlarının sonradan geliştirilen yöntemlerle yorumlanmasını ifade etmektedir (Mersha vd., 2024). Bu nedenle yorumlanabilirlik modelin genel çalışma mekanizmasına odaklanırken, açıklanabilirlik belirli bir tahminin neden üretildiğini açıklamayı amaçlamaktadır. Dolayısıyla şeffaf bir model tasarlamak ile yorumlanamayan bir modeli dışsal araçlarla açıklamak kavramsal olarak farklı problemler olup AYZ çalışmalarında bu ayrımın dikkate alınması gerekmektedir. Bu ayrım üzerine kurulan AYZ şeması, yöntemleri uygulanma zamanına göre önceden açıklanabilir ve sonradan açıklama temelli olmak üzere iki ana grupta incelenmektedir. Schwalbe ve Finzel çalışmalarında önceden açıklanabilir yaklaşımları karar ağaçları, doğrusal modeller ve kural tabanlı sistemler gibi doğası gereği açıklanabilir modellerin kapsadığını belirterek modellerde girdiden çıktıya giden yol doğrudan izlenebilir olacağını belirtmişlerdir (Schwalbe ve Finzel 2024). Buna karşılık DSA gibi karmaşık modeller için geliştirilen sonradan açıklama temelli yöntemler model eğitildikten sonra uygulanan yöntemlerdir. Bu yöntemler model yapısını değiştirmeden temsili modeller, duyarlılık analizleri veya özellik önemlilik ölçümleri aracılığıyla açıklamalar üretmektedir. Bu noktada yöntemler ayrıca modelden bağımsız ve modele özgü olarak ayrılmaktadır. Modelden bağımsız yaklaşımlar herhangi bir modele uygulanabilirken modele özgü yaklaşımlar ise belirli mimarilerin iç parametrelerine erişim gerektirmektedir (Arrieta vd., 2020).

Açıklanabilirlik yaklaşımları kapsamına göre yerel veya küresel açıklamalar olarak da sınıflandırılabilmektedir. Yerel açıklamalar modelin tek bir girdiye verdiği kararın nedenlerini incelemeye odaklanmaktadır (Mersha vd., 2024). LIME ve SHAP gibi AYZ yöntemleri karmaşık karar yüzeyini yerel olarak basitleştirerek belirli bir tahmini açıklamada kullanılırken, küresel açıklamalar ise modelin tüm veri üzerindeki genel davranışını ve karar mantığını anlamayı hedeflemektedir. Küresel açıklamaların sistemin genel tutarlılığını değerlendirmede önemli olmasına rağmen karmaşık modellerde her zaman tam bir temsil oluşturmayabilmektedir. Bu nedenle akademik literatürde güvenilir bir yapay zekâ sistemi için hem tekil kararların denetlenmesini sağlayan yerel açıklamaların hem de model davranışını bütünsel olarak ortaya koyan küresel açıklamaların birlikte değerlendirilmesi oldukça önemlidir (Schwalbe ve Finzel 2024)

3. AÇIKLANABİLİR YAPAY ZEKA YÖNTEMLERİ

AYZ yöntemleri, karmaşık modellerin karar mekanizmalarını anlaşılır hale getirmek için akademik literatürde farklı teknik yaklaşımlar altında ele alınmaktadır. Bu yöntemler model çıktısına hangi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

girdilerin ne ölçüde katkı yaptığını belirten katkı analizi yaklaşımlarıdır. Bu yaklaşımlar için geliştirilen Local Interpretable Model-agnostic Explanations (LIME), AYZ yöntemi modelden bağımsız bir yöntem olarak karmaşık bir modelin kararını yerel ölçekte daha basit ve yorumlanabilir bir model aracılığıyla belirlemek için kullanılan bir modeldir. LIME, özellikle yerel tahminlerin yorumlanmasında değişken etkilerini belirlemede ve model davranışının anlaşılmasına katkı sağlayan bir AYZ modelidir (Deliloğlu ve Pehlivanlı 2021). Benzer şekilde SHapley Additive exPlanations (SHAP) AYZ yöntemi ise oyun teorisinden türetilen Shapley değerleri aracılığıyla her bir özelliğin tahmine yaptığı marjinal katkıyı hesaplamaktadır. Sağlık uygulamalarında SHAP'ın yalnızca tekil gözlemler için değil, veri setinin geneline yönelik eğilimleri de belirleyerek değişkenler arası ilişkileri daha kapsamlı biçimde analiz ettiği gözlemlenmiştir (Toğa, 2025). Ayrıca SHAP'ın tutarlılık ve yerel doğruluk gibi kurumsal özelliklere dayanması, yöntemi girdi değişimine dayalı yaklaşımlara göre teorik açıdan daha sağlam bir çerçeve sunmaktadır (Mersha vd., 2024).

Görüntü verilerinin ve derin öğrenme modellerinin açıklanabilirliğinde ise görselleştirme tabanlı yöntemler öne çıkmaktadır. Evrişimli Sinir Ağları için geliştirilen Grad-CAM ve önem haritaları modelin karar aşamasında görüntünün hangi bölgelerine odaklandığını ısı haritaları üzerinden göstermektedir. Böylece modelin içsel gradyan bilgilerini kullanarak önemli piksel bölgeleri belirlenerek kullanıcıya modelin odaklandığı alanlar sunulmaktadır (Schwalbe ve Finzel, 2024). Ancak bu tür açıklamalar çoğu zaman modelin mantıksal gerekçesini değil, yalnızca duyarlı bölgeleri işaret etmesinden dolayı yorumların her zaman nedensel anlam taşımayabileceğine de vurgulamaktadır (Mersha vd., 2024).

Son yıllarda açıklanabilirlik araştırmaları yalnızca mevcut kararın neden üretildiğini açıklamaktan ziyade alternatif bir kararın hangi koşullarda oluşacağını inceleyen karşı-olgusal yaklaşımlarda kullanılmaya başlanmıştır. Bu yaklaşımlar, model çıktısını değiştirecek en küçük girdi değişikliğini tanımlayarak kullanıcılara eyleme dönüştürürerek geri bildirim sunmaktadır. Böylece özellikle yasal ve etik bağlamlardaki açıklamaların kararların denetlenebilirliğini arttırmaktadır (González-Arencibia vd., 2024). Bunun yanı sıra, kararların benzer örnekler üzerinden açıklanmasını amaçlayan örnek temelli yöntemler de model davranışını daha sezgisel biçimde sunulabilmesine olanak sağlamaktadır. Prototip ve eleştiri tabanlı yaklaşımlar ise soyut matematiksel açıklamalar yerine somut örnekler sağlayarak kullanıcıyı desteklemektedir (Schwalbe ve Finzel, 2024).

Sonuç olarak AYZ yöntemleri tek tip bir çözüm sunmayıp; model türü, veri yapısı ve hedef kullanıcı kitlesine bağlı olarak farklı güçlü ve zayıf yönleri belirlemektedir. Bu nedenle güvenilir bir açıklama süreci, farklı açıklama tekniklerinin birlikte değerlendirilmesini gerektiren çok boyutlu bir yaklaşım olarak ele alınması gerekmektedir.

4. GÜNCEL PROBLEMLER VE DEĞERLENDİRME ZORLUKLARI

AYZ ile ilgili akademik literatürdeki temel tartışmalardan birisi de model performansı ile açıklanabilirlik arasında bulunduğu varsayılan ödünleşim ilişkisidir. Akademik literatürde konu ile ilgili derin öğrenme gibi karmaşık modeller yüksek tahmin doğruluğu sağlamasına rağmen içsel yapıları nedeniyle "kara kutu" niteliği taşımakta ve yorumlanmaları zorlaşmaktadır. Bu nedenle karşılık karar ağaçları veya lineer modeller gibi şeffaf yapılar genellikle karmaşık veri yapılarında daha sınırlı performans göstermektedir (Mersha vd., 2024). Ancak özellikle yapılandırılmış veriler için bu ikilemin çoğu zaman yanlış kurulduğunu ve uygun veri işleme ile model tasarımı kullanıldığında hem yüksek doğruluklu hem de doğası gereği yorumlanabilir modellerin mümkün olmaktadır (Rudin vd., 2021). Buna rağmen görüntü işleme gibi yüksek boyutlu ham verilerin kullanıldığı alanlarda DSA'ları üstün performans sağlayarak model karmaşıklığı ile insan tarafından anlaşılabilirlik arasındaki ikilem güncel bir araştırma problemi olarak yerini korumaktadır.

AYZ yöntemlerinin uygulanmasında karşılaşılan bir diğer önemli sorun ise üretilen açıklamaların güvenilirliği ve kararlılığıdır. Sonradan açıklama temelli modelin gerçek karar mekanizmasını yaklaşık olarak temsil ettiğinden dolayı açıklamanın model davranışını ne ölçüde doğru yansıttığı her zaman kesin olarak benimsenmeyip makul görünen bir açıklamanın doğru olmak zorunda olmadığını vurgulayarak açıklamaların modele sadakatinin ayrıca doğrulanması gerektiğini belirtilmektedir (Nauta vd., 2023). Bu nedenle özellikle LIME gibi girdi değişimine dayalı yöntemlerin olasılıksal doğası, benzer girdiler için farklı açıklamalar üretilebilmesine yol açarak kararsızlık problemine neden olabilmektedir. Bu kararsızlığın kullanıcı güvenine zarar vererek açıklamaların tekrarlanabilirliğini zorlaştırmaktadır. Ayrıca açıklamaların nasıl değerlendirileceği konusunda akademik literatürde tam bir netlik bulunmamaktadır (Mersha vd., 2024). Bu nedenle değerlendirme yaklaşımlarını insan merkezli ve bilgisayar merkezli olarak iki gruba ayrılmaktadır (Schwalbe ve Finzel 2024). İnsan merkezli değerlendirmeler kullanıcıların açıklamayı anlama ve güven düzeyini ölçerken, bilgisayar merkezli yöntemler sadakat ve sağlamlık gibi nesnel metriklere göre yapılan değerlendirmeler olup doğruluk, tutarlılık ve bütünlük gibi çok boyutlu özellikleri kapsayan kapsamlı bir değerlendirme yaklaşımı önermektedir. Bu yaklaşım, açıklanabilirliğin tek bir metrikle ölçülebilecek ikili bir özellik olmaktan ziyade çok boyutlu bir kalite kriteri olduğunu göstermektedir. Bu nedenle gelecekteki çalışmaların sadece açıklama üretimine değil aynı zamanda açıklamaların geçerliliğinin ve kullanıcı üzerindeki bilişsel etkisinin standartlaştırılmış yöntemlerle doğrulanmasına odaklanması gerekmektedir (Nauta vd., 2023).

5. ARAŞTIRMA BOŞLUKLARI

AYZ mevcut akademik literatürde önemli ilerlemeler göstermiş olsa da alan hâlen çözülmesi gereken temel problemlere sahiptir. Açıklama yöntemlerinin doğruluğunu ölçmek için üzerinde karar birliği sağlanan standart bir değerlendirme metriği bulunmamaktadır. Açıklanabilirlik değerlendirmesinin görevi, kullanıcı ve bağlam bağımlı olması gerekirken (Doshi-Velez ve Kim, 2017), mevcut metriklerin açıklamaların yalnızca belirli yönlerini ölçebildiği ve genel bir kalite ölçütü oluşturamadığı

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

belirtilmektedir (Nauta vd., 2023). Bu durum farklı çalışmaların sonuçlarının karşılaştırılmasını güçleştirmektedir.

Sonradan açıklama temelli yöntemlerinin modele ne kadar bağlı olduğu konusu açık bir araştırma problemidir. Birçok açıklamanın gerçek karar mekanizmasını açıklamak yerine yalnızca ikna edici görünümler üretebildiği ifade edilerek özellikle modelden bağımsız yöntemlerde açıklamanın doğruluğu ile yorumlanabilirliği arasında sistematik bir denge kurulamadığı görülmektedir (Lipton, 2018; Rudin vd., 2021). Bir diğer önemli araştırma boşluğu ise kullanıcı odaklı değerlendirme eksikliğidir. Mevcut akademik çalışmaların büyük kısmı matematiksel doğruluk veya özellik önemlilik sonuçlarına odaklanırken, açıklamaların insanlar tarafından nasıl algılandığı ve karar verme sürecini nasıl etkilediği yeterince analiz edilmemesi özellikle farklı uzmanlık seviyelerindeki kullanıcıların aynı açıklamayı farklı biçimde yorumlayabilmesi, açıklanabilirliğin bağlama bağımlı bir kavram olduğunu göstermektedir (Miller, 2019; Mersha vd., 2024).

Son olarak, açıklanabilirlik ile performans arasındaki ilişkinin hangi koşullarda geçerli olduğu henüz net değildir. Bazı çalışmalar karmaşık modeller için açıklamaların kaçınılmaz olduğunu ifade ederken, bir diğer görüş ise belirli problem türlerinde doğası gereği yorumlanabilir modellerin tercih edilmesi gerektiği ifade etmektedir (Rudin vd., 2021). Bu durum, hangi uygulama alanında hangi açıklanabilirlik yaklaşımının kullanılacağına dair sistematik bir karar çerçevesinin eksik olduğunu ortaya koymaktadır.

6. AÇIKLANABİLİRLİK VE OPTİMİZASYON İLİŞKİSİ

Son yıllarda yapılan akademik çalışmalar, açıklanabilirliğin yalnızca model çıktılarını yorumlamaya yönelik bir araç olmadığını, aynı zamanda model geliştirme sürecini yönlendiren bir geri besleme mekanizması olarak kullanılabileceğini göstermektedir (Rudin vd., 2021; Molnar, 2022). AYZ modellerinden üretilen açıklamalar aracılığıyla modelin hatalı öğrendiği örüntüler, veri setindeki ön yargılar veya ilgisiz özellik bağımlılıkları tespit ederek bu bilgileri veri temizleme, özellik seçimi ve model yeniden eğitimi adımlarının iyileştirilmesine katkı sağlamada kullanılmaktadır (Nauta vd., 2023). Böylece açıklanabilirlik, model performansını sonradan değerlendiren pasif bir süreç olmaktan çıkarak eğitim sürecine entegre edilen aktif bir optimizasyon bileşeni hâline gelmektedir. Sonuç olarak yinelemeli geliştirme döngülerinde, açıklamalar üzerinden yapılan hata analizi, hiperparametre seçimi ve eğitim stratejisinin sistematik olarak güncellenmesi doğruluk ile güvenilirlik hedeflerinin birlikte optimize edilebilmesini sağlamaktadır (Doshi-Velez ve Kim, 2017).

7. SONUÇ

Çalışmada, AYZ alanının yalnızca teknik bir model yorumlama problemi olmadığını, aynı zamanda güven, etik sorumluluk ve karar destek sistemlerinin kabul edilebilirliği ile doğrudan ilişkili olan çok katmanlı bir araştırma alanı olduğu belirlenmiştir. Akademik literatür incelendiğinde, yüksek performanslı modellerin yaygınlaşmasıyla birlikte açıklanabilirliğin opsiyonel bir özellik olmaktan

çıkarak güvenilir yapay zekâ sistemlerinin temel bileşenlerinden biri hâline geldiği görülmektedir. Yorumlanabilirlik ve açıklanabilirlik ayrımı ile, önsel açıklanabilir ve sonradan açıklama temelli yaklaşımlar ile yerel ve küresel açıklamalar model davranışının farklı yönlerinin anlaşılmasını mümkün kılmaktadır. Bununla birlikte mevcut akademik çalışmalar, açıklama üretmenin tek başına yeterli olmadığı ve açıklamaların doğruluğu, kararlılığı ve kullanıcı tarafından anlamlandırılabilirliği gibi faktörlerin de sistem güvenilirliği açısından kritik olduğunu göstermektedir. Ayrıca açıklanabilirlik ile performans arasındaki ilişkinin uygulama alanına bağlı olarak değiştiği ve bu nedenle tek bir yöntemle tüm problemlerin çözülemeyeceği anlaşılmaktadır. Böylelikle model hakkındaki açıklamaların yalnızca kararların gerekçelendirilmesi için değil, aynı zamanda model geliştirme sürecini yönlendiren bir geri besleme mekanizması olarak değerlendirilmesini de sağladığı anlaşılmıştır.

Sonuç olarak AYZ, model tasarımından değerlendirme süreçlerine kadar uzanan bütüncül bir yaklaşım gerektirmektedir. Gelecekte yapılacak olan akademik çalışmalarda teknik doğruluk ile insan merkezli değerlendirmeyi birlikte ele alan standart ölçütler geliştirmeye ve açıklamaların gerçek karar süreçleriyle tutarlılığını güvence altına alan yöntemlere odaklanması, güvenilir ve sorumlu yapay zekâ sistemlerinin yaygınlaşması açısından kritik önem taşımaktadır.

KAYNAKÇA

Arrieta, A. B., Díaz-Rodríguez, N., Del Ser, J., Bennetot, A., Tabik, S., Barbado, A., ... & Herrera, F. (2020). Explainable Artificial Intelligence (XAI): Concepts, taxonomies, opportunities and challenges toward responsible AI. Information Fusion, 58, 82-115.

Deliloğlu, R. A. S., & Pehlivanlı, A. Ç. (2021). Hibrit açıklanabilir yapay zeka tasarımı ve LIME uygulaması. Avrupa Bilim ve Teknoloji Dergisi, (27), 228-236. https://doi.org/10.31590/ejosat.959030

Doshi-Velez, F., & Kim, B. (2017). Towards a rigorous science of interpretable machine learning. arXiv preprint arXiv:1702.08608.

González-Arencibia, M., Ordoñez-Erazo, H., & González-Sanabria, J. S. (2024). Explainable artificial intelligence as an ethical principle. Ingeniería, 29(2).

Lipton, Z. C. (2018). The mythos of model interpretability: In machine learning, the concept of interpretability is both important and slippery. Queue, 16(3), 31-57.

Longo, L., Brcic, M., Cabitza, F., Choi, J., Confalonieri, R., Del Ser, J., ... & Stumpf, S. (2024). Explainable Artificial Intelligence (XAI) 2.0: A manifesto of open challenges and interdisciplinary research directions. Information Fusion, 106, 102301.

Mersha, M., Lam, K., Wood, J., Alshami, A. K., & Kalita, J. (2024). Explainable artificial intelligence: A survey of needs, techniques, applications, and future direction. Neurocomputing, 599, 128111.

Miller, T. (2019). Explanation in artificial intelligence: Insights from the social sciences. Artificial Intelligence, 267, 1-38.

Molnar, C. (2022). Interpretable machine learning: A guide for making black box models explainable (2nd ed.). Leanpub.

Nauta, M., Trienes, J., Pathak, S., Nguyen, E., Peters, M., Schmitt, Y., ... & Seifert, C. (2023). From anecdotal evidence to quantitative evaluation methods: A systematic review on evaluating explainable AI. ACM Computing Surveys, 55(13s), 1-42.

Rudin, C., Chen, C., Chen, Z., Huang, H., Semenova, L., & Zhong, C. (2021). Interpretable machine learning: Fundamental principles and 10 grand challenges. Statistics Surveys, 15, 1–85.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Schwalbe, G., & Finzel, B. (2024). A comprehensive taxonomy for explainable artificial intelligence: a systematic survey of surveys on methods and concepts. Data Mining and Knowledge Discovery, 38(5), 3043-3101.

Şeker, S. E. (2025). HermAI: Hermenötik açıklanabilir yapay zeka. YBS Ansiklopedi, 1-7.

Toğa, G. (2025). Sağlık alanında açıklanabilir yapay zekâ kullanımı üzerine bir uygulama. Çukurova Üniversitesi Mühendislik Fakültesi Dergisi, 40(3), 707-723. https://doi.org/10.21605/cukurovaumfd.1729986

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ROBUST IOT INTRUSION DETECTION VIA OVERSAMPLING AND GRAPH LEARNING

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ABSTRACT

Internet of Things (IoT) networks are increasingly vulnerable to cyber-attacks due to their heterogeneous device structures, large-scale traffic generation, and inherent resource constraints. A key challenge in real-world IoT traffic is severe class imbalance, which may lead Intrusion Detection Systems (IDS) to achieve deceptively high accuracy while failing to reliably detect attacks. This study addresses the class imbalance problem in IoT-based intrusion detection and highlights the importance of performance evaluation beyond accuracy, considering reliability and discriminative capability. The BoT-IoT and ToN-IoT datasets were used to examine the impact of SMOTE-based oversampling, similarity-driven feature enrichment, and graph-based learning on IDS performance. To minimize data leakage risk, SMOTE oversampling was applied only within the training folds during cross-validation. Similarity measures such as the Jaccard coefficient, Cosine similarity, and Adamic-Adar index were computed in the feature space and incorporated as additional attributes to enhance representation for classical machine learning models. Decision Tree, Random Forest, Logistic Regression, XGBoost, and LightGBM models were trained on the enriched and balanced data and evaluated using cross-validation. In addition, a Graph Convolutional Network (GCN) was implemented to directly model structural relationships in IoT traffic. Model performance was evaluated using Accuracy and F1-score alongside imbalance-aware metrics including Matthews Correlation Coefficient (MCC) and Cohen's Kappa, supported by confusion matrix analysis. Experimental results indicate that SMOTE-based balancing and similarity-driven feature enrichment contribute to improved classification stability and detection performance. The GCN model benefits from relational information and generally provides balanced detection performance across datasets. On the ToN-IoT dataset, GCN achieved an accuracy of 0.9785 and an MCC of 0.9575, while on the BoT-IoT dataset it obtained an accuracy of 0.9801 and an MCC of 0.9610. These findings suggest that incorporating relational information can enhance IDS

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

robustness, although performance differences across models depend on the evaluation metrics considered. Overall, the proposed framework offers a practical perspective for improving IoT intrusion detection and supports more reliable performance evaluation under class imbalance conditions.

Keywords: Internet of Things, Intrusion Detection Systems, Class Imbalance, Graph Convolutional Networks.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYSIS OF THE HIGHER-ORDER ROBERT-ASSELIN-WILLIAMS (HORAW) TIME FILTER FOR IMEX DISCRETIZATIONS IN EVOLUTION EQUATIONS

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ABSTRACT

This research presents a rigorous numerical analysis of the integration of the higher-order Robert-Asselin-Williams (hoRAW) time filter with Implicit-Explicit (IMEX) methods, specifically focusing on the Crank-Nicolson-Leapfrog (CNLF) discretization for systems of evolution equations. The CNLF scheme is a cornerstone in geophysical fluid dynamics due to its efficiency in partitioning dissipative and conservative operators; however, it remains notoriously susceptible to a divergent computational mode that can compromise long-term simulations. While this instability is shown to be asymptotically stable for autonomous systems under standard Courant-Friedrichs-Lewy (CFL) conditions, our study demonstrates that it becomes exponentially unstable in non-autonomous cases where system operators are time-dependent, even when local stability conditions are satisfied. To address these artifacts, we evaluate the hoRAW filter as a non-intrusive, modular post-processing step. Unlike traditional Robert-Asselin (RA) filters which often degrade numerical accuracy to first-order, the hoRAW variant combines a higher-order Robert-Asselin (hoRA) step with a Williams-type modification to significantly enhance both stability and precision. Our findings prove that this combination increases the stability compared to standard hoRA filters and achieves better accuracy in amplitude while effectively suppressing the spurious computational mode. Through the provision of energy-based stability and rigorous error analysis, this work characterizes the hoRAW-filtered IMEX method as a robust, high-order alternative for large-scale, complex atmospheric and oceanic simulations, offering a superior balance between computational efficiency and numerical fidelity.

Keywords: Time Filter, Crank Nicolson, Leapfrog, Stability

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF ELECTRIC ARC FURNACE SLAG ON THE MECHANICAL PERFORMANCE OF CEMENTITIOUS COMPOSITES

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ABSTRACT

During steel production processes in the iron and steel industry, a significant amount of industrial by-products is generated, among which slag is one of the most prominent. Electric Arc Furnace (EAF) slag is a non-metallic by-product formed during the melting of scrap steel and has considerable potential for sustainable use in construction materials. The reuse of such industrial wastes contributes to reducing environmental impacts and improving resource efficiency.

The main objective of this study is to investigate the effects of using ground EAF slag as a partial cement replacement material on the mechanical performance of cementitious composites. Within the scope of the study, EAF slag was processed through a crusher and a ball mill, and then sieved to obtain a usable fine material. The slag was incorporated into the composite matrix at different replacement ratios, and a control mixture was prepared for comparison. Compressive strength tests were conducted to evaluate the mechanical performance. The experimental results indicated that, although a slight reduction in compressive strength was observed compared to the control mixture, the 28-day strength at low replacement level was very close to that of the control specimen. As the replacement ratio increased, a gradual decrease in strength values was observed. Overall, the use of EAF slag at low replacement levels provided acceptable mechanical performance.

Keywords: Electric arc furnace slag, cementitious composites, mechanical properties

INTRODUCTION

Concrete and cementitious composites are fundamental materials in the construction industry. Although concrete is generally defined as a mixture of cement, aggregate, and water, chemical and mineral admixtures are also widely used in modern concrete technology to improve performance. In this system, the primary component of the binding phase is cement. Cement is a finely ground dry material that does not exhibit binding properties on its own; however, it gains binding capability through the structure formed as a result of hydration reactions with water (Mehta & Monteiro, 2006).

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Cement production is considered one of the major contributors to global carbon dioxide emissions (Benhelal et al., 2013). Therefore, the use of mineral additives and industrial by-products that enable the reduction of cement content is of great importance in terms of reducing environmental impacts and improving resource efficiency.

Parallel to industrialization, global iron and steel production has reached high levels. In 2025, worldwide crude steel production was approximately 1.85 billion tons. During the same period, Türkiye ranked among the leading steel-producing countries with a production of 38.1 million tons (World Steel Association, 2026). Such a large production volume results in the generation of significant amounts of industrial by-products and waste.

Among the processes widely used in iron and steel production, the Electric Arc Furnace (EAF) process, which produces steel from scrap, plays a major role. In Türkiye, approximately 72.2% of crude steel production is carried out using the EAF process (Türkiye Çelik Üreticiler Derneği (TÇÜD), 2026). Scrap steel is remelted in an electric arc furnace through electric arcs generated by graphite electrodes; these arcs provide sufficient heat input to rapidly melt the metal charge (Peens, 2004). In large-scale EAF applications, electrode tip temperatures have been reported to approach approximately 3500°C (Zweben & Karasik, 2000). During the scrap melting process, slag is formed through the addition of slag-forming agents (limestone/dolomite), resulting in the generation of a considerable amount of electric arc furnace slag at the end of the process (Ángel et al., 2012).

Steel slag is produced during melting and oxidation processes after the removal of iron oxides and other impurities and is separated from the molten steel at the end of the production process (Santamaria et al., 2018). Depending on the production process, steel slag can be classified into different types such as blast furnace slag, basic oxygen furnace slag, electric arc furnace slag, and ladle slag. These slags generally have a chemical composition rich in CaO, SiO_2, and Fe oxides and may exhibit a cementitious character with binding capability under suitable conditions (Jiang et al., 2018).

In the literature, the binding potential of steel slag is discussed in relation to its mineralogical composition. Due to containing certain components similar to cement clinker, it is suggested that slag may exhibit a “cementitious” character under specific conditions and can even be considered a “weak cement clinker” (Shi, 2004). Within this framework, it is emphasized that steel slag can be used as a replacement material in binder systems under appropriate conditions; however, mechanical performance is reported to be sensitive to the replacement ratio. Indeed, increasing the replacement of cement with steel slag under a constant water-to-binder ratio has been associated with a reduction in compressive strength, particularly at early ages (Wang et al., 2013). On the other hand, studies have also investigated the use of steel slag not only as a binder replacement but also as an aggregate component in concrete. It has been reported that 28-day compressive strengths above 30 MPa can

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

generally be achieved in mixtures where EAF slag is used as aggregate (Manso et al., 2006). Furthermore, findings indicate that concrete incorporating EAF slag aggregate may exhibit higher compressive strength compared to conventional concrete (Pellegrino & Gaddo, 2009). Considering these results together, it can be concluded that the effect of using EAF slag in cementitious composites on mechanical performance varies depending on the mode of use and the replacement ratio; therefore, determining appropriate replacement ranges specific to each application through experimental studies is of great importance.

In this study, the effects of using ground EAF slag as a partial cement replacement material in cementitious composites on mechanical performance were experimentally investigated.

MATERIALS

In this study, CEM I 42.5 R Portland cement conforming to TS EN 197-1 was used as the binder in the preparation of mortar mixtures. The density of the cement was 3.10 g/cm³, and its specific surface area, determined in accordance with ASTM C204 based on the air permeability method, was 3385 cm²/g.

Limestone-based crushed stone was used as fine aggregate, and the maximum particle size (Dmax) was determined as 4 mm. According to measurements conducted in accordance with ASTM C128, the aggregate had a density of 2.66 g/cm³ and a water absorption ratio of 1.22%. Tap water was used in the mixtures, and the aggregate/cement/water ratio was kept constant at 2.75/1.00/0.485 by mass.

Electric Arc Furnace (EAF) slag, used as a partial cement replacement material, was supplied from Hasçelik Steelworks. Steelmaking slags typically exhibit a dense and durable microstructure due to the presence of components such as iron oxide and calcium oxide. The combined structure formed by these mineral phases contributes to the rigid and durable material behavior of the slag (Hasçelik, 2026).

In this study, the EAF slag was first processed through a crusher and subsequently ground in a ball mill to obtain a fine material. The ground slag was finally sieved to make it suitable for use in the experimental program. These preparation stages are presented in Figure 1.

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ISBN: 978-9952-610-30-7

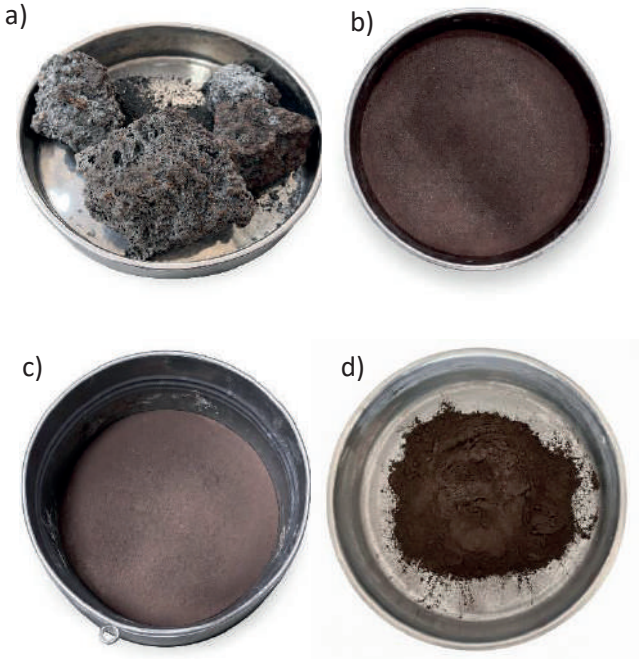


Figure 1. Grinding process of electric arc furnace (EAF) slag: (a) raw EAF slag; (b) slag after crushing; (c) slag ground in a ball mill; (d) sieved fine slag.

METHODS

Electric arc furnace slag (EAFS) was used as a partial replacement for cement at rates of 5%, 10%, 15%, and 20% by mass, and a total of five mortar mixtures, including the control mixture, were prepared. The mixture proportions investigated in this study are presented in Table 1. All mixtures were prepared using a laboratory-type mortar mixer operated at a constant speed. To control workability, a flow table test was performed, and similar flow diameters (19 ± 1 cm) were obtained for all mixtures.

Table 1. Mix Design of Mortars Containing Electric Arc Furnace Slag (EAFS)

Mix ID	Cement (kg)	Sand (kg)	Water (kg)	EAFS Replacement (%)	EAFS (kg)
CTRL	10.0	27.5	4.85	0	0.0
EAFS05	9.5	27.5	4.85	5	0.5
EAFS10	9.0	27.5	4.85	10	1.0
EAFS15	8.5	27.5	4.85	15	1.5

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EAFS20	8.0	27.5	4.85	20	2.0

The fresh mortars were cast into 50x50x50 mm cube molds and compacted using a shaking table to prevent void formation. After casting, the specimens were kept in the molds for 24 h to ensure initial setting and sufficient early-age strength development. A view of the specimens placed in the molds is presented in Figure 2.

At the end of this period, the specimens were demolded and placed in a curing tank at 23 ± 2°C, where they were stored under standard water-curing conditions until the test ages (7 and 28 days). During curing, full contact of all specimen surfaces with water was ensured, and constant temperature conditions were maintained. In this way, a stable hydration process and consistent strength development were intended.

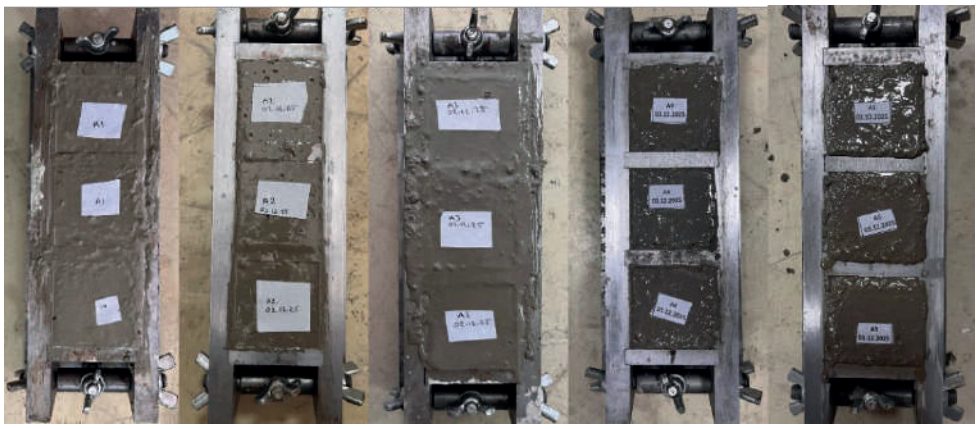


Figure 2. Placement of mortar specimens into the molds

At the end of the 7- and 28-day curing periods, the compressive strengths of the specimens were determined using a hydraulic compression testing machine under load-controlled conditions at a constant loading rate of 3 kN/s (Figure 3). Compressive strength was calculated using the equation $\sigma=P/A$, where σ is the compressive strength (MPa), P is the maximum load at failure (N), and A is the cross-sectional area of the specimen (mm^2).

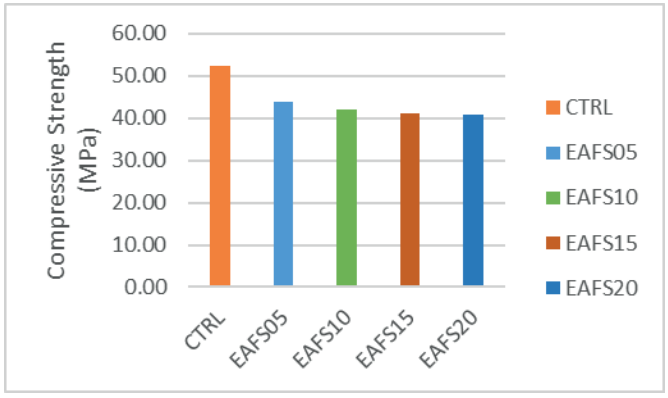
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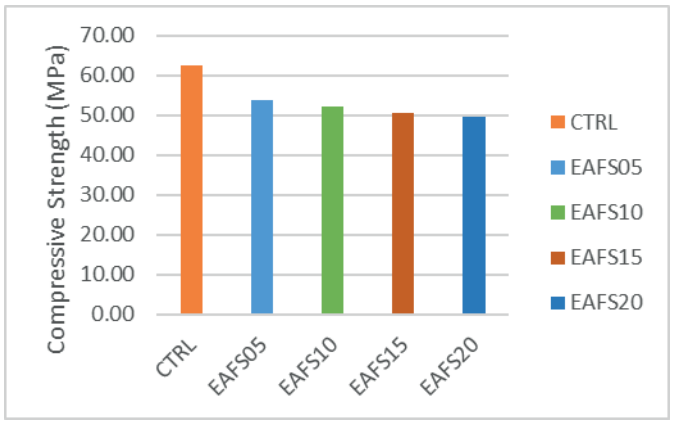
Figure 3. Hydraulic compression testing machine used in the compressive strength test of the specimens

RESULTS

The experimental findings obtained in this study are presented below. The compressive strength values measured after 7 and 28 days of curing are shown in Figure 4.



a)



b)

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ISBN: 978-9952-610-30-7

Figure 4. Compressive strength results of the mortars at (a) 7 days and (b) 28 days

An increase in strength was observed in all mixtures as the curing period increased. The compressive strength of the control specimen increased from 52.24 MPa at 7 days to 62.44 MPa at 28 days, corresponding to an approximate increase of 19.5%.

For the mixtures containing EAFS, a decreasing trend was observed in both 7-day and 28-day strength values as the replacement ratio increased. According to the 7-day results, the compressive strengths at 5%, 10%, 15%, and 20% replacement ratios were approximately 16.2%, 19.5%, 21.0%, and 21.7% lower than that of the control mixture, respectively. This may be attributed to the fact that EAFS does not exhibit a binder behavior as effective as cement at early ages, together with the reduction in binder content.

When the 28-day results were examined, strength gain was observed in all mixtures containing EAFS; however, all values remained below that of the control mixture. At 5%, 10%, 15%, and 20% replacement ratios, the 28-day compressive strengths were approximately 13.7%, 16.4%, 19.1%, and 20.8% lower than the control mixture, respectively. Nevertheless, the compressive strength of the mixture containing 5% EAFS was found to be quite close to that of the control specimen, indicating that the negative effect of low-level replacement on strength remained limited.

CONCLUSION

In this study, the effect of replacing cement with electric arc furnace slag (EAFS) at different proportions on the compressive strength of mortars was investigated. Based on the experimental results obtained, the following conclusions were drawn:

At 7 days, the compressive strengths of all mixtures containing EAFS showed a decreasing trend compared to the control mixture. This can be explained by the fact that, although steel slags have an oxide-rich composition, they do not exhibit a binder performance as effective as cement, and hydration reactions at early ages occur more limitedly. This finding is consistent with the results reported in the literature (Jiang et al., 2018).

At the end of the 28-day curing period, an increase in strength was observed in all mixtures. The compressive strength obtained for the low replacement ratio mixture (5% EAFS) was very close to that of the control specimen.

As the replacement ratio increased (EAFS10–EAFS20), the 28-day compressive strength decreased more noticeably compared to the control mixture.

KAYNAKLAR

Ángel, J., Hipólito, O., José, B., Gayo, L., García, N., Seoánez, C., Karadayı, S., Çelik, A., Ve, S., Muzaffer, T. A. Ş.), Mehmet, D., Yavuz, Y., Dinçer, Y., Betül, K., Çatal, K., Leblebici, Z., Tok, E., Savaş, Ş., Gülay, Ö., & Gürpınar, Ö. (2012). *BAT Guide for electric arc furnace iron & steel installations*.

Benhelal, E., Zahedi, G., Shamsaei, E., & Bahadori, A. (2013). Global strategies and potentials to curb CO2 emissions in cement industry. *Journal of Cleaner Production*, *51*(9), 142–161. https://doi.org/10.1016/j.jclepro.2012.10.049

Hasçelik. (2026, February). *What is Slag?* https://hascelik.com/eng/blogs/what-is-slag

Jiang, Y., Ling, T. C., Shi, C., & Pan, S. Y. (2018). Characteristics of steel slags and their use in cement and concrete—A review. *Resources, Conservation and Recycling*, *136*, 187–197. https://doi.org/10.1016/J.RESCONREC.2018.04.023

Manso, J. M., Polanco, J. A., Losañez, M., & González, J. J. (2006). Durability of concrete made with EAF slag as aggregate. *Cement and Concrete Composites*, *28*(6), 528–534. https://doi.org/10.1016/j.cemconcomp.2006.02.008

Mehta, P. K., & Monteiro, P. J. M. (2006). *Concrete: Microstructure, Properties, and Materials* (Third edition). McGraw-Hill.

Peens, M. (2004). *Modelling and Control of an Electrode System for a Three-phase Electric Arc Furnace*. University of Pretoria.

Pellegrino, C., & Gaddo, V. (2009). Mechanical and durability characteristics of concrete containing EAF slag as aggregate. *Cement and Concrete Composites*, *31*(9), 663–671. https://doi.org/10.1016/j.cemconcomp.2009.05.006

Santamaria, A., Faleschini, F., Giacomello, G., Brunelli, K., San José, J. T., Pellegrino, C., & Pasetto, M. (2018). Dimensional stability of electric arc furnace slag in civil engineering applications. *Journal of Cleaner Production*, *205*, 599–609. https://doi.org/10.1016/j.jclepro.2018.09.122

Shi, C. (2004). Steel Slag-Its Production, Processing, Characteristics, and Cementitious Properties. *Journal of Materials in Civil Engineering*, *16*(3), 230–236. https://doi.org/10.1061/ASCE0899-1561200416:3230

Türkiye Çelik Üreticiler Derneği (TÇÜD). (2026, January 22). *Türkiye'nin Ham Çelik Üretimi 2025 Yılında %3,3 Artışla 38,1 Milyon Tona Yükseldi | TÇÜD*. https://celik.org.tr/tr/bilgi-merkezi/degerlendirme/tuerkiye-nin-ham-celik-ueretimi-2025-yilinda-3-3-artisla-38-1-milyon-tona-yuekseldi

Wang, Q., Yan, P., Yang, J., & Zhang, B. (2013). Influence of steel slag on mechanical properties and durability of concrete. *Construction and Building Materials*, *47*, 1414–1420. https://doi.org/10.1016/j.conbuildmat.2013.06.044

World Steel Association. (2026). *December 2025 crude steel production and 2025 global crude steel production totals*. https://worldsteel.org/media/press-releases/2026/december-2025-crude-steel-production-2025-global-crude-steel-production/

Zweben, S., & Karasik, M. (2000). *Laboratory Experiments on Arc Deflection and Instability*. https://doi.org/http://www.doi.org/10.2172/752819

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENHANCING EARLY RETINAL DISEASE DETECTION THROUGH CONVOLUTIONAL NEURAL NETWORK (CNN) AS AN ARTIFICIAL INTELLIGENCE (AI) APPLICATION IN MEDICINE

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ABSTRACT

Vision loss is a serious health problem worldwide, and one of the main causes of this problem is retinal disease. Some of these diseases can lead to permanent vision loss, such as Age-Related Macular Degeneration (AMD), Glaucoma, Diabetic Retinopathy (DR) and Cataract. As with any other disease, the earlier it is detected, the greater the chance of slowing its progression and starting appropriate treatment early.

This study aimed to develop an algorithm based on artificial intelligence techniques to contribute to early diagnosis through retinal image analysis. The research was based on the use of Fundus Photographs (FP) and Optical Coherence Tomography (OCT) images, where macular abnormalities and changes in the optic disc were analyzed, in addition to a detailed assessment of the microvasculature, relying on Convolutional Neural Network architectures (CNN) based on deep learning. The proposed model was trained and evaluated based on large-scale datasets to ensure the accuracy and reliability of the results.

During the study, a number of technical methods were employed, including image pre-processing, data augmentation, and transfer learning, to enhance the model's generalization capability and improve its accuracy. The developed system was designed to be a Clinical decision support tool (CDSS).

The developed system was designed to serve as an auxiliary tool that could support the clinical evaluation process. The findings indicate that the artificial intelligence model can be used to detect early-stage findings of retinal diseases. In this regard, the system offers specialists a preliminary assessment mechanism in the clinical decision-making process.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

In conclusion, it is considered that artificial intelligence-based retinal image analysis systems can make meaningful contributions to the early diagnosis process. However, it should be emphasized that such systems should be positioned as auxiliary systems supporting clinical evaluation, rather than as tools for making the final diagnosis.

Keywords: Convolutional Neural Network architectures (CNN), Deep Learning, Machine Learning (ML), Artificial Intelligence (AI), Retina, Diabetic Retinopathy, Glaucoma, Cataract.

Tıpta Evrişimli Sinir Ağı (CNN) ve Yapay Zeka Uygulamalarıyla Erken Retina Hastalığı Tespitinin Geliştirilmesi

ÖZET

Görme kaybı dünya çapında ciddi bir sağlık sorunudur ve bu sorunun ana nedenlerinden biri retina hastalığıdır. Bu hastalıkların bazıları, Yaşa Bağlı Makula Dejenerasyonu (AMD), Glokom ve Diyabetik Retinopati (DR) gibi kalıcı görme kaybına yol açabilir. Diğer tüm hastalıklar gibi, ne kadar erken teşhis edilirse, ilerlemesini yavaşlatma ve uygun tedaviyi erken başlatma şansı o kadar artar.

Bu çalışma, retina görüntü analizi yoluyla erken tanıya katkıda bulunmak için yapay zeka tekniklerine dayalı bir algoritma geliştirmeyi amaçlamıştır. Araştırma, Fundus Fotoğrafları (FP) ve Optik Koherens Tomografi (OCT) görüntülerinin kullanılmasına dayanmaktadır. Bu görüntülerde, derin öğrenmeye dayalı evrişimli sinir ağı mimarileri (CNN) kullanılarak, mikrovaskülatürün ayrıntılı bir değerlendirmesinin yanı sıra maküler anormallikler ve optik diskteki değişiklikler analiz edilmiştir. Önerilen model, sonuçların doğruluğunu ve güvenilirliğini sağlamak için büyük ölçekli veri setlerine dayalı olarak eğitildi ve değerlendirildi.

Çalışma sırasında, modelin genelleme yeteneğini artırmak ve doğruluğunu iyileştirmek için görüntü ön işleme, veri artırma ve transfer öğrenimi gibi bir dizi teknik yöntem kullanıldı. Geliştirilen sistem, Klinik Karar Destek Aracı (CDSS) olarak tasarlandı.

Geliştirilen sistem, klinik değerlendirme sürecini destekleyebilecek bir yardımcı araç olarak tasarlanmıştır. Bulgular, yapay zeka modelinin retina hastalıklarının erken evre bulgularını tespit etmek için kullanılabileceğini göstermektedir. Bu bağlamda, sistem uzmanlara klinik karar verme sürecinde bir ön değerlendirme mekanizması sunmaktadır.

Sonuç olarak, yapay zeka tabanlı retina görüntü analiz sistemlerinin erken tanı sürecine anlamlı katkılar sağlayabileceği düşünülmektedir. Ancak, bu tür sistemlerin nihai tanı koyma araçları olarak değil, klinik değerlendirmeyi destekleyen yardımcı sistemler olarak konumlandırılması gerektiği vurgulanmalıdır.

Anahtar Kelimeler: Konvolüsyonel Sinir Ağı mimarileri (CNN), Derin Öğrenme, Makine Öğrenimi (ML), Yapay Zeka (AI), Retina, Diyabetik Retinopati, Glokom, Katarakt.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CORE ARCHITECTURE EFFECTS ON THE STRUCTURAL PERFORMANCE OF HYBRID SANDWICH COMPOSITES FOR AEROSPACE APPLICATIONS

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Abstract

Composite materials have revolutionized the aerospace industry due to their superior strength-to-weight ratios, corrosion resistance, and design flexibility. In this study, the structural behavior of sandwich composite plates used in aerospace applications was numerically investigated under various loading scenarios representing harsh environmental conditions. Within the scope of the study, two different wing-section sandwich configurations were modeled: Model 1, a conventional sandwich configuration consisting of T300 carbon fiber face sheets and an XPS foam core; and Model 2, a hybrid sandwich configuration incorporating a honeycomb reinforcement within the core region in addition to the base structure. The mechanical responses of both models were comparatively evaluated in terms of stress distribution, displacement, and stiffness using the finite element method. The results indicate that the core architecture plays a decisive role in the load-bearing capacity and deformation characteristics of sandwich structures. The honeycomb-reinforced Model 2 exhibited lower displacement levels and a more homogeneous stress distribution compared to the reference configuration (Model 1). These findings demonstrate that multi-core or hybrid sandwich designs provide an effective design strategy for enhancing stiffness and structural integrity in aerospace structures.

Keywords: Sandwich composite structures, carbon fiber reinforced polymer, honeycomb core, finite element method, aerospace structures

HAVACILIK UYGULAMALARI İÇİN HİBRİT ÇEKİRDEKLİ SANDVİÇ KOMPOZİTLERİN YAPISAL PERFORMANSINA ÇEKİRDEK MİMARİSİ ETKİSİ

ÖZET

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Kompozit malzemeler, üstün mukavemet-ağırlık oranları, korozyon direnci ve tasarım esneklikleri nedeniyle havacılık ve uzay endüstrisinde devrim yaratmıştır. Bu çalışmada, havacılık uygulamalarında kullanılan sandviç kompozit plakaların yapısal davranışı, zorlu çevresel koşulları temsil eden farklı yükleme senaryoları altında sayısal olarak incelenmiştir. Çalışma kapsamında iki farklı kanat kesitli sandviç yapı modellenmiştir: Model 1, T300 karbon fiber yüzey tabakaları ile XPS köpük çekirdekten oluşan konvansiyonel sandviç konfigürasyonu, Model 2 ise aynı temel yapıya ek olarak çekirdek bölgesinde bal peteği (honeycomb) takviyesi içeren hibrit sandviç konfigürasyonudur. Her iki modelin mekanik tepkisi, sonlu elemanlar yöntemi kullanılarak gerilme, yer değiştirme ve rijitlik açısından karşılaştırmalı olarak değerlendirilmiştir. Elde edilen sonuçlar, çekirdek mimarisinin sandviç yapıların yük taşıma kapasitesi ve şekil değiştirme karakteristikleri üzerinde belirleyici bir etkiye sahip olduğunu göstermektedir. Honeycomb takviyesi içeren Model 2'nin, referans konfigürasyon olan Model 1'e kıyasla daha düşük yer değiştirme değerleri sergilediği ve gerilme dağılımını daha homojen biçimde yayabildiği belirlenmiştir. Bu bulgular, çok çekirdekli veya hibrit sandviç tasarımlarının, havacılık yapılarında rijitlik ve yapısal bütünlüğün artırılmasına yönelik etkili bir tasarım yaklaşımı sunduğunu ortaya koymaktadır.

Anahtar kelimeler: Sandviç kompozit yapılar, karbon fiber takviyeli polimer, bal peteği çekirdek, sonlu elemanlar yöntemi, havacılık yapıları

1. GİRİŞ

Havacılık yapılarında ağırlığın azaltılması, yapısal dayanımın artırılması ve yakıt verimliliğinin iyileştirilmesi, modern uçak tasarımının temel hedefleri arasında yer almaktadır. Bu bağlamda, sandviç plaklar ve fiber takviyeli kompozit yapılar; yüksek özgül dayanımları, enerji sönümleme kapasiteleri ve tasarım esneklikleri sayesinde kanat, gövde ve kontrol yüzeyleri gibi kritik taşıyıcı bileşenlerde yaygın olarak kullanılmaktadır. Bununla birlikte, bu yapıların farklı yükleme koşulları ve zorlu çevresel etkiler altındaki davranışlarının güvenilir biçimde öngörülebilmesi, havacılık uygulamaları açısından halen önemli bir mühendislik problemidir.

Sandviç ve kompozit plakların dinamik davranışı ve titreşim karakteristikleri üzerine yapılan çalışmalarda, sonlu elemanlar yöntemine dayalı analitik ve sayısal modellerin yaygın olarak kullanıldığı görülmektedir. Baltacı (2014), radyal kanallı kompozit plakaların doğal frekanslarını sonlu elemanlar yöntemiyle incelemiş; Özdemirli (2006) ise sandviç plakların ani basınç yükü altındaki geçici dinamik tepkisini deneysel ve sayısal olarak karşılaştırmıştır. Benzer şekilde, Zengin vd. (2018) sandviç yapılarda çekirdek geometrisi ve sınır şartlarının gerilme dağılımına etkisini ortaya koymuştur. Kompozit plakların darbe, balistik davranışı ve enerji sönümleme mekanizmaları literatürde önemli bir araştırma alanı oluşturmaktadır. Esendemir ve Caner (2018), kompozit plaklarda darbe enerjisi, hasar oluşumu ve delik etkisini deneysel olarak incelemiş; delik varlığının hasarı artırdığını göstermiştir. Alabay (2020) ve Üstün (2020) ise nano-parçacık katkısı ve hibrit fiber

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

kullanımının darbe ve balistik dayanımı iyileştirdiğini ortaya koymuştur. Bu çalışmalar birlikte değerlendirildiğinde, kompozit yapıların darbe ve balistik performansının yalnızca fiber tipiyle değil, aynı zamanda matriks modifikasyonu ve hibrit yapılandırma yaklaşımları ile de önemli ölçüde geliştirilebildiği görülmektedir.

Kompozit yapılarda hasar oluşumu, delik etkisi ve ilerlemeli kırılma davranışı da yaygın biçimde araştırılmıştır. Esendemir ve Başaran (2023), delik konfigürasyonunun darbe hasarını artırdığını belirtmiştir. Benzer şekilde, Sayer vd. (2022) çatlaklı kompozit plakların dinamik kararlılığını incelemiş; Örün ve Salamcı (2023) delik etrafındaki farklı güçlendirme geometrilerinin dayanımı anlamlı biçimde artırabildiğini göstermiştir. Cömert (2022) ve Muyan (2023) tarafından gerçekleştirilen çalışmalar ise değişken katılıklı laminasyon yaklaşımları ve kohesif arayüz modellerinin hasar tahmininde etkili araçlar sunduğunu ortaya koymaktadır. Kompozit yapıların imalat yöntemleri ve yapılandırma stratejileri de mekanik performansı doğrudan etkilemektedir. Gülnar (2016), RTM yöntemiyle üretilen kompozit plaklarda üretim parametrelerinin mekanik özellikler üzerindeki belirleyici rolünü vurgulamıştır. Kavrar (2012), bal peteği çekirdekli karbon fiber sandviç yapıların eğilme ve burulma performansının iyileştiğini göstermiştir. Benzer şekilde, Kıyak ve Kaman (2018), kare kesitli çekirdek geometrisine sahip sandviç levhaların basma ve burkulma davranışlarını deneysel ve sayısal olarak karşılaştırmıştır. Sonuç olarak, sandviç ve kompozit plakların mekanik ve dinamik davranışlarının; çekirdek geometrisi, fiber mimarisi, delik ve hasar konfigürasyonu, nano ve polimerik katkılar ile imalat parametreleri tarafından belirgin biçimde etkilendiğini ortaya koymaktadır. Bununla birlikte, çok çekirdekli veya hibrit çekirdek mimarisine sahip sandviç yapıların, havacılık uygulamalarını temsil eden kanat benzeri geometriler üzerinde farklı yükleme koşulları altında karşılaştırmalı olarak incelendiği çalışmaların sınırlı olduğu görülmektedir.

Bu çalışma, modern uçakların ayrılmaz bir parçası olan kompozit plakaların yapısal davranışını, zorlu çevresel koşullarda görev yapan platformların kritik taşıyıcı parçaları bağlamında ele almaktadır. Çalışmada iki farklı kanat kesitli sandviç kompozit konfigürasyonu değerlendirilmiştir: Model 1, T300 karbon fiber yüzey tabakaları ile XPS köpük çekirdekten oluşan temel sandviç yapı; Model 2 ise aynı temel sandviç yapıya ilave olarak çekirdek bölgesinde bal peteği (honeycomb) takviyesi içeren hibrit konfigürasyondur. Bu iki tasarım, farklı yükleme senaryoları altında sonlu elemanlar yöntemi ile karşılaştırmalı olarak analiz edilerek, çekirdek mimarisinin ve malzeme kombinasyonunun yapısal davranış üzerindeki rolünün ortaya konması amaçlanmıştır.

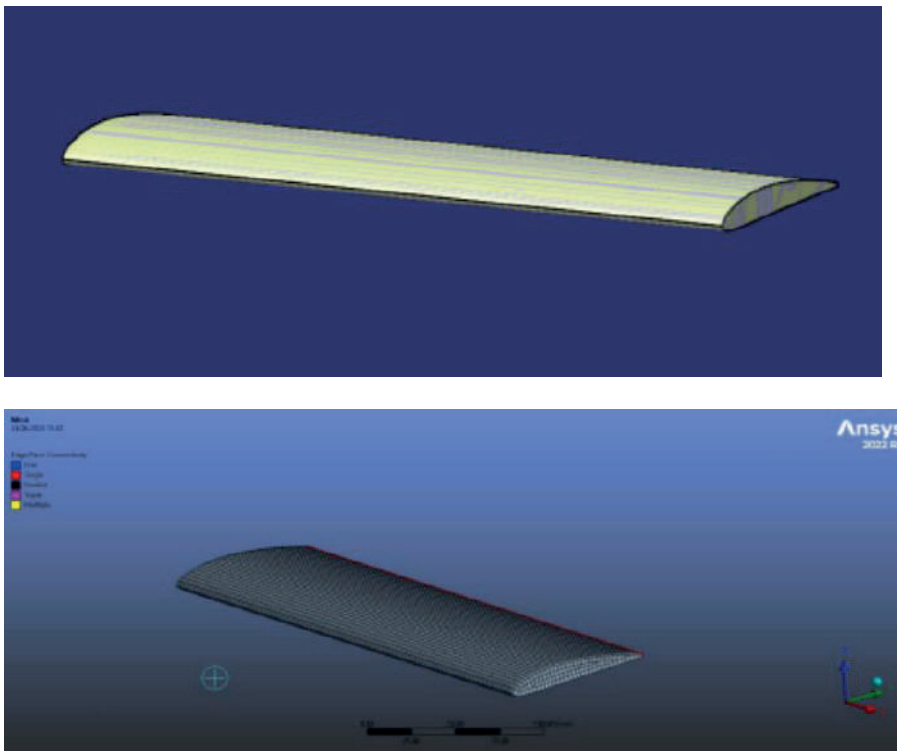
2. MALZEME VE METOT

2.1. Kanat Profilinin Modellemesi

Bu çalışmada, NACA 4412 kanat profili 100 mm kiriş uzunluğu ve 300 mm açıklık uzunluğu esas alınarak CATIA V5 ortamında modellenmiştir (Şekil 1). Sonlu elemanlar analizine uygun yüzey

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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geometrileri, katı model üzerinden türetilmiştir. Sayısal analizler ANSYS Workbench ortamında gerçekleştirilmiş ve kompozit tabaka tanımlamaları ACP (Pre) modülü kullanılarak yapılmıştır.



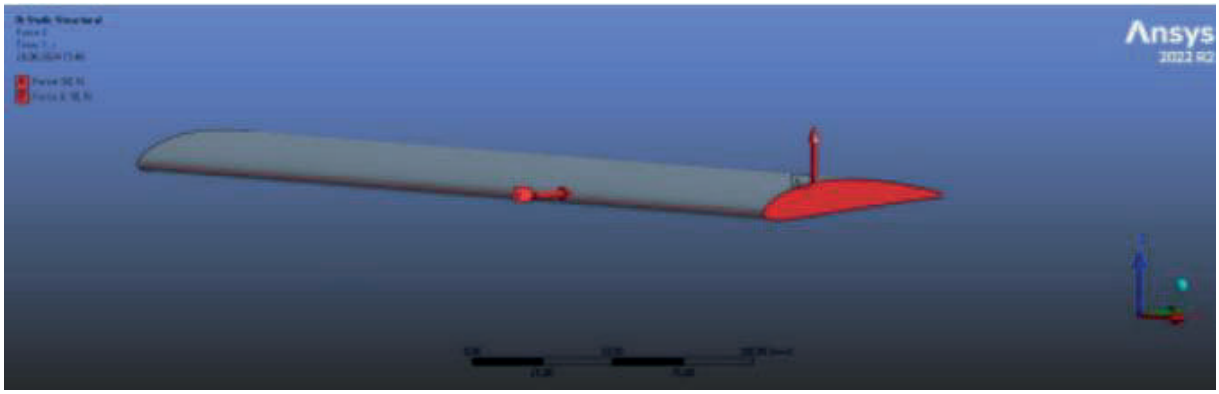
Şekil 1. NACA 4412 kanat modeli

Çalışma kapsamında iki farklı sandviç kompozit konfigürasyonu tanımlanmıştır. Model 1, XPS köpük çekirdek üzerine her iki yüzeye ±45° oryantasyonlu T300 3K karbon kumaş tabakalarının yerleştirildiği, iki yüzey tabakalı konvansiyonel sandviç yapı olarak tasarlanmıştır. Model 2 ise XPS köpük çekirdek üzerine sırasıyla +45° yönelimli T300 3K karbon kumaş, 1.5 mm kalınlığında bal peteği (honeycomb) yapı ve −45° yönelimli T300 3K karbon kumaş tabakalarının yerleştirildiği hibrit çekirdekli sandviç yapı olarak modellenmiştir.

Kompozit yüzeyler için ANSYS malzeme kütüphanesinde yer alan ve T300 karbon/epoksi dokuma kumaş ile benzer mekanik özellikler gösteren Epoxy Carbon Woven (230 GPa, Wet) malzemesi kullanılmıştır. Bal peteği çekirdek için ANSYS kütüphanesinde bulunan eşdeğer honeycomb malzemesi tanımlanmıştır. Karbon kumaş tabaka kalınlığı 0.3 mm, bal peteği çekirdek kalınlığı ise 1.5 mm olarak alınmıştır.

Model geometrisi, kanat yüzeyleri ve yan yüzeyler ayrı ayrı tanımlanacak şekilde “named selection” yöntemi ile gruplandırılmıştır. Model yaklaşık 55.450 düğüm ve 16.400 eleman içerecek biçimde ağ yapısına bölünmüş ve eleman kalitesi kontrolleri gerçekleştirilmiştir. Lif yönelimleri, ACP modülünde “rosette” tanımlamaları kullanılarak yüzeylere atanmıştır.

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Şekil 2. Kanat üzerine yük tanımlaması

Statik yapısal analizler kapsamında kanat kök bölgesi ankastre olarak sınırlandırılmış; serbest uçtan yukarı yönde 50 N büyüklüğünde yük uygulanmıştır. Ayrıca aerodinamik sürtünme etkisini temsil etmek amacıyla ön yüzeye 10 N büyüklüğünde ilave bir yük tanımlanmıştır (Şekil 2). Analizlerde yer değiştirme ve gerilme dağılımları karşılaştırmalı olarak değerlendirilmiştir.

2.2. Malzeme Seçimi

Bu çalışmada, sandviç kompozit yapıların yüzey tabakalarında T300 karbon fiber takviyeli epoksi, çekirdek malzeme olarak ise XPS (ekstrüde polistiren) köpük kullanılmıştır. Model 2'de çekirdek rijitliğini artırmak amacıyla ek olarak bal peteği (honeycomb) yapı tercih edilmiştir. Bu malzemeler, yüksek özgül dayanım, düşük yoğunluk ve havacılık uygulamalarındaki yaygın kullanımları nedeniyle seçilmiştir.

T300 karbon fiber, havacılık ve uzay uygulamalarında yaygın olarak kullanılan yüksek dayanımlı bir takviye malzemesidir. Yaklaşık 3.5 GPa çekme mukavemeti ve 230 GPa elastik modülü ile yüksek rijitlik sağlar. Düşük yoğunluğu (~1.76 g/cm^3) sayesinde yüksek mukavemet-ağırlık oranı sunar. Ayrıca korozyon direnci ve düşük termal genleşme katsayısı, zorlu çevresel koşullara maruz kalan yapılar için avantaj sağlamaktadır. Öte yandan, XPS köpük ise düşük yoğunluğu ve yeterli basma dayanımı sayesinde sandviç yapılarda çekirdek malzeme olarak yaygın şekilde kullanılmaktadır. Düşük su emme oranı, iyi ısı yalıtım özellikleri ve kolay işlenebilirliği, yapısal sandviç uygulamaları açısından tercih edilme nedenleridir.

T300 karbon fiber yüzey tabakaları ile XPS köpük çekirdeğin birlikte kullanımı, kanat yapılarında yüksek rijitlik ve düşük ağırlık gereksinimlerini karşılayan etkili bir sandviç yapı oluşturmaktadır. Model 2'de kullanılan bal peteği takviyesi ise çekirdek rijitliğini artırmaya yönelik hibrit bir yaklaşım sunmakta olup, çekirdek mimarisinin yapısal davranış üzerindeki etkisinin incelenmesine olanak sağlamaktadır.

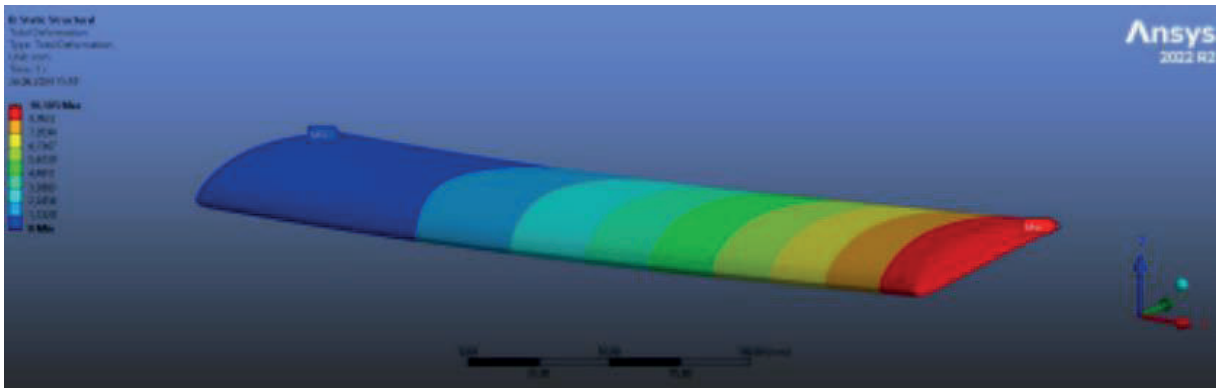
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3. BULGULAR VE TARTIŞMA

Bu çalışmada, T300 karbon fiber yüzey tabakaları ve XPS köpük çekirdekten oluşan sandviç kanat yapısının mekanik davranışı, iki farklı konfigürasyon (Model 1 ve Model 2) için statik yükleme altında sonlu elemanlar yöntemi kullanılarak incelenmiştir. Yapıların deformasyon ve gerilme dağılımları karşılaştırmalı olarak değerlendirilerek, çekirdek mimarisinin yapısal performans üzerindeki etkisi tartışılmıştır.

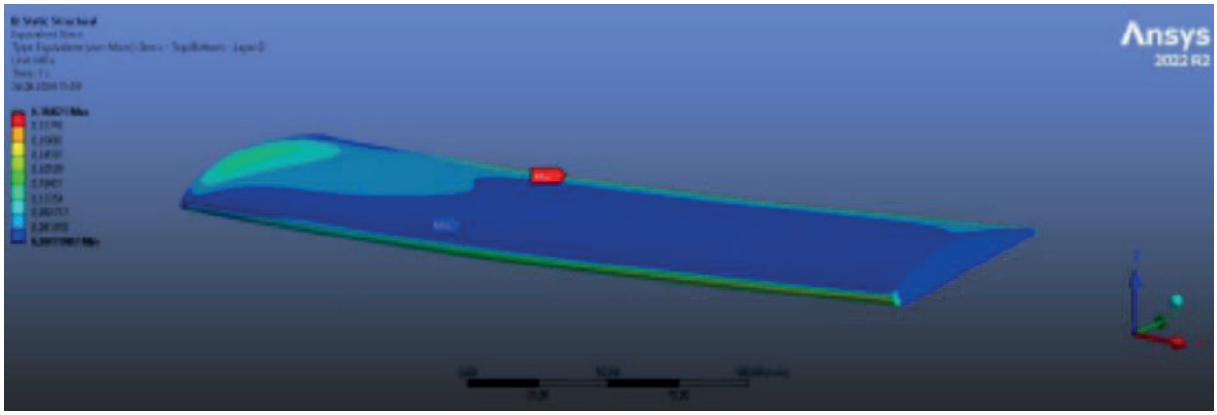
3.1. Model 1 - Referans Sandviç Yapı

Model 1 için elde edilen sonuçlar, yükleme altında kanat yüzeyinde maksimum 10.105 mm yer değiştirme meydana geldiğini göstermektedir (Şekil 3). Bu değer, sandviç yapının eğilme rijitliğinin sınırlı olduğunu ve çekirdek malzemenin yük aktarımında belirleyici rol oynadığını ortaya koymaktadır.



Şekil 3. Model 1'de kanatta oluşan deformasyon

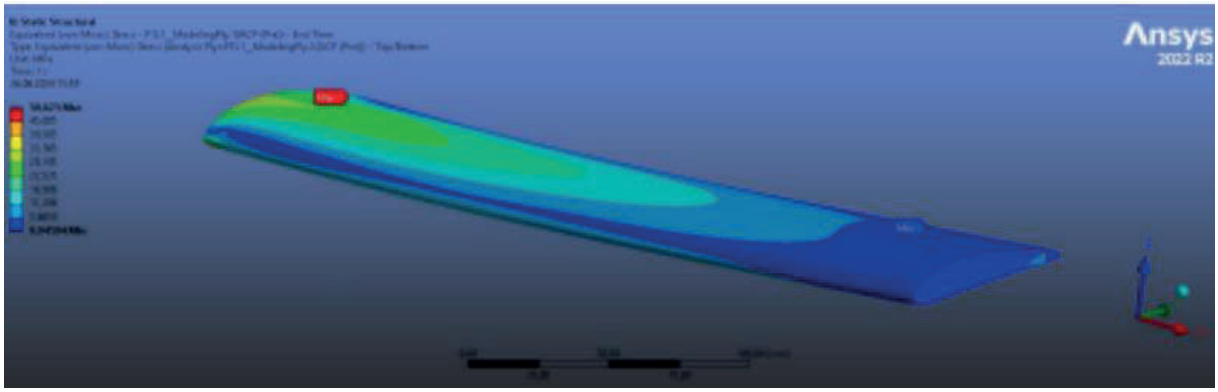
XPS köpük çekirdek üzerinde oluşan eşdeğer gerilmeler incelendiğinde, maksimum gerilmenin 0.368 MPa mertebesine ulaştığı ve bu gerilmelerin özellikle kanadın firar kenarı bölgesinde yoğunlaştığı görülmektedir (Şekil 4). Söz konusu değer, XPS köpüğün basma dayanımına (~0.3 MPa) yakın veya yer yer bu sınırı aşan seviyelerdedir. Bu durum, Model 1 konfigürasyonunda çekirdek malzemenin lokal ezilme riski taşıdığını göstermektedir.



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Şekil 4. XPS köpükte oluşan stres değerleri

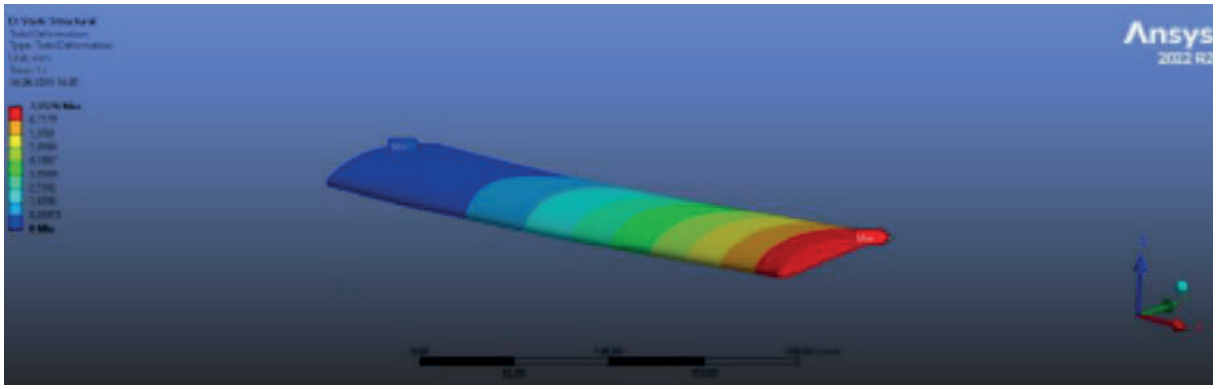
Kompozit yüzey tabakaları üzerindeki gerilme dağılımı incelendiğinde, maksimum gerilmelerin kanadın ankastre kenarı civarında yoğunlaştığı, ancak bu değerlerin karbon fiber/epoksi sistemin emniyetli çalışma aralığı içerisinde kaldığı belirlenmiştir (Şekil 5). Bu bulgu, Model 1'de yapısal zayıflığın esas olarak çekirdek malzeme kaynaklı olduğunu göstermektedir.



Şekil 5. Kompozit malzemede meydana gelen stres değerleri

3.2. Model 2 - Hibrit Çekirdekli Sandviç Yapı

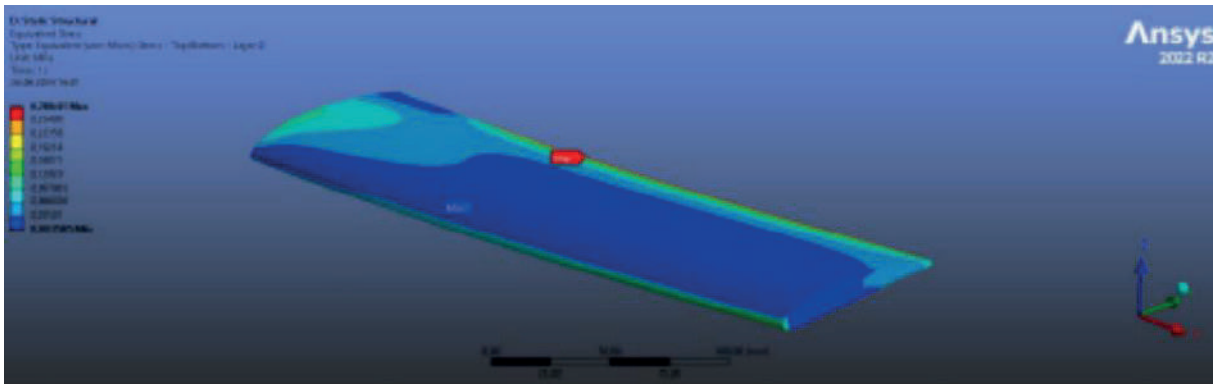
Model 2 için elde edilen maksimum yer değiştirme değeri 7.56 mm olarak hesaplanmıştır (Şekil 6). Bu sonuç, Model 1 ile karşılaştırıldığında yaklaşık %25 oranında daha düşük bir deformasyona işaret etmekte ve hibrit çekirdek mimarisinin yapısal rijitliği artırdığını göstermektedir.



Şekil 6. Kanatta oluşan deformasyon değerleri

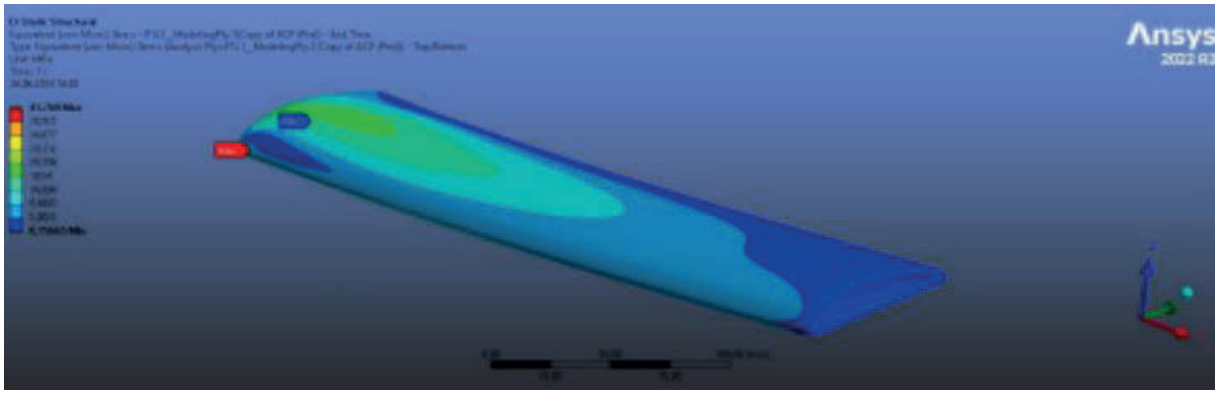
XPS köpük çekirdek üzerindeki maksimum gerilme değeri 0.286 MPa seviyesinde kalmış olup, bu değer XPS köpüğün basma dayanımının altında yer almaktadır (Şekil 7). Dolayısıyla Model 2 konfigürasyonunda çekirdek malzeme açısından lokal ezilme riski bulunmadığı söylenebilir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Şekil 7. XPS köpük üzerinde oluşan stres değerleri

Kompozit yüzey tabakaları üzerindeki gerilmeler incelendiğinde, Model 1'e kıyasla daha homojen bir dağılım elde edildiği ve maksimum gerilme seviyelerinin azaldığı görülmüştür (Şekil 8). Bu durum, bal peteği takviyesinin yük transferini daha dengeli hale getirdiğini göstermektedir.



Şekil 8. Kompozit malzeme üzerinde oluşan stres değerleri

3.3. Sonuçlar

Model 1 ve Model 2 için elde edilen maksimum yer değiştirme ve çekirdek gerilme değerleri Tablo 1'de karşılaştırmalı olarak sunulmuştur. Hibrit çekirdekli Model 2'nin, referans sandviç yapıya kıyasla hem deformasyon seviyelerini düşürdüğü hem de çekirdek malzemede oluşan gerilmeleri emniyet sınırları içerisinde tuttuğu görülmektedir.

Tablo 1. Model 1 ve Model 2 için sayısal analiz sonuçlarının karşılaştırılması

Parametre	**Model 1 (Referans Sandviç Yapı)**	**Model 2 (Hibrit Çekirdekli Sandviç Yapı)**	**Göreli Değerlendirme**
Maksimum yer değiştirme (mm)	10.105	7.558	Yaklaşık %25 azalma
XPS köpükte maksimum gerilme (MPa)	0.368	0.286	Basma dayanımı altına düşmüştür

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

XPS köpük basma dayanımı (MPa)	~0.30	~0.30	Referans
Çekirdek malzemede ezilme riski	Var (lokal)	Yok	Model 2 daha güvenli
Kompozit yüzeyde maksimum gerilme	Daha yüksek (lokal yoğunlaşma)	Daha düşük ve homojen	Model 2 daha dengeli
Gerilme dağılımı homojenliği	Düşük	Yüksek	Model 2 üstün

Her iki model birlikte değerlendirildiğinde, referans sandviç yapı olan Model 1'de çekirdek malzemenin özellikle firar kenarı bölgesinde basma dayanımı sınırlarına yaklaştığı ve lokal ezilme riski taşıdığı görülmektedir. Buna karşılık, hibrit çekirdekli Model 2'de bal peteği takviyesinin yük paylaşımını iyileştirdiği, XPS köpük üzerindeki gerilmeleri düşürdüğü ve toplam deformasyonu azalttığı belirlenmiştir.

Bu sonuçlar, sandviç yapıların mekanik performansının yalnızca yüzey tabakalarının malzeme özelliklerine değil, aynı zamanda çekirdek mimarisine de güçlü biçimde bağlı olduğunu ortaya koymaktadır. Hibrit veya çok çekirdekli sandviç tasarımlarının, özellikle havacılık uygulamalarında rijitlik gereksinimi yüksek yapılar için yapısal güvenliği artırabilecek etkili bir tasarım yaklaşımı sunduğu değerlendirilmektedir.

4. SONUÇ VE DEĞERLENDİRME

Havacılık endüstrisinde kullanılan kompozit plakaların yapısal özelliklerinin incelenmesi, bu gelişmiş malzemelerin mekanik davranışı, performansı ve potansiyel uygulamaları hakkında değerli bilgiler sağlamıştır. Bu çalışma, kompozit malzemelerin yüksek mukavemet/ağırlık oranı, korozyon direnci ve tasarım esnekliği gibi önemli avantajlarının altını çizerek, onları havacılık ve uzay uygulamaları için ideal hale getirmiştir. Çalışmanın bulguları, uçak yapılarında gelişmiş performans ve güvenlik için kompozit malzemelerin nasıl optimize edileceğinin daha iyi anlaşılmasına katkıda bulunmaktadır.

Sayısız faydasına rağmen, havacılıkta kompozit malzemelerin kullanımıyla ilgili bazı sınırlayıcı özellikler vardır. Başlıca zorluklardan biri üretim süreçlerinin karmaşıklığıdır. Kompozit üretimi, zaman alıcı ve maliyetli olabilen malzeme özellikleri ve katman yönelimleri üzerinde hassas kontrol gerektirir. Kompozit plakaların üretim ve işleme süreçleri oldukça karmaşık ve zaman alıcı olabilir. Bu süreçler, özel ekipman ve uzmanlık gerektirdiğinden, üretim maliyetlerini önemli ölçüde artırır. Buna ek olarak, kompozit yapıların denetimi ve bakımı, yüzey altı hasarın tespit edilmesindeki zorluk nedeniyle zorluklar teşkil etmektedir. Kompozit malzemelerin işlenmesi, özellikle şekillendirme ve kesme işlemleri, metal malzemelere göre daha fazla uzmanlık ve hassasiyet gerektirir. Bu durum,

üretim sürecini daha karmaşık hale getirir. Tahribatsız test yöntemleri sürekli olarak gelişirken, kompozit bileşenlerin güvenilirliğini sağlamak kritik bir endişe kaynağı olmaya devam etmektedir. Bir diğer sınırlama ise kompozitlerin nem emilimi ve sıcaklık değişimleri gibi zaman içinde mekanik özelliklerini etkileyebilecek çevresel koşullara karşı duyarlılığıdır.

İleriye bakıldığında, havacılık endüstrisinde kompozit malzemelerin geleceği umut vericidir ve çeşitli trendlerin daha fazla ilerleme kaydetmesi beklenmektedir. Üretim sürecinde ortaya çıkan atıkların yönetimi de zor olabilir ve bu atıkların çevreye zarar vermeden bertaraf edilmesi gerekmektedir. Önemli trendlerden biri, gelişmiş geri dönüştürülebilirlik ve daha hızlı üretim süreçleri sunan termoplastik kompozitler gibi yeni nesil kompozit malzemelerin geliştirilmesidir. Karbon nanotüpler ve grafen gibi nanomalzemelerin entegrasyonunun da kompozit yapıların mekanik özelliklerini ve dayanıklılığını artırması beklenmektedir. Ek olarak, eklemeli üretim ve robotik elyaf yerleştirme gibi otomatik üretim tekniklerindeki ilerlemelerin üretim maliyetlerini düşürmesi ve tutarlılığı artırması beklenmektedir. Kendi sağlıklarını ve performanslarını izleyebilen akıllı kompozitlere yönelik devam eden araştırmalar, bir başka heyecan verici sınırı temsil etmektedir. Bu malzemeler, yapısal bütünlük hakkında gerçek zamanlı veri sağlayarak hava taşıtlarının güvenliğini ve bakımını önemli ölçüde artırma potansiyeline sahiptir. Kompozit malzemelerin özelliklerinin doğru bir şekilde tahmin edilmesi ve simüle edilmesi karmaşık olabilir. Bu durum, mühendislik analizlerinin daha fazla hesaplama ve modelleme gerektirmesine neden olur.

Bu kısıtlamalar ve sınırlar, kompozit plakaların kullanımını belirli uygulamalarda sınırlayabilir. Ancak, sürekli gelişen teknolojiler ve malzeme bilimi, bu zorlukların bir kısmını aşmayı ve kompozit malzemelerin daha geniş bir yelpazede kullanılmasını sağlamayı amaçlamaktadır. Teknolojik ilerlemeler ve yenilikçi çözümlerle, kompozit malzemelerin avantajlarından daha fazla yararlanmak mümkün hale gelecektir.

Sonuç olarak, zorluklar devam etse de, kompozit malzemelerin sürekli araştırılması ve geliştirilmesi, havacılık endüstrisinde daha verimli, sürdürülebilir ve yenilikçi çözümlerin anahtarını elinde tutmaktadır. Bu çalışmadan elde edilen bilgiler gelecekteki ilerlemelerin önünü açarak kompozit malzemelerin havacılık ve uzay mühendisliğinin geleceğini şekillendirmede önemli bir rol oynamaya devam etmesini sağlayacaktır.

KAYNAKÇA

Alabay, P. (2020). Nano-parçacık ihtiva eden kompozit plakaların düşük hızlı çarpma davranışının incelenmesi (Master's thesis, Fen Bilimleri Enstitüsü).

Baltacı, Ç. Ö. (2014). *Vibration analysis of laminated composite circular plates with radial slots*. Izmir Institute of Technology (Turkey).

Cömert, U. K. (2022). *Investigation of Buckling, Post-Buckling Behaviour of Variable Stiffness Composite Plates* (Master's thesis, Middle East Technical University (Turkey)).

Esendemir, Ü., & Başaran, Ö. (2023). Dairesel Delikli Kompozit Plakaların Düşük Hızlı Darbe Davranışlarinin Deneysel Olarak İncelenmesi. *Teknik Bilimler Dergisi*, *13*(2), 20-27.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Esendemir, Ü., & Caner, A. Y. (2018). Tabakalı kompozit malzemelerin darbe davranışının deneysel olarak incelenmesi. *Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, *22*(1), 207-215.

Gülnar, M. (2016). Kompozit plaka üretim prosesi üzerine çalışmalar ve parametrelerin mekanik özelliklere etkisi (Master's thesis, Balıkesir Üniversitesi Fen Bilimleri Enstitüsü).

Kavrar, D. (2012). Bir Helikopter Kompozit Kuyruk Konisi Üretimi Ve Karakterizasyonu, (Master's thesis, İstanbul Teknik Üniversitesi Fen Bilimleri Enstitüsü).

Kıyak, B., & Kaman, M. O. (2018). Karbon Fiber Kompozit Sandviç Levhaların Yanal Mukavemet Davranışlarının Araştırılması. Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 18(2), 684-691.

Muyan, M. C. (2023). *Development of Progressive Failure Models and Their Application to Open Hole Composite Laminates and Wind Turbine Blades* (Doctoral dissertation, Middle East Technical University (Turkey)).

Örün, A. E., & Salamcı, E. (2023). Kompozit Plakalara Açılan Hafifletme Deliği Etrafındaki Güçlendirmenin Eğme Yüklemesi Altında İncelenmesi. *Avrupa Bilim ve Teknoloji Dergisi*, (51), 86-96.

Özdemirli, E. (2006). Anlık basınç yükü etkisindeki kompozit sandviç plağın dinamik davranışının deneysel ve sayısal incelenmesi.

Sayer, Ö., Öztürk, H., Yeni, E. Ç., Baltacı, A., & Ümütlü, R. C. (2022). Dynamic stability of cracked composite plates. *Bilecik Şeyh Edebali Üniversitesi Fen Bilimleri Dergisi*, *9*(1), 208-224.

Üstün, H. S. (2020). *Enhancement of ballistic properties by hybridization method of multi-layered composite panels* (Master's thesis, Izmir Institute of Technology (Turkey)).

Zengin, B., Kaymaz, K., Aşkın, M., & Taşkaya, S. (2018). Sandviç kompozit tabakalarında mekanik gerilmelerin basınca bağlı olarak ansys yazılımı ile incelenmesi. *Gümüşhane Üniversitesi Fen Bilimleri Dergisi*, 79-93.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE INTERPLAY BETWEEN INDOOR CLIMATE PARAMETERS AND STRUCTURAL DETERIORATION IN HISTORIC MASONRY BUILDINGS: A REVIEW OF CONTEMPORARY MEASUREMENT TECHNIQUES

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ABSTRACT

Historic masonry buildings possess a delicate equilibrium regarding environmental factors, dictated by the specific material properties and construction techniques of their era. Indoor climate parameters, namely temperature, relative humidity, air velocity, and CO_2 concentration, act as primary triggers for common structural pathologies such as salt crystallization, freeze-thaw cycles, biological degradation, and progressive material loss. This study aims to examine the correlation between these microclimatic variables and the resulting structural damages in masonry fabrics, while evaluating the efficacy of contemporary measurement techniques through a comprehensive literature review. Unlike traditional instantaneous sampling methods, modern approaches involving Internet of Things (IoT)-based wireless sensor networks, high-precision data loggers, infrared thermography, and non-destructive hygrothermal analysis play a pivotal role in monitoring structural health. This paper discusses the non-destructive data collection capabilities of these technologies, their advantages in long-term monitoring (longitudinal studies), and the seamless integration of high-resolution data into structural and hygrothermal simulation software. Ultimately, the study emphasizes the strategic importance of real-time monitoring and digital twin applications for the sustainable conservation of cultural heritage and the optimization of restoration decision-making processes.

Keywords: Historic Buildings, Masonry Structures, Indoor Climate, Structural Damage, Sensor Technologies.

GİRİŞ

İç mekân iklimi, bir mekân içerisindeki havanın özelliklerini tanımlayan fiziksel değişkenlerin bütünü olup; enerji ve kütle alışverişi yoluyla dış çevre ile etkileşim halinde bulunan ve mimari kabuk

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

aracılığıyla dış mekanla bağlantı kuran açık bir sistem olarak tanımlanmaktadır (Pretelli ve Fabbri, 2018).

İç mekân iklimi, yalnızca insanların konforu açısından değil, aynı zamanda somut değerlerin ve kültürel mirasın korunması açısından da büyük önem taşımaktadır. Günümüzde, modern binalarda iç mekân iklimi, ısıtma, havalandırma ve klima (HVAC) sistemleri yardımıyla kolayca düzenlenebilirken, tarihi binalarda bu mümkün değildir (Sahin vd., 2017).

Tarihi kagir yapılar sahip oldukları kalın duvar kesitleri, higroskopik malzeme yapısı ve sınırlı iklimlendirme olanakları nedeniyle modern yapılardan farklı bir mikro iklim davranışı sergilemektedir.

Tarihi kagir yapıların kabukları, iç mekân mikro iklim koşullarındaki değişimlerden oldukça fazla etkilenmekte (Camuffo, 1998); özellikle sıcaklık ve bağıl nem dalgalanmalarına bağlı olarak ortaya çıkan yoğuşma, tuz kristalleşmesi, biyolojik oluşumlar ve malzeme gerilmeleri gibi süreçler, yapı elemanlarında ve bezemelerde çeşitli hasar mekanizmalarını tetikleyebilmektedir (Şekil 1-2).



Şekil 1. Fetih Cami iç mekânında gözlemlenen bozulmalar, Erzurum (Yazar arşivi)

Tarihi kagir yapılarda iç iklime bağlı oluşan hasarlar çok boyutlu bir süreç olup; sıcaklık, bağıl nem ve hava hareketleri gibi iç mekân iklim parametrelerinin birlikte değerlendirilmesini gerektirmektedir. Bu nedenle, koruma çalışmalarında iç mekân ikliminin kontrolü ve uzun süreli izlenmesi, yapıların fiziksel bütünlüğünün korunması açısından temel bir gereklilik olarak karşımıza çıkmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 2. Muhara Kilisesi iç mekânında gözlemlenen bozulmalar, Gümüşhane (Yazar arşivi)

Yapılan çalışmanın amacı, tarihi kagir yapılarda iç mekân iklimi parametreleri ile yapı dokusunda gelişen bozulma ve hasar mekanizmaları arasındaki ilişkiyi, literatür verileri doğrultusunda ortaya koymaktır.

Çalışma kapsamında, söz konusu parametrelerin izlenmesinde kullanılan geleneksel ve çağdaş ölçüm teknikleri karşılaştırmalı olarak değerlendirilmiştir.

Çalışma; hangi iç mekân iklimi parametrelerinin hangi ölçüm cihazları ve/veya simülasyon araçları ile izlenmesinin uygun olduğunu belirleyerek, parametre/hasar/ölçüm yöntemi ilişkisini temel alan, veriye dayalı izleme yaklaşımının bakım ve hasar onarım süreçlerine sağlayabileceği katkıyı kavramsal bir çerçevede açıklamayı hedeflemektedir.

MATERYAL VE YÖNTEM

Çalışmanın kapsamı, tarihi kagir yapılar ile sınırlandırılmış olup, literatür incelemesi bibliyometrik analiz yöntemi kullanılarak gerçekleştirilmiştir. Bu çerçevede tarihi kagir yapılarda iç mekân iklimine bağlı bozulmaları ele alan araştırmalar (makale) değerlendirilerek konuya ilişkin veriler ortaya konulmuştur.

Tablo 1. Araştırmada izlenen adımlar

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Araştırma Konusunun Belirlenmesi	Veri Tabanı Seçimi	Veri Aktarımı	Bibliyometrik Analiz
Tarihi kagir yapılarda iç mekân iklimine bağlı bozulmalar	Web of Science (WoS)	Kayıtların *.txt* ve *.bib* formatlarında dışa aktarılması	Bibliometrix ve VOSviewer ile ağ analizi ve görselleştirme

Araştırma konusu kapsamında Web of Science (WoS) veri tabanından Tablo 2 araması yapılmış; 2000-2026 yılları arasında inşaat mühendisliği, yapı/inşaat teknolojisi, malzeme bilimi ve mimarlık alanlarında yapılan çalışmalar .txt ve .bib formatlarında dışa aktarılarak analiz edilmiştir.

Tablo 2. Web of Science arama sorgusu

TS= ("historic masonry" OR "historic building*" OR "heritage building*" OR "masonry building*" OR "cultural heritage")
AND
TS= ("indoor climate" OR microclimate OR "indoor environment*" OR hygrothermal OR "relative humidity" OR temperature OR moisture)
AND
TS= (damage OR deterioration OR decay OR degradation OR biodeterioration OR "salt crystallization")

BULGULAR VE TARTIŞMA

Bibliyometrik analiz sonucunda 86 farklı kaynaktan 226 çalışma elde edilmiştir (Şekil 3).



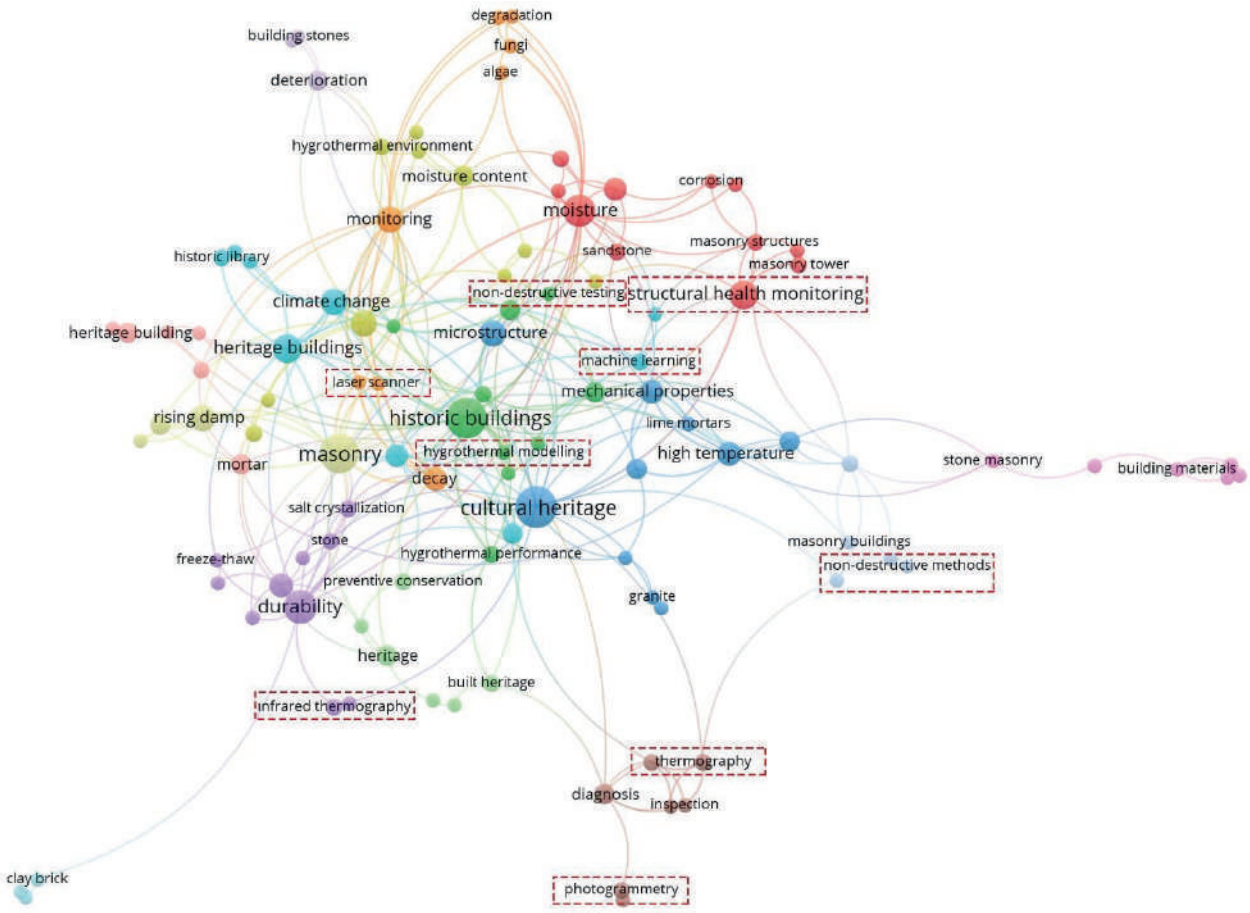
Şekil 3. Yayınlara İlişkin Ana Bilgiler

Elde edilen çalışmalarda hangi ölçüm aletlerinin ön plana çıktığını görmek amacıyla veriler VOSviewer yazılımına aktarılarak anahtar kelime eş oluşum ağ haritası oluşturulmuştur (Şekil 4).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Anahtar kelime ağı haritası, tarihi kagir yapılarda bozulma süreçlerinin belirlenmesinde tahribatsız ölçüm ve izleme tekniklerinin öne çıktığını göstermektedir. Yapı sağlığı izleme kavramının konumu, sıcaklık ve nem gibi parametrelerin sensörler aracılığıyla sürekli izlendiğini göstermektedir.

Ölçüm araçları arasında kızılötesi termografi, fotogrametri ve lazer tarama dikkat çekmektedir. Bu tekniklerin kullanılması tarihi yapılarda koruma ilkeleriyle uyumlu tanı ve izleme süreçlerinin yaygınlaştığını göstermektedir. Ayrıca makine öğrenmesi kavramı, ölçüm verilerinin analizinde yapay destekli çalışmaların da arttığını göstermektedir.



Şekil 4. Anahtar Kelime Eş Oluşum Ağı Haritası,Vosviewer

Analiz sonucunda elde edilen 20 kaynak daha detaylı bir analiz yapılarak çalışmalarda ölçülen parametreler, ölçüm cihazları ve kullanılan simülasyon araçları tespit edilmiştir (Tablo 3).

Tablo 3. Kaynakları Analiz Etme Biçimi

Makale	Süre	Bulunan Parametreler	Kullanılan Cihazlar	Program/Yazılım
Krüger vd., 2011	1 ay boyunca	Sıcaklık, bağıl nem	Sıcaklık ve nem sensörü	WUFI
Karoglou vd.,	Uzun dönem	Duvar sıcaklığı, bağıl	Nem-sıcaklık sensörleri	YOK

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2025		nem	Gömülü kapasitans sensörleri	
Lesinskis vd., 2024	12 ay boyunca (2022-2023)	Sıcaklık, bağıl nem	Sıcaklık ve bağıl nem ölçüm cihazları: HOBO MX Temp/RH/Light/Ext-Temp kit	YOK
De Vita vd., 2023	Kısa dönem	Sıcaklık, bağıl nem, U-değeri	Isı akışı ölçüm kiti Termografik kamera İç konfor ölçüm kiti	Design Builder-EnergyPlus
Alkadri vd., 2024	Kısa dönem	Sıcaklık, bağıl nem, yüzey sıcaklığı	3D Lazer Tarayıcı Termal Kamera SLR Kamera Veri Kaydedici	Rhino-Grasshopper
Aste vd., 2019	12 ay boyunca (2016-2017)	Sıcaklık, yüzey sıcaklığı, bağıl nem, hava hızı	Termo-higrometre Anemometre Termokupl	Hesaplamalı akışkanlar dinamiği (CFD)
Lerma vd., 2021	13 ay boyunca	Sıcaklık, yüzey sıcaklığı, nem	Termal kamera Veri kaydedici	ANYSS Fluent 2020
Varas-Muriel vd., 2012	13 ay boyunca	Sıcaklık, bağıl nem, çiğ noktası, mutlak nem	Veri kaydedici HOBO sensörü	SURFER 8

Tarihi kagir yapılarda iç mekân ikliminin doğru bir şekilde değerlendirilmesi bu yapıların maruz kaldığı hasar risklerinin belirlenmesi açısından büyük önem taşımaktadır. İç mekân iklimini etkileyen başlıca parametreler literatür doğrultusunda belirlenerek Tablo 4 oluşturulmuştur.

Tablo 4. İç Mekân İklimi Parametreleri

Değişken	**Parametre**	**Birim**	**Açıklama**
Fiziksel Değişkenler	Hava sıcaklığı	°C veya °F	Konfor ve malzeme davranışını etkiler.
	Ortalama radyant sıcaklık	°C veya °F	Çevre yüzeylerden yayılan ısının ortalamasını ifade eder; operatif sıcaklığın belirler.
	Mutlak nem	g_v/m^3	Yoğuşma riskinin değerlendirilmesinde kullanılır.
	Özgül nem	g_v/kg_a	Higrotermal analizlerde kullanılır.
	Bağıl nem	%	Biyolojik bozulma ve tuz hareketlerini etkiler.

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	Hava hızı (v)	m/s	Buharlaşma, ısı transferi ve konfor üzerinde etkilidir.
Kirletici Değişkenleri	Karbondioksit (CO_2)	ppm	Kullanıcı varlığından kaynaklanır.
	Karbon monoksit (CO)	ppm	Eksik yanma sonucu oluşur; ısıtma sistemlerinin varlığıyla ilişkilidir.
	Partikül madde ve toz	ppm, µg veya mg	Havada asılı katı parçacıkları ifade eder; Yüzey kirlenmesi oluşturabilir.
	Uçucu organik bileşikler (VOC)	ppm, ppb, mg/m^3	Temizlik maddeleri, yazıcılar vb. kaynaklıdır.
Işıkla İlgili Değişkenler	Aydınlatma düzeyi	lux	Görsel konfor ve malzeme bozulmalarıyla ilişkilidir.
	Ultraviyole radyasyon	µW/lm	Renk solması ve fotokimyasal bozulmalara neden olabilir.

Tarihi kagir yapılarda, uygun olmayan iç ortam koşullarına bağlı olarak yapı malzemelerinde fiziksel, kimyasal ve biyolojik bozulmalar literatür doğrultusunda belirlenmiştir (Tablo 5).

Tablo 5. Tarihi Kagir Yapılarda İç İklime Bağlı Oluşan Hasarlar

Hasar Türü	Hasar Kaynağı	Açıklama	Gözlemlenen Bozulma
Fiziksel Hasarlar	Donma-çözülme döngüleri	Gözeneklerdeki su donarak genleşir; malzemeyi çatlatır.	Taş/tuğlada çatlak, yüzey kopması
	Sıcaklık dalgalanması /Termal stres	Isıl genleşme-büzülme malzeme içi gerilim yaratır.	Derz açılması, çatlak genişlemesi
	Nem dalgalanması	Gözenek içi genleşme ve büzülme döngüleri malzemeyi yorar.	Mikro çatlaklar, harç kırılması
Kimyasal Hasarlar	Tuz-Nem etkileşimi	Tuzlar çözünüp tekrar kristalleştiğinde iç basınç oluşturur.	Efloresans, yüzey dökülmesi, kabarma
	Yükselen nem	Zeminden gelen nem malzemeyi kimyasal olarak zayıflatır.	Duvar altlarında tuzlanma, sıva kaybı
	İç yüzey kondensasyonu	Sıcak-soğuk yüzey farkı kimyasal çözünmeyi artırır.	Sıva kabarması, boya dökülmesi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Biyolojik Hasarlar	Yüksek bağıl nem (%65+)	Mikroorganizmalar nemli yüzeylerde hızla çoğalır.	Küf, mantar, siyah lekelenme
	Yetersiz havalandırma	Karbondioksit & nem birikimi biyolojik gelişimi artırır.	Biyofilm tabakaları, yüzey kararması
	Sürekli nemli duvar yüzeyleri	Biyolojik organizmalar taş/tuğlada kimyasal çözünmeyi hızlandırır.	Yüzey erimesi, biyolojik kabuklaşma

İç mekân iklimi parametreleri ve iç mekân iklimine bağlı oluşan hasarlar arasında sıkı bir ilişki vardır (Tablo 6). Gelecek dönemde iç mekânda oluşacak hasarları anlamak için bu ilişkiyi doğru bir şekilde değerlendirmek önemlidir. Tablo 6'ya göre hasarları en çok tetikleyen parametreler hava sıcaklığı, ortalama radyan sıcaklık, mutlak nem, özgül nem ve bağıl nemdir.

Tablo 6. İç Mekân İklimi Değişkenleri ve Hasar Türleri Arasındaki İlişki

Etki Düzeyi: ●Düşük ●Orta ●Yüksek ●Çok yüksek		**Hasar Türleri**										
			Fiziksel Hasarlar			**Kimyasal Hasarlar**			**Biyolojik Hasarlar**			
		Hasar Kaynağı / **Parametreler**	Donma-çözülme	Sıcaklık dalgalanması	Nem dalgalanması	Tuz-Nem etkileşimi	Yükselen nem	İç yüzey yoğuşması	Yüksek bağıl nem	Yetersiz havalandırma	Sürekli nemli duvarlar
İç Mekân İklimine Bağlı Değişkenler	**Fiziksel Değişkenler**	Hava sıcaklığı	●	●	●	●	●	●	●	●	●
		Ortalama radyant sıcaklık	●	●	●	●	●	●	●	●	●
		Mutlak nem	●	●	●	●	●	●	●	●	●
		Özgül nem	●	●	●	●	●	●	●	●	●
		Bağıl nem	●	●	●	●	●	●	●	●	●
		Hava hızı	●	●	●	●	●	●	●	●	●
	Kirletici Değişkenleri	Karbondioksit	●	●	●	●	●	●	●	●	●
		Karbon monoksit	●	●	●	●	●	●	●	●	●
		Partikül madde ve toz	●	●	●	●	●	●	●	●	●
		Uçucu organik bileşikler	●	●	●	●	●	●	●	●	●
	Işıkla İlgili	Aydınlatma düzeyi	●	●	●	●	●	●	●	●	●

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Değişkenler	Ultraviyole radyasyon	•	•	•	•	•	•	•	•	•	

Tablo 6'da en çok etkiye sahip olan sıcaklık ve nem değerleri seçilerek daha detaylı bir analizle Tablo 7 ve Tablo 8 oluşturulmuştur. Tarihi yapıya uygun ölçüm yöntemini belirlemek açısından bu tablolarda kullanılan geleneksel ve modern ölçüm yöntemleri bir arada verilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 7. Nem Değerini Ölçmek İçin Kullanılan Yöntemler

Yöntem / Araç	Türü	Avantajları	Dezavantajları	Uygunluk
Psikrometre	Geleneksel	Kullanımı kolay, düşük maliyetlidir.	Manuel kullanım, sürekli izleme yoktur.	Sınırlı
Analog higrometre	Geleneksel	Kullanımı kolaydır.	Düşük doğruluk verir.	Düşük
Çiğ noktası higrometresi	Geleneksel	Çok yüksek doğruluk sağlar.	Pahalı ve saha kullanımı zordur.	Sınırlı
Direnç tipi RH sensörü	Sensör	Düşük maliyetlidir.	Tuzlu ortamlarda hata verebilir.	Orta
Kapasitif RH sensörü	Sensör	Yüksek doğruluk sağlar.	Kalibrasyon ihtiyacı vardır.	Yüksek
Veri kaydedici	İzleme sistemi	Uzun süreli veri sağlar.	Veri yönetimi gerektirir.	Çok yüksek
Kablosuz IoT sensörü	Akıllı izleme	Gerçek zamanlı izleme, uzaktan erişim sağlar.	Maliyeti fazladır.	Yüksek
Gömülü RH sensörü	Sensör	Duvar içi nem davranışını doğrudan izler.	Yerleştirme müdahalesi gerekir.	Sınırlı
Yüzey RH sensörü	Sensör	Yoğuşma riskini gösterir.	Lokal ölçüm yapar.	Orta
Termo-higrometre	Noktasal	Hızlı tarama, kullanımı kolay.	Sürekli izleme yoktur.	Orta
WUFI	Simülasyon	Yoğuşma ve tuz riski analizi	Doğru malzeme verisi gerektirir.	Çok yüksek
Delphin	Simülasyon	Kapiler nem ve tuz taşınımı analizleri	Karmaşık ara yüze sahiptir.	Yüksek
EnergyPlus	Simülasyon	Nem ve havalandırmayı verir.	Malzeme içi nem sınırlıdır.	Orta
Dijital ikiz yaklaşımı	Hibrit	Gerçek zamanlı risk tahmini verir.	Uzmanlık ihtiyacı gerektirir.	Çok yüksek

Veri kaydediciler ve IoT tabanlı kablosuz sensörler, uzun süreli ve gerçek zamanlı veri üretmeleri sayesinde iç mekân nem değişimlerinin izlenmesinde yüksek uygunluk göstermektedir. Simülasyon araçları ölçüm verileri ile birlikte kullanıldığında tarihi kagir yapılarda malzeme içi nem hareketi, tuz taşınımı ve yoğuşma riskinin öngörülmesinde önemli bir avantaj sağlamaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Geleneksel ölçüm araçları, veri kaydediciler, termal kameralar ve IoT tabanlı sistemler iç mekân ikliminin izlenmesinde farklı ölçek ve veri üretim kapasitesine sahip yöntemlerdir. IoT tabanlı sistemler veri kaydedicilerin gelişmiş bir uzantısı olarak gerçek zamanlı, uzaktan erişilebilir ve ağ tabanlı izleme imkânı sağlayarak erken uyarı ve bütüncül performans değerlendirmesinde öne çıkmaktadır.

Tablo 8. Sıcaklık Değerini Ölçmek İçin Kullanılan Yöntemler

Yöntem / Araç	Türü	Avantajları	Dezavantajları	Uygunluk
Cam termometre	Geleneksel	Kullanımı kolaydır.	Sürekli izleme yok, kırılgandır.	Sınırlı
Bimetal termometre	Geleneksel	Elektrik gerektirmez, dayanıklıdır.	Düşük doğruluk sağlar.	Düşük
Termokupl	Sensör	Geniş ölçüm aralığı sağlar.	Kalibrasyon gerekir, hassasiyet sınırlıdır.	Orta
RTD sensör	Sensör	Yüksek doğruluk sağlar.	Maliyeti yüksektir.	Yüksek
Termistör	Sensör	Hassas ve düşük maliyetlidir.	Sıcaklık aralığı sınırlıdır.	Yüksek
Dijital sıcaklık sensörü	Sensör	Küçük boyut, veri kaydıyla uyumludur.	Kalibrasyon ihtiyacı vardır.	Yüksek
Veri kaydedici (datalogger)	İzleme sistemi	Uzun süreli veri sağlar.	Batarya ve veri yönetimi gerektirir.	Çok yüksek
Kablosuz IoT sensörü	Akıllı izleme	Gerçek zamanlı ve uzaktan izleme sağlar.	Maliyeti fazladır.	Yüksek
Gömülü sıcaklık sensörü	Sensör	Duvarın termal davranışını gösterir.	Yerleştirme müdahalesi gerekir.	Sınırlı
Yüzey sıcaklık sensörü	Noktasal ölçüm	Yoğuşma ve termal köprü tespiti yapar.	Lokal ölçüm yapar.	Orta
Kızılötesi termometre	Temassız ölçüm	Müdahalesiz hızlı tarama sağlar.	Emissivite hatası verir.	Yüksek
Termal kamera	Gelişmiş ölçüm	Isı kaybı, nem ve bozulma izlerini verir.	Maliyeti fazladır, uzmanlık gerektirir.	Çok yüksek

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

WUFI	Simülasyon	Duvar içi sıcaklık profili, donma-çözülme analizi	Malzeme verisi gerekir.	Çok yüksek
EnergyPlus	Simülasyon	İç mekân sıcaklık tahmini, HVAC etkisini verir.	Malzeme içi sıcaklık sınırlıdır.	Orta
Delphin	Simülasyon	Isı ve nem taşınımının birlikte analizini verir.	Karmaşık modelleme ara yüzüne sahiptir.	Yüksek
Dijital ikiz yaklaşımı	Hibrit	Gerçek zamanlı performans ve risk tahmini yapar.	Veri ve uzmanlık ihtiyacı gerektirir.	Çok yüksek

SONUÇLAR

- Tarihi kagir yapılarda iç mekân iklimini etkileyen parametrelerinin fiziksel, kimyasal ve biyolojik bozulmalarla doğrudan ilişkili olduğu literatür verileriyle ortaya konmuştur.
- İç mekân iklimi parametrelerinden bağıl nem ve sıcaklık yapısal bozulmalardaki temel risk faktörleridir.
- Geleneksel ölçüm cihazlarının anlık veri sağlama açısından yeterli olduğu; ancak uzun dönemli izleme ve iç mekân iklim değişkenliğini belirleme konusunda veri kaydedici ve IoT tabanlı sistemlerin daha yüksek performans sunduğu görülmüştür.
- Termal kamera vb. yüzey sıcaklık ölçümlerinin, gizli nem ve ısı köprülerini tespit etmede önemli araçlar olduğu belirlenmiştir.
- WUFI, Delphin ve EnergyPLus gibi simülasyon yazılımlarının kullanılması, olası hasar senaryolarının önceden belirlenmesinde yaygın kullanılan etkili yöntemlerdir.
- Hasar analizlerinde uygun ölçüm cihazlarının seçilmesi koruma projelerinde veriye dayalı erken müdahaleyi mümkün kılar.

KAYNAKLAR

Alkadri MF, Yuliana Y, Agung MRC, Rahman MA, Hein C 2024. Enhancing preservation: Addressing humidity challenges in Indonesian heritage buildings through advanced detection methods point cloud data. Results in Engineering, 24: 103292.

Aste N, Adhikari RS, Buzzetti M, Della Torre S, Del Pero C, Leonforte F 2019. Microclimatic monitoring of the Duomo (Milan Cathedral): Risks-based analysis for the conservation of its cultural heritage. Building and Environment, 148: 240-257.

Camuffo D 1998. Microclimate for cultural heritage. Elsevier.

De Vita M, Rotilio M, Marchionni C, De Berardinis P 2023. Architectural Heritage Indoor comfort after retrofit works: the case study of S. Vito Church in L'Aquila, Italy. Sustainability, 15(10): 8239.

Karoglou, M, Moropoulou A, Mouzakis C, Asimakopoulos S 2025. Monitoring of a historic building's masonry moisture content. Journal of Building Engineering, 104: 112313.

Krüger M, Samuels JM, Bachmaier SA, Lehmann F, Willeke J 2011. Condensation risk analysis and indoor climate manipulation assisted by continuous monitoring at Johanniskirche in Schwäbisch Gmünd. na.

Lerma C, Borràs JG, Mas Á, Torner ME, Vercher J, Gil E 2021. Evaluation of hygrothermal behaviour in heritage buildings through sensors, CFD modelling and IRT. Sensors, 21(2): 566.

Lesinskis A, Borodinecs A, Turauskis K 2024. Study on indoor air temperature and moisture behaviour in historical churches. Energy and Buildings, 310: 114083.

Pretelli M, Fabbri K 2018. Historic Indoor Microclimate of the Heritage Buildings. Springer: Berlin/Heidelberg, Germany.

Sahin CD, Coşkun T, Arsan ZD, Akkurt GG 2017. Investigation of indoor microclimate of historic libraries for preventive conservation of manuscripts. Case Study: Tire Necip Paşa Library, İzmir-Turkey. Sustainable Cities and Society, 30:66-78.

Varas-Muriel MJ, Fort R, Martínez-Garrido MI, Zornoza-Indart A, López-Arce P 2014. Fluctuations in the indoor environment in Spanish rural churches and their effects on heritage conservation: Hygro-thermal and CO2 conditions monitoring. Building and Environment, 82: 97-109.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

RELATIONSHIP BETWEEN ARTIFICIAL INTELLIGENCE AND MATHEMATICS

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Abstract

This chapter examines the reciprocal and transformative relationship between artificial intelligence and mathematics within the framework of theoretical foundations, application areas, and future perspectives. While mathematical disciplines provide the fundamental theoretical infrastructure for the development of artificial intelligence algorithms, artificial intelligence technologies accelerate, automate, and enhance mathematical research processes, enabling new discoveries. The study explores the relationship between artificial intelligence and mathematical fields such as linear algebra, probability theory, statistics, and optimization. Additionally, application areas including automated theorem proving, mathematical modeling, and data analysis are discussed. Finally, the potential impact of the interaction between artificial intelligence and mathematics on scientific research and interdisciplinary innovation is evaluated.

Keywords: Artificial intelligence, mathematical modeling, algorithms, scientific research, machine learning

1. Introduction

The rapid development of artificial intelligence technologies has led to significant transformations in both theoretical and applied areas of mathematical sciences. Mathematics plays a fundamental role in the design and development of artificial intelligence algorithms. In particular, machine learning and deep learning methods rely heavily on linear algebra, probability theory, and optimization techniques. At the same time, artificial intelligence systems are increasingly used in mathematical research for data processing, hypothesis generation, and automated proof mechanisms.

2. Theoretical Framework

The mathematical foundations of artificial intelligence systems are primarily shaped by the following disciplines: linear algebra, probability theory, statistics, optimization, and graph theory.

3. Contributions of Artificial Intelligence to Mathematical Research

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Artificial intelligence contributes through automated theorem proving, large dataset analysis, discovery of mathematical patterns, optimization of numerical methods, and automation of modeling processes.

4. Interdisciplinary Applications

AI-supported mathematical models are used in physics, biology, economics, medicine, and engineering.

5. Discussion

Artificial intelligence increases research speed and interdisciplinary collaboration, yet challenges such as bias and interpretability remain.

6. Conclusion and Future Perspectives

Future developments include autonomous mathematical discovery, explainable AI, hybrid symbolic-statistical models, and AI-supported mathematics education.

References

Goodfellow et al. (2016). Deep learning. MIT Press.
Russell & Norvig (2021). Artificial intelligence: A modern approach.
Turing (1936). On computable numbers.
Bishop (2006). Pattern recognition and machine learning.
Silver et al. (2016). Mastering the game of Go.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ÜNİVERSİTE DERSLİĞİ İÇİN MİKRO ÖLÇEKLİ KARBON AYAK İZİ DEĞERLENDİRMESİ VE KARBON NÖTR GEÇİŞ SENARYOSU

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ÖZET

Bu çalışma, bir üniversitedeki tek bir sınıfın karbon ayak izini değerlendirmeyi ve gönüllü karbon kredileri aracılığıyla karbon nötrlüğüne ulaşmak için gerekli dengeleme miktarını tahmin etmeyi amaçlamaktadır. Bu doğrultuda, sınıf düzeyindeki enerji tüketimine bağlı doğrudan ve dolaylı emisyon kaynakları sistematik biçimde belirlenmiş; elektrik kullanımı, aydınlatma sistemleri, elektronik ekipmanlar ile ısıtma ve soğutma sistemlerine ilişkin veriler ayrıntılı olarak analiz edilmiştir. Enerji tüketimi, 30 öğrenci ve bir öğretim görevlisinin katıldığı iki saatlik bir ders oturumu temel alınarak hesaplanmıştır. Uluslararası kabul görmüş emisyon faktörleri kullanılmış ve değerlendirme ISO 14064-1 standardına uygun şekilde gerçekleştirilmiştir. Toplam emisyonlar karbondioksit eşdeğeri (CO_2e) cinsinden ifade edilmiş; karbon nötrlüğüne ulaşmak amacıyla oluşturulan bir dengeleme senaryosu kapsamında gerekli gönüllü karbon kredisi miktarı belirlenmiştir. Hesaplamalar, tek bir ders oturumunun toplam karbon ayak izinin yaklaşık 10,5 kg CO_2e olduğunu göstermektedir. Bulgular, yalnızca tek bir sınıf oturumunun dahi ölçülebilir bir emisyon profili oluşturduğunu ortaya koymakta ve mikro ölçekteki enerji kullanımının çevresel etkisini vurgulamaktadır. Sonuç olarak çalışma, sürdürülebilirlik uygulamalarının üniversite kampüslerinde yalnızca kurumsal düzeyde değil, sınıflar gibi operasyonel birimler düzeyinde de bütüncül biçimde ele alınmasının önemine dikkat çekmektedir.

Anahtar Kelimeler: Kampüs sürdürülebilirliği, Net sıfır stratejisi, Karbon kredisi sertifikasyonu, Enerjiye dayalı emisyonlar

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MICRO-SCALE CARBON FOOTPRINT ASSESSMENT AND CARBON NEUTRAL TRANSITION SCENARIO FOR A UNIVERSITY CLASSROOM

ABSTRACT

This study aims to assess the carbon footprint of a classroom in a university and to estimate the number of offsets required to achieve carbon neutrality through voluntary carbon credits. For this purpose, direct and indirect emission sources associated with classroom-level energy consumption were systematically identified, and data on electricity use, lighting systems, electronic equipment, and heating and cooling systems were analyzed. Energy consumption was evaluated for a two-hour lecture session attended by 30 students and one instructor. Internationally recognized emission factors were applied, and the assessment was conducted in accordance with the ISO 14064-1 standard. The total emissions were quantified in carbon dioxide equivalent (CO_2e), and the required number of voluntary carbon credits was determined under a developed carbon offsetting scenario to achieve carbon neutrality. Based on the calculations, the total carbon footprint of a single lecture session was estimated at approximately 10.5 kg CO_2e. The findings demonstrate that even a single classroom session generates a measurable emission profile, underscoring the environmental significance of energy use at the micro scale. The study highlights the importance of integrating sustainability practices into university campuses not only at the institutional level but also within individual operational units such as classrooms.

Keywords: Campus sustainability, Net-zero strategy, Carbon credit certification, Energy-based emissions

GİRİŞ

Küresel iklim değişikliği, sera gazı emisyonlarının azaltılmasını zorunlu kılmakta olup bu sorumluluk yalnızca sanayi ve enerji sektörleriyle sınırlı değildir (Filonchyk vd., 2024). Binalar ve hizmet sektörü faaliyetleri de önemli miktarda doğrudan ve dolaylı emisyon üretmektedir. Bu bağlamda eğitim kurumları; ısıtma, soğutma, aydınlatma, havalandırma sistemleri ve elektronik ekipman kullanımı yoluyla yüksek düzeyde enerji tüketmekte ve buna bağlı olarak karbon emisyonlarına kayda değer ölçüde katkı sağlamaktadır (Aghamolaei & Fallahpour, 2023). Literatürde, yükseköğretim kurumlarının karbon ayak izi performanslarının nesnel, şeffaf ve karşılaştırılabilir göstergeler aracılığıyla değerlendirilmesi gerektiği vurgulanmaktadır (Helmers & Weiss, 2021). Üniversitelerde karbon ayak izi hesaplamaları genellikle kurumsal sera gazı muhasebesi yaklaşımlarına dayanmaktadır. Bu çerçevede, emisyonların belirlenmesi ve raporlanmasına yönelik uluslararası standartlardan biri olan ISO 14064-1, organizasyon düzeyinde sera gazı emisyonlarının nicel olarak hesaplanması ve raporlanması için kapsamlı bir rehber sunmaktadır (ISO, 2018). Bunun yanı sıra,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

üniversitelere özgü geliştirilen uygulamalı envanter çerçeveleri kampüs ölçeğinde sistematik ve bütüncül bir sera gazı envanteri oluşturulmasına olanak sağlamaktadır (Misni, 2024).

Yükseköğretim kurumlarında karbon ayak izi çalışmalarına ilişkin literatür incelendiğinde, kampüs genelinde enerji tüketimi, ulaşım, atık ve tedarik zinciri gibi farklı emisyon kaynaklarının kapsamlı biçimde değerlendirildiği görülmektedir. Valls-Val ve Bovea (2021), üniversitelerde karbon ayak izi hesaplamalarına yönelik kapsamlı literatür incelemelerinde, çalışmaların büyük ölçüde makro ölçekte (kampüs) yoğunlaştığını, alt birim veya mekân ölçeğindeki (örneğin derslik veya bina bazlı) gerçekleştirilen analizlerin ise görece sınırlı kaldığını belirtmektedir (Yáñez vd., 2019). Helmers ve Weiss (2021) ise dünya genelindeki üniversitelerin karbon ayak izi performanslarını standartlaştırılmış metrikler üzerinden karşılaştırarak kurumsal düzeyde şeffaflık ve karşılaştırılabilirliğin sürdürülebilirlik politikaları açısından kritik önem taşıdığını ortaya koymuştur.

Bu çerçevede, karbon ayak izi çalışmalarının yalnızca emisyonların belirlenmesiyle sınırlı kalmayıp, aynı zamanda azaltım ve dengeleme stratejilerini de kapsayacak şekilde ele alınması gerekmektedir. Karbon ayak izi hesaplamalarının ardından emisyonların dengelenmesi amacıyla gönüllü karbon dengeleme (offset) mekanizmaları da sıklıkla kullanılmaktadır. Gönüllü karbon piyasaları; bireyler ve kurumların emisyonlarını dengelemek amacıyla karbon azaltım projelerine yatırım yapmalarına olanak tanımaktadır. Bu programların işleyişi, firma stratejileri ve politika etkileri üzerine yapılan çalışmalar, gönüllü karbon piyasalarının iklim politikalarındaki tamamlayıcı rolünü tartışmaktadır (Li vd., 2022). Ayrıca bireylerin gönüllü karbon dengeleme uygulamalarına yönelik algı ve tutumları da bu mekanizmaların etkinliği açısından önem taşımaktadır (Karhunmaa, 2023). Karbon dengeleme projeleri kapsamında en yaygın uygulamalardan biri ağaçlandırma ve kentsel yeşil alan projeleridir. Kentsel orman ekosistemlerinin karbon tutma kapasitesine ilişkin erken dönem çalışmalardan biri olan Escobedo (2010), şehir ağaçlarının karbon depolama ve iklim düzenleme işlevlerini nicel olarak ortaya koymuştur. Benzer araştırmalar, gönüllü karbon sertifikaları aracılığıyla emisyonların dengelenmesinde önemli bir araç olarak değerlendirilmektedir (Jo vd., 2023; Guo vd., 2024).

Bu çalışmanın amacı, İstanbul Üniversitesi-Cerrahpaşa Mühendislik Fakültesi Çevre Mühendisliği Bölümü'nde seçilen bir dersliğin karbon ayak izini hesaplamak ve oluşan emisyonları dengelemek için gerekli gönüllü karbon azaltım sertifikası miktarını belirlemektir. Değerlendirme sürecinde dersliğin kullanım profili, katılımcı sayısı ve enerji tüketimi dikkate alınmıştır. Çalışmanın, üniversite bünyesinde mikro ölçekli karbon muhasebesi uygulamalarına katkı sağlaması ve yükseköğretim kurumlarında sürdürülebilirlik stratejilerinin geliştirilmesine yönelik örnek bir metodolojik yaklaşım sunması hedeflenmektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MATERYAL VE METOT

Bu çalışma, yükseköğretim kurumlarında uygulanan kurumsal sera gazı muhasebesi yaklaşımlarına dayalı olarak mikro ölçekte bir karbon ayak izi analizi gerçekleştirmektedir. Metodolojik çerçeve, organizasyonel sera gazı envanteri prensiplerini temel alan ve kampüs ölçeğindeki karbon hesaplama çalışmalarında yaygın olarak kullanılan yaklaşımlara dayanmaktadır (Helmers & Weiss, 2021; Valls-Val & Bovea, 2021). Çalışma alanı olarak İstanbul Üniversitesi-Cerrahpaşa Mühendislik Fakültesi Çevre Mühendisliği Bölümü'nce kullanılan bir derslik seçilmiş ve bir akademik dönem boyunca dersliğin kullanımına ilişkin veriler gözlemsel ve hesaplamalı yöntemlerle toplanmıştır. Çalışmanın örnek alanı olan derslikte, 30 öğrenci ve 1 öğretim elemanının katıldığı iki saatlik bir ders oturumu için enerji tüketimi analiz edilmiştir. Analiz, mikro ölçekte mekânsal birim yaklaşımıyla yalnızca seçilen dersliğe odaklanmaktadır. Çalışmanın sistem sınırı, seçilen dersliğe ait enerji tüketimi ile sınırlandırılmıştır. Emisyon hesaplamaları, ISO 14064-1:2018 standardında tanımlanan organizasyonel sera gazı envanteri yaklaşımı doğrultusunda gerçekleştirilmiştir (ISO, 2018). Bu kapsamda yalnızca elektrik tüketimine bağlı dolaylı enerji kaynaklı emisyonlar değerlendirilmiştir. Bu nedenle çalışma, tam kapsamlı bir kurumsal karbon ayak izi envanteri değil, sınırlı sistem sınırına sahip kısmi bir karbon ayak izi değerlendirmesidir.

Bir akademik dönem boyunca esas alınan parametreler olarak; (*i*) dersliğin haftalık kullanım süresi (saat/hafta); (*ii*) akademik dönem süresi (hafta), (*iii*) ortalama kullanıcı sayısı (öğrenci + öğretim elemanı), (*iv*) a ydınlatma sisteminin toplam gücü (W), (*v*) elektronik cihazların (projeksiyon, bilgisayar vb.) nominal güç değerleri (W), (*vi*) ısıtma/soğutma sistemine bağlı elektrikli ekipmanların güç değerleri (W) belirlenmiştir.

Elektrik tüketimi, cihazların nominal güç değerleri ile kullanım sürelerinin çarpılması yoluyla hesaplanmıştır (Denklem 1):

$$\text{Enerji Tüketimi (kWh)} = [\text{Güç (W)} \times \text{Süre (saat)}] / 1000 \quad (1)$$

Toplam dönemsel elektrik tüketimi, tüm ekipmanlara ait tüketimlerin toplanmasıyla elde edilmiştir. Nominal güç değerlerinin kullanılması nedeniyle hesaplamalar teorik maksimum tüketime dayanmaktadır ve gerçek zamanlı ölçüm verisi bulunmamaktadır. Bu durum çalışmanın belirsizlik kaynaklarından biridir.

SONUÇLAR VE TARTIŞMA

Bu çalışmada tek bir ders oturumuna ait karbon ayak izinin 10,5 kg CO_2e olarak hesaplanması, kısa süreli ve rutin akademik faaliyetlerin dahi ölçülebilir düzeyde sera gazı emisyonu ürettiğini göstermektedir (Tablo 1). Mutlak değer düşük görünmekle birlikte, üniversite genelinde derslik sayısı, haftalık ders saati ve akademik dönem süresi dikkate alındığında kümülatif etkinin önemli boyutlara ulaşabileceği açıktır. Bu bulgu, karbon yönetiminin yalnızca kampüs veya bina ölçeğinde değil, operasyonel alt birimler düzeyinde de değerlendirilmesi gerektiğini ortaya koymaktadır. Mikro ölçekli

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

karbon muhasebesi, kurumsal toplam emisyonların hangi mekânsal ve işlevsel bileşenlerden kaynaklandığını ayrıştırarak hedefe yönelik azaltım stratejileri geliştirilmesine olanak sağlamaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Tablo 1. Elektrik Tüketimine Bağlı Tahmini CO_2e Emisyonları

Emisyon Kaynağı	**Tüketim (kWh)**	**CO_2e (kg)**
Aydınlatma ve elektronik cihazlar	1,0	0,42
Isıtma/soğutma sistemleri	24,0	10,08
Toplam	**25,0**	**10,50**

Tablo 1'de görüldüğü üzere toplam emisyonların büyük kısmı ısıtma/soğutma sistemlerinden kaynaklanmaktadır. Bu durum, üniversite kampüslerinde enerji temelli emisyonların baskın rolüne işaret eden literatürle uyumludur. Larsen ve ark. (2013) ve Ozawa-Meida ve ark. (2013), yükseköğretim kurumlarında elektrik ve ısıl enerji tüketiminin toplam emisyonların ana belirleyicisi olduğunu ortaya koymuştur. Helmers ve Weiss (2021) ise küresel ölçekte üniversiteleri karşılaştırdıkları çalışmada, kapsam 2 emisyonlarının birçok üniversitede toplam envanterin en büyük bileşeni olduğunu belirtmektedir. Benzer biçimde, Valls-Val ve Bovea (2021) tarafından yürütülen sistematik literatür incelemesi, satın alınan elektrik kaynaklı dolaylı emisyonların neredeyse tüm karbon ayak izi çalışmalarında temel kategori olarak ele alındığını göstermektedir. Bu çalışmada elde edilen bulgular da söz konusu eğilimle paralellik göstermektedir.

Enerji kaynaklı emisyonların büyüklüğü, yalnızca tüketim miktarına değil, elektrik üretim karmasına da bağlıdır. GHG Protocol Scope 2 Guidance (WRI & WBCSD, 2015), elektrik kaynaklı emisyonların hesaplanmasında konum bazlı (location-based) ve piyasa bazlı (market-based) yöntemlerin ayrıştırılmasını önermektedir. Bu çalışmada kullanılan yaklaşım konum bazlı hesaplamaya dayanmaktadır ve ulusal elektrik üretim karmasını yansıtmaktadır. Fosil yakıt ağırlıklı enerji sistemlerinde emisyon faktörlerinin görece yüksek olması kaçınılmazdır. Nitekim Yáñez ve ark. (2019), yenilenebilir enerjiye geçiş senaryosunun kampüs ölçeğinde toplam emisyonları önemli ölçüde azaltabileceğini göstermiştir. Bu durum, mikro ölçekte belirlenen emisyon yoğunluğunun yalnızca kurumsal enerji yönetimi stratejileriyle değil, aynı zamanda ulusal enerji politikalarıyla da doğrudan ilişkili olduğunu ortaya koymaktadır.

Isıtma ve soğutma sistemlerinin toplam emisyonlardaki baskın rolü, bina enerji literatürü ile de örtüşmektedir. Ürge-Vorsatz ve ark. (2015), küresel ölçekte binalarda enerji tüketiminin en büyük payının HVAC sistemlerinden kaynaklandığını belirtmektedir. IPCC (2022) raporuna göre bina sektöründe enerji verimliliği ve düşük karbonlu enerjiye geçiş, kısa ve orta vadede en yüksek azaltım potansiyeline sahip stratejiler arasında yer almaktadır. Bu bağlamda derslik ölçeğinde zaman kontrollü

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ISBN: 978-9952-610-30-7

HVAC kullanımı, otomasyon sistemleri ve yüksek verimli ekipmanlara geçiş gibi önlemler mikro ölçekte dahi anlamlı azaltım sağlayabilir.

Metodolojik olarak çalışmada organizasyonel ve operasyonel sınırların açık biçimde tanımlanması ISO 14064-1 (ISO, 2018) standardının şeffaflık ve tutarlılık ilkeleriyle uyumludur. Ancak Scope 3 emisyonlarının kapsam dışında bırakılması, toplam karbon ayak izinin olduğundan düşük tahmin edilmesine yol açabilir. Valls-Val ve Bovea (2021) bazı üniversitelerde Scope 3 emisyonlarının toplamın yarısından fazlasını oluşturduğunu belirtmektedir. Özellikle ulaşım, ekipman üretimi ve satın alınan hizmetlerin yaşam döngüsü etkileri üniversite karbon envanterlerinde önemli paya sahiptir (Robinson et al., 2018). Bununla birlikte mevcut çalışma, operasyonel enerji kullanımını izole ederek mikro düzeyde yönetilebilir emisyon kaynaklarının görünür kılınmasını amaçlamaktadır.

Çalışmada hesaplanan 10,5 kg CO_2e'lik emisyonun gönüllü karbon azaltım sertifikaları aracılığıyla dengelenebileceği belirlenmiştir. Gönüllü karbon piyasaları, kurumsal net-sıfır hedefleri doğrultusunda hızla büyüyen bir mekanizma olarak öne çıkmaktadır. Hamrick ve Gallant (2021), gönüllü karbon piyasasının son yıllarda ciddi bir genişleme gösterdiğini ve özellikle kurumsal sürdürülebilirlik stratejileriyle entegre biçimde kullanıldığını belirtmektedir. Bununla birlikte literatürde bu mekanizmaların çevresel bütünlüğüne ilişkin önemli tartışmalar bulunmaktadır.

Karbon dengeleme projelerinin güvenilirliği ek ilave katkı (additionality), kalıcılık (permanence), doğrulanabilirlik (verifiability) ve çifte sayımın önlenmesi (double counting) gibi kriterlere bağlıdır (Schneider et al., 2019). Özellikle arazi temelli projelerde karbonun uzun vadeli depolanması iklim koşulları, arazi kullanım değişiklikleri ve yangın riskleri nedeniyle belirsizlik içermektedir. Nowak ve Crane (2002) ile McPherson ve ark. (1994), kentsel ağaçlandırmanın karbon sekestrasyonu potansiyelini nicel olarak ortaya koymakla birlikte, IPCC (2019) biyolojik karbon yutaklarının kalıcılık risklerine dikkat çekmektedir. Ayrıca Calel vd. (2025), karbon piyasalarında yönlendirilmiş teknolojik değişimin önemini vurgulayarak offset mekanizmalarının yapısal dönüşümün yerini almaması gerektiğini belirtmektedir.

Bu bağlamda karbon yönetiminde "azaltım öncelikli hiyerarşi" yaklaşımı önem kazanmaktadır. GHG Protocol (WRI & WBCSD, 2015) ve çeşitli sürdürülebilirlik çerçeveleri, önceliğin doğrudan emisyon azaltımına verilmesi, ardından verimlilik iyileştirmeleri ve son aşamada dengeleme mekanizmalarının kullanılması gerektiğini vurgulamaktadır. Helmers ve Weiss (2021) bazı üniversitelerin karbon nötr beyanlarını büyük ölçüde offset uygulamalarına dayandırdığını; ancak uzun vadeli sürdürülebilirlik açısından yapısal enerji dönüşümünün esas olduğunu ifade etmektedir. Dolayısıyla gönüllü karbon dengeleme, ders gibi mikro ölçekli faaliyetler için uygulanabilir ve farkındalık artırıcı bir araç olarak değerlendirilebilir. Bununla birlikte, kalıcı ve güvenilir karbon yönetimi stratejileri; enerji verimliliği, yenilenebilir enerjiye geçiş ve sistematik izleme-raporlama mekanizmaları ile desteklenmelidir. Mikro

ölçekli karbon muhasebesi uygulamaları, kampüs genelinde kademeli azaltım stratejilerinin geliştirilmesine veri temelli katkı sunabilir.

DEĞERLENDİRME

Bu çalışma, üniversite yerleşkelerinde mikro ölçekte karbon muhasebesi yaklaşımının uygulanabilirliğini ortaya koymayı amaçlamıştır. Bu kapsamda, seçilen bir derslik için sınırlı sistem sınırları içerisinde elektrik tüketimine bağlı karbon emisyonları hesaplanmış ve ortaya çıkan emisyonların gönüllü karbon piyasası araçlarıyla nasıl dengelenebileceği nicel olarak değerlendirilmiştir. Çalışma neticesinde tek bir ders oturumuna ait karbon ayak izi 10,5 kg CO_2e olarak hesaplanmıştır. Elde edilen bulgular, tekil bir mekânsal birimde dahi ölçülebilir ve yönetilebilir düzeyde emisyon oluştuğunu göstermekte; dolayısıyla karbon yönetiminin yalnızca kurumsal toplam değerler üzerinden değil, alt birimler düzeyinde de ele alınabileceğine işaret etmektedir. Sonuçlar ayrıca, enerji kullanım biçiminin emisyon büyüklüğü üzerindeki belirleyici etkisini ortaya koyarak davranışsal ve operasyonel iyileştirmelerin azaltım stratejilerinde öncelikli bir alan olduğunu göstermektedir. Bununla birlikte çalışmanın yalnızca elektrik tüketimi ile sınırlandırılmış olması, kampüs ölçeğindeki toplam emisyon profilinin bütüncül olarak değerlendirilmesine imkân vermemektedir. Gelecek çalışmaların ısıtma-soğutma sistemleri, ulaşım, malzeme kullanımı gibi diğer emisyon kaynaklarını kapsayacak şekilde genişletilmesi; farklı mekânsal birimlerin karşılaştırmalı analizi ve azaltım senaryolarının modellenmesi, üniversitelerde düşük karbonlu dönüşüm sürecine daha stratejik bir çerçeve kazandıracaktır. Sonuç olarak bu çalışma, derslik ölçeğinde gerçekleştirilen karbon ayak izi analizlerinin üniversite sürdürülebilirlik politikalarına entegre edilebileceğini göstermektedir. Bulgular enerji tüketiminin emisyon profilindeki belirleyici rolünü doğrulamakta; gönüllü karbon dengelemenin ise ancak doğrudan azaltım önlemleriyle birlikte uygulandığında çevresel açıdan anlamlı bir araç olabileceğini ortaya koymaktadır. Bu durum, yükseköğretim kurumlarında karbon yönetiminin mikrodan makroya uzanan bütüncül bir yaklaşımla ele alınmasını gerekli kılmaktadır.

KAYNAKLAR

Aghamolaei, R., & Fallahpour, M. (2023). Strategies towards reducing carbon emission in university campuses: A comprehensive review of both global and local scales. *Journal of Building Engineering*, *76*, 107183.

Calel, R., Colmer, J., Dechezleprêtre, A., & Glachant, M. (2025). Do carbon offsets offset carbon?. *American Economic Journal: Applied Economics*, *17*(1), 1-40.

Escobedo, F., Varela, S., Zhao, M., Wagner, J. E., & Zipperer, W. (2010). Analyzing the efficacy of subtropical urban forests in offsetting carbon emissions from cities. *Environmental Science & Policy*, *13*(5), 362-372.

Filonchyk, M., Peterson, M. P., Zhang, L., Hurynovich, V., & He, Y. (2024). Greenhouse gases emissions and global climate change: Examining the influence of CO2, CH4, and N2O. *Science of The Total Environment*, *935*, 173359.

Guo, Y., Ren, Z., Wang, C., Zhang, P., Ma, Z., Hong, S., ... & He, X. (2024). Spatiotemporal patterns of urban forest carbon sequestration capacity: Implications for urban CO2 emission mitigation during China's rapid urbanization. *Science of the Total Environment*, *912*, 168781.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Hamrick, K., & Gallant, M. (2021). *State of the voluntary carbon markets 2021*. Ecosystem Marketplace.

Helmers, E., & Weiss, M. (2021). Carbon footprinting of universities worldwide: Part I—Objective comparison by standardized metrics. *Environmental Sciences Europe, 33*(1), 81. https://doi.org/10.1186/s12302-021-00525-4

IPCC, Intergovernmental Panel on Climate Change. (2019). *Climate change and land: An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*.

IPCC, Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. https://doi.org/10.1017/9781009157926

ISO, International Organization for Standardization. (2018). *ISO 14064-1:2018: Greenhouse gases—Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*.

Jo, H. K., Park, H. M., & Kim, J. Y. (2023). Carbon offset service of urban park trees and desirable planting strategies for several metropolitan cities in South Korea. *Forests*, *14*(2), 278.

Karhunmaa, K., Salmivaara, S., Varho, V., Virtanen, M. J., Eerikäinen, T., & Vainio, A. (2023). Settling an unsettled phenomenon: citizens' views and understandings of voluntary carbon offsetting in Finland. *Journal of Environmental Policy & Planning*, *25*(5), 524-538.

Larsen, H. N., Pettersen, J., Solli, C., & Hertwich, E. G. (2013). The carbon footprint of higher educational institutions. *Journal of Cleaner Production, 48*, 39–47. https://doi.org/10.1016/j.jclepro.2011.10.007

Li, X., Ning, Z., & Yang, H. (2022). A review of the relationship between China's key forestry ecology projects and carbon market under carbon neutrality. *Trees, Forests and People*, *9*, 100311.

McPherson, E. G., Nowak, D. J., & Rowntree, R. A. (1994). *Chicago's urban forest ecosystem: Results of the Chicago Urban Forest Climate Project* (USDA Forest Service General Technical Report NE-186). USDA Forest Service.

Misni, A., Buyadi, S. N. A., & Brahimi, M. (2024). Carbon Footprint Review in Higher Learning Environment towards Campus Sustainability. *Asian Journal of Environment-Behaviour Studies*, *9*(29), 41-54.

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution, 116*(3), 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Ozawa-Meida, L., Brockway, P., Letten, K., Davies, J., & Fleming, P. (2013). Measuring carbon performance in a UK university through a consumption-based carbon footprint: De Montfort University case study. *Journal of Cleaner Production, 60*, 162–173. https://doi.org/10.1016/j.jclepro.2011.09.028

Robinson, O. J., Tewkesbury, A., Kemp, S., & Williams, I. D. (2018). Towards a universal carbon footprint standard: A case study of carbon management at a UK university. *Journal of Cleaner Production, 172*, 4436–4451. https://doi.org/10.1016/j.jclepro.2017.02.147

Schneider, L., La Hoz Theuer, S., Broekhoff, D., Füssler, J., & Kohli, A. (2019). Environmental integrity of international carbon market mechanisms under the Paris Agreement. *Climate Policy, 19*(3), 386–400. https://doi.org/10.1080/14693062.2018.1521332

Ürge-Vorsatz, D., Cabeza, L. F., Serrano, S., Barreneche, C., & Petrichenko, K. (2015). Heating and cooling energy trends and drivers in buildings. *Renewable and Sustainable Energy Reviews, 41*, 85–98. https://doi.org/10.1016/j.rser.2014.08.039

Valls-Val, K., & Bovea, M. D. (2021). Carbon footprint in higher education institutions: A literature review and prospects for future research. *Sustainability, 13*(1), 181. https://doi.org/10.3390/su13010181

World Resources Institute (WRI) & World Business Council for Sustainable Development (WBCSD). (2015). *GHG protocol scope 2 guidance: An amendment to the GHG protocol corporate standard*.

Yáñez, P., Gamboa, G., & Valderrama, C. (2019). Carbon footprint estimation in a university campus: Evaluation and insights. *Sustainability, 11*(9), 2512. https://doi.org/10.3390/su11092512

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İÇME SUYU ARITIMINDA KARBON AYAK İZİNİN DEĞERLENDİRİLMESİ: ARSENİK VE MANGANEZ GİDERİM TESİSLERİNİN KARŞILAŞTIRMALI ANALİZİ

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ÖZET

Sera gazı emisyonlarının giderek artması, enerji yoğun altyapıların çevresel performansının kapsamlı biçimde değerlendirilmesi gerekliliğini ortaya koymaktadır. Su ve atık su arıtma tesisleri, yalnızca güvenli su temin etme kapasiteleri açısından değil, aynı zamanda karbon ayak izleri bakımından da ele alınmalıdır. Bu tesislerde oluşan emisyonların büyük bölümü; elektrik tüketimi, kimyasal kullanımı ve atık yönetiminden kaynaklanan dolaylı emisyonlardan oluşmaktadır. Bu nedenle, sürdürülebilir su yönetimini desteklemek ve düşük karbonlu işletme stratejilerini hayata geçirmek için arıtma süreçlerinin karşılaştırmalı olarak değerlendirilmesi büyük önem taşımaktadır. Bu çalışma kapsamında, demir, arsenik ve manganez giderimine odaklanan iki içme suyu arıtma tesisi incelenmiştir. Her iki tesisin kapasitesi, arıtma ünitelerinin konfigürasyonu ve işletme koşulları ayrıntılı biçimde analiz edilmiştir. Birinci tesiste enerji kullanımından kaynaklanan dolaylı emisyonlar günlük 121,8 kg CO_2 olarak hesaplanmış, kimyasal kullanımının ise toplam emisyonların %20,1'ini oluşturduğu belirlenmiştir. İkinci tesiste ise enerji kaynaklı emisyonların günlük 209,5 kg CO_2 ile daha yüksek olduğu, kimyasal kullanımının toplam emisyonlar içindeki payının %33,3'e ulaştığı tespit edilmiştir. Elde edilen bulgular, arıtma teknolojisi seçiminin ve işletme uygulamalarının su arıtma tesislerinin karbon ayak izi üzerinde belirleyici bir etkiye sahip olduğunu göstermektedir. Bu sonuçlar, karbon ayak izi değerlendirmelerinin rutin işletme süreçlerine entegre edilmesinin önemini ortaya koymaktadır. Enerji verimliliğinin artırılması ve kimyasal girdilerin azaltılması, emisyonların önemli ölçüde düşürülmesine katkı sağlayarak iklim değişikliğiyle mücadeleyi destekleyebilir. Dolayısıyla, sera gazı emisyonlarının sistematik biçimde değerlendirilmesi, daha sürdürülebilir ve düşük karbonlu su arıtma stratejilerinin geliştirilmesi için güçlü ve uygulanabilir bir temel sunmaktadır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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ASSESSING CARBON FOOTPRINTS IN DRINKING WATER TREATMENT: COMPARATIVE ANALYSIS OF ARSENIC AND MANGANESE REMOVAL PLANTS

ABSTRACT

The growing challenge of greenhouse gas emissions highlight the need to evaluate the environmental performance of energy-intensive infrastructure comprehensively. Water and wastewater treatment plants, in particular, should be assessed not only for their ability to deliver safe water but also for their carbon footprint. In these systems, most emissions are indirect, stemming from electricity use, chemical consumption, and waste management. Comparing treatment processes is therefore essential for promoting sustainable water management and implementing low-carbon operation strategies. This study, therefore, analyzes two drinking water treatment plants focused on iron, arsenic and manganese removal. Both plants' capacities, treatment unit configurations, and operational conditions were examined in detail. In the first plant, indirect emissions from energy use were estimated at 121.8 kg CO_2 per day, with chemicals contributing 20.1% of total emissions. In the second plant, energy-related emissions were higher, at 209.5 kg CO_2 per day, and chemical use accounted for 33.3% of overall emissions. These results demonstrate that treatment technology and operational practices significantly influence the carbon footprint of water treatment plants. The findings emphasize the value of integrating carbon footprint assessments into routine plant operations. Optimizing energy efficiency and reducing chemical inputs can substantially lower emissions, supporting climate change mitigation. Systematic evaluation of greenhouse gas emissions thus offers a practical foundation for developing more sustainable, low-carbon water treatment strategies.

GİRİŞ

İklim değişikliği, günümüzde çevresel sürdürülebilirliği tehdit eden en önemli küresel sorunlardan biri olarak kabul edilmektedir (IPCC, 2023). Atmosfere salınan sera gazlarının artışı, küresel ortalama sıcaklıkların yükselmesine neden olmakta ve bu durum ekosistemler, su kaynakları ve insan sağlığı üzerinde önemli etkiler oluşturmaktadır (IPCC, 2023; UNEP, 2022). Bu nedenle, farklı sektörlerden kaynaklanan sera gazı emisyonlarının belirlenmesi ve azaltılmasına yönelik çalışmalar giderek önem kazanmaktadır (IEA, 2023).

Yerel yönetimler her geçen gün artan talebi, daha sıkı kalite düzenlemelerini ve iklim değişikliğinden kaynaklanan ek zorlukları karşılamak zorunda kalmaktadır (Pellikainen vd., 2023). İyileştirilmiş içme suyu kalitesi, arıtma ve kapasite genellikle daha yüksek maliyetlere, artan kaynak tüketimine ve daha büyük çevresel etkiye neden olmaktadır (Molinos-Senante vd., 2022). İklim değişikliği, su sektörü açısından giderek artan bir tehdit oluşturmaktadır (Herrador vd., 2021). Daha sık ve şiddetli görülen aşırı hava olayları, kuraklıklar, seller, uzayan büyüme mevsimleri, yükselen sıcaklıklar ve yoğun yağışlar ham su kalitesini olumsuz etkilemektedir. Ham su kalitesindeki bu bozulma ise üretim

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kapasitesinin azalmasına ve su arıtma süreçlerinde enerji tüketimi ve kimyasal kullanımına bağlı olarak dolaylı sera gazı emisyonlarına neden olmaktadır (Stokes & Horvath, 2009; Corominas vd., 2013). Özellikle pompalama, filtrasyon ve geri yıkama gibi enerji yoğun işlemler karbon ayak izinin önemli bir bölümünü oluşturmaktadır (Hofs vd., 2022). Bunun yanı sıra, arıtma süreçlerinde kullanılan kimyasalların üretimi, taşınması ve dozlanması sırasında ortaya çıkan emisyonlar da toplam karbon ayak izine katkı sağlamaktadır (Zhang vd., 2024).

Hükümetlerarası İklim Değişikliği Paneli tarafından yayımlanan raporda, sera gazı emisyonlarının azaltılmasının iklim değişikliği ile mücadelede kritik öneme sahip olduğu vurgulanmaktadır (IPCC, 2023). Bu kapsamda, su arıtma tesisleri gibi altyapı sistemlerinin karbon ayak izinin değerlendirilmesi, sürdürülebilir çevre yönetimi açısından önemli bir adım olarak görülmektedir (Turna & Solmaz, 2022). Literatürde yapılan çalışmalar, içme suyu arıtma tesislerinde karbon ayak izinin büyük ölçüde enerji tüketiminden kaynaklandığını göstermektedir (Pellikainen vd., 2023; Akash vd., 2024). Ancak arıtma yöntemine ve arıtılmak istenilen bileşenlere bağlı olarak enerji ve kimyasal tüketimi değişiklik gösterebilmekte ve bu durum tesislerin karbon ayak izini doğrudan etkilemektedir (Gupta vd., 2024). Bu bileşenler arasından yeraltı sularında yaygın olarak bulunan arsenik ve mangan, insan sağlığı açısından risk oluşturan ve içme suyundan giderilmesi zorunlu olan parametrelerdir (Aral vd., 2025). Dolayısıyla bu çalışmada, demir, arsenik ve mangan giderimi gerçekleştiren iki farklı içme-kullanma suyu arıtma tesisinin karbon ayak izi değerlendirilmiş ve tesisler enerji ve kimyasal kaynaklı emisyonlar açısından karşılaştırılmıştır. Ayrıca, toplam emisyonların yanı sıra birim kirletici giderimi başına düşen karbon ayak izi değerleri de hesaplanmıştır. Bu kapsamda elde edilen bulgular, arıtma teknolojisi ve işletme koşullarının karbon ayak izi üzerindeki etkisini ortaya koymakta ve düşük karbonlu su arıtma stratejilerinin geliştirilmesine yönelik önemli bir değerlendirme zemini sunmaktadır.

MATERYAL VE METOT

Su Arıtma Tesislerinin Kapsamı

Bu çalışmada arsenik ve mangan giderimi yapılan iki farklı içme suyu arıtma tesisi incelenmiştir. Birinci tesis filtrasyon temelli bir arıtma sistemine sahiptir. Kırklareli ili Alpullu Belediyesi sınırları içerisinde yer alan Tesis-1 2020 yılında işletmeye alınmıştır. Tesis, katalitik medya filtrasyonuna dayalı bir sistem ile arsenik ve mangan giderimi yapacak şekilde tasarlanmıştır. Kurulu kapasitesi 600 m^3/gün olan tesis, ilgili içme suyu kalite standartlarını sağlayacak biçimde işletilmektedir. İkinci tesis ise fizikokimyasal arıtım ağırlıklı bir proses içermektedir. İğneada İçme Suyu Arıtma Tesisi, içme suyu arıtma tesisi olarak tasarlanmıştır. Kimyasal dozaj, koagülasyon-flokülasyon, filtrasyon ve dezenfeksiyon adımlarını içeren proses akımına sahiptir. Tesisin proje kapasitesi 3266 m^3/gün olup, değişken ham su kalitesine uyum sağlayacak şekilde planlanmıştır.

Sera Gazı Emisyon Hesaplama Basamakları

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Bu çalışmada sera gazı emisyonları, literatürde yaygın olarak kullanılan emisyon faktörleri esas alınarak hesaplanmıştır. İçme suyu arıtma tesislerinde doğrudan emisyonların ihmal edilebilir düzeyde olması nedeniyle değerlendirme yalnızca dolaylı emisyonlar üzerinden gerçekleştirilmiştir. Dolaylı emisyonlar enerji tüketimi ve kimyasal madde kullanımına bağlı olarak hesaplanmıştır.

Tesislerin enerji kaynaklı CO_2 emisyonu, kimyasal kaynaklı CO_2 emisyonu, toplam emisyon ve birim giderim başına hesaplanan emisyon değerlerinin formülleri aşağıda belirtilmiştir.

$$E_{enerji} = EC \; x \; EF_{elektrik} \quad (1)$$

Burada E_{enerji}, enerji kaynaklı CO_2 emisyon miktarını (kg CO_2/gün), EC tesiste günlük tüketilen elektrik miktarını (kWh/gün) ve $EF_{elektrik}$ ise elektrik emisyon faktörünü (kg CO_2/kWh) ifade etmektedir.

$$M_{kimyasal} = Q \; x \; D \quad (2)$$

$$E_{kimyasal} = M_{kimyasal} \; x \; EF_{kimyasal} \quad (3)$$

Burada $M_{kimyasal}$ günlük kimyasal tüketimini (kg/gün), Q tesis tarafından günlük arıtılan su debisini (m^3/gün), D her bir kimyasalın günlük dozlama miktarını (kg/m^3), $E_{kimyasal}$ kimyasal kaynaklı CO_2 emisyon miktarını (kg CO_2/gün) ve $EF_{kimyasal}$ ise kimyasalın emisyon faktörünü (kg CO_2/kg kimyasal) ifade etmektedir.

Son olarak $E_{kimyasal}$ ve E_{enerji} verilerinden faydalanılarak;

$$E_{Toplam} = E_{kimyasal} + E_{enerji} \quad (4)$$

$$E_{Birim} = E_{Toplam} \; / \; M_{giderim} \quad (5)$$

Burada E_{Toplam} toplam emisyon miktarını (kg CO_2/gün), E_{Birim} tesiste giderilen demir, arsenik ve manganın kilogramı başına emisyon miktarı (kg CO_2/gün) ve $M_{giderim}$ ise günlük giderilen kirletici miktarını (kg/gün) ifade etmektedir.

BULGULAR VE TARTIŞMA

Tesis 1'de işletme debisi 600 m^3/gün, günlük elektrik tüketimi ise 283,3 kWh/gün olarak belirlenmiştir. 0,43 kg CO_2/kWh emisyon faktörü kullanılarak enerji tüketimine bağlı dolaylı emisyon 121,82 kg CO_2/gün olarak hesaplanmıştır. Giriş–çıkış konsantrasyonlarına dayalı kütle dengesi hesaplamalarına göre günlük giderilen kirletici miktarları; arsenik için 9,6 kg/gün, mangan için 168 kg/gün ve demir için 162 kg/gün olup toplam giderilen kirletici yükü 339,6 kg/gün'dür.

Kimyasal tüketimi kapsamında NaCl için günlük 33 kg kullanım belirlenmiş ve 0,93 kg CO_2/kg emisyon faktörü esas alınarak kimyasal kaynaklı emisyon 30,69 kg CO_2/gün olarak hesaplanmıştır. Enerji ve kimyasal kaynaklı emisyonların toplamı dikkate alındığında, tesisin toplam karbon ayak izi

152,51 kg CO_2/gün olarak bulunmuştur. Birim giderilen kirletici başına düşen emisyon değeri 0,254 kg CO_2-eşd/m^3'tür. Toplam emisyonların %79,88'i enerji tüketiminden, %20,12'si ise kimyasal kullanımından kaynaklanmaktadır.

Tesis 2'de ise işletme debisi 3266 m^3/gün, günlük elektrik tüketimi 487,12 kWh/gündür. Aynı emisyon faktörü kullanılarak enerji kaynaklı dolaylı emisyon 209,46 kg CO_2/gün olarak hesaplanmıştır. Konsantrasyon verilerine göre günlük giderilen kirletici miktarları: arsenik için 127,37 kg/gün, mangan için 261,28 kg/gün ve demir için 3233,34 kg/gün olup toplam giderilen kirletici yükü 3621,99 kg/gündür.

Kimyasal arıtım prosesinde NaCl (ön ve son klorlama), PAC, $KMnO_4$, anyonik ve katyonik polielektrolit ile NaOH kullanımı dikkate alınmıştır. Günlük tüketim miktarları ve ilgili emisyon faktörleri esas alınarak toplam kimyasal kaynaklı emisyon 104,58 kg CO_2/gün olarak hesaplanmıştır. Böylece tesisin toplam karbon ayak izi 314,04 kg CO_2/gün olarak belirlenmiş; birim giderilen kirletici başına düşen emisyon değeri ise 0,096 kg CO_2-eşd/m^3 olarak bulunmuştur. Emisyonların %66,70'i enerji tüketiminden, %33,30'u kimyasal tüketiminden kaynaklanmaktadır.

Elde edilen sonuçlar, iki tesis arasında emisyon yapısı ve karbon yoğunluğu açısından belirgin farklılıklar bulunduğunu göstermektedir. Filtrasyon ağırlıklı tesiste toplam günlük emisyon daha düşük olmakla birlikte, giderilen kirletici yükünün sınırlı olması nedeniyle birim kirletici giderimi başına düşen emisyon değeri daha yüksek hesaplanmıştır. Literatürde de düşük kapasiteli veya sınırlı giderim performansına sahip tesislerde birim emisyon göstergelerinin daha yüksek olabileceği belirtilmektedir (Stokes & Horvath, 2009).

Buna karşılık, kimyasal arıtım ağırlıklı tesiste toplam günlük emisyon daha yüksek olmasına rağmen, daha yüksek debi ve giderim kapasitesi sayesinde birim giderim başına düşen karbon yoğunluğu daha düşük belirlenmiştir. Hofs ve ark. (2022), arıtma tesislerinde karbon performansının yalnızca toplam emisyon değerleri üzerinden değil, arıtım kapasitesi ve sistem verimliliği ile birlikte değerlendirilmesi gerektiğini vurgulamaktadır. Benzer şekilde Corominas ve ark. (2013), yaşam döngüsü değerlendirmesi çalışmalarında ölçek ve proses konfigürasyonunun birim çevresel göstergeler üzerinde belirleyici olduğunu belirtmiştir.

DEĞERLENDİRME

Bu çalışma kapsamında demir, arsenik ve manganez giderimi yapan iki farklı içme-kullanma suyu arıtma tesisinin karbon ayak izi performansı dolaylı sera gazı emisyonları açısından değerlendirilmiştir. Hesaplamalar enerji tüketimi ve kimyasal kullanımına bağlı emisyon faktörleri kullanılarak gerçekleştirilmiştir. Filtrasyon ağırlıklı çalışan Tesis 1'de toplam karbon ayak izi 152,5 kg CO_2/gün olarak hesaplanmış, emisyonların yaklaşık %80'inin enerji tüketiminden kaynaklandığı belirlenmiştir. Günlük toplam kirletici giderimi 339,6 kg olup birim giderim başına emisyon değeri 0,254 kg CO_2-eşdeğer olarak bulunmuştur. Kimyasal arıtım ağırlıklı çalışan Tesis 2'de toplam karbon

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ISBN: 978-9952-610-30-7

ayak izi 314,0 kg CO_2/gün olarak hesaplanmıştır. Bu tesiste kimyasal kullanımının emisyon payı daha yüksek olup toplam emisyonun yaklaşık %33'ünü oluşturmaktadır. Günlük giderilen kirletici yükü 3622 kg ve birim giderim başına emisyon değeri 0,096 kg CO_2-eşdeğer olarak belirlenmiştir. Sonuçlar, toplam günlük emisyon değeri daha yüksek olmasına rağmen, daha yüksek giderim kapasitesi nedeniyle Tesis 2'nin birim kirletici giderimi başına daha düşük karbon yoğunluğuna sahip olduğunu göstermektedir. Bu durum, karbon ayak izi değerlendirmelerinde yalnızca toplam emisyonun değil, arıtım performansına oranlı göstergelerin de dikkate alınması gerektiğini ortaya koymaktadır. Bu yaklaşımın farklı debi, proses ve işletme koşullarına sahip tesislerde uygulanması, su arıtma sektöründe düşük karbonlu proses seçimine yönelik karar destek çalışmalarına katkı sağlayacaktır.

KAYNAKLAR

Akash, P. B., Chakraborty, P., Das, N., & Mullick, M. R. A. (2024). Assessment of carbon footprint of potable water production: A case from Bangladesh. *Green Carbon*, *2*(3), 339-349.

Aral, B., Dincer, A. R., & Aral, İ. F. (2025). Çerkezköy (Tekirdağ) İlçesi Yeraltı Su Kalitesi ve Kirlenme Potansiyelinin Araştırılması. *Afyon Kocatepe Üniversitesi Fen Ve Mühendislik Bilimleri Dergisi*, *25*(3), 667-675.

Corominas, L., Foley, J., Guest, J. S., Hospido, A., Larsen, H. F., Morera, S., & Shaw, A. (2013). Life cycle assessment applied to wastewater treatment: State of the art. *Water Research, 47*(15), 5480–5492.

Gupta, R., Lee, S., Lui, J., Sloan, W. T., & You, S. (2024). Carbon footprint assessment of water and wastewater treatment works in Scottish islands. *Journal of Cleaner Production*, *450*, 141650.

Herrador, B. G., Lund, V., Fonahn, W., Hisdal, H., Hygen, H. O., Hyllestad, S. & Nygård, K. (2021). Heavy weather events, water quality and gastroenteritis in Norway. *One Health*, *13*, 100297.

Hofs, B., Frijns, J., van Dijk, J. C., & de Vet, W. W. J. M. (2022). Carbon footprint of drinking water treatment over the plant life span. *Journal of Cleaner Production, 350*, 131430.

IEA. (2023). *CO_2 Emissions in 2022*. International Energy Agency.

IPCC. (2023). Climate Change 2023: Synthesis Report. Intergovernmental Panel on Climate Change. Geneva, Switzerland.

Molinos-Senante, M., Maziotis, A., Sala-Garrido, R., & Mocholí-Arce, M. (2022). Estimating the cost efficiency and marginal cost of carbon reductions in the production of drinking water. *Sustainable Cities and Society*, *85*, 104091.

Pellikainen, P., Eikebrokk, B., & Vahala, R. (2023). Importance of process design on carbon footprint from drinking water treatment by enhanced coagulation-filtration. *Water Practice & Technology*, *18*(11), 2653-2663.

Stokes, J., & Horvath, A. (2009). Energy and air emission effects of water supply. *Environmental Science & Technology, 43*(8), 2680–2687.

Turna, T., & Solmaz, A. (2022). Sürdürülebilir kent yönetimi ve yeşil altyapı kavramı kapsamında çevreci yaklaşımlar: İskenderun örneği. *Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi*, *13*(4), 739-748.

UNEP. (2022). *Emissions Gap Report 2022*. United Nations Environment Programme.

Zhang, Y., Liu, X., Wang, J., & Chen, Z. (2024). Unveiling the greenhouse gas emissions of drinking water treatment plants: A life cycle assessment approach. *Science of the Total Environment, 906*, 167535. https://doi.org/10.1016/j.scitotenv.2023.167535

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PIPE AGING AS A POTENTIAL DRIVER OF SECONDARY MICROPLASTIC CONTAMINATION IN DRINKING WATER DISTRIBUTION SYSTEMS: A CASE STUDY FROM ERGENE DISTRICT, TEKİRDAĞ PROVINCE, TÜRKİYE

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ABSTRACT

The global adoption of polymeric pipes within water distribution networks is accelerating, systematically replacing traditional metallic and concrete infrastructure. This widespread transition is primarily driven by the superior corrosion resistance and installation cost-effectiveness offered by modern polymers. The trend is particularly pronounced in Türkiye, where recent reports from local water and sewage authorities indicate an increase of nearly 32% in the share of high-density polyethylene (HDPE) pipes over the past three years. However, this fundamental material shift has raised questions regarding long-term durability and system safety. Polymeric pipes, including HDPE and polyvinyl chloride (PVC), may undergo degradation under combined stress conditions, such as hydraulic fluctuations and exposure to residual disinfectants (e.g., chlorine). This process, commonly referred to as oxidative embrittlement, can lead to surface cracking and the gradual release of micro- and nanoplastic particles into drinking water. Such releases may represent a potential source of environmental exposure and could contribute to conditions that may be associated with adverse outcomes under cumulative stress scenarios. Focusing on the modernizing water network in the Ergene district of Tekirdağ as a case study area, this paper aims to investigate these degradation mechanisms, conduct field-based assessments of microplastic release, and evaluate broader environmental implications through a Life Cycle Assessment perspective. A key methodological contribution of this work is the integration of spatial water distribution network data to generate a predictive visualization framework, specifically modeling oxidative embrittlement processes. The analysis identifies “pipe material” and “pipe age” as critical independent variables, as degradation dynamics are strongly dependent on these parameters. Simulated microplastic concentrations are subsequently compared with values reported in the literatüre for similar water systems, and the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

findings are interpreted within a comprehensive framework that considers cumulative structural degradation and environmental burden across the pipeline's total operational lifespan. Such research may inform the design and material selection of next-generation water distribution systems to enhance durability and minimize potential degradation-related impacts over extended service lifetimes.

Keywords: Microplastics, Water Distribution Networks, Crack Layer Theory, Polymeric Pipes, Oxidative Embrittlement.

INTRODUCTION

Globally, municipal water utilities are facing an unprecedented infrastructure crisis characterized by aging metallic and concrete networks (Clayton, 2025). These legacy systems increasingly suffer from severe internal corrosion, frequent main breaks, and unacceptably high rates of non-revenue water (NRW) loss (Espinoza & Huacho, 2025). In response, the adoption of polymeric pipes within water distribution networks (WDNs) has accelerated dramatically as municipalities seek to modernize their grids (Joseph et al., 2022). In Türkiye, and specifically within the highly urbanized and industrialized Marmara Region, this modernization trend is exceptionally evident. For instance, the latest annual report by the Istanbul Water and Sewerage Administration states that between 2022 and 2024 alone, the share of High-Density Polyethylene (HDPE) pipes in the network increased by nearly 32% (Istanbul Water and Sewage Administration, 2024). This rapid transition is primarily driven by four distinct advantages: (I) superior corrosion resistance compared to legacy iron pipes, (II) overall cost-effectiveness and ease of installation, (III) significantly reduced leakage rates, and (IV) lower initial carbon emissions during the manufacturing and transport phases.

However, the increasing reliance on these polymeric materials raises critical, long-term questions regarding their susceptibility to mechanical and chemical aging over their operational lifespan (Frigione, 2022). Polymeric pipe materials, including HDPE, Polyethylene (PE), and Polyvinyl Chloride (PVC), are not entirely inert. Throughout their service life, they are subjected to a complex array of continuous stressors (Stefan et al., 2023). Mechanically, they must endure constant hydraulic pressure fluctuations, water hammer events, and varying flow velocities. Chemically, the inner walls of these pipes are continuously exposed to reactive residual disinfectants, such as free chlorine or chloramines, which are necessary to maintain water safety (Kroeger, 2023). This dual-stress environment accelerates the degradation of the polymer matrix. The degradation manifests primarily as oxidative embrittlement, characterized by the gradual depletion of protective antioxidant coatings, the leaching of stabilizing additives, and subsequent polymer chain scission (Allen, 2025). Over time, this chemical breakdown leads to microscopic surface roughening, micro-cracking, and structural fatigue. Consequently, this deterioration results in the continuous shedding of microplastics and nanoplastics directly into the drinking water supply, posing a potential, yet heavily under-monitored, health risk to consumers (Świetlik & Magnucka, 2025). Beyond the direct physical hazards of human

ingestion and tissue accumulation, the continuous shedding of these particles presents a much more complex environmental and public health threat. Because of their hydrophobic nature and inherently high surface-to-volume ratio, microplastics can act as highly effective vectors—or a "Trojan Horse"—within the ecosystem. In a water distribution environment, they have the capacity to adsorb heavy metals, persistent organic pollutants, and residual chemical byproducts, transporting these concentrated contaminants directly to the tap. Furthermore, the roughened, degraded interior surfaces of these aging plastic pipes provide an ideal substrate for biofilm formation, which can harbor waterborne pathogens and further complicate water quality management (Wang et al., 2021).

The rate of this shedding is directly influenced by daily variations in water demand, which create fluctuating flow velocities and pressure transients (Sheng et al., 2025). During periods of high demand, the increased shear stress along the pipe wall can dislodge larger quantities of degraded plastic, causing episodic spikes in microplastic concentrations that are easily missed by infrequent or static sampling methods. Understanding this hydraulic relationship is crucial for accurately predicting spatial vulnerability across a district (Liu et al., 2025). In the context of evaluating these long-term impacts, traditional environmental assessments fall critically short. When municipalities conduct a Life Cycle Assessment to justify the installation of HDPE or PVC infrastructure, the scope is almost exclusively limited to the manufacturing, transportation, and eventual end-of-life disposal phases. The operational "use phase" of the pipe, which can last upwards of fifty years, is frequently modeled as a static, emission-free period. This assumption is a significant flaw in current sustainability models. By failing to account for the continuous generation of secondary microplastics during the pipe's service life, conventional LCAs significantly underestimate the total ecological footprint of polymeric WDNs (Zhao et al., 2016). To determine whether the immediate operational benefits truly outweigh these extended ecological impacts, it is essential to look beyond the manufacturing phase and evaluate the true, cradle-to-grave sustainability of these systems. Yet there remains a critical gap between theoretical laboratory findings and real-world infrastructure management. Most current literature relies on controlled, small-scale bench tests that do not accurately reflect the spatial, hydraulic, and demographic complexities of an actual municipal network. To bridge this gap, field-based spatial simulations are critical.

Accordingly, the primary aim of this paper is to comprehensively investigate the mechanisms of plastic pipe degradation (specifically HDPE and PVC) and the subsequent release of microplastics within active distribution environments. Specifically, this study seeks to: (1) integrate spatial mapping with theoretical degradation models to simulate microplastic oscillation through a localized municipal case study, and (2) utilize this field-based simulation to evaluate the holistic environmental impacts of polymeric networks from a Life Cycle Assessment (LCA) perspective.

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MATERIALS AND METHODS

The Ergene District of Tekirdağ Province in Türkiye was selected as the case study area. Specifically, the focus was on the central neighborhood, with the study limits defined by the district borders. Because the area supplies water to fewer than 30,000 people, its WDN was uncomplicated to simulate. Also, pipe property data obtained from the Tekirdağ Water and Sewerage Administration showed that the WDN mostly consists of polymeric pipes - namely PVC and HDPE. Together, these practical factors supported the selection of this project area. To accurately quantify the release of microplastics within the distribution network, a sequential, two-step analytical methodology was developed. First, a specific degradation parameter was calculated to assess the physical deterioration of the polymeric infrastructure. This was achieved by applying governing equations derived from Crack Layer Theory directly to the spatial pipe property data, allowing for a mathematical representation of how the material structurally weakens under operational stressors. Once the theoretical wear of the pipes was established, the second phase of the methodology translated this physical degradation into a quantifiable environmental metric: the microplastic concentration, expressed in particles per liter (MP/L). To accomplish this, the network's specific pipe properties and calculated degradation profiles were integrated with baseline microplastic concentrations previously established through empirical laboratory measurements by Zhang et al. By utilizing these two complementary methods, this study effectively bridges theoretical material failure mechanics with realistic, numerical estimations of microplastic oscillation in the municipal water supply.

In the first calculation, the “Crack Layer Theory” identified in 1984 by Chudnovsky was used. Before particles release, the polymer must degrade chemically. It defines a degradation parameter based on molecular weight changes, which drives the initiation of cracks which are the precursors to microplastics (Chudnovsky, 1984).

Choi et al. utilized this theory and calculated degradation parameter values. They also created a Degradation parameter vs. Normalized time graph given in Figure 5 which was also used in comparison with the projects results. (Choi et al., 2009).

$$u(x,t) = \begin{cases} 0 & t < t_{OIT} \\ k \times [t - t_{OIT}(x)] & t_{OIT} \leq t < t* \\ 1 & t \geq t* \end{cases} \quad (1)$$

Where,

- $u(x,t)$: The degradation parameter at point x and time t, defined as $1 - \frac{M_w(t)}{M_w(0)}$ where M_w is average molecular weight.

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- k: The rate of degradation growth. (Two simulations were made for k=0.1 and k=10 in the work of Choi et al. (2009)).
- t: Time elapsed.
- t_{OIT}: Oxidation Induction Time.
- t*: Time of complete deposition.

As a secondary method of comparison, microplastic concentration was evaluated using particles per liter (MP/L) as the standard unit. In their laboratory experiments, Zhang et al. (2022) identified the surface area-to-volume ratio as a crucial parameter for pipeline calculations, adopting an assumed constant of 0.8 cm^2mL^{-1} (Zhang et al., 2022). By integrating this specific ratio with the empirical MP/L concentrations measured in their study, Equation 2 was derived. The formula utilizes their established baseline concentration values ($C_{Literature}$) of 337±22 MP/L for HDPE and 63±13 MP/L for PVC.

$$C_{Actual} = C_{Literature} \times \frac{(\frac{S}{V})_{Pipe}}{(\frac{S}{V})_{Literature}} \quad (2)$$

Figure 1 outlines the methodological framework developed for this study. As illustrated in the flowchart, the core of the analysis revolves around the water distribution network's shapefile (.shp) data, which serves as the primary input for three distinct analytical processes. To visualize the infrastructure, this pipe property data is integrated with an OpenStreetMap base layer using QGIS. Beyond spatial mapping, the physical condition of the network is assessed by combining the shapefile data with equations derived from Crack Layer Theory to calculate a specific degradation parameter. Finally, to estimate the actual microplastic release, the physical pipe properties are evaluated alongside baseline microplastic concentrations previously established in laboratory studies by Zhang et al. By integrating theoretical degradation models with empirical lab data and spatial mapping, this workflow provides a comprehensive approach to quantifying microplastic oscillation within the study area.

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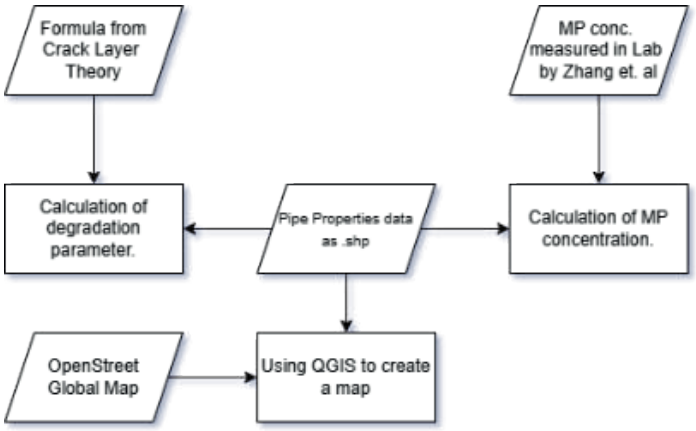


Figure 1. Flowchart of Methodology.

RESULTS

Figure 2 illustrates the spatial layout and material composition of the water distribution network within the central neighborhood of the Ergene district. As the map clearly demonstrates, the infrastructure is overwhelmingly dominated by High-Density Polyethylene (HDPE) pipes, represented by the red lines that form nearly the entire grid. In contrast, Polyvinyl Chloride (PVC) pipes, indicated by the sparse blue lines, are limited to only a few isolated segments. This visual distribution confirms the network's extensive reliance on polymeric materials. Furthermore, this disproportionate ratio suggests that any potential microplastic oscillation into the drinking water supply in this specific region will primarily be driven by the degradation and wear of the HDPE infrastructure rather than the PVC components.

After the creation of WDN map, Degradation Parameter was calculated. Since $t_{OIT} \leq t < t*$ in Equation 1, Equation 3 was used.

$$u(x,t) = k \times [t - t_{OIT}(x)] \tag{3}$$

To obtain the t value, the travel time of the water was calculated using Equation 4 with respect to the total WDN pipe length (25,962m) and the standard water velocity (V=1 m/s). The total pipe length was extracted from QGIS.

$$t = \frac{25{,}962\ m}{1\ m/s} = 25962\ s = 432\ min = 7.21\ h \tag{4}$$

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Using this t value, and the Oxidation Induction Time value corresponding to t shown in Figure 3, also taking k=0.1 assumption given by Choi et al. into consideration, Equation 5 was written and calculated (Choi et al., 2009).

$$u(25.9\ km, 432\ min) = 0.1 \times [432\ min - 50\ min] = 38.27 \qquad (5)$$

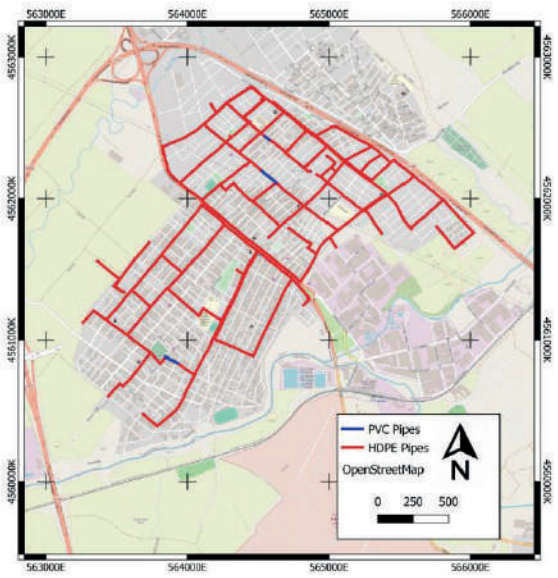


Figure 2. Polymeric Material Based Pipe Network in Project Area.

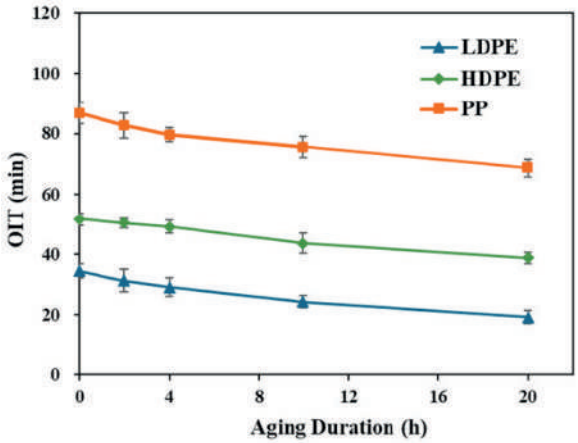


Figure 3. OIT vs Aging Duration Graph (Zhang et al., 2022).

For the calculation of concentration, formula mentioned in Equation 2 was used. Using the HDPE and PVC values mentioned by Zhang et al., for every pipe segment, calculations were made. An example of the calculation was given in Equation 6 and for both pipe material, an example of results was given in Table 1.

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$$C_{HDPE-1} = 337\ MP/L \times \frac{0.08\ cm^2/mL}{0.8\ cm^2/mL} = 33.7\ MP/L \quad (6)$$

Table 4. Examples of Results for Particle Calculation.

Pipe ID	Diameter (cm)	Length (m)	Material	S/V	C_{actual} (MP/L)
48056	50	100.82	HDPE	0.08	33.7
34251	16	29.06	PVC	0.25	19.6

Using the weighted average formulas, Equations 7a and 7b were derived. The results for the whole system were also given in Equations 7a and 7b based on pipe material.

$$C_{HDPE} = \frac{\sum(C_{actual} \times Length}{\sum Length} = 91.8\ MP/L \quad (7a)$$

$$C_{PVC} = \frac{\sum(C_{actual} \times Length}{\sum Length} = 15.4\ MP/L \quad (7b)$$

DISCUSSION

Using the slope in Figure 4, the Degradation Parameter corresponding to the t/t_{OIT} value calculated in the paper is seen as ~38.2 while the calculated value was 38.27. Such a minimal discrepancy between the empirical graph and the mathematical calculation effectively validates the reliability of the theoretical degradation model applied to the network.

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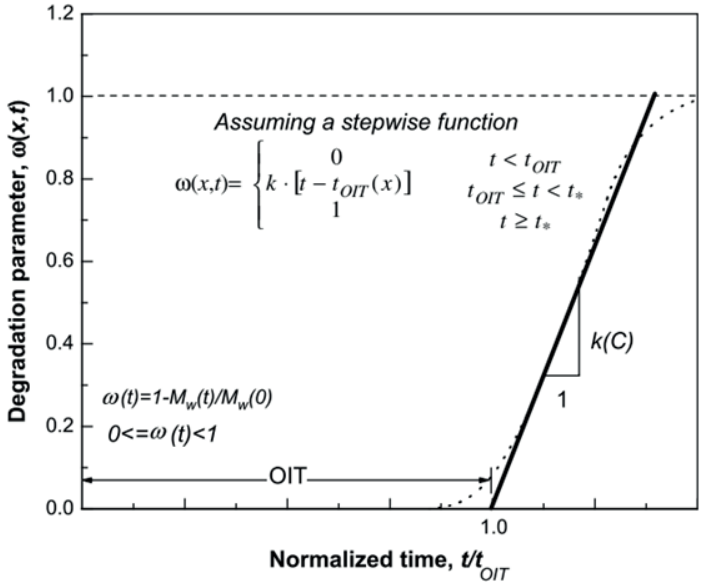


Figure 4. Evaluation of Degradation Parameter in Normalized Time (Choi et al., 2009).

Figure 5 presents a comparative analysis of microplastic concentrations (expressed in MP/L) for both PVC and HDPE pipes, drawing the calculated values from the network simulation against the baseline laboratory measurements established by Zhang et al. As illustrated in the chart, the calculated microplastic concentrations for both materials are notably lower than the empirical values recorded under controlled laboratory conditions. However, despite this overall reduction in absolute concentration, the relative degradation trend between the two materials remains highly consistent; HDPE exhibits a significantly higher microplastic release potential compared to PVC in both the literature baseline and the calculated field data.

According to EU Directive by Sinkevicius (2024), in drinking water, concentration of MP is expected to be between 0.0001 to 440 MP/L (Sinkevicius, 2024). The calculated values also meet those expectations.

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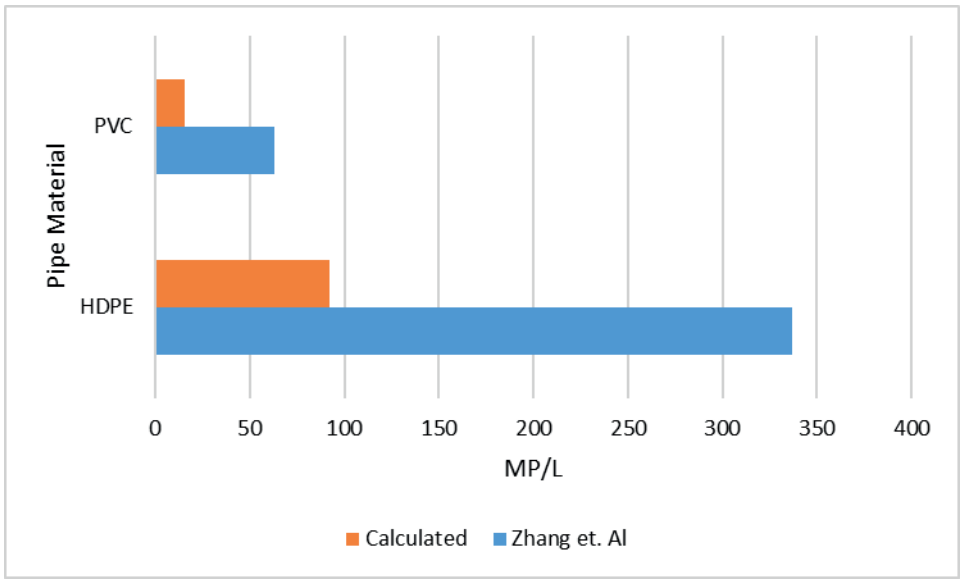


Figure 5. Calculated vs Measured MP Concentration by Pipe Material.

To evaluate the environmental impact of these infrastructure choices, the varying carbon footprints of different polymeric materials must be considered. According to a comparative assessment by Zhao et al. (2016), Polyvinyl Chloride (PVC) consistently demonstrates a higher environmental burden than Polyethylene (PE) across multiple evaluation criteria, most notably in its Global Warming Potential. This disparity is heavily driven by the manufacturing phase; the production process alone accounts for approximately 92% of the total CO2 emissions for PVC, whereas it accounts for roughly 78% for PE. Applying these metrics to the specific case study area, the water distribution network in the Ergene district is overwhelmingly composed of High-Density Polyethylene (HDPE), containing only a minimal fraction of PVC pipes. Consequently, from an initial life-cycle perspective, the current material composition of the Ergene network contributes to significantly lower baseline CO2 emissions than a predominantly PVC-based system (Zhao et al., 2016).

CONCLUSION

This study comprehensively evaluated the structural degradation and environmental implications of polymeric water distribution networks, utilizing the Ergene district of Tekirdağ as a predictive spatial case study. From an initial Life Cycle Assessment perspective, the network's heavy reliance on High-Density Polyethylene (HDPE) over Polyvinyl Chloride (PVC) presents clear upfront sustainability benefits, significantly lowering baseline CO2 emissions compared to a predominantly PVC-based system. However, the application of the Crack Layer Theory demonstrates that these polymeric infrastructures undergo continuous physical deterioration over their operational lifespan. This structural aging translates directly into the continuous shedding of microplastics. Although the simulated field concentrations for the Ergene network remained within the expected EU Directive

limits and were notably lower than accelerated laboratory maximums, the relative degradation trend remained highly consistent, with HDPE exhibiting a significantly higher microplastic release potential than PVC. Ultimately, this research highlights a critical infrastructure trade-off: while modernizing grids with HDPE effectively reduces initial carbon footprints and legacy corrosion risks, it necessitates proactive, long-term monitoring to mitigate the hidden ecological and public health costs associated with secondary microplastic contamination.

REFERENCES

Allen, N. S. (2025). Historical Perspectives and Reflections on the Degradation and Stabilization of Polymer Materials. *Journal of Vinyl and Additive Technology*.

Choi, B. H., Chudnovsky, A., Paradkar, R., Michie, W., Zhou, Z., & Cham, P. M. (2009). Experimental and theoretical investigation of stress corrosion crack (SCC) growth of polyethylene pipes. In *Polymer Degradation and Stability* (Vol. 94, Number 5). https://doi.org/10.1016/j.polymdegradstab.2009.01.016

Chudnovsky, A. (1984). *Crack Layer Theory*.

Clayton, J. (2025). *Strategies for Addressing Aging Infrastructure and Workforce Challenges in Water Distribution Systems* (Doctoral dissertation, The University of Alabama).

Espinoza, G., & Huacho, J. (2025). The Challenge of Non-revenue Water: A Soon-To-Be an Exhausted Resource. In *Equalizing the Three Pillars of Sustainability: Exploring Social Responsibility in Context* (pp. 71-91). Singapore: Springer Nature Singapore.

Frigione, M. (2022). Assessment of the Ageing and Durability of Polymers. *Polymers*, *14*(10), 1934.

Joseph, K., Sharma, A. K., & Van Staden, R. (2022). Development of an intelligent urban water network system. *Water*, *14*(9), 1320.

Istanbul Water and Sewage Administration. (2024). *İSKİ 2024 Activity Report*. https://hizmetler.iski.gov.tr/ekitap/faaliyet_raporu_2024/

Kroeger, R. (2023). *Pipe material's influence on chlorine residuals in a municipal drinking water distribution system* (Master's thesis, Oklahoma State University).

Liu, H., Zhao, M., & Jiang, F. (2025). Aging of PVC pipes induces release of microplastics: Insight into the role of the hydrophilicity of pipe inner surface. *Process Safety and Environmental Protection*, *200*. https://doi.org/10.1016/j.psep.2025.107409

Sheng, K., Yang, Z., Tang, Y., & Zhang, Y. (2025). Release of microplastics from pipe materials and their impact on stagnant water. *Journal of Water Process Engineering*, *69*. https://doi.org/10.1016/j.jwpe.2024.106872

Sinkevicius, V. (2024). Commission Delegated Decision (EU) 2024/1441 of 11 March 2024 supplementing Directive (EU) 2020/2184 of the European Parliament and of the Council by laying down a methodology to measure microplastics in water intended for human consumption. *Official Journal of the European Union*.

Stefan, D. S., Bosomoiu, M., & Teodorescu, G. (2023). The behavior of polymeric pipes in drinking water distribution system—Comparison with other pipe materials. *Polymers*, *15*(19), 3872.

Świetlik, J., & Magnucka, M. (2025). Aging of drinking water transmission pipes during long-term operation as a potential source of nano- and microplastics. *International Journal of Hygiene and Environmental Health*, *263*. https://doi.org/10.1016/j.ijheh.2024.114467

Wang, J., Guo, X., & Xue, J. (2021). Biofilm-Developed Microplastics As Vectors of Pollutants in Aquatic Environments. *Environmental Science and Technology*, *55*(19), 12780 – 12790. https://doi.org/10.1021/acs.est.1c04466

Zhang, X., Lin, T., & Wang, X. (2022). Investigation of microplastics release behavior from ozone-exposed plastic pipe materials. *Environmental Pollution*, *296*. https://doi.org/10.1016/j.envpol.2021.118758

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Zhao, C. Z., Huang, M. C., Liu, Y., & Ma, L. P. (2016). Research on life cycle assessment of plastic pipeline system. *Materials Science Forum*, *847*, 366–373. https://doi.org/10.4028/www.scientific.net/MSF.847.366

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KÜRESEL DENİZ TAŞIMACILIĞINDA SİSTEMİK BİR RİSK OLARAK PLASTİK PELET KİRLİLİĞİ

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ÖZET

Plastik peletler deniz yoluyla küresel ölçekte büyük miktarlarda taşınmakta olup deniz ortamına salındıklarında birincil mikroplastiklerin önemli bir kaynağını oluşturmaktadır. Pelet kirliliği genellikle karasal endüstriyel faaliyetlerle ilişkilendirilse de deniz taşımacılığı çevresel salım için kritik ancak çoğu zaman göz ardı edilen bir yol oluşturmaktadır. Sızıntılar; hasarlı ambalajlar, konteyner kaçakları, yük kayması, uygunsuz istifleme, aşırı yükleme veya denizde konteyner kaybı gibi nedenlerle meydana gelebilmekte ve etkileri tekil olayların ötesine geçmektedir. Bu çalışma, plastik pelet kirliliğini disiplinlerarası bir bakış açısıyla ele alarak taşımacılık uygulamaları, sızıntı mekanizmaları, raporlanmış kazalar ve uluslararası düzenleyici çerçeveyi birlikte değerlendirmektedir. 2011–2025 yılları arasında bildirilen kazalar, pelet salımlarının münferit olaylar olmadığını, küresel deniz taşımacılığı sistemi içinde tekrarlayan bir olgu olduğunu göstermektedir. Sri Lanka açıklarında meydana gelen ve yaklaşık 1.680 ton plastik peletin petrol ve tehlikeli maddelerle birlikte denize yayılmasına yol açan 2021 tarihli MV X-Press Pearl kazası, bu kirliliğin ölçeğini ve kalıcılığını ortaya koyan kritik bir örnek oluşturmaktadır. Bu olay, pelet kirliliğinin yalnızca tesadüfi hatalardan değil, deniz taşımacılığı sistemindeki yapısal kırılganlıklardan kaynaklandığını göstermektedir. Çalışmada ayrıca pelet taşımacılığına ilişkin düzenleyici rejim de incelenmiştir. Uluslararası Denizcilik Örgütü'nün yaklaşımına yönelik analizler, MARPOL Ek V ve ilgili rehber belgeler dâhil olmak üzere mevcut düzenlemelerin parçalı ve büyük ölçüde bağlayıcı olmaktan uzak olduğunu, bu durumun önleyici kapasiteyi sınırladığını ve müdahale mekanizmalarını zayıflattığını ortaya koymaktadır.

Bulgular, plastik pelet kirliliğinin yalnızca çevresel bir sorun olarak değil, sınır ötesi etkileri olan sistemik bir deniz yönetişimi sorunu olarak ele alınması gerektiğini göstermektedir. Uluslararası düzeyde bağlayıcı önleyici düzenlemelerin güçlendirilmesi, tedarik zinciri boyunca risk yönetimi uygulamalarının geliştirilmesi ve daha açık müdahale ile sorumluluk mekanizmalarının oluşturulması, pelet kaynaklı deniz kirliliğinin azaltılması için temel adımlar olarak değerlendirilmektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Anahtar Kelimeler: Birincil mikroplastikler, MARPOL Ek V, Denizcilik yönetimi, Sistemik risk, Deniz taşımacılığı, Sınır ötesi kirlilik

PLASTIC PELLET POLLUTION AS A SYSTEMIC RISK IN GLOBAL MARITIME TRANSPORT

ABSTRACT

Plastic pellets are transported globally in large volumes by sea and constitute a major source of primary microplastics when released into marine environments. Although pellet pollution is commonly associated with land-based industrial activities, maritime transport represents a critical yet often overlooked pathway of environmental release. Spills may occur due to damaged packaging, container leakage, cargo shifting, improper stowage, overloading, or container loss at sea, generating impacts that extend beyond individual incidents.

This study examines plastic pellet pollution from an interdisciplinary perspective, integrating maritime transport practices, spill mechanisms, documented incidents, and the international regulatory framework. Accidents reported between 2011 and 2025 indicate that pellet releases are not isolated anomalies but recurring events embedded within global shipping operations. The 2021 MV X-Press Pearl disaster off the coast of Sri Lanka, which released approximately 1,680 tons of plastic pellets together with oil and hazardous substances, serves as a critical case illustrating the scale and persistence of such pollution and highlighting structural vulnerabilities in maritime transport systems rather than purely accidental failures. The study further evaluates the regulatory regime governing pellet transport. Analysis of the International Maritime Organization's approach shows that existing instruments, including MARPOL Annex V and related guidance, remain fragmented and largely non-binding, limiting preventive capacity and weakening response mechanisms.

The findings suggest that plastic pellet pollution should be addressed not only as an environmental issue but as a systemic maritime governance challenge with transboundary implications. Strengthening internationally binding preventive regulations, improving risk management across the supply chain, and establishing clearer response and liability mechanisms are essential steps toward reducing pellet-related marine pollution.

Keywords: Primary microplastics, MARPOL Annex V, Maritime governance, Systemic risk, Shipping, Transboundary pollution.

GİRİŞ

Boyutları 1 µm ile 5 mm arasında değişen mikroplastikler (MP'ler), ticari ürünlerde kasıtlı olarak kullanılan birincil kaynaklardan ve daha büyük plastiklerin çevresel süreçler sonucu parçalanmasıyla oluşan ikincil kaynaklardan türeyen, küresel ölçekte yaygın ve kalıcı kirleticiler olarak tanımlanmaktadır (An vd., 2020; Hale vd., 2020). Küresel plastik endüstrisinin temel girdilerinden biri

olan bu küçük granüller, yüksek hacimlerde üretilmekte ve çoğunlukla deniz yoluyla taşınmaktadır. Plastik granüller, deniz ortamındaki mikroplastiklerin önemli kaynaklarından biri olup kirliliğin çoğunlukla karasal sanayi faaliyetleri ve taşımacılık süreçleriyle ilişkili olduğu kabul edilmektedir. Taşıma, depolama ve yükleme süreçlerinde meydana gelen sızıntılar, kazalar veya konteyner kayıpları sonucunda peletler deniz ortamına kolaylıkla karışabilmekte ve geniş alanlara yayılabilmektedir (Andreussi vs., 2024). Yüzebilir özellikleri ve çevresel dayanıklılıkları nedeniyle kıyısal ve açık deniz ekosistemlerinde uzun süre kalıcı olabilen peletler, bu nedenle küresel ölçekte giderek artan bir çevresel risk unsuru olarak değerlendirilmektedir (Galgani ve Rangel-Buitrago,2024, Cocozza vd., 2025).

Plastik pelet kirliliğine ilişkin çalışmalar ağırlıklı olarak karasal endüstriyel kaynaklara, kıyısal birikimlere veya mikroplastiklerin ekotoksikolojik etkilerine odaklanmış; deniz taşımacılığı kaynaklı pelet kayıplarının ölçeği, sürekliliği ve sistematik niteliği ise görece sınırlı biçimde ele alınmıştır (Vidal-Abad vd., 2024; Folbert vd., 2025; ITOPF, 2025). Özellikle küresel taşımacılık zinciri içinde gerçekleşen kazaların, operasyonel sızıntıların ve konteyner kayıplarının birlikte oluşturduğu toplam riskin bütüncül bir çerçevede değerlendirilmesine yönelik çalışmalar sınırlı kalmaktadır. Bu durum, plastik pelet kirliliğinin münferit olayların ötesinde, küresel deniz taşımacılığı sisteminin yapısal özelliklerinden kaynaklanan süreklilik arz eden bir risk olarak ele alınmasını gerektirmektedir. Peletlerin yüksek üretim hacmi, küresel ticaret ağlarına entegre taşınması ve çevrede uzun süre kalıcı olabilmesi, olası salımların coğrafi sınırları aşarak geniş ekosistemleri etkileyebilmesine yol açmaktadır (Saliba vd., 2022, Vithanage vd., 2023). Ayrıca sorumluluğun belirlenmesindeki güçlükler ve mevcut düzenleyici araçların sınırlı bağlayıcılığı, bu kirliliği yalnızca çevresel bir sorun olmaktan çıkararak yönetişim, risk yönetimi ve uluslararası iş birliği boyutları olan çok katmanlı bir mesele haline getirmektedir. Bu nedenle plastik pelet kirliliği, kazara ortaya çıkan izole bir çevresel olaydan ziyade, küresel deniz taşımacılığına içkin yapısal kırılganlıkların bir yansıması olarak değerlendirilebilir (Karlsson vd., 2018; Folbert vd., 2025).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 1. Deniz taşımacılığı sırasında plastik granül dökülmeleri ve sızıntılarının neden-sonuç ilişkilerine genel bakış

Uluslararası Denizcilik Örgütü'nün (IMO) plastik peletlere yönelik mevcut yaklaşımı incelendiğinde; MARPOL Ek V, eylem planları ve rehber belgelerin büyük ölçüde bağlayıcı olmayan nitelikte kaldığı görülmektedir (Hwang 2020; IMO, 2024). Plastik peletlerin çoğu zaman "zararsız katı dökme yük" olarak sınıflandırılması, taşınma ve depolama süreçlerine ilişkin önleyici tedbirlerin sınırlı kalmasına yol açmaktadır (Grgurevic vd., 2025). Bu durum, denizde meydana gelen kazalar veya operasyonel kayıplar sonrasında etkili müdahale ve sorumluluk mekanizmalarının işletilmesini de güçleştirmektedir. Ayrıca mevcut düzenlemelerin parçalı yapısı ve uygulamadaki farklılıklar, pelet salımlarının küresel ölçekte izlenmesini ve yönetilmesini zorlaştırmaktadır. Sonuç olarak, plastik pelet kirliliği yalnızca çevresel bir sorun değil, aynı zamanda uluslararası deniz taşımacılığı sistemine içkin yönetişim ve risk yönetimi eksikliklerinin bir göstergesi olarak ortaya çıkmaktadır.

Bu çalışmanın amacı, plastik pelet kirliliğini küresel deniz taşımacılığı bağlamında değerlendirerek bu kirliliğin münferit kazaların ötesinde sistemik bir risk oluşturup oluşturmadığını ortaya koymaktır. 2011–2025 yılları arasında farklı coğrafyalarda meydana gelen plastik pelet kazaları, özellikle 2021 yılında Sri Lanka açıklarında gerçekleşen MV X-Press Pearl kazası, deniz taşımacılığının bu kirlilik için önemli bir kaynak olabileceğini göstermiştir. Yaklaşık 1.680 ton plastik peletin yanı sıra petrol,

tehlikeli kimyasallar ve ağır metallerin deniz ortamına karışmasına yol açan bu olay, çalışmada temel örnek vaka olarak ele alınmıştır. Söz konusu kaza, plastik pelet kirliliğinin yalnızca tekil kazaların sonucu olmadığını, küresel deniz taşımacılığı sistemine özgü yapısal riskler ve düzenleyici boşluklarla ilişkili olabileceğini ortaya koymaktadır. Bu doğrultuda çalışma, taşımacılık uygulamaları, kaza nedenleri, çevresel etkiler ve uluslararası düzenleyici çerçeveyi birlikte değerlendirerek plastik pelet kirliliğinin deniz yönetişimi açısından taşıdığı sistemik risk boyutunu analiz etmeyi hedeflemektedir.

MATERYAL VE METOT

Bu çalışma, plastik pelet kirliliğini küresel deniz taşımacılığı bağlamında değerlendirmek amacıyla literatür taraması, olay verisi derleme ve örnek vaka analizi yöntemlerini bir arada kullanan disiplinlerarası bir yaklaşıma dayanmaktadır. 2011–2025 yılları arasında farklı coğrafyalarda meydana gelen plastik pelet kazalarına ilişkin veriler; bilimsel yayınlar, uluslararası kuruluş raporları, resmi soruşturma belgeleri ve güvenilir medya kaynakları incelenerek derlenmiştir. Bu kapsamda kazaların meydana geldiği yer, olayın nedeni, taşınan pelet miktarı, çevresel etkiler ve müdahale süreçlerine ilişkin bilgiler karşılaştırmalı olarak değerlendirilmiştir.

Çalışmada, Sri Lanka açıklarında 2021 yılında meydana gelen MV X-Press Pearl kazası temel örnek vaka olarak ele alınmıştır. Yaklaşık 1.680 ton plastik peletin yanı sıra petrol, tehlikeli kimyasallar ve ağır metallerin deniz ortamına karışmasına yol açan bu olay, plastik pelet kirliliğinin ölçeği, yayılımı ve çevresel sonuçları açısından en kapsamlı vakalardan biri olarak değerlendirilmektedir. Vaka analizi kapsamında olayın gelişimi, kirlilik türleri, etkilenen ekosistemler, müdahale süreçleri ve uzun dönemli etkiler incelenmiştir. Buna ek olarak, plastik pelet taşımacılığına ilişkin uluslararası düzenleyici çerçeve de analiz edilmiştir. Uluslararası Denizcilik Örgütü (IMO) tarafından yayımlanan MARPOL Ek V, eylem planları ve ilgili rehber belgeler incelenerek mevcut düzenlemelerin bağlayıcılığı, kapsamı ve uygulamadaki sınırlılıkları değerlendirilmiştir. Elde edilen bulgular, plastik pelet kirliliğinin münferit kazalarla sınırlı olmayan, küresel deniz taşımacılığı sistemine içkin yapısal riskler barındıran bir sorun olup olmadığını ortaya koymak amacıyla bütüncül bir çerçevede yorumlanmıştır.

SONUÇLAR VE TARTIŞMA

Çalışma kapsamında, metodoloji bölümünde tanımlanan yaklaşım doğrultusunda yayımlanmış raporlar, hükümet soruşturmaları ve bilimsel literatürden derlenen plastik pelet kazalarına ilişkin olaylar Tablo 1'de sunulmuştur. Tablo incelendiğinde, 2011–2025 yılları arasında farklı coğrafyalarda meydana gelen kazaların mekânsal dağılımının homojen olmadığı, özellikle Güney Yarımküre'de gerçekleşen bölgesel büyük olayların belirgin olduğu görülmektedir. Tabloda, ton ölçeğinde pelet kaybına yol açan ve "mega" veya "büyük" olaylar olarak sınıflandırılabilecek kazaların sayıca az olmasına rağmen çevresel etkiler açısından yüksek öneme sahip olduğu anlaşılmaktadır. Bu tür olaylar genellikle gemi kazaları veya konteyner kayıpları gibi yüksek enerjili olaylarla ilişkili olup geniş kıyı

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

alanlarında uzun süreli kirlilik oluşturma potansiyeline sahiptir. Öte yandan daha küçük ölçekli ancak sık tekrarlanan sızıntı ve operasyonel kayıpların da toplam kirlilik yüküne önemli katkı sağlayabileceği değerlendirilmiştir.

Tablo 1'de yer alan olaylar arasında MV X-Press Pearl kazası, salınan plastik pelet miktarının büyüklüğü ve eş zamanlı olarak petrol, tehlikeli kimyasallar ve ağır metallerin deniz ortamına karışması nedeniyle diğer vakalardan belirgin biçimde ayrılmaktadır (Vithanage vd.,2023; Zhang vd., 2023). Yaklaşık 1.680 ton plastik peletin çevreye yayılması, bu olayı küresel ölçekte kaydedilen en büyük pelet salımlarından biri haline getirmiştir. Şekil 1'de yaşanan olayların ardından çevresel ekosistemlere dair etkilere ilişkin görsel paylaşılmıştır (Jayathilaka vd.,2022; Perera vd., 2022; Sewwandi vd., 2022; Vos vd, 2022; Ratnayake, 2023; ITOPF,2025; Perera vd., 2026; Prasad vd., 2025; Rist vd., 2025; Gayesha vd., 2026). Olayın tropikal kıyı ekosistemlerinde meydana gelmesi, yüzey akıntıları ve kıyı dinamikleri nedeniyle peletlerin geniş alanlara hızla taşınmasına ve kıyı boyunca yoğun birikim oluşturmasına yol açmıştır. Ayrıca kazanın liman sahasına yakın bir bölgede gerçekleşmesi, insan yerleşimleri ve ekonomik faaliyetler üzerindeki etkilerin de artmasına neden olmuştur. Bu özellikler, MV X-Press Pearl vakasını yalnızca büyük ölçekli bir kaza örneği değil, aynı zamanda çoklu kirletici salımı ve yayılım dinamikleri bakımından plastik pelet kirliliğinin çevresel sonuçlarını bütüncül biçimde ortaya koyan referans bir olay olarak öne çıkarmaktadır.

Tablo 1. Yayınlanmış raporlardan, hükümet soruşturmalarından ve bilimsel literatürden derlenen olaylar

Yıl	***Yer / Ülke***	***Olay Türü***	***Tahmini Pelet Miktarı***	***Açıklama***
2012	Hong Kong, Çin **	Konteyner kaybı	~150 ton	Tayfun sonrası denize düşen konteynerlerden büyük miktarda pelet yayılımı
2017	Durban, Güney Afrika **	Konteyner kaybı	~49 ton	MSC Zoe öncesi en büyük Afrika kıyı olaylarından biri
2018	Kuzey Denizi ** (Hollanda/Almanya)	Konteyner kaybı (MSC Zoe)	Bilinmiyor	Geniş kıyı şeridinde pelet birikimi
2019	ABD Körfez Bölgesi	Endüstriyel sızıntı + taşımacılık	Yerel	Liman kaynaklı pelet salımları
2021	Sri Lanka ***	Gemi kazası (MV X-Press Pearl)	**~1,680 ton**	Pelet + petrol + kimyasallar + metaller
2022	İspanya (Galiçya kıyıları) *	Konteyner kaybı	Bilinmiyor	Atlantik kıyısında yayılım

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2023	ABD Doğu Kıyısı *	Taşımacılık kaynaklı sızıntı	Yerel	Liman operasyonlarıyla ilişkili
2024	Hindistan kıyıları *	Gemi kaynaklı kayıp	Bilinmiyor	Bölgesel kirlilik

***Mega olay (≥1000 ton) ** Büyük olay (10–100 ton) *Orta / belirsiz ölçekli olaylar

DEĞERLENDİRME

Bu çalışmada dikkate alınan olay, deniz taşımacılığı sisteminin yapısal kırılganlıklarını açık biçimde ortaya koymaktadır. Plastik peletlerin yüksek hacimlerde taşınması, ambalajlama ve istifleme süreçlerindeki zayıflıklar, konteyner güvenliği ve acil müdahale kapasitesine ilişkin sınırlılıklar, büyük ölçekli salımların yalnızca olağanüstü kazalara özgü olmadığını göstermektedir. Ayrıca peletlerin çoğu zaman çevresel açıdan düşük riskli yük olarak sınıflandırılması, önleyici tedbirlerin ve izleme mekanizmalarının yetersiz kalmasına neden olabilmektedir. Bu durum, kaza sonrasında kirliliğin yayılımını kontrol altına almayı zorlaştırmakta ve sorumluluk paylaşımına ilişkin belirsizlikleri artırmaktadır. Dolayısıyla MV X-Press Pearl kazası, plastik pelet kirliliğinin münferit bir olaydan ziyade küresel deniz taşımacılığı sistemine içkin yapısal risklerin bir sonucu olarak değerlendirilmesi gerektiğini göstermektedir.

Uluslararası Denizcilik Örgütü, deniz çevresinin korunması kapsamında son yıllarda deniz çöpleri ve plastik kirliliği konularını öncelikli gündem maddeleri arasına almıştır. Bu kapsamda, gemi kaynaklı atıkların önlenmesi, yönetimi ve izlenmesine yönelik küresel politika ve rehberler geliştirilmekte; üye devletlerden ulusal politika ve mevzuatlarını bu çerçeveyle uyumlu hâle getirmeleri beklenmektedir. IMO bünyesinde faaliyet gösteren Deniz Çevresini Koruma Komitesi, deniz kirliliğinin önlenmesine ilişkin teknik ve düzenleyici kararların alındığı ana organdır. MEPC gündemlerinde özellikle; gemi kaynaklı plastik atıklar, deniz çöpleri, atık yönetimi ve raporlama sistemleri, iyi uygulama örnekleri ön plana çıkmaktadır. MARPOL Sözleşmesi, gemilerden kaynaklanan kirliliğin önlenmesine yönelik temel uluslararası çerçeveyi oluşturmakla birlikte, yükümlülüklerin uygulanması büyük ölçüde bayrak devleti ve kıyı devleti sorumluluğuna bırakılmıştır. Ulusal düzeyde uygulamada görülen başlıca boşluklar arasında denetim kapasitesinin yetersizliği, liman alım tesislerinin teknik ve operasyonel eksiklikleri, veri paylaşımı ve izleme sistemlerinin sınırlı olması ve yaptırım mekanizmalarının etkin biçimde işletilememesi yer almaktadır. Ayrıca plastik peletlerin çoğu zaman tehlikeli yük kategorisinde değerlendirilmemesi, taşınma ve depolama süreçlerinde özel önleyici tedbirlerin zorunlu tutulmamasına yol açabilmektedir. Olay sonrası müdahale planlarının çoğu ülkede petrol kirliliğine odaklı olması da pelet gibi katı kirleticilere yönelik müdahale kapasitesini sınırlamaktadır. Bu durum, uluslararası yükümlülüklerin varlığına rağmen uygulama, izleme ve yönetişim boyutlarında önemli

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ISBN: 978-9952-610-30-7

boşlukların sürdüğünü ve plastik pelet kirliliğinin önlenmesi için daha bütüncül ulusal politikalar geliştirilmesi gerektiğini göstermektedir.

Avrupa Birliği, deniz ortamının korunması ve plastik kirliliğinin azaltılması konusunda Deniz Stratejisi Çerçeve Direktifi (MSFD), Sıfır Kirlilik Eylem Planı, Döngüsel Ekonomi girişimleri ve plastik stratejileri gibi bütüncül politika araçları geliştirmiştir. Bu yaklaşım, plastik pelet kirliliğinin yalnızca kaza sonrası müdahalelerle değil, üretimden taşımaya ve atık yönetimine kadar tüm yaşam döngüsü boyunca ele alınması gerektiğini ortaya koymaktadır. Benzer şekilde, küresel deniz taşımacılığı bağlamında pelet kayıplarının azaltılması için politika boşluklarının sistematik biçimde tespit edilmesi, uygulanabilir geçiş yol haritalarının oluşturulması ve kamu, özel sektör ve sivil toplum aktörlerinin katılımını içeren çok paydaşlı yönetişim mekanizmalarının güçlendirilmesi önem taşımaktadır. Bu tür bütüncül yaklaşımlar, mevcut düzenleyici çerçevelerin parçalı yapısını aşarak önleyici kapasitenin artırılmasına ve sorumluluk paylaşımının netleştirilmesine katkı sağlayabilir. Dolayısıyla AB politikalarının sunduğu deneyim, plastik pelet kirliliğinin küresel ölçekte yönetimi için tamamlayıcı bir referans çerçevesi olarak değerlendirilebilir.

Bu çalışma, plastik pelet kirliliğinin yalnızca çevresel bir sorun değil, küresel deniz taşımacılığı sistemine içkin yapısal kırılganlıkların bir sonucu olduğunu ortaya koymaktadır. Mevcut düzenleyici çerçeveler büyük ölçekli kazalar ve kronik sızıntılar karşısında önleyici ve müdahale kapasitesi açısından sınırlı kalmakta, sorumluluk ve izleme mekanizmaları ise çoğu zaman yetersiz olmaktadır. Bu nedenle plastik pelet kirliliğinin azaltılması, yalnızca teknik iyileştirmelerle değil, üretimden taşımaya ve kaza sonrası yönetime kadar tüm süreçleri kapsayan yenilikçi yönetişim yaklaşımlarıyla mümkün olabilir. Plastik granül kirliliği, deniz taşımacılığının tesadüfi bir yan ürünü değil, küresel plastik ticaretinin gerçeklerine henüz uyum sağlayamamış bir yönetim sisteminin öngörülebilir bir sonucudur. Küresel ölçekte bağlayıcı düzenlemelerin güçlendirilmesi, risk temelli denetim mekanizmalarının geliştirilmesi ve çok paydaşlı iş birliğinin artırılması, deniz ortamının korunması için kritik öneme sahiptir.

KAYNAKLAR

Andreussi, C. K., Harari, J., Zanetti, D. G., & Leonel, J. (2024). Plastic pellet pathways: Understanding transport patterns to Santa Catarina Island, Southwestern Atlantic Ocean. Marine Pollution Bulletin, 208, 116944. https://doi.org/10.1016/j.marpolbul.2024.116944

An L, Liu Q, Deng Y, Wu W, Gao Y, Ling W 2020. Sources of microplastic in the environment. In: Microplastics in terrestrial environments: Emerging contaminants and major challenges, 143-159. Cham: Springer International Publishing.

Cocozza, P., Scarrica, V. M., Rizzo, A., Serranti, S., Staiano, A., Bonifazi, G., & Anfuso, G. (2025). Microplastic pollution from pellet spillage: Analysis of the Toconao ship accident along the Spanish and Portuguese coasts. Marine Pollution Bulletin, 211. https://doi.org/10.1016/j.marpolbul.2024.117430

Folbert M, Stoorvogel J, & Löhr A 2025. Plastic pellet spills and leakages during maritime transportation: a transdisciplinary approach to understand the complex causal pathways. Marine Pollution Bulletin, 218, 118194.

Galgani, F., & Rangel-Buitrago, N. (2024). White tides: The plastic nurdles problem. Journal of Hazardous Materials, 470. https://doi.org/10.1016/j.jhazmat.2024.134250

Gayesha, E., Kuruppu, G. N., Dushyantha, N., & Dassanayake, S. M. (2026). Post-disaster assessment of the socio-economic and environmental impacts of the MV X-Press Pearl on coastal communities in Sri Lanka. Marine Pollution Bulletin, 222. https://doi.org/10.1016/j.marpolbul.2025.118853

Grgurevic, S., Varela, Z. S., & Boljat, M. (2025). Unseen threats at sea: Awareness of plastic pellets pollution among maritime professionals and students. Sustainability, 17, 6875. https://doi.org/10.3390/su17156875

Hale RC, Seeley ME, La Guardia MJ, Mai L, Zeng EY 2020. A global perspective on microplastics. Journal of Geophysical Research: Oceans, 125: e2018JC014719.

Hwang, D. J. (2020). The IMO Action Plan to Address Marine Plastic Litter from Ships and Its Follow-Up Timeline. In Journal of International Maritime Safety, Environmental Affairs, and Shipping (Vol. 4, Issue 2, pp. 32–39). Informa UK Ltd. https://doi.org/10.1080/25725084.2020.1779428

IMO, 2024. Recommendations for the Carriage of Plastic Pellets* By Sea In Freight Containers. MEPC.1/Circ.909. Available at: https://docs.imo.org/Category.aspx?cid=108 (Accessed 21 February 2026)

International Tanker Owners Pollution Federation Limited (ITOPF). (2025). Response to plastic pellet incidents (Technical Information Paper No. 19). ITOPF. https://www.itopf.org (Accessed at: 28 January 2026)

Jayathilaka, R. M. R. M., Weerakoon, W. R. W. M. A. P., Indika, K. W., Arulananthan, K., & Kithsiri, H. M. P. (2022). Spatio-temporal variation of plastic pellets dispersion in the coastline of Sri Lanka: An assessment of pellets originated from the X-Press Pearl incident during the Southwest monsoon in 2021. Marine Pollution Bulletin, 184. https://doi.org/10.1016/j.marpolbul.2022.114145

Karlsson, T. M., Arneborg, L., Broström, G., Almroth, B. C., Gipperth, L., & Hassellöv, M. (2018). The unaccountability case of plastic pellet pollution. Marine Pollution Bulletin, 129(1), 52–60. https://doi.org/10.1016/j.marpolbul.2018.01.041

Perera, M. M., Abhishek, P., Sewwandi, M., Wijesekara, H., & Vithanage, M. (2026). Weathering induced surface transformation and trace metal affinities of plastic nurdles discharged from the X-Press Pearl ship accident (2021–2024). Marine Environmental Research, 214. https://doi.org/10.1016/j.marenvres.2025.107767

Perera, U. L. H. P., Subasinghe, H. C. S., Ratnayake, A. S., Weerasingha, W. A. D. B., & Wijewardhana, T. D. U. (2022). Maritime pollution in the Indian Ocean after the MV X-Press Pearl accident. Marine Pollution Bulletin, 185. https://doi.org/10.1016/j.marpolbul.2022.114301

Prasad, S. J., Mohanty, P. C., Balakrishnan Nair, T. M., Joseph, S., & Srinivasa Kumar, T. (2025). Modeling and comparison of plastic nurdle drift from the MV X-Press Pearl wreck: Estimating the extent of mangroves and corals affected and peak arrival in Gampaha, Sri Lanka. Environmental Pollution, 385. https://doi.org/10.1016/j.envpol.2025.127045

Ratnayake, A. S. (2023). Marine pollution after the MV X-Press Pearl maritime disaster: Societal impacts based on research outcomes. Societal Impacts, 1(1–2), 100003. https://doi.org/10.1016/j.socimp.2023.100003

Rist, S., Ugwu, K., Sampalo, M., Karlsson, T. M., Rubesinghe, C. H., Acosta-Dacal, A., Pérez-Luzardo, O., Zumbado, M., & Almeda, R. (2025). Impacts of spilled debris from the X-Press Pearl disaster in Sri Lanka on marine plankton. Environmental Research, 274. https://doi.org/10.1016/j.envres.2025.121260

Saliba, M., Frantzi, S., & van Beukering, P. (2022). Shipping spills and plastic pollution: A review of maritime governance in the North Sea. Marine Pollution Bulletin, 181. https://doi.org/10.1016/j.marpolbul.2022.113939

Sewwandi, M., Amarathunga, A. A. D., Wijesekara, H., Mahatantila, K., & Vithanage, M. (2022). Contamination and distribution of buried microplastics in Sarakkuwa beach ensuing the MV X-Press Pearl maritime disaster in Sri Lankan sea. Marine Pollution Bulletin, 184. https://doi.org/10.1016/j.marpolbul.2022.114074

Vidal-Abad, A., Casal, M. A., Rey-Aguiño, J. M., Pichel-González, A., Solana-Muñoz, A., Poza-Nogueiras, V., Varela, Z., Galbán-Malagón, C., Ouro, P., & Fernández-Sanlés, A. (2024). Case report of plastic nurdles pollution in Galicia (NW Atlantic) following the Toconao's spill in December 2023: The

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

VIEIRA Collaborative. Marine Pollution Bulletin, 203. https://doi.org/10.1016/j.marpolbul.2024.116442

Vithanage, M., de Alwis, A., Cumaranatunga, R., Botheju, D., & Wells, M. (2023). Maritime disasters and pollution: X-Press Pearl maritime debacle. In Marine Pollution Bulletin (Vol. 196). Elsevier Ltd. https://doi.org/10.1016/j.marpolbul.2023.115532

Vos, A., Aluwihare, L., Youngs, S., Dibenedetto, M. H., Ward, C. P., Michel, A. P. M., Colson, B. C., Mazzotta, M. G., Walsh, A. N., Nelson, R. K., Reddy, C. M., & James, B. D. (2022). The M/V X-Press Pearl Nurdle Spill: Contamination of Burnt Plastic and Unburnt Nurdles along Sri Lanka's Beaches. ACS Environmental Au, 2(2), 128–135. https://doi.org/10.1021/acsenvironau.1c00031

Zhang, X., Jiang, M., Zhu, Y., Li, B., & Wells, M. (2023). The X-Press Pearl disaster underscores gross neglect in the environmental management of shipping: Review of future data needs. Marine Pollution Bulletin, 189. https://doi.org/10.1016/j.marpolbul.2023.114728

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A COMPARATIVE SPEECH ENHANCEMENT ANALYSIS ON TURKISH AND ENGLISH USING AN ATTENTION-BASED WAVE-U-NET ARCHITECTURE

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ABSTRACT

Speech enhancement (SE) is a signal processing problem aimed at improving the intelligibility and quality of speech signals in noisy environments. While the vast majority of studies in the literature focus on English datasets, performance analyses on languages with unique phonetic characteristics and agglutinative structures, such as Turkish, remain limited. In this study, an Attention Wave-U-Net architecture is proposed, which provides end-to-end enhancement via raw waveforms and is reinforced with residual blocks, channel attention, and self-attention mechanisms. Within the scope of the study, a large-scale analysis was conducted using a total of 70,939 audio files, including English and Turkish languages. To evaluate the robustness of the model, real-world noises selected from the Microsoft DNS Challenge dataset and synthetic white noise were integrated into clean signals at various SNR levels (0-15 dB). Experimental results demonstrate that the proposed method provides significant improvement in both languages yet exhibits superior performance particularly on the Turkish dataset. In Turkish data, the average PESQ score was increased to 3.1875, while an average gain of 19.7768 dB was achieved in the time-domain SI-SNR metric. In the English set, the average PESQ score was raised to 2.5813, with a recorded average SI-SNR gain of 10.6260 dB. These results reveal the adaptation capability of attention-based models to language-specific acoustic characteristics and contribute to speech enhancement research conducted on the Turkish language.

Keywords: Speech enhancement, deep learning, Wave-U-Net, VCTK, Turkish dataset

1. INTRODUCTION

A clean and intelligible speech signal is an indispensable requirement for mobile telecommunications, hearing aids, automated speech recognition (ASR) systems, and voice-command-operated interfaces. However, environmental noises—such as traffic, crowd noise, and wind—degrade signal quality and

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

adversely affect system performance. To address this issue, traditional methods primarily relied on filtering techniques to suppress noise.

With recent technological advancements, deep neural network (DNN)-based methods have replaced traditional filtering to become the standard in the field of speech enhancement (SE). Wang et al. (2014) took the first major step in this domain by demonstrating the success of time-frequency masking methods combined with deep learning. Subsequently, Pascual et al. (2017) proved the effectiveness of end-to-end models that directly process raw waveforms with the speech enhancement GAN (SEGAN) study. This approach improved signal quality by ensuring the preservation of phase information.

Among the most successful examples of time-domain models is the Wave-U-Net architecture proposed by Stoller et al. (2018). Adapting the U-Net structure for audio, this model stands out for its memory efficiency and high performance. Alternatively, DCCRN (Hu et al., 2020), which utilizes complex-valued networks, achieved state-of-the-art (SOTA) results by modeling both magnitude and phase. Furthermore, DEMUCS, developed by Defossez et al. (2020), reinforced the power of time-domain models in music source separation and speech enhancement tasks.

However, in standard U-Net architectures, skip connections between the encoder and decoder carry the risk of propagating noisy features to the output. To mitigate this, Oktay et al. (2018) proposed "attention gates" in medical imaging. Similarly, in the audio domain, Giri et al. (2019) demonstrated that attention mechanisms increase focus during noise suppression. Pandey and Wang (2019) emphasized the importance of contextual information through dense convolutional neural networks (DenseCNN).

Literature review reveals that the majority of studies concentrate on English datasets such as VoiceBank-DEMAND (Botinhao et al., 2016) and TIMIT (Garofalo et al., 1993). While there are some studies on deep learning-based speech enhancement for languages with agglutinative morphology like Turkish, they remain quite limited. To provide a new perspective to the current literature and support the scarce research in this area, this study presents a comparative performance analysis of an attention-based Wave-U-Net model on Turkish and English datasets.

2. MATERIALS AND METHODS

2.1. Dataset

In this study, a comprehensive data pool was established using a total of 70,939 audio files recorded in English and Turkish (Table 1):

- **English Dataset (Voice Cloning Toolkit (VCTK) Corpus):** The VCTK Corpus dataset, published by the University of Edinburgh's Centre for Speech Technology Research (CSTR), was utilized (Yamagishi et al., 2019). To minimize acoustic reverberation, 44,455 clean audio files were

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

selected from the "Mic1" channel, which features omni-directional characteristics. The audio files have a sampling rate of 16 kHz.

- **Turkish Dataset:** The "Turkish Speech Command Dataset," prepared by Murat Kurtkaya, was utilized (Kurtkaya, 2025). This dataset, which has a sampling rate of 16 kHz, contains 26,484 recordings consisting of isolated words from daily language.

Table 1. Dataset split

Dataset	Train	Validation	Test	Total
English	31,119	6,668	6,668	44,455
Turkish	18,540	3,972	3,972	26,484
Total	49,659	10,640	10,640	70,939

- **Noise Integration and SNR Levels:** For the generation of noisy audio files, four distinct noise sources were utilized: real-world noises (air conditioner outdoor unit, vacuum cleaner, and dishwasher) selected from the Microsoft DNS Challenge dataset (Reddy et al., 2020), and synthetic white noise. To evaluate the robustness of the model, SNR levels of 0 dB, 5 dB, 10 dB, and 15 dB were employed. The noise files were integrated into the clean audio tracks from both datasets, distributed in a balanced manner across the specified SNR levels.

2.2. Proposed Model

In this study, a DNN based on the Wave-U-Net architecture proposed by Stoller et al. (2018), reinforced with attention mechanisms, was utilized to provide end-to-end speech enhancement on raw waveforms. While maintaining the standard encoder-decoder structure, the model was redesigned with residual blocks (He et al., 2016) to enhance feature extraction capabilities and overcome the vanishing gradient problem commonly observed in deep networks.

2.2.1. Architectural Details and Attention Mechanisms

The model consists of an encoder that progressively reduces the input signal into lower-dimensional feature spaces, a bottleneck layer that processes these features with high-level representations, and a decoder that reconstructs the signal back to its original dimensions. To suppress noise components within the feature maps and emphasize speech features, two distinct attention mechanisms have been integrated:

a) **Channel Attention:** Embedded within each Residual Block, this module operates based on the "squeeze-and-excitation" principle proposed by Hu et al. (2018). Utilizing the global spatial

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information of the feature maps, this structure learns inter-channel dependencies and dynamically weights the channels that carry significant information.

b) Self-Attention: At the bottleneck layer, which represents the deepest point of the network, the self-attention mechanism developed by Vaswani et al. (2017) is positioned. This structure allows for modeling long-range dependencies across the time axis of the signal, effectively overcoming the local receptive field limitations of convolutional layers (Zhang et al., 2019).

Mathematically, for an input tensor, the output of the channel attention can be expressed as follows:

$$Y = \sigma(MLP(AvgPool(X)) + MLP(MaxPool(X))).X \quad (1)$$

Where σ represents the sigmoid activation function, and MLP denotes the multi-layer perceptron.

2.2.2. Loss Function and Optimization

During the training process, a multi-component hybrid loss function (L_{total}) was designed to ensure that the model produces consistent results in both time and frequency domains, rather than relying on a single metric. This function consists of three primary terms:

$$L_{total} = \lambda_1 L_{time} + \lambda_2 L_{SI\text{-}SNR} + \lambda_3 L_{STFT} \quad (2)$$

Where;

- L_{time}: Measures the absolute difference based on the norm L_1 (Mean Absolute Error - MAE) between the predicted and the target signal.
- $L_{SI\text{-}SNR}$: Represents the Scale-Invariant Signal-to-Noise Ratio loss as defined by Le Roux et al. (2019); it minimizes structural distortion independently of the signal's amplitude level.
- L_{STFT}: Denotes the Multi-Resolution STFT loss proposed by Yamamoto et al. (2020). This component supervises both magnitude and phase alignment through STFT transforms computed with various window sizes.

The coefficients in the loss function were experimentally determined as $\lambda_1 = 0.25$, $\lambda_2 = 0.35$, and $\lambda_3 = 0.40$. The model was trained using the AdamW optimization algorithm (Loshchilov and Hutter, 2017) with an initial learning rate of $6e$-4.

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ISBN: 978-9952-610-30-7

2.3. Evaluation Metrics

To evaluate the performance of the developed model, three different objective metrics focusing on perceptual quality, intelligibility, and signal fidelity were utilized:

2.3.1. PESQ (Perceptual Evaluation of Speech Quality): The PESQ metric, widely recognized as the industry standard for objective quality measurements, was utilized. Defined by the International Telecommunication Union (ITU-T) P.862 standard, this method analyzes the perceptual differences between the clean reference signal and the processed signal. The algorithm, which models the psychophysical characteristics of the human auditory system, generates a quality score between -0.5 and 4.5 that exhibits a high correlation with subjective mean opinion score (MOS) tests (Rix et al., 2001).

2.3.2. STOI (Short-Time Objective Intelligibility): To measure the intelligibility of the processed signals, the STOI metric, which is based on the correlation coefficient between the short-time envelopes of clean and degraded speech signals, was preferred (Taal et al., 2011). Unlike traditional methods, this metric exhibits high success in predicting the performance of especially time-frequency weighted noise reduction techniques. The STOI score takes values between 0 and 1, exhibiting a monotonic relationship with speech intelligibility, where a value of 1 represents perfect intelligibility.

2.3.3. SI-SNR (Scale-Invariant Signal-to-Noise Ratio): The SI-SNR metric was utilized to measure the model's success in the time-domain. This metric is calculated by orthogonally projecting the estimated signal onto the reference signal (Le Roux et al., 2019). Unlike conventional SNR metrics, SI-SNR does not treat potential gain differences in the output signal as errors; instead, it focuses directly on the structural integrity of the signal and the effectiveness of noise reduction. Widely used in the deep learning-based speech enhancement literature, this metric is expressed in decibels (dB), where higher values indicate superior performance.

2.4. Training Process and Evaluation

The training process was conducted on the PyTorch library utilizing NVIDIA L4 GPU hardware. To analyze the overall success of the model and the performance differences between languages, the following procedures were implemented:

- **Data Partitioning:** The Turkish and English datasets were divided into 70% training, 15% validation, and 15% test sets. To enhance the statistical reliability of the results, a method similar to "3-fold random split" was followed: while the test data remained constant across all experiments, the training and validation sets were randomly regenerated three times, and the results obtained were averaged.

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ISBN: 978-9952-610-30-7

- **Hyperparameters:** During training, the "batch size" was set to 24, and the "chunk size" was determined as 1 second (16,000 samples). The model was trained using the AdamW optimization algorithm (Loshchilov and Hutter, 2019) with the specified initial learning rate.

3. RESULTS AND DISCUSSION

3.1. Results

In this section, the performance of the proposed Attention Wave-U-Net model is presented through PESQ, STOI, and SI-SNR metrics. To verify the accuracy of the results, experiments were conducted on three different random data distributions (Data1, Data2, and Data3).

3.1.1. PESQ Performance Analysis

The test results conducted to determine the effectiveness of the proposed model on perceptual quality are presented in Table 2. The findings demonstrate that the model achieves significant improvements in noise suppression and signal reconstruction across both languages. Analysis of Table 2 reveals that for the English (ENG) dataset, the average PESQ score increased from 1.289 to 2.5813, yielding an average gain of +1.2923 points. In the Turkish (TUR) dataset, the initial noisy signal score of 1.4777 reached 3.1875 post-enhancement, exhibiting an average increase of +1.7098 points.

The highest success of the model on the Turkish dataset was recorded with a gain of +1.7287 (Data2). Notably, this value is approximately 30% higher than the peak gain observed in the English set (+1.3315). This situation indicates that the proposed attention-based Wave-U-Net architecture achieves high adaptation to the spectral characteristics of the Turkish language and exhibits a more effective performance in cleaning the noise profiles within the Turkish dataset.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Table 2. PESQ performance results on English and Turkish datasets

Datasets		PESQ		
		Noisy	**Enhanced**	**Gain**
ENG	Data1	1.2890	2.5785	1.2895
	Data2	**1.2890**	**2.6205**	**1.3315**
	Data3	1.2890	2.5449	1.2559
	Average	1.2890	2.5813	1.2923
TUR	Data1	1.4777	3.1911	1.7134
	Data2	**1.4777**	**3.2064**	**1.7287**
	Data3	1.4777	3.1650	1.6873
	Average	1.4777	3.1875	1.7098

3.1.2. STOI Performance Analysis

The STOI results, which measure speech intelligibility, are presented in Table 3. The model successfully improved the intelligibility of noisy signals in both languages. In the English dataset, the average STOI score of noisy signals increased from 0.7262 to 0.8294 (Gain: 0.1032) post-enhancement. In the Turkish dataset, the initial score of 0.7751 reached 0.8492 (Gain: 0.0741).

Contrary to the PESQ results, the net gain in STOI scores was observed to be higher in the English dataset (0.1051). This situation indicates that the model is more effective at preserving and emphasizing short-time envelope features within the English phonetic structure. The STOI scores achieved above 0.80 in both languages confirm that the model successfully maintains structural intelligibility while denosing speech signals.

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ISBN: 978-9952-610-30-7

Table 3. STOI performance results on English and Turkish datasets

Datasets		STOI		
		Noisy	**Enhanced**	**Gain**
ENG	Data1	0.7262	0.8269	0.1007
	Data2	**0.7262**	**0.8313**	**0.1051**
	Data3	0.7262	0.8300	0.1038
	Average	0.7262	0.8294	0.1032
TUR	Data1	0.7751	0.8485	0.0734
	Data2	**0.7751**	**0.8495**	**0.0744**
	Data3	0.7751	0.8495	0.0744
	Average	0.7751	0.8492	0.0741

3.1.3. SI-SNR Performance Analysis

The SI-SNR results, which measure the structural integrity of the signal, are presented in Table 4. According to the findings, the model achieved an average gain of 19.7768 dB on the Turkish dataset, nearly doubling the 10.6260 dB gain observed in the English dataset.

The 27.5638 dB level reached specifically in the Turkish Data2 set serves as the most concrete indicator of the model's signal reconstruction capability in the time-domain. Despite similar initial noise levels in the Turkish set, this significant difference highlights the architecture's superiority in isolating vocal energy within the Turkish language.

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ISBN: 978-9952-610-30-7

Table 4. SI-SNR performance results on English and Turkish datasets

Datasets		SI-SNR		
		Noisy	**Enhanced**	**Gain**
ENG	Data1	7.4993	18.2621	10.7628
	Data2	**7.4993**	**18.4812**	**10.9819**
	Data3	7.4993	17.6326	10.1333
	Average	7.4993	18.1253	10.6260
TUR	Data1	7.5004	27.2807	19.7803
	Data2	**7.5004**	**27.5638**	**20.0634**
	Data3	7.5004	26.9871	19.4867
	Average	7.5004	27.2772	19.7768

3.1.4. Spectrogram Analysis

Observations from Figure 1 and Figure 2 indicate that the model maintains consistent performance even when the datasets are randomly shuffled across three iterations. This consistency demonstrates the reliability of the study and confirms the model's robust performance.

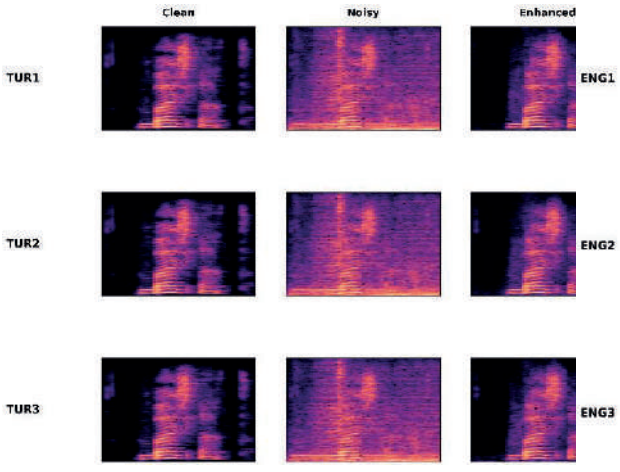


Figure 1. Spectrogram analysis of the Turkish dataset

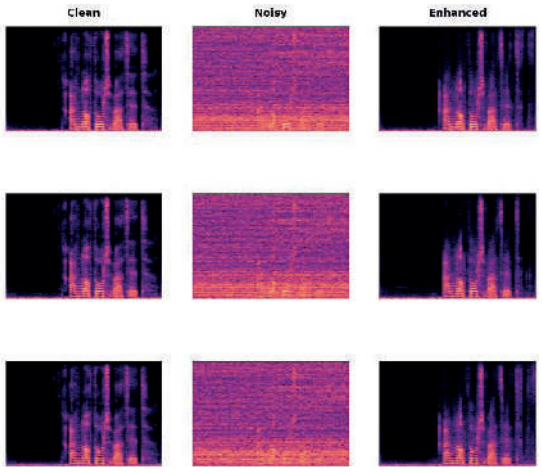


Figure 2. Spectrogram analysis of the English dataset

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ISBN: 978-9952-610-30-7

3.2. Discussion

In light of the data presented in the results section, the model's performance on the Turkish dataset was found to be more successful.

- **Comparison of Turkish and English:** The gains in PESQ (+1.7098) and SI-SNR (+19.7768 dB) on the Turkish dataset are significantly higher than those achieved on the English set. This suggests that the phonetic structure of Turkish, combined with the isolated word characteristics used in the experiments, was modeled more effectively by the architecture. Conversely, the higher STOI gain in the English set (+0.1032) proves that the model is particularly successful in preserving temporal envelope features in the VCTK dataset, which consists of fluent speech.

- **Experimental Stability:** The fact that the scores obtained from three different data distributions (Data1-2-3) are remarkably close—indicating low standard deviation—proves that the training process of the proposed architecture is highly stable and remains unaffected by random data fluctuations.

- **Architectural Evaluation:** The structure, reinforced with residual blocks and attention mechanisms, demonstrated high efficacy in the end-to-end learning process via raw waveforms. The consistent results across both Turkish and English sets reveal the architecture's capability to suppress noise and ensure signal integrity across diverse phonetic structures.

4. CONCLUSION

In this study, the speech enhancement performance of the Wave-U-Net architecture—reinforced with attention mechanisms and residual connections to provide end-to-end learning via raw waveforms—was analyzed across Turkish and English languages. The experimental findings confirm that the developed model achieves successful results in noise suppression and signal quality improvement for both languages. The model's performance on the Turkish dataset, with a 3.1875 PESQ score and a 19.7768 dB SI-SNR gain, significantly outperformed the 2.5813 PESQ score and 10.6260 dB SI-SNR gain observed in the English dataset across both primary metrics. This performance disparity reveals that the phonetic structure and noise profiles of Turkish are modeled with higher accuracy by the attention-based architecture.

However, the higher net gain in STOI scores within the English set (+0.1032), representing speech intelligibility, demonstrates the architecture's efficacy in preserving temporal envelope features within fluent speech structures. Consequently, the proposed attention-based Wave-U-Net architecture has quantitatively proven the impact of cross-linguistic phonetic differences on deep learning models and contributed to filling a gap in the Turkish speech enhancement literature.

In future studies, to further enhance success in the field of Turkish speech enhancement, research can be conducted on datasets containing fluent speech from broader and more diverse acoustic environments, rather than being limited to isolated words. Furthermore, the performance of the proposed architecture can be compared with other state-of-the-art deep learning models in the literature.

REFERENCES

Botinhao, C. V., Wang, X., Takaki, S., & Yamagishi, J. (2016). Investigating RNN-based speech enhancement methods for noise-robust text-to-speech. In 9th ISCA speech synthesis workshop (pp. 159-165).

Defossez, A., Synnaeve, G., & Adi, Y. (2020). Real time speech enhancement in the waveform domain. arXiv preprint arXiv:2006.12847.

Garofalo, J. S., Lamel, L. F., Fisher, W. M., Fiscus, J. G., Pallett, D. S., & Dahlgren, N. L. (1993). Darpa timit acoustic-phonetic continuous speech corpus cdrom. Technical report, U.S. Dept. of Commerce, NIST, Gaithersburg, MD.

Giri, R., Isik, U., & Krishnaswamy, A. (2019, October). Attention wave-u-net for speech enhancement. In 2019 IEEE Workshop on Applications of Signal Processing to Audio and Acoustics (WASPAA) (pp. 249-253). IEEE.

He, K., Zhang, X., Ren, S., & Sun, J. (2016). Deep residual learning for image recognition. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 770-778).

Hu, J., Shen, L., & Sun, G. (2018). Squeeze-and-excitation networks. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 7132-7141).

Hu, Y., Liu, Y., Lv, S., Xing, M., Zhang, S., Fu, Y., ... & Xie, L. (2020). DCCRN: Deep complex convolution recurrent network for phase-aware speech enhancement. arXiv preprint arXiv:2008.00264.

Kurtkaya, M. (2025). Turkish speech command dataset. Kaggle. Retrieved July 14, 2025, from https://www.kaggle.com/datasets/muratkurtkaya/turkish-speech-command-dataset.

Le Roux, J., Wisdom, S., Erdogan, H., & Hershey, J. R. (2019, May). SDR–half-baked or well done?. In ICASSP 2019-2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) (pp. 626-630). IEEE.

Loshchilov, I., & Hutter, F. (2017). Decoupled weight decay regularization. arXiv preprint arXiv:1711.05101.

Oktay, O., Schlemper, J., Folgoc, L. L., Lee, M., Heinrich, M., Misawa, K., ... & Rueckert, D. (2018). Attention u-net: Learning where to look for the pancreas. arXiv preprint arXiv:1804.03999.

Pandey, A., & Wang, D. (2021). Dense CNN with self-attention for time-domain speech enhancement. IEEE/ACM transactions on audio, speech, and language processing, 29, 1270-1279.

Pascual, S., Bonafonte, A., & Serra, J. (2017). SEGAN: Speech enhancement generative adversarial network. arXiv preprint arXiv:1703.09452.

Reddy, C. K., Gopal, V., Cutler, R., Beyrami, E., Cheng, R., Dubey, H., ... & Gehrke, J. (2020). The interspeech 2020 deep noise suppression challenge: Datasets, subjective testing framework, and challenge results. arXiv preprint arXiv:2005.13981.

Rix, A. W., Beerends, J. G., Hollier, M. P., & Hekstra, A. P. (2001, May). Perceptual evaluation of speech quality (PESQ)-a new method for speech quality assessment of telephone networks and codecs. In 2001 IEEE international conference on acoustics, speech, and signal processing. Proceedings (Vol. 2, pp. 749-752). IEEE.

Stoller, D., Ewert, S., & Dixon, S. (2018). Wave-u-net: A multi-scale neural network for end-to-end audio source separation. arXiv preprint arXiv:1806.03185.

Taal, C. H., Hendriks, R. C., Heusdens, R., & Jensen, J. (2011). An algorithm for intelligibility prediction of time–frequency weighted noisy speech. IEEE Transactions on audio, speech, and language processing, 19(7), 2125-2136.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N., ... & Polosukhin, I. (2017). Attention is all you need. Advances in neural information processing systems, 30.

Wang, Y., Narayanan, A., & Wang, D. (2014). On training targets for supervised speech separation. IEEE/ACM transactions on audio, speech, and language processing, 22(12), 1849-1858.

Yamagishi, J., Veaux, C., & MacDonald, K. (2019). CSTR VCTK Corpus: English multi-speaker corpus for CSTR voice cloning toolkit (version 0.92).

Yamamoto, R., Song, E., & Kim, J. M. (2020, May). Parallel WaveGAN: A fast waveform generation model based on generative adversarial networks with multi-resolution spectrogram. In ICASSP 2020-2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP) (pp. 6199-6203). IEEE.

Zhang, H., Goodfellow, I., Metaxas, D., & Odena, A. (2019, May). Self-attention generative adversarial networks. In International conference on machine learning (pp. 7354-7363). PMLR.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İKİ DOĞRULTULU DEPREM ETKİSİ ALTINDAKİ YÜZEYSEL TEMELLERDE YÜK EĞİKLİK KATSAYILARININ EC 7-3 (2025)'E GÖRE HESAPLANMASI

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ÖZET

Bu çalışmada, iki yatay doğrultuda eşzamanlı deprem etkisi altındaki yüzeysel temellerde yük eğiklik katsayılarının hesaplanmasına açıklık getirilmesi amaçlanmıştır. Türkiye Bina Deprem Yönetmeliği (TBDY-2018) kapsamında tanımlanan deprem yük birleşimleri esas alınarak, Eurocode 7-3 (2025)'te verilen yük eğiklik katsayısı bağıntılarının uygulanışı sayısal bir örnek üzerinden gösterilmiştir. Bu amaçla, deprem bölgesinde projelendirilmiş sekiz katlı betonarme bir binaya ait yapısal analiz sonuçları kullanılarak temele etkiyen devrilme momentleri, düşey yükler ile iki doğrultudaki taban kesme kuvvetleri belirlenmiş, yatay kuvvetlerin vektörel bileşkesi ve plan düzlemindeki yönü dikkate alınarak yük eğiklik katsayıları hesaplanmıştır. Elde edilen sonuçlar, iki doğrultulu deprem etkisinin yük eğiklik katsayıları aracılığıyla temel taşıma gücünü önemli ölçüde azaltabildiğini göstermiştir. Çalışmada, iki doğrultulu yükleme durumunda yük eğiklik katsayılarının sistematik ve tutarlı bir biçimde hesaplanmasına yönelik uygulama adımları ortaya konularak bu hususta literatürdeki belirsizliğin giderilmesine katkı sunulmuştur.

Anahtar Kelimeler: Yüzeysel temel, Taşıma gücü, Yük eğiklik katsayısı, İki doğrultulu yükleme

CALCULATION OF LOAD INCLINATION FACTORS FOR SHALLOW FOUNDATIONS UNDER BIDIRECTIONAL SEISMIC LOADING ACCORDING TO EC 7-3 (2025)

ABSTRACT

This study aims to clarify the calculation of load inclination factors for shallow foundations subjected to simultaneous seismic loading in two horizontal directions. Based on the seismic load combinations defined in the Turkish Building Earthquake Code (TBEC-2018), the application of the load inclination factor equations provided in Eurocode 7-3 (2025) is demonstrated through a numerical example. For this purpose, structural analysis results of an eight-story reinforced concrete building designed in a seismic region were utilized to determine the overturning moments, vertical loads, and base shear forces acting on the foundation in two orthogonal directions. The load inclination factors were

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

calculated by considering the vectorial resultant of the horizontal forces and its orientation in the foundation plan. The results indicate that bidirectional seismic effects may significantly reduce the bearing capacity of shallow foundations through load inclination factors. By presenting systematic and consistent calculation steps for bidirectional loading conditions, the study contributes to reducing the existing ambiguity in the literature on this issue.

Keywords: Shallow foundation; Bearing capacity; Load inclination factor; Bidirectional loading

1. GİRİŞ

Türkiye Bina Deprem Yönetmeliği-2018 (TBDY-2018)'e göre deprem etkisi altındaki binaların temel taşıma gücü, aşağıda verilen genel taşıma gücü denklemiyle hesaplanmaktadır.

$$q_k = cN_c s_c d_c \boldsymbol{i_c} g_c b_c + qN_q s_q d_q \boldsymbol{i_q} g_q b_q + 0.5\gamma B' N_\gamma s_\gamma d_\gamma \boldsymbol{i_\gamma} g_\gamma b_\gamma \quad (1)$$

Bu denklemde; q_k taşıma gücü karakteristik dayanımını, c zeminin kohezyon değerini, B' temelin etkin genişliğini (kısa kenarını), q temel tabanı seviyesindeki sürşarj yükünü, γ zeminin birim hacim ağırlığını, N_c, N_q, N_γ taşıma gücü katsayılarını, s, d, i, g ve b sırasıyla şekil, derinlik, yük eğiklik, zemin yüzeyi eğimi ve temel taban eğimi düzeltme katsayılarını ifade etmektedir.

Eş. (1) ile hesaplanan taşıma gücü karakteristik dayanımı, TBDY-2018'de γ_{Rv} olarak tanımlanan dayanım katsayısına bölünerek "*taşıma gücü tasarım dayanımı*" (q_t) elde edilmektedir (Eş. 2). TBDY-2018'de yüzeysel temeller için $\gamma_{Rv} = 1.4$ alınması önerilmektedir.

$$q_t = \frac{q_k}{\gamma_{Rv}} \quad (2)$$

TBDY-2018'e göre temel taşıma gücünün yeterli kabul edilebilmesi için, statik ve deprem etkilerini içeren yükleme durumlarının her biri için hesaplanan taşıma gücü tasarım dayanımının, ilgili yük birleşimine karşılık gelen temel taban basıncından büyük veya ona eşit olması gerekmektedir ($q_0 \leq q_t$). Bu eşitsizlikte yer alan temel taban basıncı (q_0), ilgili yük birleşimi altında temele etkiyen düşey yüklerin etkin temel taban alanına (A') bölünmesiyle hesaplanmaktadır.

Deprem gibi son derece karmaşık bir dinamik olayın yapı üzerindeki etkileri, mühendislik uygulamalarında eşdeğer statik yaklaşımlar çerçevesinde idealize edilerek yansıtılmaktadır. Newton'un ikinci hareket kanununa dayalı olarak elde edilen eşdeğer statik taban kesme kuvvetleri ve devrilme momentleri, yapısal analizlerde depremin etkisini yansıtan girdileri oluşturmaktadır. Geoteknik temel tasarımında da deprem etkisi, bu taban kesme kuvvetleri ve devrilme momentler aracılığıyla taşıma gücü hesaplarına dahil edilmektedir.

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TBDY-2018'de deprem etkilerini içeren yapısal analizlerde dikkate alınması önerilen yük birleşimleri Eş. (3)–(6)'da verilmiştir. Bu eşitliklerden görüleceği üzere, deprem etkisinin iki yatay doğrultuda eşzamanlı olarak dikkate alınması esası benimsenmiştir. Örneğin Eş. (3)'te deprem etkisinin esas doğrultusu X yönü olup, aynı anda bunun %30'u oranında Y yönündeki deprem etkisi de hesaba katılmaktadır. Benzer bir yaklaşım diğer yük birleşimleri için de geçerlidir. Böylece yapıların yalnızca tek bir doğrultuda değil, iki yatay doğrultuda eşzamanlı olarak deprem etkisine maruz kalacağı varsayılmaktadır.

$$G + Q + 0.2S \pm E_{d(X)} \pm 0.3E_{d(Y)} + 0.3E_{d(z)} \quad (3)$$

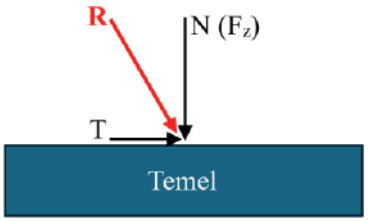
$$G + Q + 0.2S \pm E_{d(Y)} \pm 0.3E_{d(X)} + 0.3E_{d(z)} \quad (4)$$

$$0.9G + H \pm E_{d(X)} \pm 0.3E_{d(Y)} - 0.3E_{d(z)} \quad (5)$$

$$0.9G + H \pm E_{d(Y)} \pm 0.3E_{d(X)} - 0.3E_{d(z)} \quad (6)$$

TBDY-2018'e göre taşıma gücü hesaplarında deprem etkisi; yük eğiklik katsayıları (i_c, i_q, i_γ), etkin temel genişliği (B') ve etkin temel taban alanı kullanılarak dikkate alınmaktadır. Bu çalışmada özellikle yük eğiklik katsayılarının hesaplanmasına odaklanılmıştır.

Statik durumda yükler çoğunlukla temel tabanına dik doğrultuda etki eder. Ancak deprem sırasında oluşan yatay taban kesme kuvvetleri ile düşey yüklerin bileşkesi, temele eğik doğrultuda etkiyen bir bileşke kuvvet oluşturur (Şekil 1). Yükün eğik doğrultuda etki etmesi, taşıma gücünü azaltıcı bir etki göstermekte olup, bu azalım bazı durumlarda önemli mertebelere ulaşabilmektedir (Hansen, 1970). Bu nedenle deprem etkisinin temel taşıma gücü hesabına doğru biçimde yansıtılabilmesi için yük eğiklik katsayılarının uygun ve tutarlı bir şekilde hesaplanması büyük önem taşımaktadır.



Şekil 1. Taban kesme kuvvetleri nedeniyle bina temeline etkiyen eğik yük, R

Yük eğiklik katsayılarına ilişkin olarak literatürde farklı bağıntılar önerilmiştir. Özellikle G. G. Meyerhof (1956), J. Brinch Hansen (1961, 1970) ve A. S. Vesic (1975) tarafından geliştirilen yaklaşımlar yaygın olarak kullanılmaktadır. Ayrıca resmi standart niteliğindeki Eurocode 7-3 (2025)'te de, bu çalışmalardan yararlanılarak geliştirilmiş bağıntılar yer almaktadır.

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Literatürdeki temel eksiklik, iki yatay doğrultuda eşzamanlı etkiyen deprem kuvvetlerinin yük eğiklik katsayılarının hesabına nasıl dahil edileceğinin açık bir biçimde ortaya konulmamış olmasıdır. Çoğu kaynakta yükün yalnızca tek bir doğrultuda eğik olduğu varsayılmış, iki doğrultulu eğik yük etkimesi durumuna ilişkin uygulama adımları ayrıntılı bir biçimde verilmemiştir (Örneğin Coduto vd., 2016; Das ve Sivakugan, 2019).

Bu çalışmada, sayısal bir uygulama üzerinden EC 7-3 (2025)'te önerilen yük eğiklik katsayılarının, iki yatay doğrultuda eşzamanlı olarak deprem etkisine maruz kalan binalarda nasıl hesaplanması gerektiğine açıklık getirilmesi amaçlanmıştır. Bu amaçla, deprem bölgesinde projelendirilmiş sekiz katlı betonarme bir binaya ait yapısal analiz sonuçları kullanılmıştır.

2. KURAMSAL TEMELLER

EC-7-3 (2025)'te yük eğiklik katsayılarının hesabına ilişkin bağıntılar Eş. (7)–(13)'te verilmiştir. Bu bağıntılar, temele etkiyen düşey yük (N) ile temel tabanına teğet doğrultuda etkiyen yatay yük (T) arasındaki ilişkiye dayanmaktadır.

$$i_c = \frac{1}{2}\left(1 + \sqrt{1 - \frac{T}{A' c_u}}\right) \qquad (\phi = 0°) \text{ ve } (T \le A' c_u) \text{ için} \qquad (7)$$

$$i_c = i_q - \left(\frac{1 - i_q}{N_c \tan\phi}\right) = \frac{i_q N_q - 1}{N_q - 1} \qquad (\phi > 0°) \text{ için} \qquad (8)$$

$$i_q = \left(1 - \frac{T}{N}\right)^m \qquad (\phi > 0°) \text{ için} \qquad (9)$$

$$i_\gamma = \left(1 - \frac{T}{N}\right)^{m+1} \qquad (\phi > 0°) \text{ için} \qquad (10)$$

$$m = m_B = \frac{2 + (B'/L')}{1 + (B'/L')} \qquad (T \text{ kuvveti } B' \text{ doğrultusundan etki ediyorsa}) \qquad (11)$$

$$m = m_L = \frac{2 + (L'/B')}{1 + (L'/B')} \qquad (T \text{ kuvveti } L' \text{ doğrultusundan etki ediyorsa}) \qquad (12)$$

$$m = m_\theta = m_L \cos^2\theta + m_B \sin^2\theta \qquad (T \text{ kuvveti başka bir doğrultudan etki ediyorsa}) \qquad (13)$$

Eş. (7)-(13)'te; T: Temel tabanına teğet olarak etkiyen yük, N: Temel tabanına dik olarak etkiyen yük, θ : T'nin doğrultusu ile L' ekseni arasındaki plan açısı (temelin plan düzleminde T ile L' arasındaki açı), A' : Etkin temel taban alanı, N_c, N_q, taşıma gücü katsayıları, c_u zeminin drenajsız kohezyon değeridir.

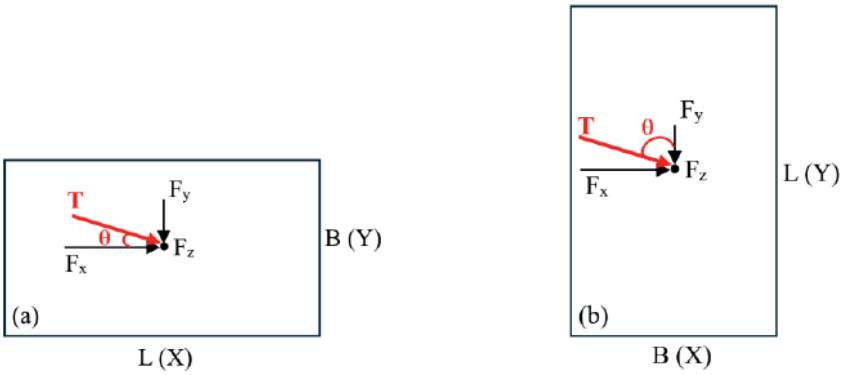
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EC 7-3'te verilen bu bağıntıların aşağıdaki durumlara göre tanımlandığı görülmektedir:

- T kuvvetinin yalnızca B' doğrultusunda etkimesi,
- T kuvvetinin yalnızca L' doğrultusunda etkimesi,
- T kuvvetinin temel planında herhangi bir doğrultudan etkimesi.

Burada kritik nokta, θ açısının tanımıdır. EC 7-3 (2025)'e göre θ açısı, temel plan düzleminde T kuvveti ile L' doğrultusu arasında kalan açı olarak tanımlanmaktadır. Dolayısıyla temelin X-Y koordinat sistemine yerleşimi nasıl olursa olsun, θ daima T ile L' ekseni arasındaki açı olarak alınmalıdır.

EC 7-3 (2025)'te verilen tanımlamaya uygun olarak, yapısal analizlerde temel planının X-Y koordinat düzlemine yerleştirilme biçimine göre θ açısının nasıl alınması gerektiği Şekil 2'de gösterilmiştir.



Şekil 2. Depremin X doğrultusundan etkimesi durumunda; a) Temelin uzun kenarı X ekseni doğrultusunda, b) Temelin kısa kenarı X ekseni doğrultusunda iken T kuvvetinin ve θ açısının konumu

Her ne kadar EC 7-3 (2025)'te açıkça belirtilmemiş olsa da, iki doğrultulu deprem etkisi altında T kuvveti, X ve Y doğrultularındaki taban kesme kuvvetlerinin vektörel bileşkesi alınarak hesaplanabilmektedir (Eş. 14).

$$T = \sqrt{F_x^2 + F_y^2} \tag{14}$$

θ açısı ise temelin X-Y koordinat düzlemine yerleşimine göre Eşitlik (15) veya (16) ile belirlenmekte olup, açının büyüklüğü depremin doğrultusuna bağlı olarak değişmektedir.

$$\theta = arctan\frac{F_y}{F_x} \tag{15}$$

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$$\theta = arctan\frac{F_x}{F_y} \quad (16)$$

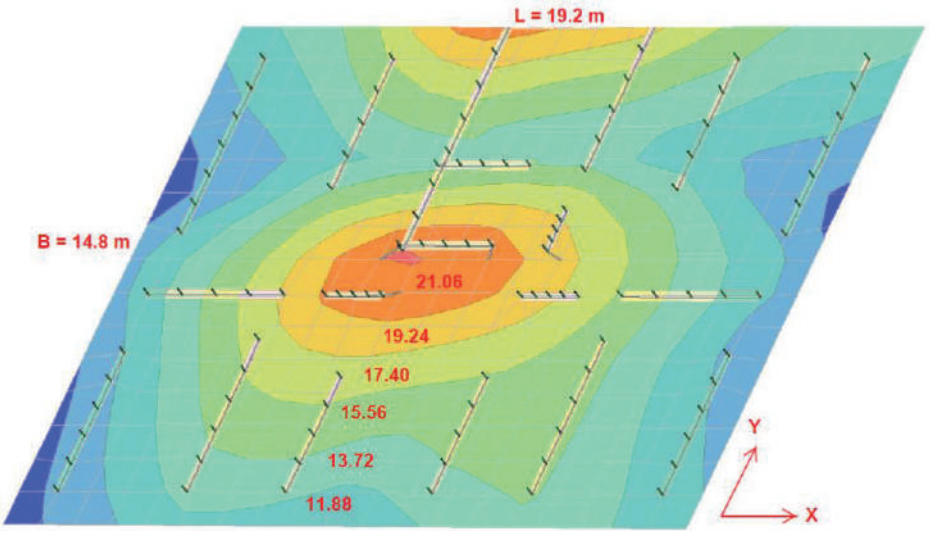
Bu açıklamalar, iki doğrultulu deprem etkisinin yük eğiklik katsayılarının hesabına sistematik ve tutarlı bir biçimde dahil edilmesini kolaylaştırmaktadır.

3. SAYISAL UYGULAMA

İki doğrultuda eşzamanlı deprem etkisi altında EC 7-3 (2025)'te verilen bağıntılarla yük eğiklik katsayılarının hesaplanmasını açıklamak amacıyla, sekiz katlı betonarme bir binaya ait yapısal analiz raporundan elde edilen veriler kullanılarak sayısal bir uygulama gerçekleştirilmiştir.

Hesaplarda kullanılan bina temelinin plan ölçüleri B=14.8 m, L=19.2 m'dir. Zeminin drenajsız kohezyon değeri c_u=60 kPa, içsel sürtünme açısı ϕ= 3° olarak tayin edilmiştir. TBDY-2018'de verilen bağıntılarla ϕ= 3° için taşıma gücü katsayıları N_c = 5.90, N_q = 1.309 olarak hesaplanmıştır.

Yapısal analizlerin sonucunda elde edilen, temele etkiyen gerilmelerinin dağılımı Şekil 3'te sunulmuştur. Yapısal analizler sonucunda, Eş. (3)–(6)'da verilen yük birleşimlerine karşılık gelen düşey yükler, taban kesme kuvvetleri ve devrilme momentleri belirlenmiş ve Şekil 4'te sunulmuştur.



Şekil 3. Temel gerilmeleri

Yük bileşeni	Fx	Fy	Fz	Mx	My
1 - G + Q	0.00	0.00	33140.11		
2 - 1.4 G + 1.6 Q	0.00	0.00	44492.82		
3x- G + Q + 0.2 S + Edx + 0.3 Edy + 0.3 Edz	3344.25	1416.21	55397.04	49556.24	22529.12
3y- G + Q + 0.2 S + Edy + 0.3 Edx + 0.3 Edz	1003.15	4677.05	53472.34	14866.87	75097.06
4x- 0.9G + Edx + 0.3 Edy - 0.3 Edz	3344.48	1423.80	6936.24	49556.24	22529.12
4y- 0.9G + Edy + 0.3 Edx - 0.3 Edz	1003.38	4684.64	8860.94	14866.87	75097.06

Şekil 4. Temele etkiyen yükler

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

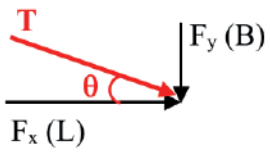
Şekil 4'te sunulan yük birleşimlerinden 3x sıra numaralı yük birleşimi esas alınarak Eş. (7)-(16)'da verilen bağıntılarla yük eğiklik katsayıları aşağıdaki gibi hesaplanmıştır.

$$e_B = \frac{M_y}{F_z} = \frac{22529.12}{55397.04} = 0.4067\ m$$

$$e_L = \frac{M_x}{F_z} = \frac{49556.24}{55397.04} = 0.8946\ m$$

$$B' = B - 2e_B = 14.8 - 2 \times 0.4067 = 13.99\ m$$

$$L' = L - 2e_L = 19.2 - 2 \times 0.4067 = 17.41\ m$$



$$T = \sqrt{F_x^2 + F_y^2} = \sqrt{3344.25^2 + 1416.21^2} = 3631.76\ kN$$

$$\theta = arctan\frac{F_y}{F_x} = \frac{1416.21}{3344.25} = 22.95°$$

$$m_B = \frac{2 + (B'/L')}{1 + (B'/L')} = \frac{2 + (13.99/17.41)}{1 + (13.99/17.41)} = 1.55446$$

$$m_L = \frac{2 + (L'/B')}{1 + (L'/B')} = \frac{2 + (17.41/13.99)}{1 + (17.41/13.99)} = 1.44554$$

$$m = m_\theta = m_L cos^2\theta + m_B sin^2\theta = 1.44554\ cos^2 22.95 + 1.55446\ sin^2 22.95 = 1.4621$$

$$i_q = \left(1 - \frac{T}{N}\right)^m = \left(1 - \frac{3631.76}{55397.04}\right)^{1.4621} = 0.9056$$

$$i_\gamma = \left(1 - \frac{T}{N}\right)^{m+1} = \left(1 - \frac{3631.76}{55397.04}\right)^{1.4621+1} = 0.8462$$

$$i_c = i_q - \left(\frac{1 - i_q}{N_c \tan\phi}\right) = 0.9056 - \left(\frac{1 - 0.9056}{5.90 \tan 3}\right) = 0.600$$

$$i_c = \frac{i_q N_q - 1}{N_q - 1} = \frac{0.9056 \times 1.309 - 1}{1.309 - 1} = 0.600$$

4. SONUÇ VE ÖNERİLER

Bu çalışmada, iki doğrultulu deprem etkisi altındaki yüzeysel temeller için yük eğiklik katsayılarının hesaplanmasına ilişkin uygulama esasları sayısal bir örnek üzerinden ortaya konulmuştur.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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EC 7-3 (2025)'te verilen bağıntılar kullanılarak gerçekleştirilen hesaplamalar, yük eğiklik katsayılarının temel taşıma gücünü bu örnek özelinde yaklaşık %60 oranında azalttığını göstermiştir. Bu sonuçlara göre, yük eğiklik katsayılarının tasarım taşıma gücünü önemli ölçüde azaltabileceği görülmüştür.

Bu çalışmayla, iki doğrultulu deprem etkisinin yük eğiklik katsayılarının hesabına açık ve sistematik biçimde dahil edilmesine yönelik bir uygulama çerçevesi sunulmuştur.

Gelecek çalışmalarda, elde edilen sonuçların literatürde yaygın olarak kullanılan G. G. Meyerhof (1956), J. Brinch Hansen (1961, 1970) ve A. S. Vesic (1975) tarafından önerilen bağıntılarla karşılaştırılması; farklı zemin parametreleri, temel boyut oranları ve yük kombinasyonları için parametrik analizler yapılarak yük eğiklik katsayısının taşıma gücü üzerindeki etkisinin belirlenmesi hedeflenmektedir.

KAYNAKLAR

Coduto, D.P., Kitch, W.A., Yeung, Man-chu,R. (2016). Foundation Design: Principles and Practices (3rd ed.). Pearson Education, Inc. USA.

Das, B.M., Sivakugan, N. (2019). Principles of Foundation Engineering (9th. ed.). Cengage Learning, Inc., Boston, USA.

EC-7-3 (2025), Eurocode 7 - Geotechnical Design - Part 3: Geotechnical structures. European Standard, EN 1997-3: 2025, European Committee for Standardization, Brussels.

Hansen, J. B. (1961). A General Formula for Bearing Capacity, Bulletin No. 11, Danish Geotechnical Institute, Copenhagen.

Hansen, J. B. (1970). A Revised and Extended Formula for Bearing Capacity, Bulletin No. 28, Danish Geotechnical Institute, Copenhagen.

Meyerhof, G. G. (1956). Discussion on "Rupture surfaces in sand under oblique loads." Proc. Am. Soc. Civil Engrs., Journal of the Soil Mechanics and Foundations Division, 82 (3): 15-19.

TBDY-2018. Türkiye Bina Deprem Yönetmeliği (2018). İçişleri Bakanlığı, Afet ve Acil Durum Yönetimi Başkanlığı. Ankara, Türkiye.

Vesić, A. S. (1975). Bearing Capacity of Shallow Foundations. Foundation Engineering Handbook, 1st ed. pp.121-147. Winterkorn, Hans F. and Fang, Hsai-Yang, Eds., Van Nostrand Reinhold, New York. 751 pp.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

YAĞIŞ SÜREKLİLİK EĞRİLERİ: İSTANBUL ÖRNEĞİ

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ÖZET

Küresel ısınma ve iklim değişikliğinin yol açtığı yağış rejimlerindeki değişiklikler, özellikle son yıllarda hem ani sel olaylarının hem de kronik kuraklık sorunlarının sıklığını artırmıştır. Kuraklık etkisi, yıllık toplam yağış değerlerindeki azalma olarak kendini gösterebilirken, aşırı yağış ve seller artan sıcaklıklar sonucunda da ortaya çıkabilir. Bu sorunları azaltmak için, sellere neden olabilecek yüksek yağışların, kuraklık önlemlerinde dikkate alınması gereken düşük yağışlarla birlikte ele alınabilmesi daha da önemlidir. Özellikle kentsel alanlarda kuraklığa karşı alınabilecek önlemlerden biri olan yağmur suyu hasadı (YSH) gibi çalışmalarda, ne kadar suyun geleceğinin tahmin edilmesi incelenmelidir. Bu çalışma, İstanbul'un tamamını temsil eden ortalama aylık toplam yağış değerlerinin hangi aşılma olasılıklarına sahip olduğunu analiz ederek, kentsel su yönetimi ve YSH sistemleri için bilimsel bir temel sağlamayı amaçlamaktadır. Çalışmada, 2018-2022 dönemi için İstanbul ve çevresindeki 40 meteoroloji gözlem istasyonundan elde edilen aylık toplam yağış verileri kullanılmıştır. Noktasal istasyon verileri, Thiessen poligonları yöntemi kullanılarak alansal ortalamalara dönüştürüldü ve Weibull formülü kullanılarak yağış süreklilik eğrisi (YSE) oluşturuldu. Sonuçta, İstanbul'un su stratejisi için kritik eşikleri değerleri olarak, %10 aşım olasılığı (sellerle ilişkili) 125.47 mm; %30, %40 ve %50 aşım olasılıkları, yağmur suyu hasadı uygulanabilirlik parametreleri (sırasıyla 79.21 mm, 65.38 mm ve 54.22 mm), ve %90 güvenilir tedarik eşiği 11.77 mm bulunmuştur. Bu sonuçlar, sürdürülebilir bir alternatif su kaynağı sağlamak için yağmur suyu hasadı depolama kapasitelerini optimize ederken yüksek yoğunluklu olaylardan kaynaklanan riskleri azaltmak için sağlam bir çerçeve sunmaktadır. Sonuç olarak, bu araştırma, iklim değişikliği karşısında kentsel su direncini artırmak ve yağmur suyu hasadı potansiyelini en üst düzeye çıkarmak için geleneksel aritmetik ortalamalar yerine olasılığa dayalı süre verilerinin benimsenmesinin gerekliliğini vurgulamaktadır.

Anahtar Kelimeler: Aylık toplam yağış, Yağış süreklilik eğrisi, Aşılma olasılığı, Yağmur suyu hasadı

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Precipitation Duration Curves: A Case Study for Istanbul

ABSTRACT

Changing precipitation regimes resulting from global warming and climate change have increased the frequency of both sudden flood events and chronic drought problems in especially recent years. The effects of drought can manifest as a decrease in total annual rainfall, while excessive rainfall and floods can also occur as a result of rising temperatures. In order to reduce these problems, it is even more important to be able to experience both high precipitation, which can cause floods, and low precipitation, which should be taken into account for drought measures. Especially in studies such as rainwater harvesting (RWH), which is one of the measures that can be taken in urban areas against drought, the estimation of how much water will come should be studied. This study aims to provide a scientific basis for urban water management and groundwater systems by analyzing the exceedance probabilities of average monthly total rainfall values representative of the whole of Istanbul. The study utilized monthly total precipitation data from 40 meteorological observation stations in and around Istanbul for the period 2018–2022. Point station data were converted into areal averages using the Thiessen polygons method, and precipitation duration curve (PDC) were constructed using the Weibull formula. The analysis identified critical thresholds for Istanbul's water strategy: a 10% exceedance probability (associated with floods) of 125.47 mm; RWH feasibility parameters at 30%, 40%, and 50% exceedance (79.21 mm, 65.38 mm, and 54.22 mm, respectively); and a 90% reliable supply threshold of 11.77 mm. These results provide a robust framework for mitigating risks from high-intensity events while optimizing RWH storage capacities to ensure a sustainable alternative water source. Ultimately, this research highlights the necessity of adopting probability-based duration data over traditional arithmetic averages to maximize RWH potential and enhance urban water resilience in the face of climate change.

Keywords: Monthly total precipitation, Precipitation duration curve, Exceedance probability, Rainwater harvesting.

GİRİŞ

1850-1900 dönemine kıyasla 2001-2020 döneminde 0.99°C daha yüksek olan küresel yüzey sıcaklıklarındaki artış, küresel su döngüsünü temelden değiştirmiştir (IPCC, 2023). İklim değişikliği, 21. yüzyılın en kritik küresel çevre sorunlarından biri olarak, su kaynaklarının sürdürülebilir yönetimini önemli ölçüde tehdit etmektedir (Asif vd., 2023; Ciampittiello vd., 2024; Lindner & Stamm, 2025). Yağış rejimlerinde değişiklik, sıcaklık artışı, buharlaşma ve aşırı hava olaylarının (kuraklık, sel) sıklığında artış gibi yollarla su kaynaklarının miktarını ve kalitesini olumsuz etkileyen iklim değişikliği, özellikle tarım, içme suyu ve ekosistemler üzerinde su kıtlığı ve kalite sorunlarını artırmaktadır (Asif vd., 2023; Ciampittiello vd., 2024; Garrote, 2017; Lal Srivastav vd., 2021; Lindner

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& Stamm, 2025). Ayrıca, artan nüfus, kentleşme ve ekonomik büyüme gibi sosyo-ekonomik faktörler de su talebini artırarak mevcut baskıyı şiddetlendiriyor (Edwin Golda ve Poyyamoli, 2012; Marques vd., 2022; O'Connell, 2017).

Bu durum ekosistemi etkilemenin (Bandh vd., 2021; Chang & Bonnette, 2016; Denissen vd., 2022; Sharabian vd., 2018) yanında, tarım (Malhi vd., 2021; Semeraro vd., 2023; Yang vd., 2024; Yuan vd., 2024), içme suyu temini (Hashempour vd., 2020; Kohlitz vd., 2020; Leveque vd., 2021; Ramião vd., 2024; Vorstius vd., 2024) gibi kritik alanlarda da su güvenliği riski oluşturmaktadır.

Çok sayıda kent, mevcut ve gelecekteki iklim değişikliğinin etkilerini azaltmak amacıyla hem küçük ölçekli hem de büyük ölçekli su altyapı projelerine yoğunlaşmış, böylece su güvenliğini artırmayı hedeflemiştir (Daloğlu Çetinkaya vd., 2023; Kumar vd., 2021; Sahin vd., 2017; Vogl vd., 2017). Marmara Bölgesi'nde yer alan dünyanın en önemli ticaret ve hizmet merkezlerinden biri ve ülkemizin ihracat lokomotifi olan İstanbul (Köse vd., 2023), artan konut ve endüstriyel talepler nedeniyle su kıtlığına önlem olması amacıyla, kapsamlı bölge içi ve bölgeler arası su altyapı yatırımlarına yönelmiştir. Bu altyapı, yalnızca metropol sınırları içerisindeki suyun aktarımını değil, aynı zamanda çevredeki su kaynaklarından da su temin ederek hem kentsel hem de bölgesel ölçekte yerel su ihtiyaçlarını karşılamayı amaçlamaktadır (Daloğlu Çetinkaya vd., 2023; Saatci, 2013). İstanbul'da iklim değişikliğinin etkileri incelendiğinde, öncelikli sorunlar arasında sıcak hava dalgaları, kuraklık ve değişen yağış rejimleri yer almaktadır. Kuzeyde planlanan projelerden kaynaklanabilecek zararları azaltmak için yeşil altyapının güçlendirilmesi ve ormanlık alanların artırılması kritik öneme sahiptir. Ayrıca karbon yutaklarının genişletilmesi, atık yönetimi, ulaşım ve yenilenebilir enerjiye yatırım yapılması, orman su kaynaklarının korunması, yağmur suyu hasadı ve atık su geri kazanımının geliştirilmesi İstanbul Büyükşehir Belediyesi için hayati öneme sahiptir (İBB, 2021). Yağış değişkenliğini anlamak, küresel ve yerel ölçeklerde klimatolojik, hidrolojik, meteorolojik ve tarımsal olguları kavramak ve analiz etmek açısından büyük önem taşımaktadır (Nath vd., 2024).

MATERYAL VE METHOD

Çalışmada İstanbul ilinin ortalama aylık toplam yağış değerlerini bulmak amacıyla kullanılan Thiessen Poligon yönteminde, çalışma alanı ve çevresindeki meteoroloji istasyonlarının birleştirilmesiyle oluşturulan üçgen ağları kullanılmıştır. Bu üçgenlerin orta dikmeleri birleştirilerek her istasyon için poligonlar elde edilmiş ve bu poligonlar, meteoroloji istasyonları içinde kalan bölgeleri kapsar ve yıllık ortalama yağış değerleri alansal ortalama olarak belirlenir. Aşağıda görülen For. 1 kullanılarak hesaplanır (Chow vd. 1988).

$$Y_{ort} = \frac{\sum Y_i A_i}{\sum A} \qquad (1)$$

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A_i: i. gözlem istasyonlarına ait çokgen alanı,

Y_i: i. gözlem istasyonun aylık toplam yağış değerini

Y_{ort}: Ele alınan çalışma alanındaki ortalama aylık toplam yağış değerini göstermektedir.

Yağmur suyu hasadı (YSH), evlerde, ticari ve endüstriyel tesislerde, sulama ve tarım alanlarında su ihtiyacını karşılamak için yağmur suyunun çatılar, teraslar, avlular ve diğer geçirimsiz yüzeylerden toplanarak depolanması ve yeniden kullanılmasıdır. YSH, su temin etmek amacıyla eski çağlardan beri kullanılan bir yöntemdir. Son yıllarda, artan su ihtiyacı ve azalan su kaynakları nedeniyle, toplumsal, çevresel ve iklimsel değişiklikler ışığında, yeni teknolojiler kullanılarak birçok alternatif uygulama geliştirilmeye başlanmıştır. Su kıtlığıyla mücadelede ve su kaynaklarının verimli kullanılmasında etkili bir yol olan YSH, aynı zamanda sel ve erozyonu azaltmaya da yardımcı olabilir. Atık suyun geri kazanımı ve kullanımı ile YSH yöntemleri, önümüzdeki yıllarda karşılaşılacak su sorunlarının çözümü için önemli yöntemler arasında yer almaktadır (Selimoğlu ve Yamaçlı, 2023).

Depolama tankı, genellikle çatı YSH sistemlerinin en maliyetli bileşenidir. Bu nedenle, depolama tankı kapasitesinin tasarımı için dikkatli bir analiz gereklidir. Depolama tankının büyüklüğünü belirlemek için çeşitli faktörlere dikkat edilir. Bu faktörler arasında, amaç, yerel yağış miktarı, su talebi, kurak günlerin sıklığı, su toplama alanı büyüklüğü, su ihtiyacı, estetik kaygılar, kişisel tercihler ve bütçe yer almaktadır. Depolama tankı yeraltına veya yerüstüne inşa edilebilir. Farklı amaçlar için gerekli depo boyutunu hesaplarken, bölgenin yağış rejimi ve kuraklığına göre çeşitli hesaplama yöntemleri kullanılabilir. Amaca ve yağış rejimine bağlı olarak ihtiyaç duyulan su miktarı ile toplanabilen su miktarı karşılaştırılarak, depo kapasitesi belirlenir. Bu süreç, çatı YSH sisteminin en maliyetli bileşeni olan depo kapasitesinin belirlenmesinde önemli bir rol oynar (İncebel, 2012).

Bir gidiş çizgisinden yararlanarak, verinin bir değere eşit veya değerden büyük olduğu zaman yüzdesi hesaplanıp, düşey eksene veriler ve yatay eksene zaman yüzdeleri yerleştirildiğinde oluşan eğriye süreklilik eğrisi denilir. Süreklilik eğrisini elde ederken mümkün olduğu kadar uzun bir süreye ait veri gidiş çizgisini kullanmak uygun olur. Eğri sayesinde zamanın belli bir yüzdesinde aşılan yağış gözlemlenebilir (Ağıralioğlu vd., 2009). Çalışmada kullanılan Weibull denklemi ile aşılma olasılığı (P) değerini hesaplarken kullanılan formül (For.2) aşağıda görülmektedir (Stedinger vd. 1993).

$$P = \frac{i}{n+1} \cdot 100 \qquad (1)$$

i: Büyükten küçüğe sıralanan aylık toplam yağış değerlerinin sıra numarasını

n: Veri setindeki aylık toplam yağış değerlerinin toplam adedini göstermektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

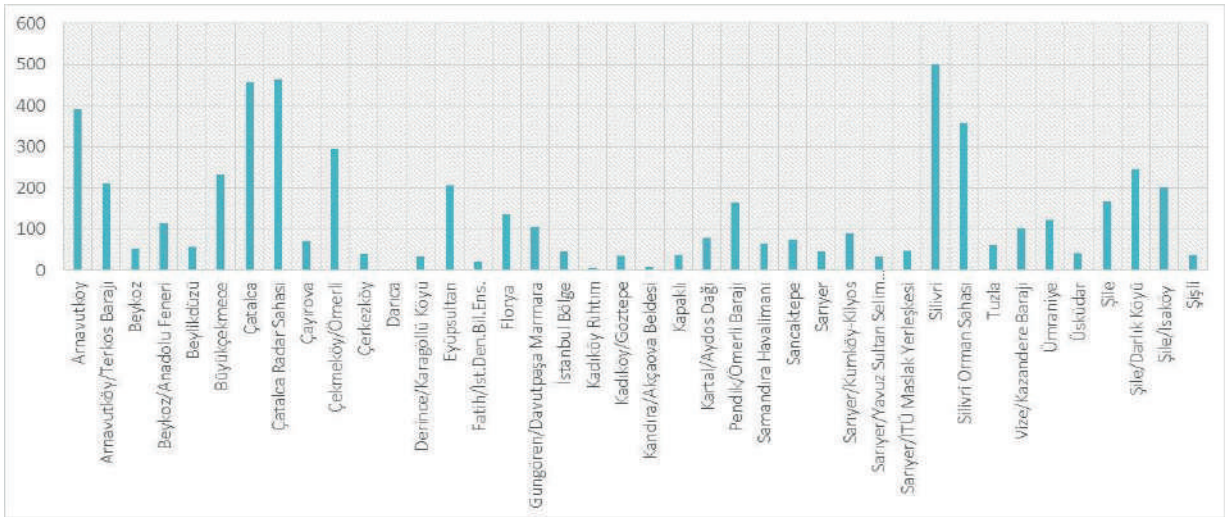
BULGULAR

Türkiye'de nüfus yoğunluğunun en yüksek olduğu il İstanbul'dur. 2024 yılı itibarıyla yaklaşık 15 milyon 701 bin 602 kişi (Türkiye nüfusunun %18.3'ü) İstanbul'da yaşamaktadır. Türkiye'de kilometrekare başına 111 kişi düşerken, İstanbul'da bu sayı 2 bin 934'tür (TUİK, 2025). Çalışmada kullanılan meteoroloji gözlem istasyonlarının konumları ile istasyonlara ait Thiessen çokgenleri ve İstanbul il sınırı Şekil 1'de gösterilmiştir.



Şekil 1. Çalışmada kullanılan meteoroloji gözlem istasyonlarının Thiessen poligonları ve İstanbul il sınırı

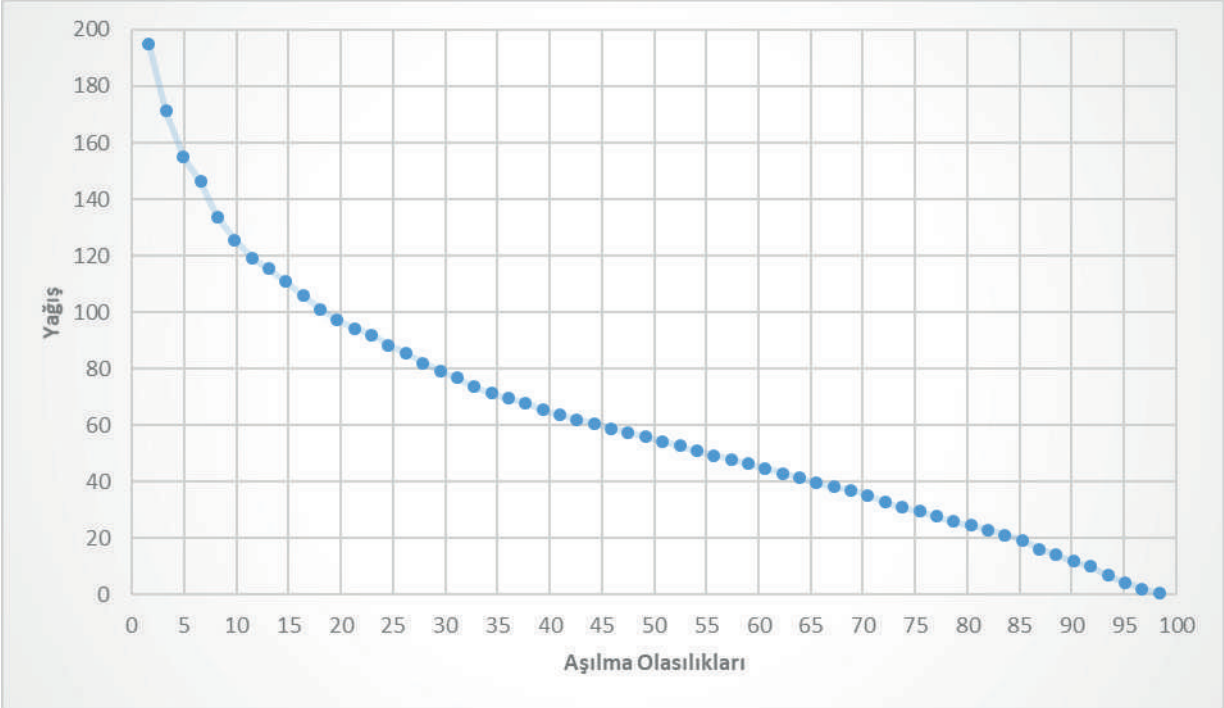
Şekil 1'de görülen İstanbul iline ait ortalama değerlerin hesabında kullanılan Thiessen alan değerleri Şekil 2'de görülmektedir.



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Şekil 2. İstanbul ili ortalama aylık toplam yağış hesabı için meteoroloji istasyonlarına ait Thiessen alanlarının değişimi

Her istasyonun 2018-2022 yılları arasındaki 60 adet aylık toplam yağış değerleri ile Thiessen alanları kullanılarak İstanbul iline ait ortalama aylık toplam yağış değerleri elde edilmiştir. Daha sonra Weibull denklemi kullanılarak bulunan aşılma olasılıklarına göre değişimleri bulunarak YSE belirlenmiştir (Şekil 3).



Şekil 3. İstanbul ilinin ortalama aylık toplam yağışlarının YSE grafiği

Çalışmada özellikle %10, 30, 40, 50 ve 90 aşılma olasılığına sahip olan aylık toplam yağış değerleri belirlenmiş ve Tablo 1'de verilmiştir.

Tablo 1. %10, 30, 40, 50 ve 90 aşılma olasılıklarındaki aylık toplam yağış değerleri

Aşılma Olasılığı (%)	Aylık Toplam Yağış Değeri (mm)
10	125.47
30	79.21
40	65.38
50	54.22
90	11.77

İstanbul ili ve çevresindeki meteoroloji gözlem istasyonları çalışma sahasında aynı sıklıkla dağılmamıştır. Ele alınan istasyonlardan Silivri istasyonu 502 km² değeriyle ilin ortalama hesaplarında en yüksek değere, Darıca istasyonu ise 0.13 km² ile en az etkiye sahiptir. Çalışma bölgesindeki 5 istasyonun ifade ettiği alanın 300 km²'den büyük olduğu gözlenmiştir.

2018-2022 yılları arasındaki İstanbul ili ortalama aylık toplam yağış değerlerinin %10, %30, %40, %50 ve %90 aşılma olasılığına sahip olan verileri; 125.47 mm, 79.21 mm, 65.38 mm, 54.22 mm ve 11.77 mm olarak hesaplanmıştır.

SONUÇLAR

%30, 40 ve 50 aşılma olasılıklarındaki aylık toplam yağış süreklilik değerlerinin yağmur suyu hasadı veya yeşil çatılar gibi uygulamalarda kullanılabileceği ve ortalamalarla kıyaslanabileceği düşünülmektedir. %10 aşılma olasılığındaki aylık toplam yağış değerleri, %30, 40 veya 50 aşılma olasılığı yağışlarına göre ne kadar bir yağışın potansiyel olarak depolanamayacağı ve yağmur suyu drenaj hatlarıyla uzaklaştırılması gereken miktarın tespiti amacıyla kullanılabilir. %90 aşılma olasılığındaki aylık toplam yağış süreklilik değerinin ise güvenilir yağmur suyu hasadı gibi çalışmalarda kullanılarak en az toplanması beklenen yağışların değerlendirilmesi ve projelendirme önceliklerine karar verilmesinde faydalı olacağı düşünülmektedir. Bu farklı aşılma olasılığı yaklaşımlarının klasik kullanılan yöntemde pek çok açık kalan bilgilere ışık tutacağı anlaşılmaktadır.

TEŞEKKÜR

Bu çalışma, Karabük Üniversitesi Bilimsel Araştırma Projeleri Birimi tarafından KBÜBAP-22-YL-105 proje numarasıyla desteklenmiştir.

REFERANSLAR

Ağıralioğlu, N., Cığızoğlu, K., Yılmaz, L., Coşkun, G., Aksoy, H., Toprak F., Eriş, E., Algancı, U., Andiç, G., Usta, G., Beşiktaş, M. ve Ülken, İ., (2009). Akım Ölçümleri Olmayan Akarsu Havzalarında Teknik Hidroelektrik Potansiyelin Belirlenmesi.", Tübitak Bilimsel ve Teknolojik Araştırma Projelerini Destekleme Programı, İstanbul.

Asif, Z., Chen, Z., Sadiq, R., & Zhu, Y. (2023). Climate Change Impacts on Water Resources and Sustainable Water Management Strategies in North America. Water Resources Management, 37(6–7), 2771–2786. https://doi.org/10.1007/s11269-023-03474-4

Bandh, S., Shafi, S., Peerzada, M., Rehman, T., Bashir, S., Wani, S., & Dar, R. (2021). Multidimensional analysis of global climate change: a review. Environmental Science and Pollution Research, 28, 24872–24888. https://doi.org/10.1007/s11356-021-13139-7

Chang, H., & Bonnette, M. R. (2016). Climate change and water-related ecosystem services: impacts of drought in california, usa. Ecosystem Health and Sustainability, 2. https://doi.org/10.1002/ehs2.1254

Chow, V. T., Maidment, D. R., & Mays, L.W., (1988). Applied Hydrology, McGraw- Hill Book Company, New York.

Ciampittiello, M., Marchetto, A., & Boggero, A. (2024). Water Resources Management under Climate Change: A Review. In Sustainability (Switzerland) (Vol. 16, Number 9). Multidisciplinary Digital Publishing Institute (MDPI). https://doi.org/10.3390/su16093590

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Daloğlu Çetinkaya, I., Yazar, M., Kılınç, S., & Güven, B. (2023). Urban climate resilience and water insecurity: future scenarios of water supply and demand in Istanbul. Urban Water Journal, 20(10), 1336–1347. https://doi.org/10.1080/1573062X.2022.2066548

Garrote, L. (2017). Managing Water Resources to Adapt to Climate Change: Facing Uncertainty and Scarcity in a Changing Context. Water Resources Management, 31(10), 2951–2963. https://doi.org/10.1007/s11269-017-1714-6

Denissen, J., Teuling, A., Pitman, A., Koirala, S., Migliavacca, M., Li, W., Reichstein, M., Winkler, A., Zhan, C., & Orth, R. (2022). Widespread shift from ecosystem energy to water limitation with climate change. Nature Climate Change, 12, 677–684. https://doi.org/10.1038/s41558-022-01403-8

Edwin Golda A. and Poyyamoli, G. (2012). Climate Change and Sustainable Management of Water Resources . In W. Leal Filho (Ed.), Climate Change and the Sustainable Use of Water Resources (pp. 431–447). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-22266-5_27

Hashempour, Y., Nasseri, M., Mohseni-Bandpei, A., Motesaddi, S., & Eslamizadeh, M. (2020). Assessing vulnerability to climate change for total organic carbon in a system of drinking water supply. Sustainable Cities and Society. https://doi.org/10.1016/j.scs.2019.101904

IPCC. (2023). Climate Change 2023: AR6 Synthesis Report (P. Arias, M. Bustamante, I. Elgizouli, G. Flato, M. Howden, C. Méndez-Vallejo, J. J. Pereira, R. Pichs-Madruga, S. K. Rose, Y. Saheb, R. Sánchez Rodríguez, D. Ürge-Vorsatz, C. Xiao, N. Yassaa, J. Romero, J. Kim, E. F. Haites, Y. Jung, R. Stavins, … C. Péan, Eds.). https://doi.org/10.59327/IPCC/AR6-9789291691647

İBB Çevre Koruma ve Geliştirme Dairesi. (2021). Istanbul Climate Change Action Plan.

İncebel, C., (2012). Alternatif Su Kaynaklarının Endüstriyel Kullanıma Kazandırılması İçin Çatı Yağmur Suyu Hasadı (Ostim Örneği), Yüksek Lisans Tezi, Gazi Üniversitesi Fen Bilimleri Enstütüsü, Ankara.

Kohlitz, J., Chong, J., & Willetts, J. (2020). Rural drinking water safety under climate change: The importance of addressing physical, social, and environmental dimensions. Resources, 9(6), 1–18. https://doi.org/10.3390/resources9060077

Kumar, N., Poonia, V., Gupta, B. B., & Goyal, M. K. (2021). A novel framework for risk assessment and resilience of critical infrastructure towards climate change. Technological Forecasting and Social Change, 165, 120532. https://doi.org/10.1016/J.TECHFORE.2020.120532

Lal Srivastav, A., Dhyani, R., Ranjan, M., Madhav, S., & Sillanpää, M. (2021). Climate-resilient strategies for sustainable management of water resources and agriculture. Environmental Science and Pollution Research, (28), 41576–41595. https://doi.org/10.1007/s11356-021-14332-4/Published

Leveque, B., Burnet, J., Dorner, S., & Bichai, F. (2021). Impact of climate change on the vulnerability of drinking water intakes in a northern region. Sustainable Cities and Society, 66, 102656. https://doi.org/10.1016/j.scs.2020.102656

Lindner, A., & Stamm, J. (2025). Integrating Climate Change Adaptation and Water Resource Management: A Critical Overview. Standards, 5(1), 4. https://doi.org/10.3390/standards5010004

Malhi, G. S., Kaur, M., & Kaushik, P. (2021). Impact of Climate Change on Agriculture and Its Mitigation Strategies: A Review. Sustainability. https://doi.org/10.3390/SU13031318

Marques, A. C., Veras, C. E., & Rodriguez, D. A. (2022). Assessment of water policies contributions for sustainable water resources management under climate change scenarios. Journal of Hydrology, 608. https://doi.org/10.1016/j.jhydrol.2022.127690

Nath, H., Adhikary, S. K., Nath, S., Kafy, A. Al, Islam, A. R. M. T., Alsulamy, S., Khedher, K. M., & Shohan, A. A. A. (2024). Long-term trends and spatial variability in rainfall in the southeast region of Bangladesh: implication for sustainable water resources management. Theoretical and Applied Climatology, 155(5), 3693–3717. https://doi.org/10.1007/s00704-024-04843-8

O'Connell, E. (2017). Towards Adaptation of Water Resource Systems to Climatic and Socio-Economic Change. Water Resources Management, 31(10), 2965–2984. https://doi.org/10.1007/s11269-017-1734-2

Ramião, J. P., Pascoal, C., & Carvalho-Santos, C. (2024). Climate change adaptation for drinking water and ecological flows through sustainable agricultural practices. International Journal of Water Resources Development, 40, 832–851. https://doi.org/10.1080/07900627.2024.2339241

Sahin, O., Siems, R., Richards, R. G., Helfer, F., & Stewart, R. A. (2017). Examining the potential for energy-positive bulk-water infrastructure to provide long-term urban water security: A systems approach. Journal of Cleaner Production, 143, 557–566. https://doi.org/10.1016/J.JCLEPRO.2016.12.074

Selimoğlu, P., & Yamaçlı, R., (2023). Sürdürülebilirlik Sürecinde Yağmur Suyu Hasadı: Sinop Üniversitesi Kuzey Yerleşkesi Örneği, Türk Tarım Ve Doğa Bilimleri Dergisi, 10(4).

Semeraro, T., Scarano, A., Leggieri, A., Calisi, A., & De Caroli, M. (2023). Impact of Climate Change on Agroecosystems and Potential Adaptation Strategies. Land. https://doi.org/10.3390/land12061117

Sharabian, M., Ahmad, S., & Karakouzian, M. (2018). Climate Change and Eutrophication: A Short Review. Engineering, Technology & Applied Science Research. https://doi.org/10.48084/ETASR.2392

Stedinger, J.R., Vogel, R.M., & Foufoula-Georgia, E., (1993). Frequency Analysis of Extreme Events", Chapter 18. In Maidment, D.R., Ed., Handbook of Hydrology, McGraw Hill, New York, 18.1-18.66.

TUİK (2025, February 6). Address-Based Population Registration System Results, 2024. https://data.tuik.gov.tr/

Vogl, A. L., Goldstein, J. H., Daily, G. C., Vira, B., Bremer, L., McDonald, R. I., Shemie, D., Tellman, B., & Cassin, J. (2017). Mainstreaming investments in watershed services to enhance water security: Barriers and opportunities. Environmental Science & Policy, 75, 19–27. https://doi.org/10.1016/J.ENVSCI.2017.05.007

Vorstius, C., Rowan, J. S., Brown, I., Leith, F., & Frogbrook, Z. (2024). Supporting the development of climate-resilient water safety plans through a risk-screening framework for drinking water source protection. Journal of Water and Climate Change, 15(10), 5207–5218. https://doi.org/10.2166/wcc.2024.293

Yang, Y., Tilman, D., Jin, Z., Smith, P., Barrett, C., Zhu, Y., Burney, J., D'Odorico, P., Fantke, P., Fargione, J., Finlay, J., Rulli, M., Sloat, L., Van Groenigen, K. J., West, P., Ziska, L., Michalak, A., & Lobell, D. (2024). Climate change exacerbates the environmental impacts of agriculture. Science, 385. https://doi.org/10.1126/science.adn3747

Yuan, X., Li, S., Chen, J., Yu, H., Yang, T., Wang, C., Huang, S., Chen, H., & Ao, X. (2024). Impacts of Global Climate Change on Agricultural Production: A Comprehensive Review. Agronomy. https://doi.org/10.3390/agronomy14071360

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STEEL REINFORCEMENT COMBINATION PROBLEMS AND SOLUTION SUGGESTIONS IN CONSTRUCTION

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Reinforced concrete structures constitute the basic load-bearing systems of modern civil engineering. The performance of these structures largely depends on the continuity, integrity and correct assembly of steel reinforcement. Reinforcement joining techniques continue to be a critical engineering problem in terms of structural safety, service life, constructability, economy and sustainability. This study aims to systematically examine steel reinforcement joining techniques used in reinforced concrete structures, reveal the main problems encountered in practice and develop engineering-based solution suggestions. The study is based on literature review, evaluation of existing regulations and synthesis of findings obtained from field applications in a holistic framework. The need for joining reinforcement in reinforced concrete structures is inevitable due to the production, transportation and placement limitations of reinforcement bars. The fact that standard production lengths are generally limited to 12-14 meters creates the necessity of combining large span beams, columns and shear walls. In this context, the three most common joining methods, lap splice, mechanical splice and welded splice, are discussed in detail. Each method has strengths and weaknesses in terms of structural performance, applicability, cost and risk profile. The overlay method is the most widely preferred technique, especially in residential and medium-sized buildings, due to its practicality and low cost. However, the effectiveness of this method largely depends on ensuring sufficient overlap length. In the TS 500 standart, it is recommended that the overlap length be at least 40–60 times the reinforcement diameter. However, in field applications, it is observed that these ratios decrease to 20–30 diameter levels due to time pressure, material constraints or design errors. This situation leads to insufficient adherence capacity, reinforcement shifting under load, and ultimately increased crack widths. In the study, it was observed that insufficient overlap length could cause a 20–35% loss of capacity, especially in tension zones.

Mechanical joining methods are increasingly preferred, especially for large diameter reinforcements (Ø20–Ø40 mm) and dense reinforcement arrangements. Thanks to coupler systems, reinforcement continuity is ensured in a more controlled manner and a more compact detail is achieved compared to overlapping. This improves concrete placement by reducing reinforcement congestion, especially in

column-beam connection areas. Experimental studies show that the tensile capacity of correctly installed mechanical joints is in most cases at the level of 95–105% of the reinforcement yield strength. However, assembly quality is a critical parameter, and performance decreases occur due to incorrect tightening, dirty surfaces or production tolerances. Although welded jointing provides high structural continuity, it carries certain risks in practice. The heat effect occurring during the welding process can change the microstructure of steel reinforcement and reduce its ductility. Especially in earthquake zones, the risk of sudden brittle fracture has been found to be higher in welded connections. For this reason, many modern earthquake codes restrict welded joints in plastic hinge areas or require special quality control procedures. In the study, it was observed that the energy absorption capacity of welded connections may be 10–25% lower than that of overlapping. The main problems encountered in field applications are grouped under three main headings: loss of adherence, reinforcement congestion and application errors. Loss of adherence is caused by factors such as insufficient overlap, poor quality concrete, segregation, insufficient vibration and corroded reinforcement surfaces. Reinforcement congestion is a serious problem, especially in structures with high seismic design requirements, and prevents proper placement of concrete, leading to void formation and local strength losses. Application errors are one of the most critical problems; It is caused by incorrect reinforcement placement, non-standard welding practices, inappropriate coupler selection and inadequate quality control processes. Solution suggestions for these problems are presented in a multidimensional framework. First of all, it was emphasized that the reinforcement joining details should be determined in full compliance with national and international standards (TS 500, Eurocode 2, ACI 318) during the design phase. It is recommended to increase minimum overlap lengths, observe diameter limitations and evaluate alternative joining methods, especially in critical areas. Secondly, it is stated that mechanical couplers used in the field must be certified, undergo regular quality control tests and assembly personnel must be trained.

The study also evaluated reinforcement joining techniques from a life cycle cost perspective. Although the initial cost of mechanical joints can be 30–70% higher than lapping, they have been shown to be competitive in terms of total cost as they reduce maintenance costs and improve structure performance in the long term. It has been emphasized that mechanical joints are more advantageous, especially in corrosion-sensitive environments (marine structures, chemical plants). In terms of sustainability, it has been argued that using less material and joining details that provide better performance can reduce the carbon footprint. Reducing reinforcement density and optimizing concrete volume thanks to compact mechanical connections provides both economic and environmental benefits. In conclusion, steel reinforcement joining techniques play a decisive role in the safety, durability and sustainability of reinforced concrete structures. Although lap, mechanical and welded connections are each suitable under certain conditions, choosing the right method; It should be done according to the building type, loading conditions, earthquake risk, constructability and cost criteria. It was concluded that future

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

research should focus on joint performance, corrosion resistance and new generation hybrid joining techniques, especially under earthquake effects. This study provides a holistic assessment that can provide decision support for both design engineers and field practitioners.

Keywords: Steel reinforcement, reinforced concrete, mechanical coupler, welded connection

EXPERIMENTAL INVESTIGATION OF THE USABILITY OF CHICKEN MANURE ASH IN SOIL IMPROVEMENT

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ABSTRACT

The continuous increase in population and housing demand has led to construction activities on soils with low bearing capacity and weak engineering properties, creating significant geotechnical challenges. Traditional soil stabilization methods, particularly chemical stabilization using cement and lime, are widely applied; however, their high economic cost and environmental impact have encouraged the search for sustainable and cost-effective alternatives. In this context, this study experimentally investigates the usability of Coarse Chicken Manure Ash (CMA), a by-product of poultry waste-based energy production in Türkiye, as a soil improvement material.

The soil used in this research is low-plasticity clay (CL) obtained from Adapazarı city (Türkiye). After sampling, the soil was air-dried, oven-dried at 105 ± 5 °C, sieved, and homogenized to ensure consistency. The Chicken Manure Ash was supplied from a local energy production facility in Sakarya where poultry waste is incinerated. Initially, comprehensive characterization tests were conducted on the natural soil, including Atterberg limits (Casagrande and cone penetration methods), grain size distribution (sieve and hydrometer analyses), Standard Proctor compaction, and specific gravity tests.

The Standard Proctor test results were subsequently used to calibrate the Harvard compaction apparatus, ensuring that the compaction energy applied during specimen preparation corresponded to the target compaction conditions. The calibrated Harvard apparatus was then employed for compaction (Determination of the optimum water content and Maximum dry density of each percentage) and preparation of specimens used in Unconfined Compression (UU/UCS) tests. Soil–ash mixtures were prepared by adding CMA at various percentages by dry weight, and each mixture was adjusted to its respective optimum moisture content prior to compaction. Mechanical performance was

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

evaluated through Unconfined Compressive Strength (UCS/UU). Results indicate that the addition of CMA decreases the maximum dry density while also slightly decreasing the optimum water content of the soil mixture. The unconfined compression test (UCS/UU) indicates an increase in the sample strength as the CMA percentage increases from 0% to 15%. All experiments were conducted under controlled laboratory conditions to ensure reliability and repeatability. The results aim to evaluate the effectiveness of Chicken Manure Ash in improving the mechanical behaviour of cohesive soils and to assess its potential as a sustainable soil stabilization material.

Keywords: Cohesive Soil, Unconfined Compressive Strength (UCS), Soil Stabilization, Sustainable Ground Improvement, Chicken Manure Ash (CMA).

INTRODUCTION

The performance and safety of civil engineering structures are fundamentally governed by the engineering properties of the underlying soil. Inadequate soil strength, excessive compressibility, and high plasticity are among the most common causes of foundation distress, settlement, and structural damage (Turan et al., 2022). Historical case studies demonstrate the severe consequences of insufficient understanding of ground conditions. The differential settlement of the Leaning Tower of Pisa is widely cited as a classical example of foundation instability due to weak compressible clay layers, and the Vajont Dam Collapse (Barla & Paronuzzi, 2013). Similarly, the failure of the Teton Dam illustrates the importance of subsurface characterization and soil–water interaction in geotechnical engineering.

Rapid urbanization and population growth have significantly reduced the availability of ideal construction sites. Engineers increasingly encounter soft clays, expansive soils, loose sands, and heterogeneous fills (Garvin, 2007). Instead of relocating projects or relying solely on deep foundations, soil stabilization techniques are commonly employed to improve in-situ ground conditions in a cost-effective and sustainable manner. One such method is soil reinforcement (Shukla et al., 2009).

Soil reinforcement comprises a range of engineering techniques designed to improve the mechanical performance of soils by increasing their strength, stiffness, and overall stability. Many natural soils lack sufficient bearing capacity or exhibit excessive compressibility, low shear resistance, or high sensitivity to moisture variations. Without improvement, such conditions can lead to settlement, instability, or even structural failure. Reinforcement techniques address these challenges by modifying the soil's internal structure, enhancing interparticle interaction, or introducing materials capable of resisting tensile and shear stresses. Through these approaches, engineers can safely construct embankments, foundations, retaining systems, pavements, and slopes on problematic ground. Soil stabilization methods can be categorized into mechanical, chemical, and structural techniques. Mechanical methods include compaction and densification, while structural methods involve

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ISBN: 978-9952-610-30-7

inclusions such as geogrids and soil nails. Chemical stabilization, however, remains one of the most widely adopted approaches in practice due to its efficiency and adaptability.

Cement and lime are traditionally used stabilizing agents. Cement stabilization improves soil strength through hydration reactions that form calcium silicate hydrates (C–S–H), which bind soil particles and reduce compressibility. Lime stabilization is particularly effective in clayey soils, where cation exchange and pozzolanic reactions reduce plasticity and swelling potential (Shen et al., 2021). Another commonly used material is ash, especially fly ash, for soil reinforcement.

Ash-Based Stabilization in Geotechnical Engineering

Industrial by-products and agricultural ashes have gained considerable attention as alternative stabilizers. Among these, fly ash has been extensively investigated. Research by Pandian et al. (2001), demonstrated significant improvement in California Bearing Ratio (CBR) values of soil–fly ash mixtures. Mahvash et al. (2017), reported enhanced mechanical behaviour and improved compaction characteristics in sandy soils treated with Class F fly ash. Dixit et al. (2016), demonstrated how soil characteristics vary with increasing fly ash content, which is demonstrated in Table 1:

Table 1. Impact of Fly Ash on Soil Characteristics (Dixit et al., 2016)

% of fly ash as a contaminant	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index	Shrinkage Limit (%)	Specific gravity	Optimum moisture content (%)	Maximum Dry Density (Kg/m^3)	California Bearing Ratio Value(%) @ 5 mm
0	36.95	24.44	12.51	10.57	2.63	19.33	16.48	3.10
5	36.80	24.88	11.92	10.51	2.60	20.08	16.45	3.10
10	36.50	24.97	11.53	9.28	2.58	21.03	16.44	3.12
15	35.66	24.19	11.47	8.56	2.55	21.43	16.40	3.13
20	35.01	24.15	10.86	7.30	2.53	21.83	16.53	3.16
25	34.92	24.39	10.53	7.02	2.40	21.97	15.75	3.22
30	34.72	24.60	10.12	6.30	2.33	22.37	14.93	3.11

This table shows that the plasticity index, shrinkage limit, specific gravity and maximum dry density of the mixture decreases as the percentage of ash in the soil increases while the optimum moisture content and the California bearing ratio increase, demonstrating an increase in soil strength.

A study by Rangaswamy (2016), showed the same pattern but also analysed the impact of bottom ash, which did not impact much. (Li et al., 2025) have further demonstrated that time affects the strength of the soil, as waiting for the soil to cure for 28 days causes it to exhibit significantly more unconfined compression strength.

Recent studies by Ahmed et al. (2024), Di Sante et al. (2025) and Gallego-Quintana et al. (2023) have further highlighted the role of curing time, activator content, and alkali activation in enhancing ash-based stabilization performance.

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In addition to fly ash, agricultural wastes such as rice husk ash, palm oil fuel ash, and wood ash have demonstrated reductions in Plasticity Index (PI) and increases in Unconfined Compressive Strength (UCS). These improvements are commonly attributed to:

- Cation exchange
- Flocculation–agglomeration
- Pozzolanic reactions
- Modification of particle grading

However, the effectiveness of ash-based stabilization is highly dependent on ash chemistry, fineness, calcium content, and curing conditions.

Chicken Manure Ash (CMA)

This research focuses on coarse Chicken Manure Ash, which is generated through the combustion of poultry litter and manure. It typically contains calcium-rich compounds, phosphates, potassium, and trace minerals. While Chicken Manure Ash has been investigated in agriculture and cementitious materials, its application in soil stabilization remains very limited.

Unlike fly ash, which has established classification systems and design guidelines, Chicken Manure Ash lacks standardized geotechnical evaluation frameworks. There is insufficient data regarding its influence on soil characteristics and its optimal dosage levels.

Given its chemical composition, CMA has potential to contribute to cementitious bonding and soil modification. However, comprehensive experimental validation is necessary.

Research Gap and Objective

Although numerous studies have evaluated fly ash and other biomass ashes, Chicken Manure Ash remains significantly underexplored in geotechnical engineering. There is currently no established understanding of its stabilization mechanisms, optimum mix proportions, or curing-dependent strength behaviour.

The objective of this study is therefore to experimentally investigate the effect of Chicken Manure Ash on soil plasticity, compaction characteristics, and unconfined compressive strength, and to assess its suitability as a sustainable soil stabilization material.

MATERIALS AND METHODS

Soil

Soil samples were obtained from a site in Adapazarı and transported to the laboratory. In the lab, the natural moisture content of the soil was measured, before the soil is carefully laid down and allowed to air dry until friable. It is then crushed with a mortar and transferred to a metal container to be dried at

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105°C (to remove pore water without altering mineralogical composition). After oven-drying for 24 hrs, the soil characteristics are measured. Preliminary physical characterization included:

- Natural water content
- Specific gravity (pycnometer method)
- Grain size distribution (sieve and hydrometer analysis)
- Atterberg limits (Liquid Limit and Plastic Limit)

The experiment is carried out using ASTM D6913/D6913M, D7928, D4318, D 2487, D2488, and the soil was classified according to TS1500/2000. Figure 1 and Table 2 were obtained from the lab tests.

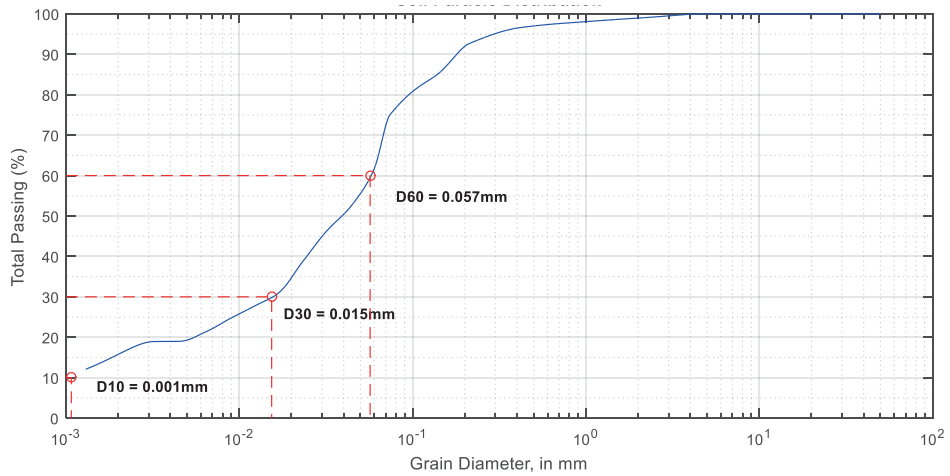


Figure 1. Particle Distribution Curve of Soil Sample

Table 2. Summary of Soil Sample Properties

Physical Properties of Clay Soil		
Property	Value	Unit
Passing No.200 sieve	99.98	(%)
Liquid Limit	25.0	LL (%)
Plastic Limit	18.2	PL (%)
Plasticity Index	6.8	IP (%)
Optimum Moisture Content	17.85	w_{opt} (%)
Maximum Dry Unit Weight	16.38	γ_{kmaks} (kN/m³)
Specific Gravity	2.89	Gs

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Clay Fraction (< 0.002 mm)	19	(%)
Soil Classification (TS1500/2000) Low Plasticity silty Clay (CL-ML)		

Chicken Manure Ash (CMA)

CMA was obtained from controlled combustion of poultry litter. The ash was oven-dried, pulverized to eliminate agglomerations, and sieved through a 425 µm sieve to ensure uniformity. The material was stored in sealed containers to prevent moisture contamination and delivered to the university by a local supplier.

The physical properties of CMA, including particle size distribution and specific gravity, were determined prior to mixing with soil. Figure 2 shows the results obtained.

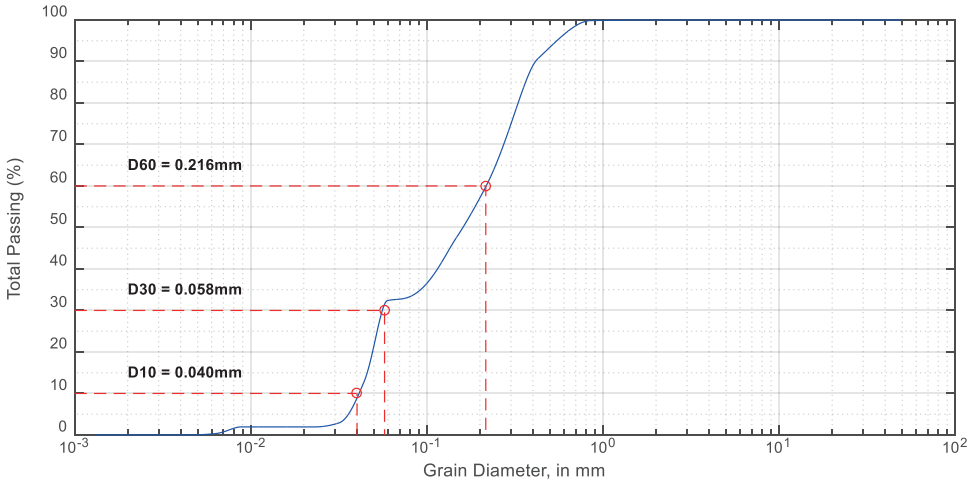


Figure 2. Particle Distribution Curve of Coarse CMA

Similarly to the soil, the important characteristic of the ash is shown in Table 3.

Table 3. Summary of Chicken Manure Ash Sample Properties

Physical Properties of Coarse CMA		
Property	Value	Unit
Passing No.200 sieve	36	(%)
Liquid Limit	36.4 (NP)	LL (%)
Plastic Limit	Non-Plastic	PL (%)
Plasticity Index	-	IP (%)

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Optimum Moisture Content	-	w_{opt} (%)
Maximum Dry Unit Weight	-	γ_{kmaks} (kN/m³)
Specific Gravity	2.62	Gs
Clay Fraction (< 0.002 mm)	0	(%)
Cannot be classified using Soil Classification (TS1500/2000) The particle-size distribution graph shows that the CMA is uniformly graded		

Mix Proportions

Soil–CMA mixtures were prepared at various percentages by dry weight of soil, and each mixture was assigned a specific label, as summarized in Table 4.

Table 4. Chosen Percentages for Research

	Coarse CMA	Soil	Sample Label
1	0%	100%	NS
2	1%	99%	AA1
3	5%	95%	AA5
4	8%	92%	AA8
5	10%	90%	AA10
6	15%	85%	AA15

These percentages were selected based on typical ranges used in ash-based stabilization research and to allow identification of an optimum content.

Each mixture was blended in dry condition before controlled addition of water to ensure homogeneity.

Harvard Apparatus Calibration

The Harvard miniature compaction apparatus was adopted to reduce material consumption and testing time while enabling direct preparation of specimens for UCS testing. Prior to its use, calibration was performed to verify that the compaction energy applied was equivalent to that of the Standard Proctor test.

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To start with, we use the **General Compaction Energy Formula (Free-Fall), which is the exact equation used for Proctor.**

$$E = \frac{N \cdot n \cdot W \cdot H}{V}$$

where: E= compaction energy per unit volume (J/m³), N= number of blows per layer, n= number of layers, W= weight of rammer (N), H= drop height (m), and V= mold volume (m³)

Standard Proctor (Reference Calculation)

Values obtained from ASTM D698 and the calculation demonstrate that the energy applied to the soil from standard proctor is:

$E_{Proctor} \approx 5.93 \times 10^5$ J/m³

Standard Proctor Energy≈ 600 kJ/m³

Now for the Free-Fall Harvard Compaction Energy (ASTM D558), with the values taken from the lab, the approximate energy applied to the soil with 4 layers and 10 hit per layers is:

$E_{Harvard} \approx 6.01 \times 10^5$ J/m³

The calculated energies were found to be comparable on a per-unit-volume basis. This indicates that even though the volume of the apparatus is different, as well as the size of the hammer, the energy per unit volume applied to the soil is similar. As such, those two experiments can be assumed to demonstrate the same level of compaction. Additional tests were performed to verify the results of those experiments, and it was seen that they compact the soil to the same extent, therefore can be used interchangeably.

Unconfined Compressive Strength (UCS)

After the calibration experiment, the Optimum Moisture Content (OMC) and the Maximum Dry Density (MDD) of each sample is determined using the Harvard experiment. From the results, the MDD decreases while the OMC increased, which corresponds to the behaviour of fly-ash in literature. Following this, cylindrical specimens were prepared at their respective OMC and MDD values. Specimens were tested under unconfined compression to determine peak compressive strength. The Mohr circles were constructed, shown in figure 3, clearly showing the impact of the ash on the soil.

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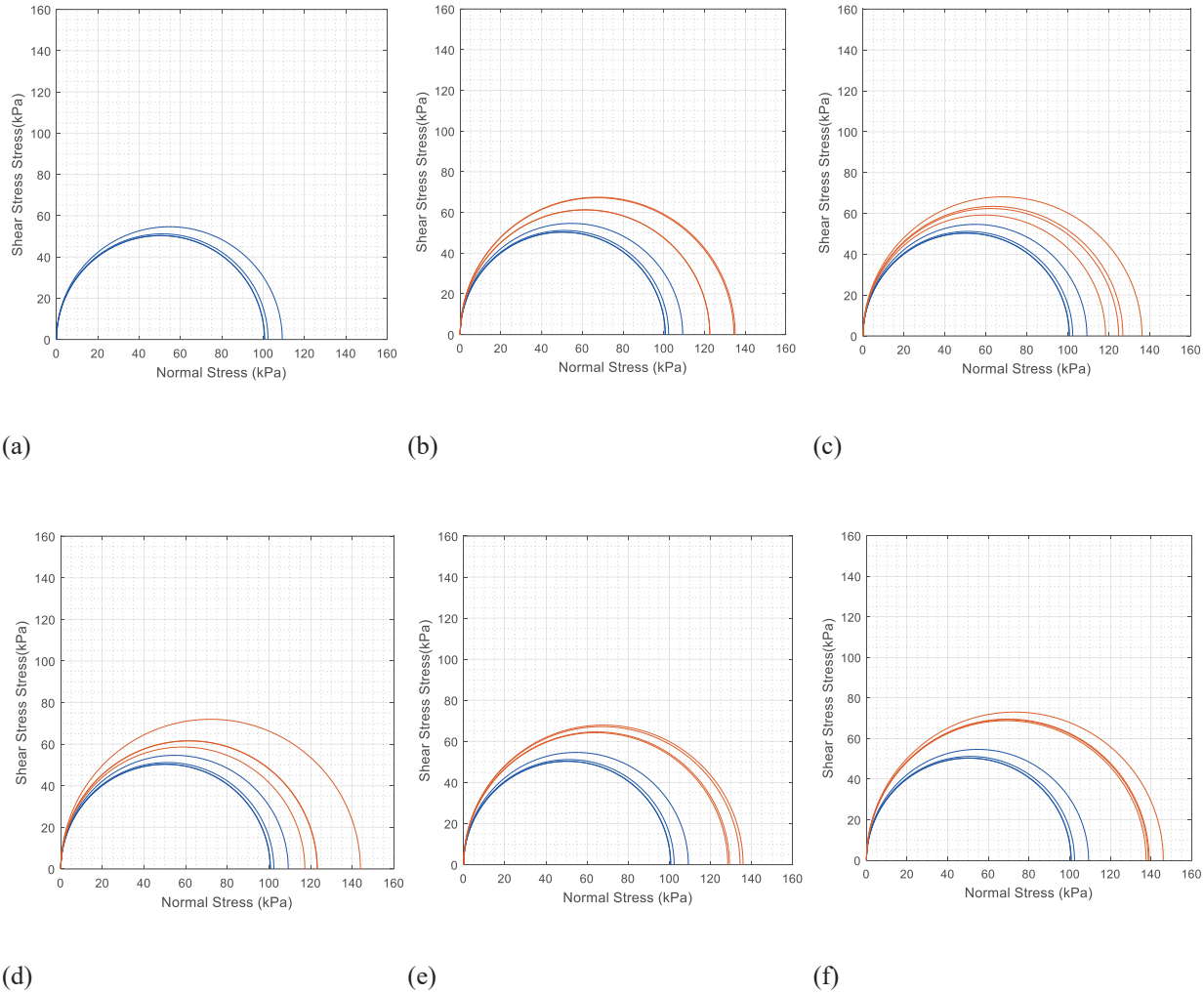
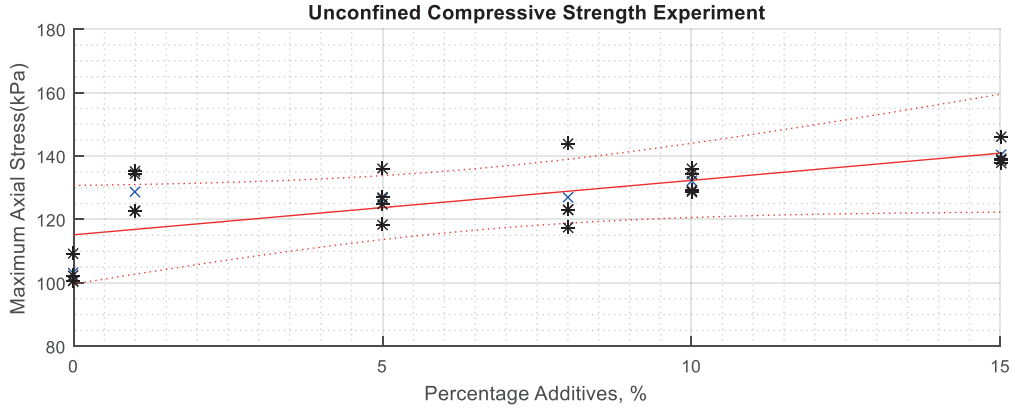


Figure 3. Mohr Circles for (a) 0% Ash, (b) 1% Ash, (c) 5% Ash, (d) 8% Ash, (e) 10% Ash, and (f) 15% Ash

The blue line represents the natural soil without any addition of ash. The oranges lines show the Mohr circles after ash has been added to the soil. Figure 4 summarizes the results from the Mohr circles.



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Figure 4. Direct Relationship between Percentage Additive and Unconfined Compression Strength of the Soil

This graph clearly shows the increase in strength of the soil as the percentage of ash is increased. CMA impacts positively on the strength of the soil. The Maximum Axial stress of the soil increases with the increase in percentage of additives. To better demonstrate the extent of the improvement, Table 5 shows the percentage increase in strength.

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Table 5. Increase in Unconfined Compression Strength of the Soil for Each Percentage of Additives Used

Percentage	Proctor		Harvard		q_u (kN/m^2)	% increase
	OMC, %	MDD, kN/m³	OMC, %	MDD, kN/m³		
0	17.5	16.4	18.1	16.8	103.25	-
1	17.7	16.4	17.9	16.6	128.5	+24.46
5	18.2	16.3	18.3	16.6	126.5	+22.52
8	18.9	16.1	19	16.5	126.5	+22.52
10	19.2	16.2	19.2	16.4	131.5	+27.36
15	19.6	16.1	19.7	16.3	140	+35.59

The increase in strength is about 20% at 1% additives, which is significant and goes up to 35% at 15% additives. This behaviour corresponds to fly ash in literature, but many more properties of the ash must be analysed before its actual performance can be clearly classified similarly to fly ash.

CONCLUSION

This study experimentally evaluated the feasibility of using Coarse Chicken Manure Ash (CMA) as an alternative stabilizing material for low-plasticity clay obtained from the Adapazarı region. Laboratory investigations focused on the effects of varying CMA content on compaction characteristics and unconfined compressive strength, together with an assessment of the suitability of the Harvard compaction method as a practical substitute for the Standard Proctor test.

The results demonstrate that CMA has a measurable and beneficial influence on the mechanical behavior of the tested soil. Increasing CMA content led to a gradual reduction in Maximum Dry Density (MDD), which can be attributed to the lower specific gravity and more porous structure of the ash compared to the natural soil. At the same time, the Optimum Moisture Content (OMC) showed a slight increase, indicating a higher water demand for proper lubrication and bonding within the soil–ash matrix. Most importantly, the Unconfined Compressive Strength (UCS) improved significantly with increasing CMA percentage, reaching an enhancement of approximately 35% at 15% CMA addition. This strength gain suggests improved interparticle bonding, likely caused by cation

exchange, flocculation–agglomeration, and possible pozzolanic interactions between the calcium-rich ash and the clay minerals.

The calibration study confirmed that the Harvard compaction apparatus can reproduce compaction energy levels comparable to those of the Standard Proctor test. This finding is important from a practical standpoint, as the Harvard method allows faster specimen preparation with reduced material usage while still producing reliable and repeatable results for strength evaluation.

Overall, the experimental findings indicate that Chicken Manure Ash is a promising sustainable material for soil stabilization. Its use not only improves engineering performance but also offers an environmentally responsible solution for managing poultry waste by converting an agricultural by-product into a value-added construction material.

REFERENCES

Ahmed, M., Ahmed, M., & Afzal, L. (2024). Geotechnical properties of cement-stabilised fill material: Developing a linear regression model for predicting unconfined compression strength and undrained shear stress. *Vietnam Journal of Science, Technology and Engineering*, *66*(3), 114–119.

Barla, G., & Paronuzzi, P. (2013). The 1963 Vajont landslide: 50th anniversary. *Rock Mechanics and Rock Engineering*, *46*(6), 1267–1270.

Di Sante, M., Khan, M. K., Calò, L., Fratalocchi, E., & Mazzieri, F. (2025). The Combined Use of Fly Ash and Lime to Stabilize a Clayey Soil: A Sustainable and Promising Approach. *Geosciences*, *15*(9), 346.

Dixit, A., Nigam, M., & Mishra, R. (2016). Effect of fly ash on geotechnical properties of soil. *International Journal of Engineering Technologies and Management Research*, *3*(5), 1907–2454.

Gallego-Quintana, P., Ojeda-Farias, O. F., Alvarez-Rosario, A., Alvarez-Sánchez, E. J., Landa-Ruiz, L., Terán-Torres, B. T., Mendoza-Rangel, J. M., & Baltazar-Zamora, M. Á. (2023). Analysis of the Mechanical Properties of a Stabilized Subgrade Type Soil under a Sustainable Approach for Construction. *Materials*, *16*(19), 6395.

Garvin, M. J. (2007). Rethinking mega-project development strategies: A case study of the Central Artery/Tunnel Project. *Structure and Infrastructure Engineering*, *3*(2), 147–157.

Li, L. H., Ning, T., Zhan, Z. Q., Gui, Y. L., & Zhang, C. (2025). Study on mechanical properties of fly ash and coir fiber improved expansive soil subgrade. *Acta Geotechnica*, 1–21.

Mahvash, S., López-Querol, S., & Bahadori-Jahromi, A. (2017). Effect of class F fly ash on fine sand compaction through soil stabilization. *Heliyon*, *3*(3).

Pandian, N. S., Krishna, K. C., & Sridharan, A. (2001). California bearing ratio behavior of soil/fly ash mixtures. *Journal of Testing and Evaluation*, *29*(2), 220–226.

Rangaswamy, K. (2016). Influence of burnt ash additives on stabilisation of soft clay soils. *Innovative Infrastructure Solutions*, *1*(1), 25.

Shen, Y., Tang, Y., Yin, J., Li, M., & Wen, T. (2021). An experimental investigation on strength characteristics of fiber-reinforced clayey soil treated with lime or cement. *Construction and Building Materials*, *294*, 123537.

Shukla, S., Sivakugan, N., & Das, B. (2009). Fundamental concepts of soil reinforcement—an overview. *International Journal of Geotechnical Engineering*, *3*(3), 329–342.

Turan, C., Javadi, A. A., Vinai, R., & Beig Zali, R. (2022). Geotechnical characteristics of fine-grained soils stabilized with fly ash, a review. *Sustainability*, *14*(24), 16710.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

RECENT TRENDS IN FUNCTIONAL FOODS IN TURKEY AND GLOBAL MARKETS

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ABSTRACT

Functional products, which offer health benefits beyond essential nutrients at competitive prices, are increasingly gaining traction in the global food market. An aging population, the increasing prevalence of chronic diseases, growing consumer health awareness, and increased interest in nutrition are significantly driving global demand for functional foods. Products containing probiotics and prebiotics, enriched dairy products, plant-based functional foods, and bioactive products constitute a significant portion of the global market.

The Turkish functional food market, while smaller in volume than the global market, has shown remarkable resilience in recent years. Functional products compatible with traditional diets, especially yogurt and fermented dairy products, are more easily adopted commercially. Regulatory restrictions, health claim rules, information in persistent sections, and pricing characteristics are important variables in the development of the Turkish industry.

This study was conducted using a comparative algorithm to determine the availability of functional foods in both Türkiye and global markets, and to enhance market dynamics and growth potential.

Key words: Functional foods, global market, Turkish market, health claims

1. INTRODUCTION

In recent years, functional foods have quickly gained popularity as a category that goes beyond simple calories and essential nutrients to offer a "health-supporting" value proposition through ingredients targeted at particular physiological goals. The rising incidence of chronic illnesses, an older population, improved health literacy, and consumers' growing desire to reduce risks through diet are the main drivers of this industry's growth. The quality of scientific data and the regulatory framework are crucial elements impacting commercial success since functional foods act as a "bridge category" connecting clinical nutrition and ordinary consumption (Fekete et al., 2025; Ponte et al., 2025).

Particularly in sub-segments such as "functional beverages," "probiotic/prebiotic products," "fortified dairy products," and "fiber and plant-based bioactives," the global market for functional foods is

growing. This expansion appears to be linked to the introduction of new products as well as the growth of "clean label," customized nutrition, microbiome-centric products, and wellness sectors (Abdul Manan, 2025; Gupta et al., 2023). According to the literature, a number of factors, such as perceived health benefits, price, sensory appeal, dependability, and the persuasiveness of label claims, affect consumer decisions (Ponte et al., 2025; Sgroi et al., 2024).

The problem for Turkey is twofold: First, the traditional consumption of fermented foods (like yogurt, ayran, kefir, and pickles) allows the concept of functional foods to converge with the discourse of "traditional health." Second, because health claims and labeling regulations have a direct impact on market communication, product development and marketing language are often reframed within the legal parameters. According to this scenario, consumer demand, regulation, monitoring, and health claim management are all closely related to the growth of functional items in the Turkish market (Ministry of Agriculture and Forestry, 2023).

By comparing the status of functional foods in the Turkish and international markets, this study seeks to evaluate the structural determinants of the market, the importance of product categories, consumer behavior trends, and the influence of the regulatory environment. Through a framework drawn from recent literature and regulatory documents, the study aims to examine where Turkey deviates from and complies with international trends.

2. THE CONCEPT OF FUNCTIONAL FOODS AND PRODUCT CATEGORIES

Functional foods are defined differently in the literature, but they all emphasize "a scientifically verified physiological benefit that extends beyond basic nutrition." The main focus of these definitions is on "bioactive components" (e.g., polyphenols, phytosterols, omega-3 fatty acids, bioactive peptides), "microbiota modulation" (probiotics, prebiotics, and postbiotics), and "enrichment/fortification" approaches (Fekete et al., 2025; Marcìa-Fuentes et al., 2025). Recent years have seen a discussion in practice over the definition of functional foods, especially in light of the diversity of probiotic-based products and the growth of the functional beverage category, which is based on "product format" (Abdul Manan, 2025; Gupta et al., 2023).

When considering product categories, probiotic/prebiotic products rank among the most significant market segments worldwide. Prebiotic fibers (inulin, FOS/GOS, etc.) have become crucial to the "gut health" narrative, and probiotic products are becoming more widely available, especially in fermented dairy products and beverage formats (Gupta et al., 2023). This segment's scientific and commercial success depends on the claimed effect's proven effectiveness in the target demographic, strain selection, survivability, and stability over the course of the shelf life (Abdul Manan, 2025). However, by lowering the requirement for living microorganisms, the development of postbiotics offers a fresh

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

chance for industrial stability. This interest is demonstrated by the recent increase in screening research on postbiotic consumption patterns and knowledge levels in Turkey (Kahve & Yıldız, 2026).

The second main type of functional foods consists of fortified goods. This category includes goods that are fortified with vitamins and minerals, milk and yogurt that are loaded with omega-3, products that contain plant sterols, and formulations that are aimed at particular groups of people, such as youngsters, athletes, and the elderly. The crucial questions at hand are the enhanced component's bioavailability and matrix integration. Furthermore, scientific evidence and regulatory compliance limit the statements that can be put on the label (Susanna, 2023).

Plant-based functional goods and foods high in natural bioactive chemicals make up the third category. Trends such as "superfood" narratives, an emphasis on polyphenol and antioxidant content, and the addition of functional components to plant-based proteins can all be used to evaluate this group. According to the research, the claim of "high bioactive content" is insufficient; instead, important considerations include dosage, daily consumption, interactions, and the quantifiability of the intended physiological consequence. As a result, when functional foods make a "health claim" in marketing materials, they must use an evidence-based approach to product development (Fekete et al., 2025; Marcìa-Fuentes et al., 2025).

In the end, one of the most important classification axes for functional items is compliant claim management. Regulation (EC) No 1924/2006 governs nutrition and health claims in the European Union, and EFSA evaluations set the necessary standard of evidence (Susanna, 2023). Labeling and communication language are significantly impacted by the 2023 amendments in Turkey regarding nutrition and health claims (Ministry of Agriculture and Forestry, 2023). As a result, in practice, functional food categories are differentiated not just by product format and ingredients but also by their prospective claims.

3. TURKEY AND THE GLOBAL FUNCTIONAL FOOD MARKET: PRESENT CONDITION AND COMPARATIVE EVALUATION

Demand driven by "preventive health" reasons and supply characterized by "product innovation" along with effective health communication are driving the growth of the global functional food sector. With a focus on the microbiome and digestive health, the functional beverage industry—which includes probiotic drinks, prebiotic sodas, protein beverages, and electrolyte-based products—has been a major growth driver in recent years (Gupta et al., 2023). This expansion has also improved customer segmentation: Customers with higher levels of health literacy, a tendency to read labels, and a preference for empirical data react differently to different products and communication strategies than consumers who are more influenced by social media, trends, and popular health narratives (Ponte et al., 2025; Sgroi et al., 2024).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

One of the main features of the global market is that marketing promises are strictly defined by regulations. A comprehensive regulatory framework pertaining to definitions, evidence requirements, and application processes governs health claims in the EU; this encourages the creation of more "evidence-based" products while limiting the language used in marketing (Susanna, 2023). The main source of information that successfully establishes the "scientific basis" threshold in the functional food market is EFSA's health claim structure and evaluations (Lenssen et al., 2018).

The Turkish market has a more discriminating framework when it comes to product diversity and claim regulation, although growing in line with global trends and growing health consciousness. In Turkey, probiotic dairy products and fermented foods like kefir and probiotic yogurts are very popular. Probiotic yogurt is the most popular product consumed in Turkey, according to research on the topic. Price, accessibility, and habitual behavior all have an impact on consumption patterns (Kıyak & Yılmaz, 2022). According to reports, a sizable portion of Turkish consumers believe that homemade probiotic goods are “healthier,” with classic products like yogurt and ayran being produced domestically. According to the findings, the Turkish functional food business is impacted by both conventional practices and industrial products, as well as the idea of "home-made health" (Çelik et al., 2022).

One of the main factors influencing the language used in the market in Turkey is the regulatory environment. The basis for labeling and claims has been updated by the Turkish Food Codex Nutrition Claims Regulation, which was published in the Official Newspaper on April 20, 2023. At the same time, criteria that the industry must follow in managing health claims have been clarified by guidelines and implementation principles. For the presentation of scientific data and the creation of claims for the introduction of functional foods into the Turkish market, this regulatory framework is essential (Ministry of Agriculture and Forestry, 2023).

Comparatively speaking, the product format and innovation environment are more broad in the global market: functional beverages, customized nutrition solutions, and formulations targeted at certain demographics are more frequently developed quickly. As a "secure core category," fermented and dairy products remain strong in Turkey, while the expansion of functional beverages and innovative ingredients is more gradual. A favorable environment for the creation of novel goods in line with international trends is created by Turkey's agricultural variety, long history of fermented product culture, and ability to collaborate between academia and industry. The increasing data on functional food knowledge and consumption frequency suggests that the market has matured, according to recent research conducted in Turkey (Çelik et al., 2022).

4. THE GLOBAL FUNCTIONAL FOOD MARKET'S LEADING COUNTRIES

Japan is the first nation to systematically address functional foods on a regulatory basis, which has earned it a historical leadership position. The "Foods for Specified Health Uses (FOSHU)" system

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

established a global benchmark and required scientific evidence to market functional foods with health claims at an early stage. Today, Japan has implemented a more adaptable "Foods with Function Claims (FFC)" application in addition to the FOSHU system. The dual structure fosters product innovation and establishes a market environment that preserves consumer confidence. The global market's primacy is further bolstered by the high awareness of functional foods and the regular consumption habits of Japanese consumers (Sato et al., 2025).

The "Health Functional Foods Act" of South Korea is a unique legal framework that governs functional foods. The approval processes for functional constituents, production standards, labeling, and advertising controls are comprehensively addressed by this legislation. In South Korea, functional foods are primarily focused on cognitive functions, the immune system, and digestive health. Consumer confidence is bolstered by state-supported control mechanisms and scientific evidence requirements. South Korea is regarded as one of the most advanced countries in the functional food market in terms of regulation-based market maturity (Jeong, 2024).

The United States stands out in the functional food market with greater product diversity, innovative formats, and rapid commercialization capacity. Functional beverages, protein and fiber-based products, and microbiome-focused foods hold a significant share in the US market. The regulatory approach in the US offers a more flexible structure compared to the European Union, which increases the pace of innovation in the market. Strong consumer demand, widespread retail channels, and marketing capacity make the US one of the global volume leaders in functional foods (Chhabra et al., 2025).

In contrast, the European Union countries establish leadership in the functional food market by adhering to rigorous regulatory frameworks and maintaining high scientific evidence standards. Regulation (EC) No 1924/2006 evaluates nutrition and health claims, necessitating scientific sanction from the European Food Safety Authority (EFSA) for the appropriate use of health claims. Although this method restricts marketing claims, it improves the empirical foundation and reliability of functional foods. The European market is notably strong in probiotic dairy products, fiber-enriched foods, and products containing plant sterols (Susanna, 2023).

The population scale and rapid development potential of China make it a standout in the functional food market. The demand for functional foods is increasing at an accelerated pace due to the increasing urbanization, lifestyle changes, and increased health awareness. The Chinese market is experiencing significant growth, particularly in the realm of plant-based functional products and bioactive constituents that are linked to traditional medicine methods. China is regarded as one of the primary contributors to the expansion of the global functional food market in this context (Garg et al., 2024).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

In general, Japan and South Korea are the most prominent regions in the functional food market in terms of regulation and market maturity, while the United States and China are the most prominent in terms of volume and growth dynamics. The European Union is the most prominent in terms of scientific evidence and consumer confidence. These countries share the commonality of treating functional foods as both commercial products and as a component of preventive health and nutrition policies (Cámara et al., 2026).

CONCLUSION

Functional foods have evolved from regular products that satisfy nutritional requirements to a central role in global food systems as a critical instrument for enhancing quality of life and preserving health. The global demand for functional foods is steadily increasing due to the growing burden of chronic diseases, an aging population, rising health awareness, and consumers' shifting toward preventive nutrition approaches. Functional foods have become a strategic area from both a scientific and economic standpoint as a result of this trend.

The development of the functional food market is closely associated with the regulatory approaches, consumer awareness, and innovation capacities of countries when assessed on a global scale. In terms of market maturity, Japan and South Korea are distinguished by their structures that established science-based regulatory frameworks and defined functional foods at an early stage. The European Union prioritizes the reliability of functional foods through its strict health claim regulations and high scientific evidence standards. Conversely, the United States and China are significant players in the global market due to their high market volume, rapid commercialization, and product diversity. These diverse methodologies demonstrate that the functional food market is not a uniform structure, but rather a result of multidimensional and country-specific dynamics.

Functional foods are regarded as a significant potential area for Turkey. Turkey's robust agricultural infrastructure, traditional food culture, and abundance of bioactive compounds, which are derived from fermented foods, provide significant benefits that facilitate consumer adoption of functional foods. Nevertheless, the rate of market development is significantly influenced by the heterogeneous structure of consumer awareness, regulatory restrictions, and regulations regarding health claims.

Therefore, in order to ensure the sustainable development of functional foods in Turkey and throughout the world, it is imperative to implement comprehensive policies that are designed to increase consumer awareness, establish health claim strategies that are in accordance with the regulatory framework, and adhere to scientific evidence-based product development. Functional foods are anticipated to assume a more significant role in the future, both as a high-value-added innovation area in the food sector and in supporting public health, once these conditions are satisfied.

REFERENCES

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Abdul Manan, M. (2025). Progress in probiotic science: Prospects of functional probiotic-based foods and beverages. *International Journal of Food Science*, *2025*(1), 5567567.

Cámara, M., Fernández-Ruiz, V., Díaz, L. D., Ciudad-Mulero, M., Cámara, R. M., Morales, P., & de Cortes Sánchez-Mata, M. (2026). Functional foods: Production, marketing, and regulatory issues. In *Bioactive Components for Functional Foods* (pp. 393–412). Elsevier.

Çelik, A. D., Sarıoğlu, T., & Dağıstan, E. (2022). *Determination of consumers' attitude and behaviours about probiotic products: a case study of TR63 region in Turkey:*278-287.

Chhabra, N., Shiriskar, J., & Srinivasan, G. (2025). Current and future market of the dietary supplements and nutraceuticals in the global Economy. In *Dietary Supplements and Nutraceuticals* (pp. 1–48). Springer.

Fekete, M., Lehoczki, A., Kryczyk-Poprawa, A., Zábó, V., Varga, J. T., Bálint, M., Fazekas-Pongor, V., Csípő, T., Rząsa-Duran, E., & Varga, P. (2025). Functional Foods in Modern Nutrition Science: Mechanisms, Evidence, and Public Health Implications. *Nutrients*, *17*(13), 2153.

Garg, V., Velumani, D., Lin, Y.-C., & Haye, A. (2024). A comprehensive review of probiotic claims regulations: Updates from Asia-Pacific, United States, and Europe. *PharmaNutrition*, *30*, 100423.

Gupta, A., Sanwal, N., Bareen, M. A., Barua, S., Sharma, N., Olatunji, O. J., Nirmal, N. P., & Sahu, J. K. (2023). Trends in functional beverages: Functional ingredients, processing technologies, stability, health benefits, and consumer perspective. *Food Research International*, *170*, 113046.

Jeong, M. (2024). 20th Anniversary of the Health Functional Foods Act: Achievements and Challenges. *Food Supplements and Biomaterials for Health*, *4*(3).

Kahve, A. N., & Yıldız, Y. (2026). Awareness, Knowledge and Consumption of Postbiotics Among Students at Two Different Universities in Türkiye: A Cross-Sectional Survey. *The European Research Journal*, *Advanced Online Publication*, 1–10.

Kıyak, B. D., & Yılmaz, İ. (2022). Consumers' attitudes toward probiotic dairy products in the post-Covid-19 normalization process. *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi*, *29*(1), 250–264.

Lenssen, K. G. M., Bast, A., & de Boer, A. (2018). Clarifying the health claim assessment procedure of EFSA will benefit functional food innovation. *Journal of Functional Foods*, *47*, 386–396.

Marcìa-Fuentes, J. A., Aleman, R. S., Areche, F. O., Flores, D. C., Roman, A. V., Martín-Vertedor, D., & Montero-Fernández, I. (2025). Functional foods: a review of foods ingredient and their health benefits. *Food and Humanity*, 100953.

Ministry of Agriculture and Forestry. (2023, April 20). Turkish Food Codex Regulation on Nutrition Claims (Official Newspaper No. 32169). Republic of Türkiye.

Ponte, L. G. S., Ribeiro, S. F., Pereira, J. C. V., Antunes, A. E. C., Bezerra, R. M. N., & da Cunha, D. T. (2025). Consumer perceptions of functional foods: A scoping review focusing on non-processed foods. *Food Reviews International*, *41*(6), 1738–1756.

Sato, K., Kodama, K., & Sengoku, S. (2025). The Co-Evolution of markets and regulation in the Japanese functional food industry: balancing risk and benefit. *Foods*, *14*(9), 1581.

Sgroi, F., Sciortino, C., Baviera-Puig, A., & Modica, F. (2024). Analyzing consumer trends in functional foods: A cluster analysis approach. *Journal of Agriculture and Food Research*, *15*, 101041.

Susanna, T. (2023). *Health claims made on foods: Findings on the implementation and application of Regulation (EC) No 1924/2006*.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FUNCTIONAL COMPONENTS ENHANCING IMMUNE SYSTEM: NUTRITION AND MICROBIOTA PERSPECTIVE

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ABSTRACT

The immune system is essential for the preservation of physiological homeostasis, the regulation of inflammation, the preservation of tissue integrity, and the protection against infections. Genetic characteristics, environmental conditions, and, particularly, nutritional status are all closely associated with the immune response's functionality. In this context, the interaction between the immune system and functional foods and the bioactive components present in these foods is a significant area of research. Among the primary components of functional foods that are associated with immunity are vitamins, minerals, omega-3 polyunsaturated fatty acids, polyphenols, bioactive peptides, and prebiotic, probiotic, and postbiotic nutrients. These components are assessed in the context of the epithelial barrier structure's protection, the overall modulation of the immune response, the balancing of inflammatory processes, and mechanisms associated with the intestinal environment. Furthermore, critical factors such as metabolic characteristics, individual nutritional status, and dietary patterns are assessed when assessing the relationship between functional components and the immune system. This overview presents a comprehensive approach that is consistent with the current scientific framework and examines functional components that support the immune system from a nutritional and dietary perspective.

Key words: functional components, immune system, microbiota

1. INTRODUCTION

The immune system is a sophisticated and multi-faceted defense mechanism that safeguards the organism from infectious pathogens. The interplay between the innate and adaptive immune systems is essential for pathogen identification, neutralization, and the establishment of immunological memory. The efficacy of these systems is intricately linked to genetic determinants as well as environmental exposures, lifestyle choices, and particularly nutritional status. Current literature unequivocally indicates that nutrition is a primary modulator influencing both the intensity and the configuration of immune response (Calder, 2020; Gombart et al., 2020).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Insufficient or imbalanced nutrition can result in deficiencies in the proliferation, differentiation, and effector capabilities of immune cells. Deficiencies in micronutrients, specifically, have been linked to elevated infection rates, unregulated inflammatory responses, and extended healing durations (Chandra, 1993; Maggini et al., 2018). Protein-energy malnutrition leads to diminished T-lymphocyte responses and reduced antibody synthesis, whereas deficits in vitamins and minerals adversely impact innate immunological functions (Calder et al., 2020; Childs et al., 2019).

Nutritional strategies designed to bolster the immune system have become increasingly significant in recent years. Functional foods are characterized as foods that deliver vital nutrients while also influencing physiological activities through their bioactive constituents. Vitamins, minerals, polyunsaturated fatty acids, polyphenols, bioactive peptides, and prebiotic/probiotic constituents in functional meals modulate the immune response by influencing several phases of the immune system (Carpena et al., 2022; Sharma & Yadav, 2022).

The impact of functional components on the immune system is complex and encompasses multiple mechanisms. The primary mechanisms of these benefits include enhancing antioxidant defense systems, regulating reactive oxygen species (ROS), and altering inflammatory signaling pathways (Ding et al., 2018; Kunst et al., 2023). The modulation of cellular signaling pathways, specifically NF-κB and MAPK, by functioning components is crucial for maintaining cytokine production (Sobhani et al., 2021).

Recent studies have revealed that the immune system interacts strongly with the gut microbiota. The gut microbiota plays a central role in the development and maintenance of mucosal immunity, and functional components can directly affect this microbial ecosystem (Belkaid & Hand, 2014; Zheng et al., 2020). Modulation of the microbiota composition through prebiotic and probiotic components, increased short-chain fatty acid production, and strengthening of the intestinal barrier integrity are defined as important mechanisms in supporting the immune system (Valdes et al., 2018).

Following the COVID-19 pandemic, both scientific interest and consumer awareness of functional foods that support the immune system have increased significantly. This process has necessitated more detailed research into the efficacy, optimal doses, and long-term effects of immune-supporting functional components. Current literature indicates that functional components have significant potential to support immune function when used at appropriate doses and in synergistic combinations (Zhang & Liu, 2020).

2. THE RELATIONSHIP BETWEEN NUTRITION AND THE IMMUNE SYSTEM

The link between nutrition and immunity involves various biological processes, such as fulfilling the energy and substrate needs of immune cells, preserving epithelial barrier integrity, and resolving inflammatory reactions. Innate immunity encompasses fast response mechanisms, including phagocytosis, antimicrobial peptide synthesis, and the release of inflammatory mediators, whereas

adaptive immunity facilitates sustained infection control via antigen-specific responses and immunological memory. Each of these responses is contingent upon the sufficiency of macro- and micronutrients; for instance, protein deficit may inhibit lymphocyte proliferation, whilst deficiencies in micronutrients might disturb cytokine equilibrium (Dawson et al., 2025; Munteanu & Schwartz, 2022).

The influence of micronutrients on immunity extends beyond merely "correcting deficiencies"; numerous vitamins and minerals serve as cofactors in enzymatic systems that govern immune cell development and effector activities. Zinc is essential for thymic hormone function, T-cell maturation, and the modulation of antiviral responses; selenium is crucial for managing oxidative stress via antioxidant mechanisms (e.g., selenoenzymes). In inflammatory situations characterized by elevated oxidative stress, inadequate antioxidant capacity may lead to functional "fatigue" of immune cells and a heightened risk of tissue damage (Maggini et al., 2018; van Neerven, 2025).

A crucial idea elucidating the connection between diet and immunity is immunometabolism. Upon the activation of immune cells, glucose, amino acid, and lipid metabolism undergo reprogramming; this process facilitates the biosynthetic demands and signal transduction essential for combating infection. Lipid mediators, particularly omega-3-derived specialized pro-resolving mediators (SPMs), can mitigate excessive and prolonged inflammation by actively participating in the resolution phase of inflammation; thus, an immune enhancement strategy should encompass not only the amplification of the response but also timely resolution (Calder, 2015; Perez-Hernandez et al., 2021).

At the clinical level, the immunological effects of nutritional interventions are frequently evaluated by metrics such as "infection incidence/duration," "vaccine response," "inflammatory markers," or "mucosal immunity." Population heterogeneity is crucial in this context: baseline factors such as vitamin D status, age, comorbidities, and lifestyle can substantially influence the intervention's efficacy. Recent meta-analyses indicate that vitamin D's efficacy in preventing acute respiratory infections may be restricted in the general population; nevertheless, varying results may occur in specific subgroups or under particular circumstances (Jolliffe et al., 2021).

The gastrointestinal system, a significant sensory interface of the immune system, plays a crucial role in defining the link between nutrition and immunity. Dietary elements regulate the microbiota; metabolites generated by the microbiota (e.g., short-chain fatty acids) enhance epithelial barrier integrity and affect the equilibrium of immunological tolerance and activation. In this context, functional components aim to directly influence immune cells as well as indirectly modulate immunity through the microbiota. The prebiotic/probiotic/postbiotic axis has been shown to possibly influence outcomes including mucosal IgA response, anti-inflammatory cytokine profile, and resistance to pathogen colonization (Salminen et al., 2021; Zheng et al., 2020).

3. KEY FUNCTIONAL COMPONENTS SUPPORTING THE IMMUNE SYSTEM

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

3.1. Vitamins (A, C, D, E)

Vitamin A is crucial for preserving epithelial integrity and mucosal immunity; it contributes to processes like T-cell development and intestinal homing through retinoic acid. Compromised integrity of mucosal surfaces may allow pathogen transfer and exacerbate inflammation; thus, enough vitamin A is seen essential for "barrier"-based immunity. Moreover, it is highlighted that vitamin A deficiency may heighten vulnerability to specific infections, particularly during critical stages such as youth and pregnancy (Gürbüz & Aktaç, 2022; Huang et al., 2018).

Vitamin C enhances innate immunological processes, including neutrophil chemotaxis and phagocytosis, while its robust antioxidant properties safeguard immune cells from oxidative harm. Vitamin E enhances cellular integrity by mitigating lipid membrane oxidation and aids in the regulation of inflammatory processes. In clinical settings, the impact of these vitamins is frequently assessed by "duration of illness," "severity of symptoms," or "oxidative stress markers"; nevertheless, variations in dosage, formulation, and study population can substantially influence the outcomes (Li et al., 2023; Maggini et al., 2018).

Vitamin D has been a highly contested element in the realm of immunology for the past five years. The existence of vitamin D receptors in monocytes, dendritic cells, and T/B cells indicates that it may influence the immune response by affecting antimicrobial peptide expression and cytokine profiles. Current meta-analyses indicate that the overall impact size in preventing acute respiratory infections may be constrained, with variations influenced by baseline vitamin D levels, dose regimen, and study design. Consequently, instead of broad assertions like "vitamin D enhances immunity universally," it is advisable to tailor vitamin D supplementation based on specific risk groups and deficient levels (Ao et al., 2021; Zulkipli & Ahmad, 2026).

3.2. Minerals (Zinc, Selenium, Iron)

Zinc is essential for T-cell maturation, antiviral responses, and mucosal barrier activities; shortage is associated with heightened susceptibility to infections. Selenium is a fundamental component of antioxidant defense through selenoproteins and may help mitigate tissue damage during infection or inflammation when oxidative stress is elevated. Iron serves as a double-edged sword: shortage can impair immunological activities, while excess iron may facilitate pathogen proliferation. Therefore, iron therapies must be assessed with regard to infection risk and the clinical context (Gombart et al., 2020; Terpiłowska & Siwicki, 2011).

3.3. Omega-3 Fatty Acids (EPA/DHA) and Pro-Resolving Mediators

The connection between EPA and DHA and immunity extends beyond their "anti-inflammatory" properties; these fatty acids serve as precursors for specialized pro-resolving mediators (SPMs) that regulate the active resolution of inflammation. SPMs initiate a "resolution" procedure that facilitates the physiological cessation of inflammation and promotes tissue repair, rather than merely suppressing

inflammation. This methodology offers a theoretical foundation for the judicious application of functional food constituents in metabolic disorders and specific inflammatory bowel diseases characterized by chronic inflammation. Moreover, existing preclinical and clinical evidence indicates that omega-3-derived mediators may possess protective properties in diseases such intestinal inflammation (Lee & Tribble, 2025; Perez-Hernandez et al., 2021).

4. GUT MICROBIOTA, FUNCTIONAL COMPONENTS, AND IMMUNITY

The gut microbiota is important in the formation, education, and maintenance of the immune system, frequently termed the "second immune organ." The presence of a substantial number of human immune cells in gut-associated lymphoid tissue (GALT) underscores the physiological significance of microbiota–immune interactions. Microbial antigens and metabolites deliver essential signals that influence innate and adaptive immune responses (Belkaid & Hand, 2014). Recent research indicates that dietary functional components indirectly influence the immune response by modifying the composition and functional capability of the microbiota (Makki et al., 2018; Salminen et al., 2021).

The influence of the microbiota on the immune system extends beyond microbial diversity; microbial metabolites, especially short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate, directly impact the functionality of immune cells. SCFAs facilitate the preservation of immunological tolerance and mitigate inflammatory responses by promoting the development of regulatory T cells (Tregs). Recent evaluations highlight that dietary fibers and prebiotic elements confer a protective influence on mucosal immunity by enhancing SCFA synthesis (Jenkins & Mason, 2022; Vinelli et al., 2022).

Prebiotics in functional foods (e.g., inulin, fructooligosaccharides, galactooligosaccharides) preferentially promote the proliferation of beneficial microbes, enhancing microbiota equilibrium. Consumption of prebiotics has been shown to enhance the integrity of the intestinal epithelial barrier and diminish pathogen translocation. Moreover, prebiotics have demonstrated the ability to regulate cytokine profiles, which are crucial in the immune response, and to mitigate low-grade inflammation (Bindels et al., 2015; Valdes et al., 2018).

Probiotics are living bacteria that confer health benefits to the host when ingested in enough quantities. Numerous probiotic strains, chiefly Lactobacillus and Bifidobacterium species, have been documented to enhance mucosal IgA synthesis, modulate dendritic cell activities, and confer a competitive edge against infections. Current work underscores that the effects of probiotics are strain-specific, rendering the blanket assertion that "probiotics enhance immunity" scientifically inadequate (Hill et al., 2014; Zmora et al., 2018).

In recent decades, the notion of "postbiotics" has acquired significance as an immune-supporting functional component. Postbiotics are characterized as entities that lack live microorganisms yet produce biological effects via microbial cell components or metabolites. Short-chain fatty acids,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

components of microbial cell walls, and enzymatic products have been documented to effectively regulate inflammation and modulate immunological signaling pathways. Postbiotics are proposed to enhance the stability and safety of functional food formulations owing to the absence of living microorganisms (Aguilar-Toalá et al., 2018; Shi et al., 2024).

Scientific interest in the microbiota-immune axis has intensified in the post-COVID-19 pandemic period. Recent research indicates that dysbiosis may correlate with the severity of infections and inflammatory responses, and that nutritional methods aimed at the microbiota could provide a beneficial intervention. Microbiota-based functional interventions should be regarded as components of comprehensive nutrition and lifestyle strategies, rather than as isolated therapy methods (Calder, 2020; Dhar & Mohanty, 2020).

5. ASSESSMENT OF CURRENT CLINICAL AND EXPERIMENTAL RESEARCH ON FUNCTIONAL COMPONENTS ENHANCING IMMUNE FUNCTION

Current studies assessing the impact of functional components on the immune system encompasses a broad spectrum of methodologies, including in vitro tests and randomized controlled clinical trials. In evaluating these studies, the model type, intervention duration, dosage, beginning nutritional condition, and assessed immunological parameters are significant considerations. Functional components maintain immunological homeostasis and have balanced effects on the inflammatory response, rather than unilaterally "enhance" the immune response, according to recent systematic reviews (Calder et al., 2020; Skenderidou et al., 2025).

The current clinical research on vitamin D indicates that its immune-supportive effects are dependent on binding. In the general population, vitamin D supplementation may have a limited effect on preventing acute respiratory infections, according to meta-analyses published in 2023–2024. However, more pronounced results may be achieved in individuals with low baseline levels or in specific risk groups. These results indicate that functional components should be incorporated into targeted nutrition strategies rather than being treated as a universal solution (Jolliffe et al., 2021).

Recent research on omega-3 fatty acids (EPA and DHA) suggests that the immune response is regulated throughout the resolution phase of inflammation. Specialized pro-resolving mediators (SPMs), recently delineated, facilitate the active resolution of inflammation, in contrast to traditional anti-inflammatory methods. Research involving both animals and humans has demonstrated that omega-3-derived SPMs regulate the cytokine profile and mitigate excessive inflammation. This process indicates that functional lipids can modulate the immune system without its suppression (Calder, 2015; Djuricic & Calder, 2021).

Clinical studies indicate that the effects of probiotics and prebiotics on immunity are predominantly specific to particular strains and components. Certain *Lactobacillus* and *Bifidobacterium* strains have been documented to elevate mucosal IgA levels and reduce illness duration; however, these benefits

cannot be universally applied to all probiotics. Recent research indicates that synbiotics enhance intestinal barrier integrity and diminish inflammatory indicators (Kazemi et al., 2019; Sanders et al., 2019; Shi et al., 2024).

Experimental research on polyphenols and bioactive peptides suggests that these substances can influence immunological signaling pathways at the cellular level. Polyphenols have been shown to diminish inflammatory cytokine production by inhibiting the NF-κB and MAPK pathways, whilst bioactive peptides modulate macrophage and lymphocyte function. Nonetheless, to achieve clinical relevance from these findings, extended and meticulously structured treatments in human trials are required (González et al., 2011; Sobhani et al., 2021).

The existing literature indicates that functional components influence the immune system in a "balancing" rather than a "stimulating" manner. This indicates that the immune-enhancing properties of functional foods ought to be assessed within the context of long-term dietary practices rather than short-term interventions (Calder, 2020; Salminen et al., 2021).

REFERENCES

Aguilar-Toalá, J. E., Garcia-Varela, R., Garcia, H. S., Mata-Haro, V., González-Córdova, A. F., Vallejo-Cordoba, B., & Hernández-Mendoza, A. (2018). Postbiotics: An evolving term within the functional foods field. *Trends in Food Science & Technology*, *75*, 105–114.

Ao, T., Kikuta, J., & Ishii, M. (2021). The effects of vitamin D on immune system and inflammatory diseases. *Biomolecules*, *11*(11), 1624.

Belkaid, Y., & Hand, T. W. (2014). Role of the microbiota in immunity and inflammation. *Cell*, *157*(1), 121–141.

Bindels, L. B., Delzenne, N. M., Cani, P. D., & Walter, J. (2015). Towards a more comprehensive concept for prebiotics. *Nature Reviews Gastroenterology & Hepatology*, *12*(5), 303–310.

Calder, P. C. (2015). Marine omega-3 fatty acids and inflammatory processes: Effects, mechanisms and clinical relevance. *Biochimica et Biophysica Acta (BBA) - Molecular and Cell Biology of Lipids*, *1851*(4), 469–484. https://doi.org/https://doi.org/10.1016/j.bbalip.2014.08.010

Calder, P. C. (2020). Nutrition, immunity and COVID-19. *BMJ Nutrition, Prevention & Health*, *3*(1), 74–92. https://doi.org/10.1136/bmjnph-2020-000085

Calder, P. C., Carr, A. C., Gombart, A. F., & Eggersdorfer, M. (2020). Optimal nutritional status for a well-functioning immune system is an important factor to protect against viral infections. *Nutrients*, *12*(4), 1181.

Carpena, M., da Pereira, R., Garcia-Perez, P., Otero, P., Soria-Lopez, A., Chamorro, F., Alcaide-Sancho, J., Fraga-Corral, M., Prieto, M. A., & Simal-Gandara, J. (2022). An Overview of Food Bioactive Compounds and Their Properties. *Membrane Separation of Food Bioactive Ingredients*, 39–79.

Chandra, R. K. (1993). Nutrition and the immune system. *Proceedings of the Nutrition Society*, *52*(1), 77–84.

Childs, C. E., Calder, P. C., & Miles, E. A. (2019). Diet and immune function. In *Nutrients* (Vol. 11, Issue 8, p. 1933). Multidisciplinary Digital Publishing Institute.

Dawson, S. L., Todd, E., & Ward, A. C. (2025). The interplay of nutrition, the gut microbiota and immunity and its contribution to human disease. *Biomedicines*, *13*(2), 329.

Dhar, D., & Mohanty, A. (2020). Gut microbiota and Covid-19-possible link and implications. *Virus Research*, *285*, 198018.

Ding, S., Jiang, H., & Fang, J. (2018). Regulation of immune function by polyphenols. *Journal of Immunology Research*, *2018*(1), 1264074.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Djuricic, I., & Calder, P. C. (2021). Beneficial Outcomes of Omega-6 and Omega-3 Polyunsaturated Fatty Acids on Human Health: An Update for 2021. In *Nutrients* (Vol. 13, Issue 7). https://doi.org/10.3390/nu13072421

Gombart, A. F., Pierre, A., & Maggini, S. (2020). A review of micronutrients and the immune system–working in harmony to reduce the risk of infection. *Nutrients*, *12*(1), 236.

González, R., Ballester, I., López-Posadas, R., Suárez, M. D., Zarzuelo, A., Martínez-Augustin, O., & Medina, F. S. De. (2011). Effects of flavonoids and other polyphenols on inflammation. *Critical Reviews in Food Science and Nutrition*, *51*(4), 331–362.

Gürbüz, M., & Aktaç, Ş. (2022). Understanding the role of vitamin A and its precursors in the immune system. *Nutrition Clinique et Métabolisme*, *36*(2), 89–98.

Hill, C., Guarner, F., Reid, G., Gibson, G. R., Merenstein, D. J., Pot, B., Morelli, L., Canani, R. B., Flint, H. J., & Salminen, S. (2014). The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. *Nature Reviews Gastroenterology & Hepatology*, *11*(8), 506–514.

Huang, Z., Liu, Y., Qi, G., Brand, D., & Zheng, S. G. (2018). Role of vitamin A in the immune system. *Journal of Clinical Medicine*, *7*(9), 258.

Jenkins, G., & Mason, P. (2022). The role of prebiotics and probiotics in human health: A systematic review with a focus on gut and immune health. *Food Nutr. J*, *6*, 245.

Jolliffe, D. A., Camargo, C. A., Sluyter, J. D., Aglipay, M., Aloia, J. F., Ganmaa, D., Bergman, P., Bischoff-Ferrari, H. A., Borzutzky, A., & Damsgaard, C. T. (2021). Vitamin D supplementation to prevent acute respiratory infections: a systematic review and meta-analysis of aggregate data from randomised controlled trials. *The Lancet Diabetes & Endocrinology*, *9*(5), 276–292.

Kazemi, A., Noorbala, A. A., Azam, K., Eskandari, M. H., & Djafarian, K. (2019). Effect of probiotic and prebiotic vs placebo on psychological outcomes in patients with major depressive disorder: A randomized clinical trial. *Clinical Nutrition*, *38*(2), 522–528.

Kunst, C., Schmid, S., Michalski, M., Tümen, D., Buttenschön, J., Müller, M., & Gülow, K. (2023). The influence of gut microbiota on oxidative stress and the immune system. *Biomedicines*, *11*(5), 1388.

Lee, C.-T., & Tribble, G. D. (2025). Correction: Roles of specialized pro-resolving mediators and omega-3 polyunsaturated fatty acids in periodontal inflammation and impact on oral microbiota. *Frontiers in Oral Health*, *6*, 1691158.

Li, X.-Y., Meng, L., Shen, L., & Ji, H.-F. (2023). Regulation of gut microbiota by vitamin C, vitamin E and β-carotene. *Food Research International*, *169*, 112749.

Maggini, S., Pierre, A., & Calder, P. C. (2018). Immune function and micronutrient requirements change over the life course. *Nutrients*, *10*(10), 1531.

Makki, K., Deehan, E. C., Walter, J., & Bäckhed, F. (2018). The impact of dietary fiber on gut microbiota in host health and disease. *Cell Host & Microbe*, *23*(6), 705–715.

Munteanu, C., & Schwartz, B. (2022). The relationship between nutrition and the immune system. *Frontiers in Nutrition*, *9*, 1082500.

Perez-Hernandez, J., Chiurchiù, V., Perruche, S., & You, S. (2021). Regulation of T-cell immune responses by pro-resolving lipid mediators. *Frontiers in Immunology*, *12*, 768133.

Salminen, S., Collado, M. C., Endo, A., Hill, C., Lebeer, S., Quigley, E. M. M., Sanders, M. E., Shamir, R., Swann, J. R., & Szajewska, H. (2021). The International Scientific Association of Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of postbiotics. *Nature Reviews Gastroenterology & Hepatology*, *18*(9), 649–667.

Sanders, M. E., Merenstein, D. J., Reid, G., Gibson, G. R., & Rastall, R. A. (2019). Probiotics and prebiotics in intestinal health and disease: from biology to the clinic. *Nature Reviews Gastroenterology & Hepatology*, *16*(10), 605–616. https://doi.org/10.1038/s41575-019-0173-3

Sharma, L., & Yadav, A. (2022). Role of functional foods in human health and disease prevention. In *Bioactive Components: A Sustainable System for Good Health and Well-Being* (pp. 225–243). Springer.

Shi, J., Wang, Y., Cheng, L., Wang, J., & Raghavan, V. (2024). Gut microbiome modulation by probiotics, prebiotics, synbiotics and postbiotics: a novel strategy in food allergy prevention and treatment. *Critical Reviews in Food Science and Nutrition*, *64*(17), 5984–6000.

Skenderidou, I., Leontopoulos, S., & Skenderidis, P. (2025). Functional Food Ingredients Enhancing Immune Health: A Systematic Review. *International Journal of Molecular Sciences*, *26*(17), 8408.

Sobhani, M., Farzaei, M. H., Kiani, S., & Khodarahmi, R. (2021). Immunomodulatory; anti-inflammatory/antioxidant effects of polyphenols: A comparative review on the parental compounds and their metabolites. *Food Reviews International*, *37*(8), 759–811.

Terpiłowska, S., & Siwicki, A. K. (2011). Review paper The role of selected microelements: selenium, zinc, chromium and iron in immune system. *Central European Journal of Immunology*, *36*(4), 303–307.

Valdes, A. M., Walter, J., Segal, E., & Spector, T. D. (2018). Role of the gut microbiota in nutrition and health. *Bmj*, *361*.

van Neerven, R. J. J. (2025). Macronutrients, Micronutrients, and Malnutrition: Effects of Nutrition on Immune Function in Infants and Young Children. *Nutrients*, *17*(9), 1469.

Vinelli, V., Biscotti, P., Martini, D., Del Bo', C., Marino, M., Meroño, T., Nikoloudaki, O., Calabrese, F. M., Turroni, S., & Taverniti, V. (2022). Effects of dietary fibers on short-chain fatty acids and gut microbiota composition in healthy adults: a systematic review. *Nutrients*, *14*(13), 2559.

Zhang, L., & Liu, Y. (2020). Potential interventions for novel coronavirus in China: A systematic review. *Journal of Medical Virology*, *92*(5), 479–490.

Zheng, D., Liwinski, T., & Elinav, E. (2020). Interaction between microbiota and immunity in health and disease. *Cell Research*, *30*(6), 492–506.

Zmora, N., Zilberman-Schapira, G., Suez, J., Mor, U., Dori-Bachash, M., Bashiardes, S., Kotler, E., Zur, M., Regev-Lehavi, D., & Brik, R. B.-Z. (2018). Personalized gut mucosal colonization resistance to empiric probiotics is associated with unique host and microbiome features. *Cell*, *174*(6), 1388–1405.

Zulkipli, I. N., & Ahmad, L. (2026). Vitamin D and the immune system. In *The Impact of Vitamin D on Health and Disease* (pp. 71–107). Elsevier.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CYBERSECURITY RISKS IN DIGITAL MARITIME APPLICATIONS: CURRENT SITUATION AND FUTURE PROJECTIONS

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ABSTRACT

In the last decade, the maritime sector has rapidly shifted its course towards digitalization, moving away from traditional navigation methods. Today, a wide range of data-driven technologies are used, from autonomous ships to smart port management systems. However, while this digitalization drive has increased efficiency, it has also turned maritime vessels and port infrastructure into a new playground for cyber pirates. This study aims to uncover the invisible dangers in the digitalized maritime ecosystem and to examine the real impact of these cyber risks on ship safety. The study adopts a qualitative research method to reflect the reality in the field rather than theoretical approaches. In this context, critical cyber incidents recently recorded in global maritime transport have been examined using case analysis. In addition, the applicability of existing IMO (International Maritime Organization) regulations and cybersecurity standards in the field has been evaluated from a comparative perspective. The data obtained from the research shows that cyber threats are no longer limited to data theft; It clearly demonstrates that the physical routes of ships can be interfered with, particularly through methods such as GPS spoofing and AIS manipulation. The most striking finding is that the uncontrolled integration of operational technology (OT) networks, which manage the vital functions of ships, with information networks (IT) creates a serious defence gap. Overall results imply that cyber resilience in maritime transport is not merely a technical "software update," but a holistic "safety culture." Including cybersecurity in the design from the shipbuilding stage and increasing personnel awareness of these invisible threats is an unavoidable necessity for the future of the blue economy.

Keywords: Digital Maritime; Maritime Cybersecurity; Cyber-Physical Systems; OT Security; Ship Navigation Safety; Risk Assessment

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

1. INTRODUCTION

The maritime sector is an ecosystem that dominates more than 80% of global trade (UNCTAD, 2024), forming the backbone of the world economy. With the process called "Maritime 4.0," ships are no longer just floating masses of metal, but "floating computers" connected to complex data networks. While this digitalization drive increases efficiency, opening up traditionally isolated (air-gapped) systems to the internet has introduced the concept of cyberpiracy into the literature. Cyberattacks have the potential to cause disruptions in logistics operations, economic losses, and even environmental disasters (Erbas et al., 2024), making cybersecurity a critical priority in the maritime sector rather than an optional feature (Akpan et al., 2022). In this context, an in-depth analysis of the cybersecurity risks posed by digitized maritime practices and the search for strategic solutions to these risks are of great importance (Bolbot et al., 2022; Farah et al., 2022). This study aims to comprehensively examine the cyber threats posed by digitalization, as well as the advantages it provides, considering the unique security challenges of maritime infrastructure, and to discuss the impact of these threats on operational continuity (Koca & Erdoğan, 2024; Mohsendokht et al., 2024). This study will focus particularly on identifying new vulnerabilities arising from the integration of advanced digital systems such as autonomous vessels and port automation, and developing proactive defence mechanisms against these threats (Erbas et al., 2024). The digital transformation, accelerated especially by the COVID-19 pandemic, has created new cyber risk opportunity structures in the maritime sector and increased the severity of cyberattacks that can cripple critical systems (Kuhn et al., 2021). With this transformation, the inadequacy of traditional perimeter defence and the need for more dynamic defence strategies have become a concrete reality. This clearly demonstrates that cybersecurity threats are not merely a technological issue, but require a holistic approach encompassing the human factor and business processes (Kapalidis et al., 2022). Therefore, managing cybersecurity risks in the maritime sector requires leaders to have a complete understanding of technological risks and cyber threats (Tatar et al., 2024).

However, research shows that maritime leaders lack a complete picture of technological risks and cyber threats, and even those who believe cyberattacks pose a high or medium risk to their organizations are often unprepared (Tatar et al., 2024). According to the same study, this increases the potential for significant cyberattacks that could have tangible impacts on the stability and security of international trade and energy sectors. Consequently, this vulnerability makes more structured and implementable risk management models essential to ensure the continuity of maritime operations.

The aim of this study is to conduct an in-depth analysis of cybersecurity risks in the digitalized maritime sector, to evaluate existing strategic solution approaches against these risks, and to propose innovative defence mechanisms against future threats.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

1.1. Cyber-security in maritime domain

With digitalization in the maritime sector, cybersecurity threats have increased, and ships and port infrastructures have become interconnected in complex networks. This process, known as Maritime 4.0, has led to the integration of IT and OT systems, creating cybernetic-physical systems and resulting in the autonomy and remote control of ships; this has brought with it new attack vectors (e.g., GNSS spoofing, sensor manipulation, and communication disruptions) (Kavallieratos & Katsikas, 2020; Yousaf et al., 2024). Erbas et al., emphasizing the critical role of the maritime sector for global trade, examined the logistical and economic consequences of cyberattacks through a systematic literature review; they stated that new threats have emerged with the interconnection of ship subsystems (Erbas et al., 2024). This situation proves that cyber risks are not only a data security breach but also a systemic risk threatening global supply chain resilience. Similarly, Mohsendokht et al. analysed the dependencies of risk factors by developing a Bayesian network model based on cyber incidents over the past 20 years and revealed that maritime infrastructures are vulnerable to broad impacts at the national/international level (Mohsendokht et al., 2024). Likewise, a bibliometric analysis conducted by Chaal et al. (2023) found that the highest cyber risks in autonomous vessels are concentrated in navigation and communication systems.

In addition to cyber threats, strategic solution approaches for managing these risks are also extensively covered in the literature. Tatar et al. (2024), demonstrating the inadequacy of maritime leaders' awareness of cyber risks with empirical data, argued that integrated risk assessment models are an operational necessity. Completing this managerial gap (Kanwal et al., 2022), they emphasized that cybersecurity performance can be improved not only through technology but also through the synchronized management of dimensions such as regulations, procedures, continuous training, and the human factor.

In the search for technical solutions, Yousaf et al. (2024) proved that navigation awareness systems are the most critical risk points with their hybrid method developed for autonomous cargo ships, and offered a methodology for proactive defence strategies. However, although current studies show progress in threat modelling and training, holistic approaches that integrate autonomous systems and the human factor are still limited in the literature (Akpan et al., 2022; Chaal et al., 2023; Erbas et al., 2024; Koca & Erdoğan, 2024).

2. MATERIALS AND METHODS

This study comprehensively reviews and analyses the literature focusing on cybersecurity risks, threat analyses, and strategic solutions in digital maritime applications using a systematic approach. The research methodology is based on a systematic literature review conducted through academic databases; keywords such as "maritime cybersecurity," "cyber risks in shipping," and "digital maritime cyber threats" were used, with priority given to publications from the last 20 years (Bolbot et al., 2022;

Erbas et al., 2024; Farah et al., 2022). The studies examined include methods such as Bayesian network models based on cyber incidents in the last two decades (Mohsendokht et al., 2024), bibliometric analyses (Bolbot et al., 2022), and survey-based risk assessments (Tatar et al., 2024), and the dependencies of threats, risk factors, and solution approaches were categorized and synthesized. In this process, 38 academic articles and case reports were reviewed, highlighting specific areas such as autonomous systems, human factors, and pandemic-related risks through qualitative analysis (Akpan et al., 2022; Koca & Erdoğan, 2024; Kuhn et al., 2021). The findings identified gaps in the existing literature and formed the basis for developing recommendations in subsequent sections of the study.

3. RESULTS AND DISCUSSION

In this context, a systematic literature review conducted to fill the gaps in the field of maritime cybersecurity has revealed important research topics related to cybersecurity (Bolbot et al., 2022; Enoch et al., 2021; Tatar et al., 2024). The literature clearly shows that new threats emerge with the interconnection of ship subsystems (Erbas et al., 2024), that the dependencies of risk factors are analysed using Bayesian network models based on cyber incidents of the last 20 years (Mohsendokht et al., 2024), and that the types of risks brought about by the Industry 4.0 revolution are highlighted through bibliometric analyses (Bolbot et al., 2022). Furthermore, gaps such as insufficient cyber risk awareness among leaders (Tatar et al., 2024) and the lack of holistic approaches to autonomous systems and the human factor (Akpan et al., 2022; Koca & Erdoğan, 2024) have been identified. These findings highlight the need to develop proactive defence mechanisms focused on threat modelling, risk analysis, and training.

3.1. Current Cyber Threat Landscape

A 150% increase in cyberattacks targeting the maritime sector was observed between 2024-2025; this increase resulted from the acceleration of digitalization and IT/OT integration, leading to the connection of ships and port infrastructures to complex networks (Mohsendokht et al., 2024; Yousaf et al., 2024). In particular, the DNV ShipManager incident in 2023 disrupted data synchronization for approximately 1,000 ships, causing disruptions in global operations and once again proving the critical importance of software supply chain security (Blank Rome LLP, 2023). Vulnerabilities in the sector were not limited to software errors; the $300 million loss suffered by Maersk as a result of the NotPetya attack demonstrated the financial destructiveness of cyber risks (Jensen, 2018).

Current data reveals that state-sponsored APT (Advanced Persistent Threat) groups are systematically targeting port logistics networks and critical maritime infrastructure. Significant cyber incidents reported by CSIS (2025) confirm that attacks targeting critical infrastructure and maritime OT systems pose a strategic threat to national security.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

3.2. GNSS/GPS Spoofing and Physical Effects

In geopolitically tense regions like the Red Sea and the Eastern Mediterranean, "spoofing" incidents have reached thousands daily. Attackers suppress the real signals from satellites, causing the ship to perceive itself as being in a different location. The grounding of a container ship in May 2025 due to this reason is the most concrete evidence that digital attacks can turn into physical disasters.

3.3. IT/OT Convergence and Loss of Control

The uncontrolled convergence of Operational Technology (OT) networks, which manage vital functions such as the ship's main engine, steering control, and ballast systems, with Information Technology (IT) networks brings with it unique security challenges stemming from the proliferation of industrial control systems (Boyes, 2015). These systems, traditionally considered isolated (air-gapped), become open to the internet with digitalization, making it possible for attackers to gain access to OT control through email phishing or malware updates. Boyes (2015) emphasizes that the cyber-physical risks created by this diffusion cannot be fully managed with classical IT security methods (Farah et al., 2022; Fjørtoft et al., 2023). PLC interfaces left open to the internet open the door to scenarios such as an attacker slowing down the ship's engine speed, changing course, or manipulating the fuel system; this can lead to physical accidents and operational paralysis (Yousaf et al., 2024).

Cyber incident analyses over the past 20 years show that IT/OT convergence increases risk dependencies, and Bayesian network models have revealed that the most critical factor in such incidents is the lack of network segmentation (Mohsendokht et al., 2024). Particularly in autonomous ships, cyber vulnerability is increasing with the widespread adoption of remote access technologies; for example, vulnerabilities in remotely controlled systems can trigger new waves of attacks on a global scale (Chaal et al., 2023; Fjørtoft et al., 2023). As highlighted in the literature, the interconnection of onboard systems creates new threat vectors, and traditional security measures prove insufficient (Akpan et al., 2022; Erbas et al., 2024). In this context, the adoption of network isolation and zero-trust architectures is critical in preventing loss of control. Furthermore, insufficient cybersecurity awareness and training deficiencies in the maritime sector increase the success rate of attacks such as ransomware and phishing (Larsen et al., 2024).

The uncontrolled convergence of Operational Technology (OT) networks, which manage vital functions such as the ship's main engine, steering control, and ballast systems, with Information Technology (IT) networks creates serious defence gaps (Bolbot et al., 2022; Erbas et al., 2024; Li et al., 2024; Tatar et al., 2024). When traditionally isolated OT systems are integrated into IT networks during the digitalization process, it becomes possible for cyber attackers to gain access to OT control by infiltrating the IT layer through email phishing, malware updates, or virus-infected files downloaded from the internet (Farah et al., 2022; Fjørtoft et al., 2023; Tatar et al., 2024). PLC

interfaces left open to the internet open the door to scenarios such as an attacker slowing down the ship's engine speed, changing course, manipulating the fuel system, or disrupting dynamic positioning systems; This situation can lead to physical accidents, operational paralysis, and even environmental disasters (Tam et al., 2021; Yousaf et al., 2024). For example, in 2013, malware downloaded by the crew on an oil platform in the Gulf of Mexico spread from IT to OT systems, disabling thrusters that maintained the platform's position and halting operations (Tatar et al., 2024). Such integrations expand the attack surface, further increasing the risks of IT/OT entanglement on autonomous vessels, with inadequate network segmentation emerging as a common vulnerability (Larsen et al., 2024; Tatar et al., 2024; Yousaf et al., 2024).

3.4. Strategic measures and policy recommendations

Combating cyber threats requires a multi-layered "Depth of Defence" strategy, ranging from ship-level to national policies. This approach, based on BIMCO and IMO guidance, integrates the identification, protection, detection, response, and remediation functions of the NIST Cybersecurity Framework, avoiding reliance on a single layer of defence and minimizing vulnerabilities (Tatar et al., 2024). At the ship level, technical and operational measures such as segmentation of IT/OT networks, isolation of PLC interfaces, redundant PNT systems, and mandatory cyber training for the crew are prioritized (Amro & Gkioulos, 2022; Mohsendokht et al., 2024); while at the company level, procedural standardization and incident response plans, and at the national/international level, ISPS Code, ISM Code updates, Maritime-ISACs, and mandatory cyberresilience certifications should support this approach (Johansson et al., 2023; Tatar et al., 2024). This multi-layered structure plays a critical role in managing the digital transformation risks of the maritime sector by increasing proactive resilience against threat actors (Amro & Gkioulos, 2022). In this context, collaborating with cybersecurity experts, developing comprehensive cybersecurity policies, and creating incident response plans are of great importance (Mohsendokht et al., 2024).

3.4.1. National and International Policy Recommendations

To build global resilience against cyber threats, flag states and international organizations need to enhance their regulatory roles. The most fundamental reference in this regard is Resolution MSC.428(98) published by the IMO (2017). This resolution mandates that companies address cyber risks in their Security Management Systems (SMS), making cybersecurity an integral part of maritime safety (Ahmed et al., 2024; Tatar et al., 2024). It is essential that this legal framework be supported by standards such as the NIST Cybersecurity Framework to guarantee the resilience of IT/OT systems.

Mandatory Certification: Countries must establish mandatory cyberresilience certifications for maritime equipment and ships. Flag states should conduct regular audits by integrating cybersecurity maturity as a "seaworthiness" criterion; for example, the cyber risk management provisions added to the ISM Code with IMO Resolution MSC.428 require companies to address cyber risks in their

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Security Management Systems from January 1, 2021 (Ahmed et al., 2024; Tatar et al., 2024). These certifications should guarantee the resilience of IT/OT systems based on standards such as the NIST Cybersecurity Framework, and include IEC 62443 compliance for PLCs and navigation equipment, referencing the rules of classification societies (e.g., DNV Cyber Secure) (Johansson et al., 2023). Thus, cyber maturity in autonomous vessels should be integrated with physical security criteria, minimizing vulnerabilities increased by digitalization.

Maritime-ISAC Establishment: By establishing "Maritime Information Sharing and Analysis Centers" at the national level, cyberattack data, threat intelligence, and incident reports should be shared in real-time among stakeholders (shipowners, ports, flag states) (Tatar et al., 2024; Todorov, 2021). In line with BIMCO and IMO guidance, national coordination should be ensured based on the risk analysis and information sharing elements of the ISPS Code; for example, anonymous reporting mechanisms should be developed through public-private partnerships, as in national priorities such as the US MTS (Tatar et al., 2024). These centres will increase resilience across the sector by creating proactive early warning systems against threats such as ransomware and spoofing.

Legal Definition: Under the UN Convention on the Law of the Sea, cyberattacks against ships should be defined as "modern piracy" or piracy; international sanctions mechanisms should be implemented, drawing parallels with acts of violence, extortion, and plunder at sea (Johansson et al., 2023; Küçük et al., 2024; Sime, 2023). The narrow definition of UNCLOS Article 101 should be broadened to include remotely controlled cyberattacks (e.g., AIS spoofing or GNSS jamming) within the scope of piracy, and sanctions should be enforced by flag states and port states (Jin et al., 2025). This approach will strengthen global trade security by adapting to the technological evolution of traditional piracy (Nilasari & Steele, 2022).

3.4.2. Technical and Operational Solution Proposals

Mandating physical or logical isolation between critical navigation networks and crew entertainment and administrative networks, i.e., implementing network segmentation, will effectively prevent ransomware and phishing attacks from spreading to OT systems by narrowing the attack surface created by IT/OT convergence (Amro & Gkioulos, 2022). In addition to this measure, the integration of redundant PNT systems is vital to reduce GPS/GNSS dependency; terrestrial-based eLoran stations, alternative satellites such as Galileo/GLONASS, inertial navigation systems, and shore-based AtoNs should be used as active backups to ensure operational continuity with consistency checks and position verification mechanisms against jamming and spoofing attacks (Mohsendokht et al., 2024).

Furthermore, regular simulation-based training, i.e., cyber drills, should be mandatory to increase crew cybersecurity awareness; these trainings should cover "Cyber Emergency Scenarios" to enable personnel to quickly switch to manual navigation, steering control, and emergency procedures when the system fails, and awareness programs based on NIST and BIMCO guidelines should be

implemented (Chupkemi & Mersinas, 2024). In addition, tightening firmware and software management is unavoidable; firmware integrity verification, automatic updates, and patch management should be mandatory for OT devices such as PLC, ECDIS, and AIS, and malicious injections should be prevented through signed updates against supply chain risks (Li et al., 2024).

On the other hand, strengthening anomaly detection and monitoring systems with AI-based real-time threat monitoring tools will establish early warning mechanisms in accordance with BIMCO/IMO guidelines by providing abnormal network traffic, behavioural analysis, and data integrity checks (Tatar et al., 2024). In access control, unauthorized access should be minimized by implementing multi-factor authentication, role-based access, and a zero-trust architecture, along with mandatory VPN and encryption protocols for remote access (Mohsendokht et al., 2024). To enhance data security, end-to-end encryption and data integrity hashes should be used in communication links and stored data, and authentication mechanisms should be integrated into GNSS signals (Farah et al., 2022). Finally, ship-based plans should be developed for incident response and recovery processes, backup systems and off-line modes should be regularly tested, and the detection, response, and remediation functions of NIST CSF should be integrated and strengthened with security audits and reporting (Zhou et al., 2021).

Mandating physical or logical isolation between critical navigation networks and crew entertainment and administrative networks, i.e., implementing network segmentation, will effectively prevent ransomware and phishing attacks from spreading to OT systems by narrowing the attack surface created by IT/OT convergence (Amro & Gkioulos, 2022). In addition to this measure, the integration of redundant PNT systems is vital to reduce GPS/GNSS dependency; terrestrial-based eLoran stations, alternative satellites such as Galileo/GLONASS, inertial navigation systems, and shore-based AtoNs should be used as active backups to ensure operational continuity with consistency checks and position verification mechanisms against jamming and spoofing attacks (Mohsendokht et al., 2024). Furthermore, regular simulation-based training, i.e., cyber drills, should be mandated to increase crew cybersecurity awareness. These trainings should cover "Cyber Emergency Scenarios" to enable personnel to quickly switch to manual navigation, steering control, and emergency procedures when the system fails, and awareness programs based on NIST and BIMCO guidelines should be implemented (Chupkemi & Mersinas, 2024). On the other hand, tightening firmware and software management is also inevitable; firmware integrity verification, automatic updates, and patch management should be made mandatory for OT devices such as PLC, ECDIS, and AIS, and malicious injections should be prevented with signed updates against supply chain risks (Li et al., 2024). In addition, strengthening anomaly detection and monitoring systems with AI-based real-time threat monitoring tools will establish early warning mechanisms in accordance with BIMCO/IMO guidelines by providing abnormal network traffic, behavioural analysis, and data integrity checks (Tatar et al., 2024). In access control, multi-factor authentication, role-based access, and a zero-trust architecture

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

should be implemented, along with mandatory VPN and encryption protocols for remote access to minimize unauthorized entry (Mohsendokht et al., 2024). To enhance data security, end-to-end encryption and data integrity hashes should be used for communication links and stored data, and authentication mechanisms should be integrated into GNSS signals (Farah et al., 2022). Finally, ship-based plans should be developed for incident response and recovery processes, backup systems and off-line modes should be regularly tested, and NIST CSF's detection, response, and recovery functions should be integrated and strengthened with security audits and reporting (Zhou et al., 2021).

This widespread cybersecurity vulnerability in the maritime sector highlights the significant consequences of transitioning to digitalization without a comprehensive risk assessment (Tatar et al., 2024). In this context, addressing fundamental issues such as the lack of cybersecurity policies and procedures (Moen et al., 2024), outdated ship systems, the fragility of autonomous systems (Fjørtoft et al., 2023), and human-related security vulnerabilities plays a central role in seeking strategic solutions. Current findings indicate that insufficient cybersecurity awareness among maritime personnel shows that human error remains a significant threat (Moen et al., 2024). This is closely related to deficiencies in cybersecurity training and awareness programs, as well as shortcomings in managerial aspects such as company procedures and compliance audits (Kanwal et al., 2022). Therefore, with the innovations brought about by digital transformation, significant challenges arise in the field of human resources management in maritime operations, and traditional job positions are put at risk while the need for new skill sets increases (Theotokas et al., 2024). This situation parallels the "competence traps" created by employees clinging to their past successes and resisting change, as noted by Kane et al., and the difficulties organizations face in changing mindsets and beliefs (Raza et al., 2022). In this context, continuous training for employees and managers in the maritime sector and their active participation in change processes are critical to adapting to the challenges of digitalization and effectively using new technologies (Theotokas et al., 2024; Tijan et al., 2021).

4. CONCLUSION

This study comprehensively demonstrates that the digital transformation of the maritime sector, in line with the "Maritime 4.0" vision, brings with it critical cyber-physical risks as well as operational efficiency. The uncontrolled convergence of traditionally isolated ship systems with internet-accessible Information Technology networks has made the maritime infrastructure, which forms the backbone of global trade, vulnerable to cyber piracy. Findings obtained from a systematic literature review prove that cyber threats are no longer limited to data theft; they have reached a level where they can directly interfere with the physical routes and vital functions of ships through methods such as position spoofing and system manipulation. One of the most striking results of the study is that the weakest link in the sector is not technological deficiencies, but rather managerial and human-centred weaknesses. Insufficient cyber risk awareness at the leadership level and the crew's unpreparedness for digital crises weaken the effectiveness of technical defence mechanisms. In this context, cybersecurity

should not be considered merely the responsibility of an IT unit, but rather an integrated safety culture issue encompassing all stakeholders, extending from the design phase to the operational process. The proliferation of autonomous systems and smart ports is transforming the impact of these risks from a local problem into a systemic issue threatening the stability of global supply chains. From a forward-looking strategic perspective, adopting a multi-layered approach to ensuring cyber resilience is inevitable. In addition to technical network isolation and anomaly detection systems, it is necessary to define cyberattacks as modern piracy under international law and to include mandatory cyber resilience certifications in seaworthiness criteria. Ultimately, the sustainability of the blue economy depends on the professional management of the balance between the technological advantages provided by digitalization and the threats posed by cyber risks. This study offers both a theoretical and practical foundation for maritime stakeholders to develop a proactive defence architecture, serving as a roadmap for the secure navigation of the sector in its digital future.

REFERENCES

Ahmed, Y. A., Θεοτοκάτος, Γ., Maslov, I., Wennersberg, L. A. L., & Nesheim, D. A. (2024). Regulatory and legal frameworks recommendations for short sea shipping maritime autonomous surface ships. *Marine Policy*, *166*, 106226. https://doi.org/10.1016/j.marpol.2024.106226

Akpan, F., Bendiab, G., Shiaeles, S., Karamperidis, S., & Michaloliakos, M. (2022). Cybersecurity Challenges in the Maritime Sector. *Network*, *2*(1), 123. https://doi.org/10.3390/network2010009

Amro, A., & Gkioulos, V. (2022). Cyber risk management for autonomous passenger ships using threat-informed defense-in-depth. *International Journal of Information Security*, *22*(1), 249. https://doi.org/10.1007/s10207-022-00638-y

Blank Rome LLP. (2023). *Maritime Ransomware: The DNV ShipManager Incident Analysis.*

Boyes, H. (2015). *Cybersecurity of industrial control systems: The challenges of diffusion.* IEEE Security & Privacy.

Bolbot, V., Kulkarni, K., Brunou, P., Banda, O. A. V., & Musharraf, M. (2022). Developments and research directions in maritime cybersecurity: A systematic literature review and bibliometric analysis. *International Journal of Critical Infrastructure Protection*, *39*, 100571. https://doi.org/10.1016/j.ijcip.2022.100571

Chaal, M., Ren, X., BahooToroody, A., Basnet, S., Bolbot, V., Banda, O. A. V., & Gelder, P. van. (2023). Research on risk, safety, and reliability of autonomous ships: A bibliometric review [Review of *Research on risk, safety, and reliability of autonomous ships: A bibliometric review*]. *Safety Science*, *167*, 106256. Elsevier BV. https://doi.org/10.1016/j.ssci.2023.106256

Chupkemi, D. C., & Mersinas, K. (2024). Challenges in Maritime Cybersecurity Training and Compliance. *Journal of Marine Science and Engineering*, *12*(10), 1844. https://doi.org/10.3390/jmse12101844

CSIS. (2025). *Significant Cyber Incidents: Critical Infrastructure and Maritime OT Systems.*

Enoch, S. Y., Lee, J. S., & Kim, D. S. (2021). Novel security models, metrics and security assessment for maritime vessel networks. *Computer Networks*, *189*, 107934. https://doi.org/10.1016/j.comnet.2021.107934

Erbas, M., Khalil, S. M., & Tsiopoulos, L. (2024). Systematic literature review of threat modeling and risk assessment in ship cybersecurity. *Ocean Engineering*, *306*, 118059. https://doi.org/10.1016/j.oceaneng.2024.118059

Farah, M. A. B., Ukwandu, E., Hindy, H., Brosset, D., Bureš, M., Andonović, I., & Bellekens, X. (2022). Cyber Security in the Maritime Industry: A Systematic Survey of Recent Advances and Future Trends. *Information*, *13*(1), 22. https://doi.org/10.3390/info13010022

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Fjørtoft, K., Parvasi, S. P., Nesheim, D. A., Wennerberg, L. A. L., Mørkrid, O. E., & Psaraftis, H. N. (2023). Assessing the resilience of sustainable autonomous shipping: New methodology, challenges, opportunities. *Cleaner Logistics and Supply Chain*, *9*, 100126. https://doi.org/10.1016/j.clscn.2023.100126

IMO. (2017). *Resolution MSC.428(98): Maritime Cyber Risk Management in Safety Management Systems.*

Jensen, L. (2018). *Cyber Security in the Shipping Industry.* SeaIntelligence Consulting.

Jin, Y., Yuan, F., Liu, C., & Li, S. (2025). Navigating the digital seas: Legal challenges and global governance of maritime cyber operations. *Frontiers in Marine Science*, *12*. https://doi.org/10.3389/fmars.2025.1616906

Johansson, T. M., Echebarria Fernández, J., Dalaklis, D., Pastra, A., & Skinner, J. A. (2023). *Autonomous Vessels in Maritime Affairs Law and Governance Implications*.

Kanwal, K., Shi, W., Kontovas, C. A., Yang, Z., & Chang, C. (2022). Maritime cybersecurity: are onboard systems ready? *Maritime Policy & Management*, *51*(3), 484. https://doi.org/10.1080/03088839.2022.2124464

Kapalidis, C., Karamperidis, S., Watson, T., & Koligiannis, G. (2022). A Vulnerability Centric System of Systems Analysis on the Maritime Transportation Sector Most Valuable Assets: Recommendations for Port Facilities and Ships. *Journal of Marine Science and Engineering*, *10*(10), 1486. https://doi.org/10.3390/jmse10101486

Kavallieratos, G., & Katsikas, S. (2020). Managing Cyber Security Risks of the Cyber-Enabled Ship. *Journal of Marine Science and Engineering*, *8*(10), 768. https://doi.org/10.3390/jmse8100768

Koca, Y. N., & Erdoğan, S. (2024). Are We Ready for Digitalisation? A Study of the Challenges and Barriers to Digitalisation and Technology Use in the Turkish Maritime Sector. *Polish Maritime Research*, *31*(2), 132. https://doi.org/10.2478/pomr-2024-0029

Küçük, N., Yıldız, S., Uğurlu, Ö., & Wang, J. (2024). Hotspot analysis of global piracy and armed robbery incidents at sea: A decadal review of regional vulnerabilities and security strategies [Review of *Hotspot analysis of global piracy and armed robbery incidents at sea: A decadal review of regional vulnerabilities and security strategies*]. *Ocean & Coastal Management*, *260*, 107480. Elsevier BV. https://doi.org/10.1016/j.ocecoaman.2024.107480

Kuhn, K., Bıçakcı, S., & Shaikh, S. A. (2021). COVID-19 digitization in maritime: understanding cyber risks. *WMU Journal of Maritime Affairs*, *20*(2), 193. https://doi.org/10.1007/s13437-021-00235-1

Larsen, M. H., Lund, M. S., & Bjørneseth, F. B. (2024). Maritime decision-makers and cyber security: deck officers' perception of cyber risks towards IT and OT systems. *International Journal of Information Security*, *23*(3), 1721. https://doi.org/10.1007/s10207-023-00810-y

Li, M., Zhou, J., Chattopadhyay, S., & Goh, M. (2024). Maritime Cybersecurity: A Comprehensive Review [Review of *Maritime Cybersecurity: A Comprehensive Review*]. *arXiv (Cornell University)*. Cornell University. https://doi.org/10.48550/arxiv.2409.11417

Moen, I., Oruç, A., Amro, A., Gkioulos, V., & Kavallieratos, G. (2024). Survey-based analysis of cybersecurity awareness of Turkish seafarers. *International Journal of Information Security*, *23*(5), 3153. https://doi.org/10.1007/s10207-024-00884-2

Mohsendokht, M., Li, H., Kontovas, C. A., Chang, C., Qu, Z., & Yang, Z. (2024). Decoding dependencies among the risk factors influencing maritime cybersecurity: Lessons learned from historical incidents in the past two decades. *Ocean Engineering*, *312*, 119078. https://doi.org/10.1016/j.oceaneng.2024.119078

Nilasari, N., & Steele, L. (2022). UNCLOS Definition of Piracy: Is it still Relevant for Modern Piracy? *Mulawarman Law Review*, 89. https://doi.org/10.30872/mulrev.v7i2.943

Raza, Z., Woxenius, J., Vural, C. A., & Lind, M. (2022). Digital transformation of maritime logistics: Exploring trends in the liner shipping segment. *Computers in Industry*, *145*, 103811. https://doi.org/10.1016/j.compind.2022.103811

Shahbakhsh, M., Emad, G. R., & Cahoon, S. (2021). Industrial revolutions and transition of the maritime industry: The case of Seafarer's role in autonomous shipping. *The Asian Journal of Shipping and Logistics*, *38*(1), 10. https://doi.org/10.1016/j.ajsl.2021.11.004

Sime, T. H. (2023). A Critical Reflection on African Maritime Cybersecurity Frameworks. *Scientia Militaria South African Journal of Military Studies*, *51*(3). https://doi.org/10.5787/51-3-1426

Tam, K., Hopcraft, R., Moara-Nkwe, K., Misas, J. D. P., ANDREWS, W. C., Harish, A. V., Giménez, P., Crichton, T., & Jones, K. (2021). Case Study of a Cyber-Physical Attack Affecting Port and Ship Operational Safety. *Journal of Transportation Technologies*, *12*(1), 1. https://doi.org/10.4236/jtts.2022.121001

Tatar, U., Karabacak, B., Keskin, O. F., & Foti, D. P. (2024). Charting New Waters with CRAMMTS: A Survey-Driven Cybersecurity Risk Analysis Method for Maritime Stakeholders. *Computers & Security*, 104015. https://doi.org/10.1016/j.cose.2024.104015

Theotokas, I., Lagoudis, I. N., & Raftopoulou, K. (2024). Challenges of maritime human resource management for the transition to shipping digitalization. *Journal of Shipping and Trade*, *9*(1). https://doi.org/10.1186/s41072-024-00165-0

Tijan, E., Jović, M., Aksentijević, S., & Pucihar, A. (2021). Digital transformation in the maritime transport sector. *Technological Forecasting and Social Change*, *170*, 120879. https://doi.org/10.1016/j.techfore.2021.120879

Todorov, Y. (2021). Maritime Cyber(in)security: A Growing Threat Imperils EU Countries. *Connections The Quarterly Journal*, *20*, 73. https://doi.org/10.11610/connections.20.3-4.04

Yousaf, A., Amro, A., Kwa, P. T. H., Li, M., & Zhou, J. (2024). Cyber risk assessment of cyber-enabled autonomous cargo vessel. *International Journal of Critical Infrastructure Protection*, *46*, 100695. https://doi.org/10.1016/j.ijcip.2024.100695

Zhou, X., Liu, Z., Wang, F.-W., & Wu, Z. (2021). A system-theoretic approach to safety and security co-analysis of autonomous ships. *Ocean Engineering*, *222*, 108569. https://doi.org/10.1016/j.oceaneng.2021.108569

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GENERATIVE AI AS A FORCE MULTIPLIER FOR SOCIAL ENGINEERING

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ABSTRACT

The rapid development of generative AI technologies and their rise in the cybersecurity threat ecosystem have significantly changed the nature, scale, and credibility of social engineering attacks. Traditional phishing attempts are easier to detect due to language errors, translation inconsistencies, and standard templates; however, new AI-powered attacks successfully imitate corporate communication language and deliver personalized content. They increase their persuasive effectiveness by designing scenarios that consider the target's role with in the organization, ongoing projects, or sectoral developments.

In addition, deepfake-based voice and image manipulations, particularly scenarios such as "CEO fraud" involving the imitation of senior executives' voices or images, combined with an emphasis on urgency and confidentiality, create powerful psychological pressure on employees, weakening human-centered trust relationships and existing identity verification practices. This study examines this transformation along two main axes by evaluating the current global literature and publicly reported case examples:

(i) As a result of the widespread availability of advanced cyber attack capabilities, even threat actors with low technical expertise can produce complex and sophisticated social engineering scenarios

(ii) The need for defense strategies to evolve from an "implicit trust" approach in corporate communications to a "Content-Centric Zero Trust" architecture, where the source and integrity of all digital content is continuously verified.

Within the scope of this study, an integrated defense framework supporting this architecture is proposed to increase corporate resilience. The proposed model includes verification mechanisms that must be performed through a second communication channel in critical business processes, the use of up-to-date and stronger identity verification methods, the application of multi-layered approval steps in privileged transactions, and simulation-based practical training.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

As a result, it is assessed that the corporate impacts of AI-generated manipulations will lead to serious reputational and financial losses. In this context, the recommended actions are: implementing solutions such as anti-deepfake, designing the process so that critical requests are subject to double verification through a separate channel, and most importantly, applying AI-based simulations that increase employee awareness.

This study identifies AI-based social engineering threats that organizations may face and introduces a set of applicable control measures. It aims to operationalize the proposed approach through simulation scenarios.

Keywords: Social Engineering, Generative Artificial Intelligence, Cybersecurity

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

WASTE HEAT RECOVERY AND PCM-BASED THERMAL ENERGY STORAGE (TES) IN MOBILE DIESEL GENERATOR SYSTEMS FOR EMERGENCY APPLICATIONS

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During natural disasters, electricity and natural gas infrastructures often become inoperable; in such cases, energy needs are primarily met by diesel generators. These generators serve as the fundamental source for interrupted energy supplies. Under emergency response conditions, a significant heating requirement arises to sustain search-and-rescue activities and healthcare services. This requirement encompasses both space heating and domestic hot water demand. Diesel generators discharge heat to the environment through their radiators (T>80 °C) and exhaust gases (T>300 °C) during operation. It is possible to transfer this available waste heat to a gas or liquid medium using heat exchangers. The resulting hot stream can then be utilized for ambient heating. Meeting the heating demand arising in emergencies through the recovery of waste heat from diesel generators is an innovative method. A model has been designed where waste heat is transferred directly to water via two different exchangers. The heat exchangers used for engine cooling water and exhaust gas were sized based on full-load conditions, while partial-load performances were evaluated using the ϵ-NTU method. However, a mismatch may exist between the generator's electrical load profile and the thermal demand. This situation can lead to efficiency losses in direct heat transfer scenarios. Thermal energy storage (TES) systems offer a solution to bridge this gap and ensure more effective use of waste heat. Traditionally, heat storage is performed using double-coil boilers in a water medium. Alternatively, other storage media such as Phase Change Materials (PCM) or heat transfer oils can be evaluated. In this study, an analysis was conducted on the storage and utilization of waste heat using different PCM types and configurations within a limited-volume mobile generator cabin. PCM-based storage systems provide long-term heat retention capacity in low-volume environments due to their high energy density and constant melting temperatures. Optimization was performed using a multi-objective approach; the objective functions included the energy recovery rate, system weight, cost, and safe operating temperature limits (water ≤95 °C, exhaust ≥200 °C). Consequently, paraffin-based PCM with an appropriate melting temperature provided the highest heat recovery rate. These findings demonstrate that PCM-based thermal storage in limited-volume mobile energy systems offers higher energy efficiency and more compact design possibilities compared to water-based storage. This study

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

provides a methodology for the systematic optimization of PCM material selection and operating conditions in emergency response scenarios.

Keywords: phase change material (PCM), thermal energy storage, waste heat recovery, emergency generators

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EVALUATION OF DIGITAL TWIN STUDIES IN CULTURAL HERITAGE STRUCTURES WITH A FOCUS ON CONSERVATION WITHIN THE CONTEXT OF STRUCTURAL AND ENVIRONMENTAL PERFORMANCE ANALYSIS

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ABSTRACT

The preservation, sustainability and transmission to future generations of historical buildings, which have been built throughout history and constitute unique examples of our cultural heritage, are of great importance. Before undertaking any intervention on these structures, it is necessary to analyse their current condition in a comprehensive, accurate and holistic manner and to understand in detail the structural, environmental and physical problems that have arisen over time. This requirement demonstrates that technical and technological developments over time have made significant contributions to preservation of historical structures. Advancing digital technologies offer important contributions to understanding the current state of historical structures, identifying problems, and finding solutions. In this context, digital twin technology, one of the methods that has recently come to the fore, enables real-time monitoring of historical structures, making it possible to carry out precise and detailed analyses. With this method, problems and potential risks that arise over time in structures can be identified in greater detail, and conservation and restoration processes can be carried out more effectively based on scientific principles. Within the scope of this study, it was aimed to analyse digital twin applications in historical structures in line with conservation criteria set out in international conservation legislation. The analyses revealed that digital twin applications make significant contributions to conservation processes; it was concluded that this technology should be used more widely and effectively in identifying and solving problems in historical structures.

Keywords: Digital Twin, Historical Building, Cultural Heritage Conservation

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KÜLTÜREL MİRAS YAPILARINDA DİJİTAL İKİZ ÇALIŞMALARININ YAPISAL VE ÇEVRESEL PERFORMANS ANALİZİ BAĞLAMINDA KORUMA ODAKLI DEĞERLENDİRİLMESİ

ÖZET

Tarihsel süreç içinde inşa edilmiş ve kültürel mirasımızın özgün örneklerini oluşturan tarihi yapıların korunması, sürdürülebilirliklerinin sağlanması ve gelecek nesillere aktarılması büyük önem taşımaktadır. Bu yapılara yönelik herhangi bir müdahale öncesinde, mevcut durumlarının kapsamlı ve doğru bir biçimde analiz edilmesi; yapıda zaman içerisinde ortaya çıkan yapısal ve çevresel sorunların ayrıntılı olarak anlaşılması gerekmektedir. Bu durum teknik ve teknolojik imkânlarla birlikte farklı disiplinler arası iş birliğini zorunlu kılmaktadır. Gelişen dijital teknolojiler, tarihi yapıların mevcut durumunun anlaşılması, sorunların tespiti ve çözümlenmesinde önemli katkılar sunmaktadır. Öne çıkan yöntemlerden biri olarak dijital ikiz teknolojisi, tarihi yapıların gerçek zamanlı izlenmesine olanak tanıyarak hassas ve detaylı analizlerin gerçekleşmesini sağlamaktadır. Bu sayede yapılarda zamanla ortaya çıkan sorunlar ve potansiyel riskler daha detaylı bir biçimde belirlenebilmekte, koruma ve restorasyon süreçleri bilimsel temellere dayalı olarak daha etkin bir biçimde gerçekleştirilebilmektedir. Bu bağlamda çalışmada, tarihi yapılarda dijital ikiz uygulamalarının, uluslararası mevzuattan belirlenen koruma kriterleri bağlamında analiz edilmesi amaçlanmıştır. Yapılan analizler neticesinde dijital ikiz uygulamalarının koruma süreçlerine önemli katkılar sağladığı ortaya konmuş; tarihi yapılarda sorunların tespiti ve çözümünde bu teknolojinin daha da yaygınlaştırılarak kullanılması gerektiği sonucuna ulaşılmıştır.

Anahtar Kelimeler: Dijital İkiz, Tarihi Bina, Kültürel Miras Koruma

GİRİŞ

Kültürel mirasımızın özgün örnekleri arasında yer alan tarihi yapıların, koruma ilkeleri doğrultusunda sürdürülebilirliklerinin sağlanarak geleceğe taşınması büyük önem arz etmektedir. Bu hedef doğrultusunda tarihi yapıların farklı ölçek ve boyutlardaki sorunlarının kapsamlı bir biçimde analiz edilmesi ve bilimsel temellere dayalı çözüm yöntemlerinin geliştirilmesi gerekmektedir. Tarihi yapılarda gözlemlenen fiziksel ve çevresel problemlerin tespiti ve çözümlenmesinde dijital teknolojiler her geçen gün daha da etkili hale gelmektedir. Teknolojik imkanların artışı, bu araçların koruma amaçlı süreçlere nasıl entegre edileceğine yönelik yeni araştırma alanlarını ortaya çıkarmıştır (Liu ve Wang, 2024). Literatürde, tarihi yapılarda belgeleme ve veri toplamaya yönelik çalışmalar ile birlikte, özellikle üç boyutlu görselleştirme teknikleri ve BIM uygulamaları yaygın bir biçimde çalışılmaktadır. Bu gelişmeler doğrultusunda dijital ikiz teknolojisi bu çalışmaları daha da ileri bir seviyeye taşımıştır. Dijital ikiz teknolojileri sayesinde tarihi yapıların fiziksel varlığı ile oluşturulan dijital temsilleri, sensör sistemleri aracılığıyla gerçek zamanlı izlenebilmekte; sürekli veri akışı ile yapıların sorunları

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

tespit edilebilmektedir (Akgöz ve Ergin, 2025; Özata, 2026). Gerçek zamanlı süreçte tespit edilen verilerle koruma bağlamında müdahale yaklaşımları geliştirilmekte, geleceğe yönelik daha sağlıklı ve sürdürülebilir kararlar alınabilmektedir. Literatür incelendiğinde tarihi yapılarda farklı amaçlarla dijital ikiz teknolojilerinin kullanıldığı görülmektedir. Bu çalışmada ise tarihi yapılarda gerçekleştirilen dijital ikiz uygulamalarının uluslararası kuruluşlar ve ilgili mevzuatta yer alan koruma kriterleri çerçevesinde değerlendirilmesi amaçlanmıştır. Bu kapsamda, tarihi yapılarda hasar tespiti, sürdürülebilirlik bağlamında enerji performansı ve ısıl davranış analizi ile iç mekân mikro iklimi ve kullanıcı konforunun değerlendirilmesi başlıklarında tablolar arayıcılığı ile karşılaştırmalı analizler gerçekleştirilmiştir. Sonuç olarak dijital ikiz teknolojilerinin kültürel miras yapılarının korunması sürecinde önemli katkılar sunduğu ortaya konmuş, bu teknolojinin tarihi yapılarda daha da yaygın ve etkin kullanılması gerektiği sonucuna varılmıştır.

YÖNTEM

Dijital ikiz modern yapılarda olduğu gibi tarihi yapılarda da, yapıların daha iyi anlaşılıp veri takibi ile daha enerji etkin ve sağlıklı bir biçimde gelecek nesillere aktarılmasında önemli bir teknolojik gelişmedir. Bir tarihi yapının dijital ikizinin oluşturulmasında belirlenen amaç doğrultusunda bazen oldukça karışık olabilen birçok farklı yöntemin bir araya gelmesi gerekmektedir. Aşağıda şemada genel olarak tarihi yapılarda dijital ikiz aşamaları ifade edilmiştir (Şekil 1).



Şekil 1. Tarihi yapılarda dijital ikiz uygulamalarında başlıca aşamalar

Dijital ikiz ile birlikte farklı ölçeklerde tarihi yapılarda çeşitli uygulamalar gerçekleştirilebilmektedir. Örneğin dijital ikizin kullanıldığı tarihi yapılar için önemli alanlardan birisi yapıların üzerlerinde zamanla oluşan çatlakların, deformasyonların tespit edilmesidir. Tespitlerle birlikte yapının üzerindeki

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ISBN: 978-9952-610-30-7

deprem etkileri veya sağlık durumu analiz edilmesidir. Benzer bir biçimde yapı kabuğunda zaman içerisinde sıcaklık, nem gibi fiziksel etkilerle bozulmalar gerçekleşebilmektedir. Dijital ikizle belirli zaman aralıklarında gerçekleştirilen tespitlerle tarihi yapılarda bozulmalar tespit edilebilmekte ve çözüm önerileri geliştirilebilmektedir. Bununla birlikte sensörler arayıcılığı ile mekân içerisindeki fiziksel koşullar tespit edilmekte ve yapılarda ısıl konfor durumu ve havalandırma gereksinimi anlaşılabilmektedir. Ancak tüm bu çalışmaların tarihi yapılar söz konusu olduğunda uluslararası koruma kriterleri ile uyumlu olması önemlidir. Çalışma kapsamında tarihi yapılarda fiziksel etkiler oluşturan uygulamaların koruma kriterleri kapsamında analiz edilmesi amaçlanmıştır. Literatür incelemesi sonucu konu kapsamında tarihi yapılara müdahale uygulamaları veya önerilerini içeren üç genel başlık halinde(Tarihi yapılarda hasarların tespiti, enerji performansı ve ısıl davranış analizi ve iç mekân mikroiklim ve kullanıcı konfor şartları bağlamında değerlendirilmesi) analizler yapılmıştır. Tespit edilen başlıklar kapsamında uygulamalar, konu ile ilişkili olduğu değerlendirilen, uluslararası koruma literatüründen elde edilen değerlendirme kriterleri (özgünlük, bütüncül koruma, minimum müdahale, geri alınabilirlik, belgeleme ve izlenebilirlik) çerçevesinde irdelenmiştir(Icomos, 1964) (Icomos, 2011) (Icomos,1999).

Tablo 1. Konu ile ilişkili uluslararası değerlendirme kriterleri

İlke	**Genel Açıklama**	**Kaynak**
Özgünlük	Tarihi yapılarde gerçekleştirilen müdahaleler yapıda özgün malzeme ve güvenilir belgelerle yapılmalı özgünlük ve bütünlükleri korunmalıdır.	Venedik Tüzüğü Madde 9(Icomos, 1964) Valetta ilkeleri (Icomos, 2011)
Bütüncül koruma	Tarih yapı ve alanlara yönelik müdahalelerde bütünlüğün korunması gerekmektedir.	Venedik Tüzüğü Madde 14(Icomos, 1964)
Minimum Müdahale	Tarihi yapılara yönelik uygulamalarda gereksiz müdahalelerden kaçınılmalı, minimum müdahale ile değişiklikler yapılmalıdır.	Burra Tüzüğü Madde 3(Icomos, 1999)
Geri Alınabilirlik	Kültürel niteliği olumsuz etkileyen, azaltan uygulamalar gerektiğinde eski durumuna döndürülmelidir.	Burra Tüzüğü Madde 15(Icomos, 1999)
Belgeleme ve İzlenebilirlik	Koruma çalışmalarına dair kayıtlar kamuya açık sürekli bir arşive yerleştirilerek tutulmalıdır.	Burra Tüzüğü Madde 32(Icomos, 1999)

Analizler aşağıda başlıklar altında açıklanmış, müdahaleler ve tespitlerin tarihi yapılara etkileri göz önünde bulundurularak değerlendirmeler yapılmıştır.

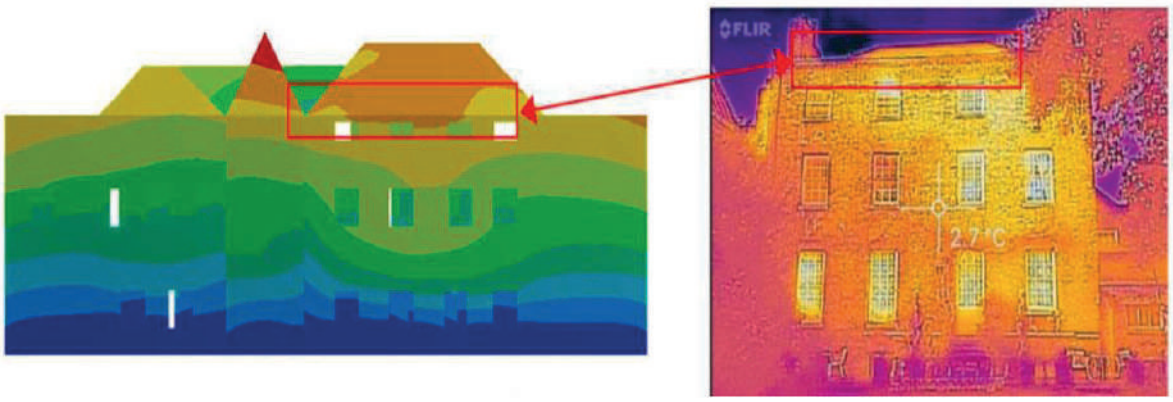
DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TARİHİ YAPILARDA DİJİTAL İKİZ KULLANIM ALANLARI

Literatürde tarihi yapılara yönelik fiziksel etkiler oluşturan dijital ikiz uygulamaları, uluslararası koruma mevzuatında tespit edilen koruma ilkeleri çerçevesinde, üç ana başlık halinde aşağıda açıklanmıştır.

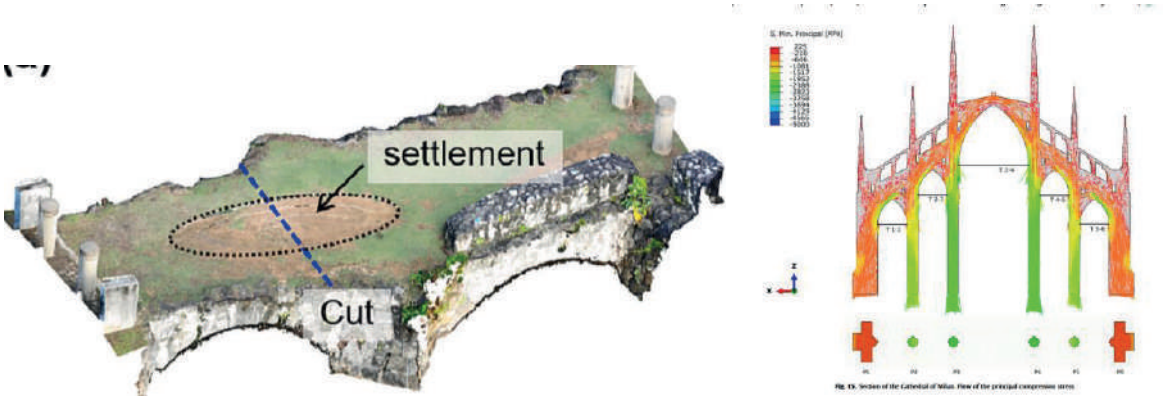
Tarihi Yapılarda Hasarların Tespiti Amaçlı Kullanım

Dijital ikiz teknolojisinin tarihi yapılarda kullanıldığı önemli alanlardan biri, yapılarda oluşmuş veya meydana gelebilecek hasarların tespit edilmesidir. Bu çalışmalardaki hasarlar, sensörler aracılığıyla izlenerek, tarihi yapılarda oluşan fiziksel hasarlar saptanmakta ve yapıların korunmasına yönelik önlemler geliştirilebilmektedir. Bu alanda yaygın ve etkin bir biçimde kullanılan yöntemlerden bir diğeri ise, 3 boyutlu tarama teknolojisidir. Farklı boyutlarda yapılarda gerçekleştirilen çalışmalar ile tarihi yapılar, gelişmiş tarama cihazları ile milimetre hassasiyetinde ölçülebilmektedir. Taramalarda kullanılan yöntemler yapının türüne ve durumuna göre farklılaşmakta, ölçümlerin sanal ortama aktarımında çeşitli teknikler bir araya getirilerek uygulamalar gerçekleştirilmektedir. Yapılan tarama çalışmaları ile tarihi yapılar detaylarına kadar ölçülmekte, milyonlarca noktadan oluşan nokta bulutları oluşturulmakta ve ölçümler dijital ikiz kapsamında geliştirilen yazılımlara aktarılmaktadır. Bu sayede yapıların sanal ortamda birebir temsilleri oluşturulabilmekte, milimetre hassasiyetinde gerçekleştirilen ölçümlerle, yapılarda gerçekleşen sehimler, çatlaklar tespit edilebilmekte, ilerleme durumları izlenebilmektedir. Bu çalışmalara ek olarak bazı projelerde ise tarihi yapı elemanlarına nem ve sıcaklık sensörleri yerleştirilerek yapı elemanlarının fiziksel özellikleri takip edilebilmekte, riskler anlaşılmakta, çözüm önerileri geliştirilmektedir(Kong ve Hucks, 2023) (Cheng vd., 2024) (Angjeliu vd., 2020).



(a)

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ISBN: 978-9952-610-30-7



(b) (c)

Şekil 2. Yapıda sıcaklığa bağlı deformasyon gösterimi (a) (Cheng vd., 2024), lazer tarama ölçümü ile çökme tespiti (b) (Kong ve Hucks, 2023), basınç gerilme akışı gösterimi (c) (Angjeliu vd., 2020)

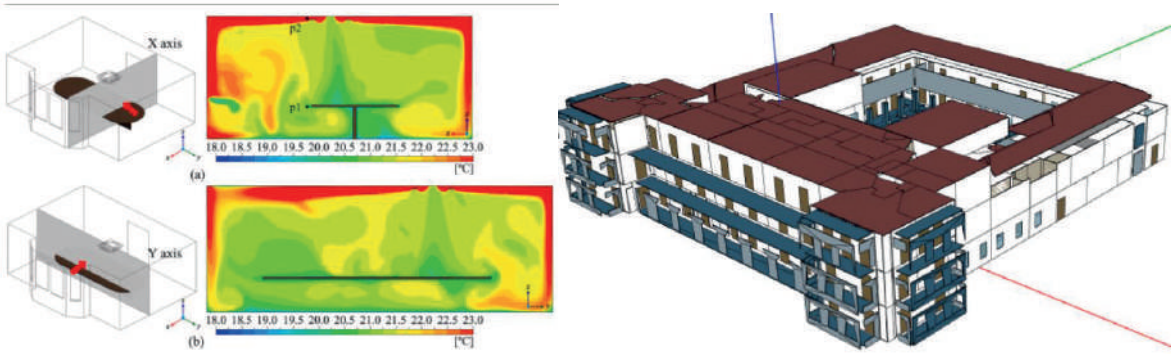
Dijital ikiz çalışmalarında, elde edilen nokta bulutları bir tripot üzerine kurulu lazer tarama cihazları veya mobil sistemler gibi çeşitli yöntemlerle üretilebilmektedir. Burada yapıya doğrudan fiziksel bir müdahalede bulunulmamakta, temassız ölçümlerle tarihi yapının özgünlüğüne zarar verilmemektedir. Ayrıca bu yöntemle yapılarda genel taramalar üretilerek bütüncül değerlendirmeler yapılabilmektedir. Çalışmalarda sürekli veya aralıklarla ölçülen veriler, detaylı bir biçimde kaydedilebilmekte, yapının hasar gelişim durumu etkili bir biçimde analiz edilebilmektedir. Analizler neticesi duruma göre önleyici koruma yaklaşımları geliştirilebilmektedir. Lazer tarama teknolojilerine ek olarak tarihi yapılarda dijital ikizle hasar tespitinde kullanılan önemli yöntemlerden biriside sensörlerin kullanılmasıdır. Yapılarda sensörler arayıcılığı ile hasara sebep olan numune alımı yapılmamakta ve yapılardaki hasar durumu düzenli olarak takip edilebilmektedir. Yapılarda birçok farklı noktaya yerleştirilen sensörlerle bütüncül analizler yapılabilmektedir. Tüm bu çalışmalar tarihi yapılarda dijital ikiz yönteminin, yapılarda zamanla oluşabilecek hasarların tespiti ve müdahale karalarının verilmesinde, tahribatsız bir analiz yöntemi olarak önemli faydalar içerdiğini göstermektedir.

Tarihi Yapıda Enerji Performansı ve Isıl Davranış Analizi

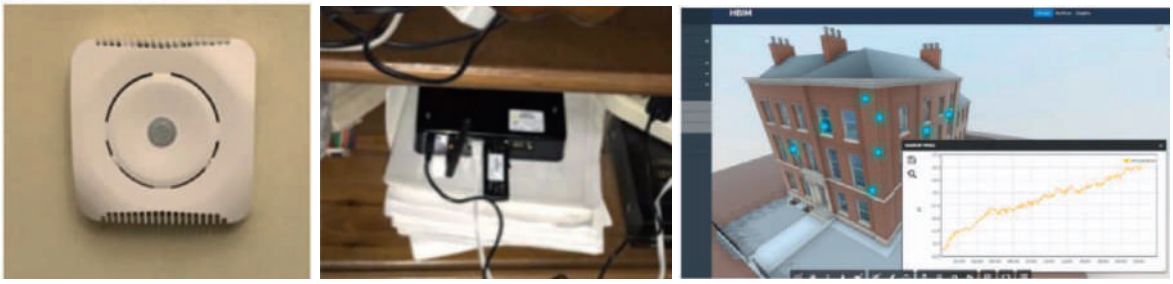
Tarihi yapılarda dijital ikiz teknolojisinin yaygın kullanıldığı alanlarından bir diğeri, yapılarda termal konfor ve enerji performansının analiz edilmesine yönelik çalışmalardır. Bu kapsamda, yapıların mevcut durumunu gösteren enerji davranışları sayısal ortamda simüle edilebilmekte ve farklı kullanım durumlarında enerji tüketim eğilimleri değerlendirilebilmektedir. Çalışmalardan elde edilen verilerle çevresel koşulların daha detaylı anlaşılması sağlanmakta, gereksiz iklimlendirme sistemi kullanımlarının önüne geçilmiş olunmaktadır. Bu amaçla, yapıların belirli mekânlarına sıcaklık, bağıl nem ve hava hızı gibi farklı parametreleri ölçen sensörler yerleştirilmektedir. Sensörlerden elde edilen veriler gerçek zamanlı olarak dijital ikize aktarılmakta; böylece yapının konfor şartlarının anlaşılması ve sorunlu alanlara yönelik çözüm önerilerinin geliştirilmesi sağlanmaktadır. Benzer biçimde, sensör

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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verileri üç boyutlu BIM modelleri ile entegre edilerek yapının daha dinamik dijital temsilleri oluşturulabilmektedir. Sürekli güncellenen verilerle modeller beslenmekte ve güvenilir simülasyon çalışmaları ile tarihi yapılarda enerji verimliliğe yönelik müdahale öncesi en uygun senaryoların belirlenebilmesi sağlanabilmektedir(Jouan ve Hallot, 2019)(Url-l) (Cheng vd., 2024) (Zhang, vd., 2023) (Nagy ve Ashraf, 2021).



(a) (b)



(c) (d) (e)

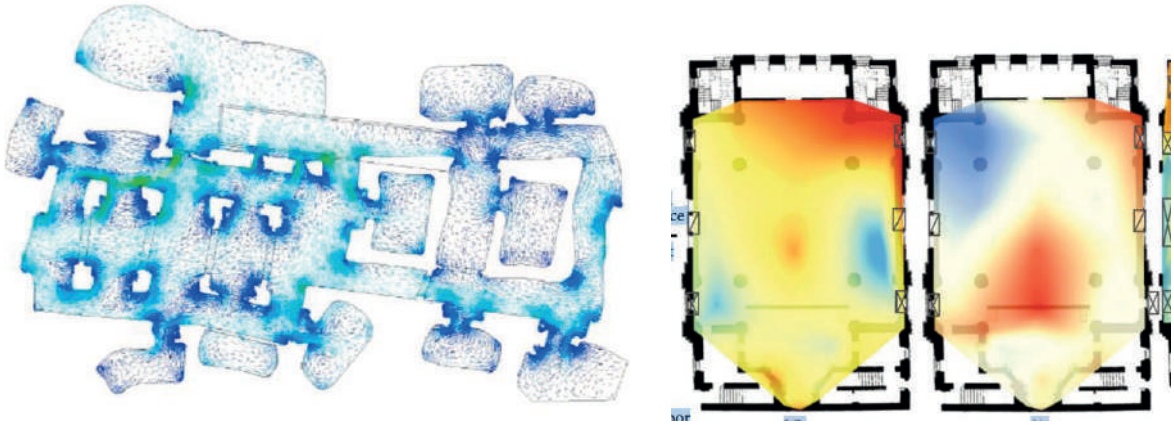
Şekil 3. İç mekân hava sıcaklık dağılımı (a) (Kang vd., 2024), DT destekli Enerji modeli uyuglaması (b) (Zhang, vd., 2023), örnek ışık yoğunluğu sensörü (c), takip ünitesi (d), gerçek zamanlı data takibi (e) (Nagy ve Ashraf, 2021).

Konu bağlamında tarihi yapılarda gerçekleştirilen dijital ikiz temelli çalışmaların, uluslararası koruma kriterleri kapsamında önemli katkılar sağladığı görülmektedir. Gerçek zamanlı ve yüksek doğruluklu üretilen veriler sayesinde enerji analiz modelleri kalibre edilebilmekte, böylece yapıların mevcut durumu ve sayısal modelleri arasında uyum sağlanabilmektedir. Elde edilen verilerle geleceğe yönelik simülasyonlar yapılmakta, olası yoğuşma, nem birikimi, küf oluşumu ve malzeme bozulmaları gibi tehdit ve riskler önceden tespit edilebilmektedir. Çalışmalarla tarihi yapılarda özgün cephe ve malzemelerin korunması sağlanmakta; yapıların daha doğru ve konforlu bir biçimde iyileştirilerek yaşatılmasına katkı sağlanmaktadır.

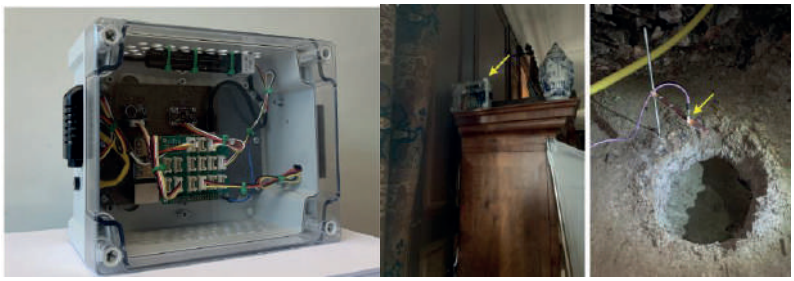
DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İç Mekân Mikroiklim ve Kullanıcı Konfor Şartları Bağlamında Değerlendirilmesi

Tarihi yapılarda dijital ikiz uygulamalarının öne çıkan kullanım alanlarından biriside, iç mekân iklim koşullarının izlenmesi ve bunun hem kullanıcı konforu hemde tarihi yapıya zararlı etkilerinin tespit edilmesi çalışmalarıdır. Bu çalışmalarda iç mekânlara yerleştirilen sıcaklık, nem, toz, karbondioksit, uçucu organik bileşikler (VOC) sensörleri ile mikroiklim verileri toplanmakta, elde edilen ölçümler sayesinde, nem ve sıcaklık değişimlerinin yapıda oluşturabileceği küf ve diğer fiziksel riskleri belirlenebilmektedir. Ayrıca karbondioksit sensörleri ilede iç mekân iklim kalitesi tespit edilebilmekte, mevcut durum ve ileride ortaya çıkabilecek riskler sistematik bir şekilde ortaya konabilmektedir (Ni vd., 2025) (Liu ve Wang, 2024) (Nagy ve Ashraf, 2021) (Caciora vd., 2024).



(a) (b)



(c)

Şekil 4. Hava hızı vektör dağılımı (a) (Zhang vd., 2022), planda, sıcaklık ve nem dağılımı (b) (Caciora vd., 2024), sensör kutusu ve sensörler (c) (Ni et all., 2025)

Konu kapsamında gerçekleştirilen dijital ikiz uygulamaları sayesinde, tarihi yapılardaki müdahalelerin özgün yapı malzemesine ne ölçüde zarar verdiği belirlenebilmekte ve uygun müdahale yaklaşımları geliştirilebilmektedir. Ayrıca, tüm yapı üzerinde uygulanabilecek analizlerle bütüncül bir koruma yaklaşımı oluşturulabilmektedir. Dijital ikiz aracılığıyla incelenen yapılarda önleyici koruma tedbirleri alınabilmekte ve simülasyonlar yardımıyla zamana bağlı zararların boyutu tespit edilebilmektedir. Bu yöntemler, yapı kabuğuna minimum müdahale ile önemli koruma önlemlerinin hayata

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

gerçekleştirilmesini sağlamakta, süreç içerisinde ortaya çıkan zararlı fiziksel olayların tespit edilmesi ile koruma çalışmalarının etkinliği artırılabilmektedir.

TARTIŞMA VE SONUÇ

Tarihsel süreçte inşa edilmiş kültürel mirasımızın önemli unsurlarını oluşturan tarihi yapıların gelecek nesillere aktarılmasında bilimsel, doğru ve etkin yöntemlerle sorunlarının tespit edilmesi ve en uygun yöntemlerle uygulamaların gerçekleştirilmesi büyük önem arzetmektedir. Gelişen teknolojilerle birlikte problemlerin çözümü dahada mümkün hale gelmiş, önerilen yaklaşımlarla tarihi yapılara olan katkı dahada artmıştır. Bu bağlamda çalışmada, tarihi yapılarda dijital ikiz uygulamalarının uluslararası koruma ilkeleri bağlamında değerlendirilmesinin yapılması amaçlanmıştır. Uluslararası koruma ilkeleri kapsamında, uygulamaların değerlendirildiği önemli noktalar tespit edilmiş ve uygulamaya yönelik başlıklar kapsamında analizler yapılmştır (Tablo 2).

Tablo 2. Uluslararası koruma ilkeleri kapsamında uygulamaların değerlendirilmesi

İlke	**Tarihi Yapılarda Hasarların Tespiti Amaçlı Kullanımın koruma bağlamında analizi**	**Tarihi yapıda sürdürülebilirlik enerji performansı ve ısıl davranışın koruma bağlamında analizi**	**İç Mekân Mikroiklim ve Kullanıcı Konfor şartlarının koruma bağlamında analizi**
Özgünlük	-Yapılarda hasarların ve ilerleme durumlarının tespit edilerek özgünlüğün korunmasına katkı sağlanmaktadır. -Yapılarda tespit edilen hasarlara yönelik müdahalelerin simülasyonlarının yapılması ile tarihi yapılarda geleceğe dönük olumsuz etkiler tespit edilmektedir. -Ölçümler lazer tarama, sensör gibi yöntemlerle yapılmakta, yapılarda tahribe sebep olabilecek fiziksel müdahaleler minimum seviyede tutularak, yapılarda hasarsız ölçümlerle özgünlük korunmaktadır.	-Dijital ikiz ile birlikte tarihi yapılarda zamana bağlı sensörlerle mekânların ısıl davranış analizleri yapılmakta, optimum çözüm yaklaşımları ile gereksiz kullanımlarla yapılarda oluşabilecek riskler önlenebilmektedir. -Elde edilen gerçek zamanlı verilerden, mevcut durum analizi ile birlikte simülasyonlar aracılığı ile geleceğe yönelik zararlı etkiler öngörülebilmekte, bu duruma göre müdahale yaklaşımı belirlenebilmektedir. Bu sayede gelecek dönemlerde yapının özgünlüğüne etki edebilecek hasarların önüne geçilmiş olacaktır.	-Yapı ve insan sağlığı kapsamında yapılan karbondioksit, partikül gibi ölçümlerle yapı kabuğuna zararlı bozucu etkiler zamana bağlı olarak anlaşılmakta, yerinde teçhizat kullanımı ile olası hasarların önüne geçilerek özgünlük korunmaktadır. -Elde edilen verilerle simülasyonlar yapılabilmekte geleceğe yönelik zararlı etkiler önlenebilmektedir. -Yapılarda daha sağlıklı yapı ortamı oluşturularak, harap olmasının önüne geçilmekte, sürdürülebilir bakımı ile özgünlüğünün korunmasına katkı sağlanmış olunmaktadır.
Bütüncül Müdahale	-Tarihi yapılarda lazer tarama, çeşitli sensörler ve 3D	-Tarihi yapılarda farklı mekânlardan iç ve dış	-Tarihi yapılarda sıcaklık, nem, partikül gibi ölçümlerle

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

	modelleme gibi yöntemlerle bütüncül yapılan detaylı analizlerle, yapılarda gözlemlenen veya oluşabilecek fiziksel etkiler değerlendirilebilmektedir. Örneğin tarihi yapılarda lazer tarama ölçümleri ve detaylı görselleştirme ile amaç kapsamında bütün bir yapıda gerçekleşen hasarlar tespit edilebilmekte düzenli ölçümlerle zamana bağlı fiziksel durum anlaşılmaktadır.	ortamlardan çeşitli sensörlerle elde edilen bütüncül yaklaşımla yapı çevresi ile birlikte daha detaylı anlaşılabilmektedir. - Doğru müdahalelerle konforlu ve enerji etkin mekânlar sağlanarak daha kapsamlı bir yaklaşımla tarihi yapıların yaşatılarak korunması gerçekleştirilmektedir.	karbondioksit gibi çeşitli gazların etkilerinin daha bütüncül analizleri yapılabilmektedir. -Elde edilen verilerle en uygun müdahale yaklaşımları seçilmekte yapının bütünsel yapısı ve özgünlüğü korunmaktadır.
Minimum Müdahale	-Yapılarda hasarlara sebep olan etmenler zamana bağlı olarak daha doğru bir biçimde değerlendirilmekte buda yapılarda gereksiz uygulamaların önüne geçilmesini sağlayarak, minimum müdahaleler ile çözüm önerilerinin ortaya konmasını sağlamaktadır. -Tarihi yapılarda ölçümlerde tahribatsız yöntemler kullanılarak tarihi yapıya en az etki ile tespitler yapılmaktadır.	-Yapıda detaylı ısıl konfor analizleri ile yapılarda iç ortam kalitesi kontrol edilerek yapıya yük oluşturacak gereksiz HVAC sistemlerinin önüne geçilebilmektedir. -Yapıdan gerçek zamanlı elde edilen verilerle, yapı kabuğuna müdahale yaklaşımı içeren yalıtım sistemleri gibi uygulamalar simülasyonlar kullanılarak en az müdahale gerçekleştirilebilmektedir.	-Yapı ve çevresinde yapılan mikroiklim analizleri ile yapıdaki durumun doğru bir biçimde tespit edilmesi sağlanmakta, bu sayede gereksiz müdahalelerin önüne geçilmiş olmaktadır. -Yapıda detaylı çevresel analizlerle özellikle yüksek özgünlük değerindeki yapılarda, iç ortam kalitesinin sağlanarak yapıya yük oluşturabilecek gereksiz HVAC sistemlerinin önüne geçilebilmektedir.
Geri Alınabilirlik	-Dijital ikiz uygulamalarından elde edilen veriler kullanılarak geri dönüş simülasyonları gerçekleştirilebilmekte ve olası zararlı etkiler değerlendirilerek gerektiğinde müdahaleler geri alınabilecek şekilde planlanmaktadır.	Tarihi yapılarda konfor şartlarının iyileştirilmesine yönelik yapılan müdahaleler, dijital ikiz ve simülasyon verileri ile değerlendirilmekte ve gerektiğinde geri alınabilecek biçimde tasarlanmaktadır.	- İç mekân mikroiklimi ve kullanıcı konforu kapsamında gerçekleştirilen sistem iyileştirmeleri simülasyon ve sensör verileri ile sürekli takip edilmekte, olumsuz şartların oluşması durumunda geri alınabilmektedir.
Belgeleme ve	-Dijital ikiz teknolojisi ile birlikte yapıların detaylı 3	-Yapılarda yalnızca 3 boyutlu model çalışmaları değil, aynı	- Tarihi yapılarda zararlı gazların etkileri ve konfor

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İzlenebilirlik	boyutlu modelleri oluşturulmakta ve belgelenmektedir. -Yapılarda 3 boyutlu veriler ve sensörlerden elde edilen zamana bağlı performans ve fiziksel durum verileri kaydedilmekte, böylece yapıların mevcut durumu sürekli izlenebilmektedir.	zamanda yapının ısıl performansı da uzun zamanlı olarak ölçülmekte, izlenmekte ve belgelenmektedir. Bu sayede yapının sürdürülebilirlik ve enerji performansına yönelik müdahaleler sürekli takip edilebilmektedir.	şartlarının durumu izlenmekte ve belgelenmektedir. -İzlenebilirlik sayesinde, yapıların özgünlüğü korunarak sistem iyileştirmeleri ve müdahaleler değerlendirilebilmektedir.

Değerlendirmeler neticesinde, dijital ikiz uygulamalarının uluslararası koruma kriterleri kapsamında tarihi yapılara önemli faydalar sağladığı tespit edilmiştir. Özellikle tarihi yapıların özgün değerlerinin korunmasında, gerçek zamanlı izleme yöntemleri ile gerçekleşen tespit ve analiz çalışmalarının erken müdahale olanaklarını artırdığı ve gerçekleşebilecek risklerin önceden belirlenmesine imkân sağladığı görülmüştür. Dijital ikiz çalışmaları çerçevesinde, mevcut durum analizleri ile birlikte geleceğe yönelik simülasyonlarla hasar olasılıklarının daha doğru bir biçimde tespit edilmesi sağlanmaktadır. Tarihi yapılarda koruma kriterleri kapsamında düşündüğümüzde uygulama ve müdahalelerin tarihi yapılarda minimum şekilde olması ve geri döndürülebilir olması önemlidir. Dijital ikiz çalışmalarında tespit yöntemleri ile tarihi yapılarda yapı kabuğundan numune almadan minimum müdahalelerle tespitler yapılabilmektedir. Ayrıca elde edilen verilerle simülasyonlar yapılabilmekte en az müdahale ile etkili senaryolar tespit edilerek yapıda en az müdahale ile etkin çözümler uygulanabilmektedir. Çalışmalarda 3 boyutlu modeller kullanılarak, sürece bağlı fiziksel durumuda içeren daha detaylı belgeleme çalışmaları yapılmakta ve kronolojik olarak takip edilebilecek şekilde kaydedilmektedir. Bu durum günümüz çalışmalarına önemli veri sağlamakla birlikte, gelecek dönemlerde yapılacak çalışmalarada güvenilir detaylı bir veri altyapısı oluşturması açısından önemlidir. Sonuç olarak dijital ikiz uygulamaları, kültürel miras koruma çalışmalarında sadece teknik bir araç olmanın ötesinde, uluslararası koruma ilkeleri ile uyumlu karar destek sistemi olarak değerlendirilebilecek önemli bir yöntem olarak öne çıkmaktadır.

KAYNAKÇA

Akgöz, G. ve Ergin, G. 2025. Tarihi yapıların sürdürülebilirliğinde dijital ikiz kullanımı: Bir çoklu durum çalışması. yedi: Sanat, Tasarım ve Bilim Dergisi, 34, 121-137. doi:10.17484/yedi.1648438

Angjeliu, G., Coronelli, D., & Cardani, G. 2020. Development of the simulation model for Digital Twin applications in historical masonry buildings: The integration between numerical and experimental reality. *Computers & Structures*, *238*, 106282.

Caciora, T., Ilies, D. C., Costea, M., Blaga, L., Berdenov, Z., Ilies, A., ... & Baias, S. 2024. Microclimate assessment in a 19th-century heritage building from Romania. *Indoor Air*, *2024*(1), 2989136

Cheng, J. C., Zhang, J., Kwok, H. H., & Tong, J. C. 2024. Thermal performance improvement for residential heritage building preservation based on digital twins. *Journal of Building Engineering*, *82*, 108283.

Icomos, Venice Charter, International Charter For The Conservation And Restoration Of Monuments And Sites, Online available from: http://www.icomos.org, 1964.

Icomos,Walletta Principles on the Protection and Management of Historical Cities and Urban Areas, Online available from: https://www.icomos.org/Paris2011/GA2011_CIVVIH_text_EN_FR_final_20120110.pdf, 2011

Icomos, Burra Charter, The Charter for Places of Cultural Significance, Online available from: http://australia.icomos.org, 1999.

Jouan, P., & Hallot, P. 2019. Digital twin: A HBIM-based methodology to support preventive conservation of historic assets through heritage significance awareness. *The international archives of the photogrammetry, remote sensing and spatial information sciences*, *42*, 609-615

Kang, Y., Yuk, H., Jo, H. H., & Kim, S. 2024. Indoor thermal environment assessment of a historic building for a thermal and energy retrofit scenario using a CFD model. Case Studies in Thermal Engineering, 63, 105330.

Kong, X., & Hucks, R. G. 2023. Preserving our heritage: A photogrammetry-based digital twin framework for monitoring deteriorations of historic structures. *Automation in Construction*, *152*, 104928.

Liu, Z., & Wang, J. 2024. Protection and utilization of historical sites using digital twins. *Buildings*, *14*(4), 1019.

Nagy, G., & Ashraf, F. 2021. HBIM platform & smart sensing as a tool for monitoring and visualizing energy performance of heritage buildings. *Developments in the Built Environment*, *8*, 100056.

Ni, Z.; Hupkes, J.; Eriksson, P.; Leijonhufvud, G.; Karlsson, M.; Gong, S. Parametric Digital Twins for Preserving Historic Buildings: A Case Study at Löfstad Castle in Östergötland, Sweden. IEEE Access 2025, 13, 3371–3389

Özata, S. 2026. Opportunities and challenges of the Internet of Things (IoT) for cultural heritage safeguarding and resilience. In A. C. Apay (Ed.), *Innovative and different ideas in civil engineering and architecture* (pp. 5–28). LAP LAMBERT Academiz Publishing

Url-1- Twinview. 2025. Preserving the past through the future: How digital twins are transforming heritage conservation. https://www.twinview.com/insights/preserving-the-past-through-the-future-how-digital-twins-are-transforming-heritage-conservation

Zhang, J., Kwok, H. H., Luo, H., Tong, J. C., & Cheng, J. C. 2022. Automatic relative humidity optimization in underground heritage sites through ventilation system based on digital twins. *Building and Environment*, *216*, 108999.

Zhang, J., Chan, C. C., Kwok, H. H., & Cheng, J. C. 2023. Multi-indicator adaptive HVAC control system for low-energy indoor air quality management of heritage building preservation. *Building and Environment*, *246*, 110910.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DEVELOPMENT OF AN ENVIRONMENTALLY FRIENDLY CEM II/B-M (P-LL) 42.5R CEMENT: TECHNICAL, ECONOMIC AND ENVIRONMENTAL FEASIBILITY ANALYSIS

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ABSTRACT

The global cement industry is transforming due to climate targets, rising energy costs, and regulations such as CBAM. This study assesses the feasibility of transitioning at Seza Cement Plant (Elazığ, Türkiye) from CEM II/A-LL 42.5R to lower-clinker CEM II/B-M (P-LL) 42.5R by reducing the clinker factor from 80% to 67% using local limestone and pumice without sacrificing performance. Five blends were tested per TS EN 197-1; Blend 3 (67% clinker, 23% limestone, 5% pumice) was optimal, delivering 49.5 MPa 28-day strength, 112.31 TRY/ton cost savings, and 110.5 kg CO_2/ton reduction (~221,000 t CO_2/year at 2 Mt/y). The shift is technically viable and could generate 887.6 million TRY/year via operational savings and carbon-credit potential.

Keywords: Sustainable cement, clinker reduction, pumice, CO_2 emissions, cost analysis.

GİRİŞ

Çimento, modern altyapının en temel bağlayıcı malzemelerinden biri olmasına karşın, üretim prosesi doğası gereği yüksek karbon ayak izine sahiptir. Klinker üretiminde kireçtaşının kalsinasyonu ve yüksek sıcaklıklı fırın işletimi hem proses hem de yakıt kaynaklı emisyonları artırmakta; bu nedenle sektör, "düşük karbonlu çimento" dönüşümünün en kritik odaklarından biri olarak değerlendirilmektedir (Barbhuiya et al., 2024). Uluslararası raporlamalarda çimento üretiminin emisyon yoğunluğunun yaklaşık 0,6 $tCO_2 \cdot t^{-1}$ mertebesinde seyrettiği ve azaltımın büyük ölçüde klinker oranı (clinker factor) düşürme, alternatif bağlayıcılar ve proses optimizasyonu ile mümkün

olduğu vurgulanmaktadır (IEA, 2024). Bu bağlamda en uygulanabilir kısa/orta vadeli stratejilerden biri, Portland klinkerinin bir kısmını tamamlayıcı çimentomsu malzemeler (Supplementary Cementitious Materials, SCM) ile ikame ederek "karışık/kompozit çimentolar" üretmektir. Literatürde; kalker (limestone) ilavesinin yalnızca inert bir dolgu gibi davranmadığı, çimento hidratasyonu sırasında alüminat fazlarıyla etkileşerek karboalüminat oluşumlarını etkileyebildiği; uygun incelik ve oranlarda dayanım gelişimine katkı sağlayabildiği rapor edilmiştir (Lothenbach et al., 2008; Ramezanianpour et al., 2014). Benzer şekilde doğal puzolanlar (ör. pomza), yüksek SiO_2/Al_2O_3 içeriği sayesinde portlandit ($Ca(OH)_2$) ile reaksiyona girerek ikincil C–S–H oluşumunu destekleyebilmekte; uygun tane boyutu dağılımı ve kür koşullarında mekanik performans ve dayanıklılık açısından avantajlar sağlayabilmektedir (Turanli et al., 2005; Uzal et al., 2003). Bu yaklaşımlar, EN 197-1 kapsamında tanımlanan Portland kompozit çimentoların (ör. CEM II/B-M) daha düşük klinker oranlarıyla hedef dayanım sınıflarını yakalamasına imkân tanımaktadır (CEN, 2011). Düzenleyici ve piyasa dinamikleri de bu teknik dönüşümü hızlandırmaktadır. Avrupa Birliği'nin Sınırda Karbon Düzenleme Mekanizması (SKDM/CBAM) çimento dâhil belirli sektörlerde ithal ürünlerin gömülü emisyonlarının raporlanmasını ve kademeli yükümlülükleri çerçevelemekte; CBAM'ın 1 Ocak 2026 itibarıyla yürürlüğe girdiği ve uygulamanın operasyonel olarak devreye alındığı resmi olarak duyurulmuştur (European Commission, 2026; European Union, 2023). Bu gelişme, özellikle AB ile ticaret bağlantısı olan üreticiler için karbon yoğunluğunu düşüren ürün portföyü değişikliklerini yalnızca çevresel değil, aynı zamanda rekabetçilik açısından da stratejik hâle getirmektedir. Bu çalışma, Türkiye'de endüstriyel ölçekte üretim yapan bir çimento tesisinde, mevcut CEM II/A-LL 42,5R ürününden daha düşük klinker oranlı CEM II/B-M (P-LL) 42,5R ürününe geçişin teknik uygulanabilirliğini ve etkilerini ele almaktadır. Hedef, mekanik performanstan ödün vermeden klinker oranını %80 seviyesinden %67 seviyesine indirirken, yerel kalker ve pomza kaynaklarının uygun oranlarda kullanımıyla hem maliyet hem de emisyon yoğunluğunda iyileşme sağlamaktır. Bu kapsamda, %67–%70 klinker aralığında beş farklı karışım tasarlanmış; kimyasal kompozisyon (XRF tabanlı oksit analizi) ve karışım modülleri üzerinden uygunluk değerlendirilmiş; standart dayanım tayini yaklaşımıyla (EN 196-1) basınç dayanımı, priz ve genleşme gibi temel performans parametreleri incelenmiştir (CEN, 2016). Elde edilen bulgular, kompozit çimento yaklaşımıyla 42,5R sınıfı gerekliliklerinin sağlanabildiğini; seçilen karışım özelinde ton başına maliyet avantajı ve ton başına CO_2 azaltımı potansiyelinin oluştuğunu göstermektedir. Dolayısıyla çalışma, saha koşullarına uyarlanabilir bir ürün geçiş metodolojisi sunmakta; SKDM/CBAM gibi karbon temelli dış baskıların arttığı bir dönemde, klinker faktörünü düşürmeye yönelik "yerel hammadde + standarda uygun kompozit çimento" stratejisinin teknik ve ekonomik önemini ortaya koymaktadır.

MATERYAL VE METOT

Kullanılan Hammaddeler

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Çalışmada kullanılan ana hammaddeler; döner fırın çıkışından temin edilen Portland klinkeri, yerel ocak kaynaklı kalker (LL), doğal pomza (P) ve priz düzenleyici alçıtaşıdır. Tüm hammaddeler üretim öncesi temsil edici olacak şekilde numuneleme–homojenizasyon adımlarından geçirilmiş; karışım tasarımında oranlar kütlece yüzde (% m/m) olarak tanımlanmıştır.

Kimyasal Karakterizasyon (XRF) ve Klinker Modülleri

Hammaddelerin kimyasal bileşimleri X-ışını floresans (XRF) analizi ile belirlenmiş ve karışım tasarımında temel girdi olarak kullanılmıştır. XRF sonuçları oksit bazında raporlanmıştır (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, K_2O, Na_2O). Hammaddelere ait kompozisyonlar Tablo 1'de verilmiştir.

Tablo 1. Hammaddelerin XRF Kimyasal Analiz Sonuçları (%)

Malzeme	SiO2	Al2O3	Fe2O3	CaO	MgO	SO3	K2O	Na2O
Klinker	20,59	5,61	3,68	65,17	1,86	0,90	0,73	0,55
Pomza	45,21	15,32	12,24	9,53	8,24	-	1,96	3,40
Kalker	0,50	0,01	0,13	55,69	0,38	0,08	0,01	0,02
Alçı	0,74	0,01	0,07	32,27	0,08	44,85	0,04	0,02

Klinkerin potansiyel faz kompozisyonu ve reaktivitesi hakkında hızlı bir öngörü sağlamak amacıyla XRF oksit verilerinden klinker modülleri hesaplanmıştır. Modüller; kireç doygunluk faktörü (LSF), silikat modülü (SM) ve alümina modülü (AM) olarak ele alınmıştır.

$$LSF = \frac{65,17}{2,8(20,59)+1,2(5,61)+0,65(3,68)} = 97,76 \quad (1)$$

$$SM(Silikat\ Modl) = \frac{20,59}{5,61+3,68} = 2,22 \quad (2)$$

$$AM(Almina\ Modl) = \frac{20,59}{5,61+3,68} = 1,52 \quad (3)$$

Bu çalışma kapsamında Tablo 1'deki klinker oksit değerleri kullanılarak LSF = 97,76, SM = 2,22 ve AM = 1,52 olarak hesaplanmıştır. Pomzanın yüksek SiO_2 ve Al_2O_3 içeriği (Tablo 1), hidratasyon sırasında açığa çıkan kalsiyum hidroksit (CH, $Ca(OH)_2$) ile reaksiyona girerek ikincil bağlayıcı fazların (özellikle C–S–H jel fazı) oluşumuna katkı verebilecek puzolanik karaktere işaret etmektedir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Deneysel Tasarım ve Karışım Oranları

Mevcut üretimde kullanılan referans çimento (CEM II/A-LL 42,5R) ile karşılaştırma yapabilmek için klinker oranı düşürülmüş ve CEM II/B-M (P-LL) 42,5R hedefiyle 5 farklı deneme karışımı hazırlanmıştır. Karışımların kütlece oranları Tablo 2'de verilmiştir.

Tablo 2. Karışımların Kütlece Oranları

Referans Numunesi: Klinker (%80), Kalker (%15), Alçı (%5)				
Numune No.	Klinker (%)	Kalker (%)	Pomza (%)	Alçı (%)
1	70	13	12	5
2	67	13	15	5
3	67	23	5	5
4	67	22	6	5
5	67	21	7	5

Karışım tasarımında temel hedef; klinker faktörünün düşürülmesine rağmen 42,5R sınıfı için gereken mekanik performansın korunması ve katkı kombinasyonlarının işlenebilirlik/öğütülebilirlik üzerindeki etkilerinin izlenmesidir.

Öğütme ve İncelik Kontrolü (Blaine)

Deneme karışımları, mukavemet gelişimi ile incelik arasındaki güçlü ilişki nedeniyle kontrollü şekilde öğütülmüştür. Çimento inceliği, Blaine özgül yüzey alanı yaklaşımıyla izlenmiştir. Karışımların hedef mukavemet seviyelerine ulaşabilmesi için referans ürüne kıyasla daha ince öğütme ihtiyacı doğmuş ve her numune için elde edilen Blaine değerlerinin hangi aralıklarda gerçekleştirildiğine dair değerler Tablo 3'te verilmiştir.

Tablo 3. Numunelerin Blaine Değerleri

Referans Numunesi: 4700 (cm^2/g)	
Numune No.	Blaine Değeri (cm^2/g)
1	4750
2	4788

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

3	4800
4	4810
5	4820

Bu yaklaşım, karışımlar arasında incelik kaynaklı mukavemet sapmalarını azaltmak ve katkı tip/oranının etkisini daha net gözlemek amacıyla uygulanmıştır.

Fiziksel Deneyler (standart kıvam–priz–genleşme)

Karışımların işlenebilirlik davranışını değerlendirmek için standart kıvam su ihtiyacı belirlenmiş ve Vicat yöntemi ile priz süreleri ölçülmüştür. Denemelerde standart kıvam için gerekli su/çimento oranı %26,0–%26,8 aralığında değişmiştir. Pomza içeriğinin arttığı karışımlarda (özellikle Numune 3 ve Numune 4) gözenekli yapı nedeniyle su ihtiyacında sınırlı artış gözlenmiştir. Hacim kararlılığı/soundness değerlendirmesi Le Chatelier prensibine dayalı genleşme deneyi ile gerçekleştirilmiştir. Tüm fiziksel deneyler, ilgili standart metotların tarif ettiği numune hazırlama ve ölçüm adımlarına uygun şekilde yürütülmüştür.

Mekanik Deneyler (basınç dayanımı)

Karışımların mekanik performansı, standart harç numuneleri üzerinden basınç dayanımı ile değerlendirilmiştir. Harç numuneleri 40×40×160 mm prizmatik kalıplarda hazırlanmış; kalıptan çıkarma ve kür adımları standart prosedüre uygun şekilde gerçekleştirilmiştir. Basınç dayanımı ölçümleri belirlenen yaşlarda (özellikle erken yaş ve 28 gün) yapılmış; her bir karışım için tekrarlı numuneler üzerinden ortalama değerler raporlanmıştır. Elde edilen dayanım değerleri, hedef sınıf uygunluğu açısından ilgili çimento standardındaki sınıflandırma kriterleri ile karşılaştırılmıştır.

BULGULAR

Fiziksel test sonuçları

Karışımların standart kıvama gelmesi için gereken su/çimento oranı %26,0–%26,8 aralığında ölçülmüştür. Pomza oranının arttığı karışımlarda su ihtiyacı gözenekli yapı nedeniyle sınırlı düzeyde artış göstermiştir. Seçilen Numune 2 için su ihtiyacı %26,1 olarak belirlenmiştir.

Hedeflenen mukavemet seviyelerine ulaşabilmek için deneme karışımları referans ürüne kıyasla daha ince öğütülmüştür. Blaine incelikleri Tablo 3'teki ile aynıdır.

Basınç dayanımı sonuçları

Basınç dayanımı testleri (TS EN 196-1) sonucunda elde edilen 1 ve 7 günlük değerler ile 28 günlük projeksiyon değerleri Tablo 4'te verilmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Tablo 4. Basınç Dayanım Test Sonuçları (MPa)

Numune	Klinker	Katkı tipi	1 gün	7 gün	28 gün (proj.)
Referans	%80	Kalker (%15)	16,9	42,5	51,4
Numune 1	%70	Kalker + Pomza	14,6	41,0	50,5
Numune 2	%67	Kalker + Pomza	15,0	40,4	50,9
Numune 3	%67	Kalker (%23)	16,0	40,2	49,5*
Numune 4	%67	Kalker (%22)	14,6	38,8	49,0*
Numune 5	%67	Kalker (%21)	14,3	39,1	48,5**

* Numune 3–4 için 28 günlük dayanımın 48–50 MPa bandında gerçekleşeceği öngörülmüştür.

** Numune 5 için 28 günlük dayanımın 48–50 MPa bandında gerçekleşeceği varsayılmıştır.

TARTIŞMA

Bu çalışmanın en kritik çıktısı, klinker faktörü düşürülmesine rağmen 42,5R sınıfı performansının korunabildiğini göstermesidir. Bu durum yalnızca "karışım oranı" ile açıklanamaz; sonuçların arkasında (i) klinkerin reaktivitesini belirleyen modül/faz yapısı, (ii) kalker ve pomzanın hidratasyon kimyasına etkisi ve (iii) incelik (Blaine) ile erken yaş reaksiyon kinetiğinin yönetilmesi gibi birbirini tamamlayan mekanizmalar bulunmaktadır (Taylor, 1997; Lothenbach et al., 2008). İlk olarak, klinker modüllerinin (LSF–SM–AM) yüksek dayanım potansiyeline işaret etmesi önemlidir. Yüksek LSF, pratikte daha yüksek alit (C_3S) oluşumu eğilimiyle ilişkilendirildiğinden, erken yaş dayanımının korunmasında temel "itici güç" görevi görür (Taylor, 1997). Bu, düşük klinkerli karışımlarda beklenen erken yaş dayanım kaybının sınırlanabilmesini açıklayan ana unsurlardan biridir. Ancak tek başına yeterli değildir; çünkü klinker azaltıldıkça toplam hidratasyon ısısı ve C–S–H (kalsiyum-silikat-hidrat) üretim kapasitesi azalır. Bu boşluk, karışım tasarımı ve proses ayarlarıyla kapatılmalıdır. İkinci olarak, kalker (LL) ve doğal puzolan (pomza, P) birlikte kullanıldığında, sistem sadece "seyreltme (dilution)" mantığıyla davranmaz. Kalker çok ince tane boyutlarında çekirdeklenme (nucleation) etkisiyle C–S–H oluşumunu hızlandırabilir; ayrıca alüminat fazlarıyla etkileşerek karboalüminat fazlarını destekleyebilir. Bu etki, özellikle uygun SO_3 dengesi ve yeterli alüminat varlığında hidratasyon ürün dağılımını değiştirerek erken yaş performansını olumlu etkileyebilir (Lothenbach et al., 2008). Pomza ise CH (kalsiyum hidroksit) ile reaksiyona giren puzolanik bileşenleri sayesinde zamanla ikincil C–S–H üretir; bu da orta/uzun yaş dayanım gelişimini ve mikro yapı yoğunlaşmasını destekleme potansiyeli

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

taşır (Ramezanianpour, 2014). Dolayısıyla burada elde edilen performans korunumu, kalker+pomza kombinasyonunun "reaktivite + mikro-yapı" katkılarının, düşük klinker kaynaklı bağlayıcı kaybını kısmen telafi edebildiğini düşündürmektedir. Üçüncü olarak, incelik yönetimi sonuçların yorumlanmasında belirleyici bir faktördür. Düşük klinkerli çimentolarda hedef sınıfın yakalanabilmesi için daha ince öğütmeye gidilmesi literatürde sık görülen bir yaklaşımdır; çünkü incelik artışı, hidratasyon hızını ve erken yaş dayanımını yükseltirken aynı zamanda su ihtiyacını ve bazı durumlarda rötre/çatlak hassasiyetini artırabilir (Taylor, 1997). Bu çalışmada pomza içeriği yükselen karışımlarda su ihtiyacının artma eğilimi göstermesi, pomzanın gözenekli ve yüksek özgül yüzeyli yapısının su tutma kapasitesiyle uyumludur. Bu nedenle pratik uygulamada, yalnızca dayanım hedefi değil, işlenebilirlik–su talebi–öğütme enerjisi üçlüsünün birlikte optimize edilmesi gerekir. Çevresel açıdan bakıldığında, klinker faktörünün düşürülmesi doğrudan "gömülü CO_2" azaltımı anlamına gelir; bunun en önemli tarafı, azaltımın proses değişikliği gerektirmeden (özellikle kısa vadede) ürün kompozisyonu üzerinden sağlanabilmesidir. Literatürde de çimentoda emisyon azaltımının en yüksek kaldıraçlarından birinin klinker ikamesi olduğu vurgulanmaktadır (IEA, 2024). Bu çalışmanın değeri, yerel kalker ve pomza gibi erişilebilir hammaddelerle bu kaldıraçtan yararlanılabileceğini sahada göstermesidir. Son olarak, çalışmanın uygulanabilirliğini güçlendirmek için bazı sınırlılıklar ve tamamlayıcı doğrulamalar dikkate alınmalıdır. Hammaddelerin kimyasal bileşimi tek başına yeterli olmayıp, mineralojik yapı (XRD), tane boyutu dağılımı, LOI (kızdırma kaybı), reaktivite indeksleri gibi parametreler parti bazlı değişkenlik gösterebilir; bu da karışımların uzun süreli stabilitesini etkiler (Ramezanianpour, 2014). Ayrıca düşük klinkerli sistemlerde dayanıklılık performansı (sülfat dayanımı, klorür geçişi, karbonatlaşma, geçirimsizlik) en az dayanım kadar kritik bir seçim kriteridir. Bu nedenle endüstriyel ölçekli geçişten önce, seçilen karışım/karışımlar için dayanıklılık odaklı test paketiyle doğrulama yapılması ve proses kontrol limitlerinin (Blaine, SO_3 hedefi, katkı dozaj penceresi) standardize edilmesi önerilir.

SONUÇ

Bu çalışma kapsamında CEM II/A-LL 42,5R referans üründen, klinker oranı düşürülmüş CEM II/B-M (P-LL) 42,5R kompozit çimentoya geçişin teknik ve çevresel açıdan uygulanabilir olduğu gösterilmiştir. Teknik uygunluğa bakıldığında, klinker oranı %67–%70 aralığına düşürülen deneme karışımlarında 7 günlük basınç dayanımları 38,8–41,0 MPa aralığında, 28 günlük projeksiyon dayanımları ise 48,5–50,9 MPa bandında elde edilmiştir. Bu sonuçlar, 42,5R sınıfı hedefiyle uyumlu bir performansa işaret etmektedir. İşlenebilirlik ve proses etkisi incelendiğinde, standart kıvam için gerekli su/çimento oranı %26,0–%26,8 aralığında kalmıştır. Pomza oranının artması su ihtiyacını sınırlı düzeyde yükseltmiş; genel olarak karışımların işlenebilirliği korunmuştur. Hedef dayanım seviyelerine ulaşmak için karışımların daha ince öğütülmesi gerekmiş ve Blaine inceliği 4700 cm^2/g seviyesinden ~4750–4820 cm^2/g aralığına çıkmıştır. Çevresel katkı açısından, klinker kaynaklı emisyon yaklaşımıyla (850 kg CO_2/ton klinker), klinker oranının %80 → %67 düşürülmesi sonucunda

emisyonlar 680 → 569,5 kg CO_2/ton çimento seviyesine gerilemekte ve 110,5 kg CO_2/ton çimento azaltım sağlanmaktadır. Bu büyüklük, düşük klinkerli ürün stratejisinin karbon düzenlemeleri ve sürdürülebilir üretim hedefleri açısından anlamlı bir kazanım sunduğunu göstermektedir. Öneriler / uygulama adımları ise paragraph içerisinde devam eden maddelerce açıklanmıştır. (i) Seçilen karışımın endüstriyel ölçekte sürekliliği (değirmen stabilitesi, ürün homojenliği ve kalite dalgalanmaları) doğrulanmalıdır. (ii) Pomza ve kalker için giriş kalite kontrol parametreleri (XRF, tane boyutu/incekilik, LOI vb.) standartlaştırılmalı ve parti bazlı izlenmelidir. (iii) Ürün geçişi öncesinde/sonrasında dayanıklılık odaklı tamamlayıcı testler (örn. sülfat dayanımı, klorür geçişi, karbonatlaşma ve su geçirimsizlik) ile uzun vadeli performans güvence altına alınmalıdır. Bu yaklaşım, yerel puzolan ve kalker kaynaklarına erişimi olan diğer tesislerde de düşük klinkerli kompozit çimento üretimine geçiş için uygulanabilir bir çerçeve sunmaktadır.

TEŞEKKÜR

Bu çalışmanın yürütülmesi sırasında sağlanan kurumsal destek ve imkânlar için SYCS İnşaat Çimento Sanayi ve Ticaret A.Ş.'ye teşekkür ederiz. Ayrıca üretim denemeleri ile laboratuvar test süreçlerinde katkı sağlayan ilgili birim çalışanlarına desteklerinden dolayı teşekkür ederiz.

KAYNAKLAR

ASTM, 2011. ASTM C114-11 Standard Test Methods for Chemical Analysis of Hydraulic Cement. West Conshohocken, PA: ASTM International.

Barbhuiya S, Kanavaris F, Das BB, Idrees M 2024. Decarbonising cement and concrete production: Strategies, challenges and pathways for sustainable development. Journal of Building Engineering, 86: 108861.

CEN, 2011. EN 197-1:2011 Cement – Part 1: Composition, specifications and conformity criteria for common cements. Brussels: European Committee for Standardization.

CEN, 2016. EN 196-1:2016 Methods of testing cement – Part 1: Determination of strength. Brussels: European Committee for Standardization.

CEN, 2016. EN 196-3:2016 Methods of testing cement – Part 3: Determination of setting times and soundness. Brussels: European Committee for Standardization.

CEN, 2018. EN 196-6:2018 Methods of testing cement – Part 6: Determination of fineness. Brussels: European Committee for Standardization.

European Commission, 2026. CBAM successfully entered into force on 1 January 2026. Directorate-General for Taxation and Customs Union. Available at: European Commission website [19.02.26]

European Union, 2023. Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism (Text with EEA relevance). Official Journal of the European Union, L 130: 52–104.

IEA, 2024. Cement. International Energy Agency, Paris. Available at: IEA website [19.02.26]

ISO, 2010. ISO 29581-2:2010 Cement – Test methods – Part 2: Chemical analysis by X-ray fluorescence. Geneva: International Organization for Standardization.

Lothenbach B, Le Saout G, Gallucci E, Scrivener K 2008. Influence of limestone on the hydration of Portland cements. Cement and Concrete Research, 38(6): 848–860.

Ramezanianpour AA 2014. Cement Replacement Materials: Properties, Durability, Sustainability. Berlin Heidelberg: Springer, 336 pp.

Taylor HFW 1997. Cement Chemistry. 2nd Edition. London: Thomas Telford, 459 pp.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Turanli L, Uzal B, Bektas F 2005. Effect of large amounts of natural pozzolan addition on properties of blended cements. Cement and Concrete Research, 35(6): 1106–1111.

Uzal B, Turanli L 2003. Studies on blended cements containing a high volume of natural pozzolans. Cement and Concrete Research, 33(11): 1777–1781.

EFFECTS OF ALLOYING A356 ALLOY WITH Cu ON MICROSTRUCTURE, CORROSION BEHAVIOR and MECHANICAL BEHAVIOR

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ABSTRACT

Research examines how Copper (Cu) micro-alloying affects the A356 (Al-Si-Mg) aluminum alloy's microstructure, corrosion properties, and mechanical strengths. The A356's low density, good castability, and high ratio of strength to weight after T6 heat treatment continues to make it a material of choice in a variety of high-performance automotive and structural applications. Mechanical performance improvement requires a careful balance of alloy components. There is generally a linear relationship between strength and ductility/ corrosion resistance due to Cu additions. The effects described in this article were studied systematically. To accomplish this, three additional alloys containing different amounts of copper were made at three different weight percentages: 0.2%, 0.5%, and 1.0%. These alloys were made using low pressure die-Casting Equipment and treated with a T6 Standard Heat Treatment. The resulting microstructures were analyzed extensively by Optical Microscopy and Scanning Electron Microscopy (SEM) combined with Energy Dispersive Spectroscopy (EDS). This allowed for an examination of the composition and spatial location of the second-phase particles within each alloy. In addition, testing of the corrosion resistance of the alloys was performed according to ASTM B117 specifications for 96 hours via salt-spray Testing using a 5% NaCl Solution. It was noted that higher concentrations of copper increased the number of intermetallic Cu-based phases with increasing volume fraction, which coarsen and segregated from the grain boundaries and inhibited dislocation motion. Increased Cu content improved tensile and yield strengths, but created fracture points that reduced elongation; in addition, the presence of Cu rich noble metal phases within the aluminum matrix produced local galvanic corrosion cells that reduced localized corrosion resistance, and produced an environment conducive to pitting. Therefore, the overall conclusion is that an optimum combination of mechanical performance versus the potential for the environmental degradation of A356 can only occur at a specific quantity of Cu added to the alloy.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: A356 Alloy, Micro-Alloying, Mechanical Behavior, Microstructure

CHANGE IN PORE WATER PRESSURE IN SINGLE AND DOUBLE-LAYERED SOILS

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ABSTRACT

To understand the engineering behavior of soils, it is necessary to determine the shear strength parameters (cohesion and internal friction angle). Soil behavior varies depending on whether loading occurs under drained or undrained conditions, and these differences directly influence geotechnical design. In particular, for saturated fine-grained soils such as clays and silts, excess pore water pressures generated under undrained conditions (rapid loading) can significantly reduce effective stress, leading to a loss of strength and stiffness. Shear strength parameters can be investigated in the laboratory through triaxial cell shear tests in terms of total stresses (undrained) and effective stresses (drained). Moreover, soils in nature commonly exhibit a layered structure. Therefore, unlike single-layer soils, the generation and distribution of pore water pressure in double-layer systems may differ. Identifying this difference is important for accurately evaluating the effect of stratification on undrained behavior. In this study, the development of excess pore water pressure under static loading was investigated for clay and silt samples collected from the Adapazarı region in both single-layer and double-layer configurations. Clay, silt, clay-silt (clay on top-silt at bottom), and silt-clay (silt on top-clay at bottom) specimens prepared in the laboratory using the slurry method were subjected to consolidated undrained (CU) triaxial shear tests, and the change in excess pore water pressure during shearing was recorded simultaneously from both the base and the top. The tests were repeated under different cell pressures (100 kPa, 200 kPa, and 300 kPa). The experimental findings showed that the relative position of the clay and silt layers affects pore water pressure response under undrained loading conditions. Consequently, it was determined that the shear strength parameters vary depending on soil type, confining (cell) pressure, and layer arrangement.

Keywords: Shear strength, pore water pressure, layered soils, triaxial cell shear test.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TEK VE ÇİFT TABAKALI ZEMİNLERDE BOŞLUK SUYU BASINCININ DEĞİŞİMİ

ÖZET

Zeminlerin mühendislik davranışlarının anlaşılabilmesi için kayma direnci parametrelerinin (kohezyon ve kayma direnci açısı) belirlenmesi gerekir. Zemin davranışı, drenajlı veya drenajsız yükleme koşullarına bağlı olarak farklılık gösterir ve bu farklılıklar geoteknik yapı tasarımını doğrudan etkiler. Özellikle kil ve silt gibi suya doygun ince daneli zeminlerde drenajsız koşullarda (ani yükleme) gelişen aşırı boşluk suyu basıncı, daneler arası temas gerilmesi olan efektif gerilmeyi önemli ölçüde azaltarak dayanım ve rijitlik kaybına yol açabilir. Kayma direnci parametreleri, laboratuvarda üç eksenli hücre kesme deneyleri ile toplam gerilmeler (drenajsız) ve efektif gerilmeler (drenajlı) cinsinden değerlendirilebilir. Öte yandan zeminler doğada çoğunlukla katmanlı bir yapı sergiler. Bu nedenle tek tabakalı zeminden farklı olarak çift tabakalı sistemlerde boşluk suyu basıncının gelişimi ve dağılımı değişebilmektedir. Bu farklılığın ortaya konulması, katmanlaşmanın drenajsız davranış üzerindeki etkisinin doğru değerlendirilmesi açısından önemlidir. Bu çalışmada, Adapazarı bölgesinden alınan kil ve silt numunelerinin hem tek hem de çift tabakalı durumlarında statik yükleme altında aşırı boşluk suyu basıncının gelişimi incelenmiştir. Bulamaç yöntemiyle laboratuvar ortamında hazırlanan kil, silt, kil-silt (kil üstte-silt altta), silt-kil (silt üstte-kil altta) numuneleri konsolidasyonlu drenajsız (CU) üç eksenli hücre kesme deneyine tabi tutularak kesme sırasında oluşan aşırı boşluk suyu basıncındaki değişim eş zamanlı olarak hem numune altından hem de numune üst başlığından izlenmiştir. Deneyler farklı hücre basınçları (100 kPa, 200 kPa, 300 kPa) altında tekrarlanmıştır. Elde edilen deneysel bulgular, killi ve siltli tabaka konumlarının drenajsız yükleme koşulları altında boşluk suyu basıncı üzerinde etkiye sahip olduğunu göstermiştir. Sonuç olarak kayma direnci parametrelerinin zeminin türüne, hücre basıncına ve tabaka konumuna bağlı değişkenlik gösterdiği tespit edilmiştir.

Anahtar kelimeler: Kayma direnci, boşluk suyu basıncı, tabakalı zeminler, üç eksenli hücre kesme deneyi.

GİRİŞ

Zeminlerin mühendislik davranışının doğru biçimde anlaşılması, güvenli ve ekonomik geoteknik tasarımın temelini oluşturur (Mitchell ve Soga, 2005). Özellikle ince daneli ve suya doygun zeminlerde yükleme koşullarına bağlı olarak gelişen boşluk suyu basıncı değişimleri, zeminin taşıma gücü, deformasyon davranışı ve stabilitesi üzerinde belirleyici rol oynar. Drenajsız yükleme durumlarında gelişen aşırı boşluk suyu basıncı, daneler arası efektif gerilmeyi azaltarak kayma dayanımında önemli düşüşlere ve ani dayanım kayıplarına neden olabilir (Terzaghi, 1943; Skempton, 1954). Bu durum, özellikle deprem etkileri, hızlı yüklemeler, dolgu inşaatı ve kazı çalışmaları gibi mühendislik uygulamalarında kritik öneme sahiptir. Bu nedenle kayma direnci parametrelerinin ve

boşluk suyu basıncı gelişiminin doğru değerlendirilmesi, zemin davranışının güvenilir şekilde öngörülmesi açısından vazgeçilmezdir. Zeminlerin drenajsız davranışı ve boşluk suyu basıncı gelişimi uzun yıllardır geoteknik mühendisliğinin temel araştırma konularından biridir. Efektif gerilme prensibinin ortaya konulmasıyla birlikte, doygun zeminlerin dayanım ve deformasyon özelliklerinin boşluk suyu basıncı ile doğrudan ilişkili olduğu açıkça gösterilmiştir (Wood, 1990). Üç eksenli deneyler aracılığıyla drenajsız dayanımın belirlenmesi ve gerilme yolu analizleri konusunda klasik çalışmalar önemli bir bilgi birikimi oluşturmuştur. Bununla birlikte doğal zeminlerin çoğunlukla homojen değil, katmanlı yapıda bulunması nedeniyle son yıllarda araştırmalar, farklı zemin türlerinin birlikte bulunduğu sistemlerde boşluk suyu basıncı gelişiminin incelenmesine yönelmiştir (Duncan ve ark., 2014). Özellikle farklı sıkışabilirlik ve geçirgenlik özelliklerine sahip tabakaların bir arada bulunduğu durumlarda boşluk suyu basıncı dağılımının homojen zeminlerden farklı olduğu ve tabaka konumunun gerilme aktarımı ile deformasyon mekanizmasını etkilediği çeşitli deneysel ve sayısal çalışmalarla ortaya konulmuştur (Schiffman ve Stein, 1970).

Katmanlı zemin sistemlerinde drenajsız davranışın anlaşılması, özellikle alüvyal zeminler, deltalar ve dolgu alanları gibi heterojen zemin ortamlarında büyük önem taşımaktadır. Farklı zemin türlerinin üst üste yer aldığı durumlarda, kesme sırasında gelişen boşluk suyu basıncının tabakalar arasında farklı büyüklüklerde oluşabileceği ve bu durumun efektif gerilme dağılımını doğrudan etkileyebileceği bilinmektedir. Bununla birlikte literatürde, tabaka konumunun boşluk suyu basıncı gelişimi üzerindeki etkisini deneysel olarak doğrudan karşılaştırmalı biçimde inceleyen çalışmalar sınırlıdır. Özellikle aynı zemin türlerinin farklı yerleşim düzenlerinde (üstte veya altta bulunması) drenajsız davranışa etkisinin sistematik olarak değerlendirilmesi, mühendislik uygulamaları açısından önemli bir araştırma alanı oluşturmaktadır. Bu kapsamda gerçekleştirilen çok sayıda deneysel ve teorik çalışma, katmanlaşmanın drenajsız davranış ve boşluk suyu basıncı gelişimi üzerinde belirgin etkiler oluşturduğunu ve zemin tabakalarının konumuna bağlı olarak gerilme ve deformasyon tepkisinin anlamlı biçimde değiştiğini ortaya koymuştur (Schiffman ve Stein, 1970; Pyrah, 1996; Ronad, 2014; Xie ve ark., 2016; Zhang ve ark., 2022; Zhou ve ark., 2023). Özener ve ark. (2009), tabakalı kum zeminlerde dinamik yükleme altında boşluk suyu basıncı gelişimi ve sıvılaşma mekanizmasını sarsma tablası model deneyleri ile incelemiş, özellikle düşük geçirgenlikli ara tabakaların ve gevşek-sıkı tabaka düzeninin boşluk suyu basıncı oluşumu ve deformasyon davranışı üzerinde belirleyici olduğunu göstermiştir. Ayoubi ve Pak (2017) ise deprem yüklemesi altında iki tabakalı zeminler üzerindeki sığ temellerin davranışını sayısal olarak incelemiş ve daha rijit veya sıkı bir tabakanın varlığının, homojen sıvılaşabilir zemine kıyasla oturmaları önemli ölçüde azaltabildiğini ortaya koymuştur. Statik yükleme koşullarında yapılan deneysel çalışmalar da benzer şekilde tabaka diziliminin gerilme ile şekil değiştirme davranışını ve boşluk suyu basıncı tepkisini doğrudan etkilediğini göstermektedir (Zhifu ve ark., 2023).

Bu çalışmada, Adapazarı bölgesinden temin edilen kil ve silt zeminlerinin tek tabakalı ve çift tabakalı sistemlerde drenajsız davranışı deneysel olarak incelenmiştir. Laboratuvarda bulamaç yöntemiyle

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

hazırlanan kil, silt, kil-silt (kil üstte silt altta) ve silt-kil (silt üstte kil altta) numuneleri konsolidasyonlu drenajsız (CU) üç eksenli kesme deneylerine tabi tutulmuş ve kesme sırasında oluşan aşırı boşluk suyu basıncı hem numunenin altından hem de üstünden eş zamanlı olarak ölçülmüştür. Deneyler farklı hücre basınçları altında tekrarlanarak çevre gerilmesinin etkisi değerlendirilmiştir. Bu kapsamda, tabaka türü ve konumunun drenajsız yükleme altındaki boşluk suyu basıncı gelişimine ve dolayısıyla kayma direnci parametrelerine etkisinin ortaya konulması amaçlanmıştır.

MALZEMELER VE METOT

Malzemeler

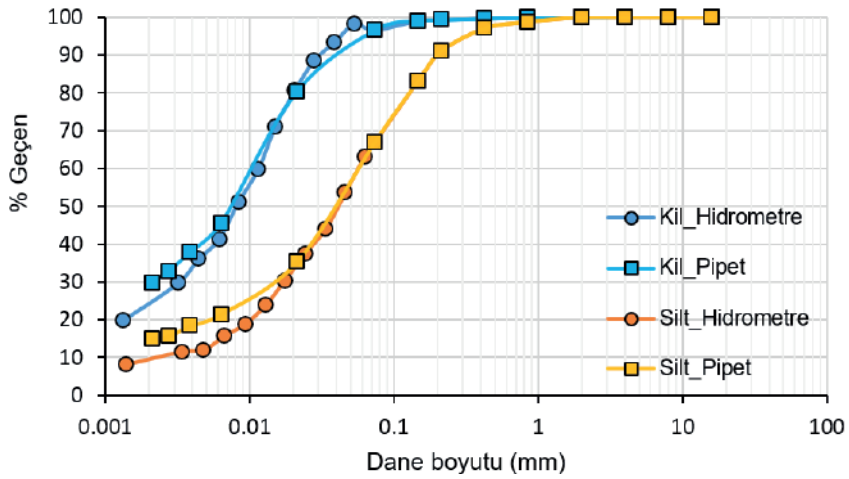
Bu çalışmada kullanılan zemin numuneleri Adapazarı bölgesinden temin edilen doğal kil ve silt zeminleridir. Numunelerin mühendislik özelliklerinin belirlenebilmesi amacıyla öncelikle kapsamlı fiziksel zemin deneyleri gerçekleştirilmiştir. Bu kapsamda likit limit (Casagrande ve koni penetrometer testleri ile), plastik limit, özgül ağırlık ve dane boyu dağılımı deneyleri yapılmıştır. Dane boyu dağılımı, ince danaler için hidrometre ve pipet yöntemleri, kaba daneler için ise elek analizi kullanılarak belirlenmiştir. Tüm fiziksel deneyler Türk Standardı TS 1900'e uygun olarak yürütülmüş, deney sonuçlarına bağlı olarak zeminlerin sınıflandırılması TS 1500 standardına göre yapılmıştır. Elde edilen fiziksel özellikler ve zemin sınıfları Tablo 1'de sunulmuştur. Hidrometre ve pipet deneylerinden elde edilen dane dağılım eğrileri ise Şekil 1'de verildiği gibidir. Sonuçlara göre kil numunesi CI (orta plastisiteli kil), silt numunesi ise ML (düşük plastisiteli silt) zemin sınıfında yer almakta olup, plastisite, ince dane oranı ve mühendislik davranışı bakımından birbirinden belirgin şekilde farklı özellikler sergilemektedir.

Tablo 1. Çalışmada kullanılan zeminler ve özellikleri

Özellik	**Adapazarı kili**	**Adapazarı silti**
Likit limit, Casagrande (%)	45	29
Likit limit, Koni (%)	44	32
Plastik limit (%)	25	NP
Plastisite indisi (%)	20	NP
Özgül ağırlık	2.668	2.657
İnce dane oranı (%)	97	67
Kum oranı (%)	3	33
Kil oranı, hidrometre (%)	24	9

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Kil oranı, pipet (%)	30	15
Zemin sınıfı (TS1500, 200)	CI	ML



Şekil 1. Hidrometre ve pipet deneylerinden elde edilen dane boyutu dağılımları

Metot

Bu çalışmada zemin numuneleri hem tek tabakalı hem de çift tabakalı olacak şekilde hazırlanarak konsolidasyonlu drenajsız (CU) üç eksenli basınç deneylerine tabi tutulmuştur. Deneyler sonucunda numunelerin gerilme-şekil değiştirme ilişkileri belirlenmiş, kesme süreci boyunca numunenin üst ve alt kısımlarında gelişen aşırı boşluk suyu basınçları eş zamanlı olarak ölçülmüştür. Böylece tabaka düzeninin drenajsız davranış ve boşluk suyu basıncı gelişimi üzerindeki etkisi karşılaştırmalı olarak değerlendirilmiştir.

CU deneyleri için numuneler bulamaç (slurry) yöntemi kullanılarak laboratuvarda hazırlanmıştır. Bu yöntemde zeminler, doğal çökelme koşullarını temsil edecek şekilde su ile karıştırılarak homojen bir hale getirilmiştir. Numuneler likit limit değerinin yaklaşık 1.5 katı su muhtevasında hazırlanmış ve karışım içerisindeki hava kabarcıklarının uzaklaştırılması amacıyla desikatörde havası alınmıştır. Hava içermeyen bu bulamaç, pleksiglass ön konsolidasyon hücresine bir huni yardımıyla dökülerek boşluksuz ve homojen yerleşim sağlanmıştır. Numune yerleştirildikten sonra, konsolidasyonun gerçekleşmesine olanak tanıyan bu düzenek içerisinde 100 kPa düşey gerilme altında ön konsolidasyona tabi tutulmuştur.

Çift tabakalı zemin numunelerinde ise aynı işlem tabaka tabaka uygulanmıştır. İlk tabaka yerleştirilip ön konsolidasyon süreci başlatıldıktan sonra ikinci tabaka aynı prosedür izlenerek oluşturulmuş ve tüm sistem birlikte konsolide edilmiştir. Bu yöntem, ince daneli zeminlerin su ortamında çökelmesiyle

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oluşan doğal flüvyal (akarsu kaynaklı) çökelme koşullarını temsil etmeyi amaçlamaktadır. Ön konsolidasyonu tamamlanan numuneler daha sonra üç eksenli hücreye alınarak CU kesme deneylerine tabi tutulmuştur.

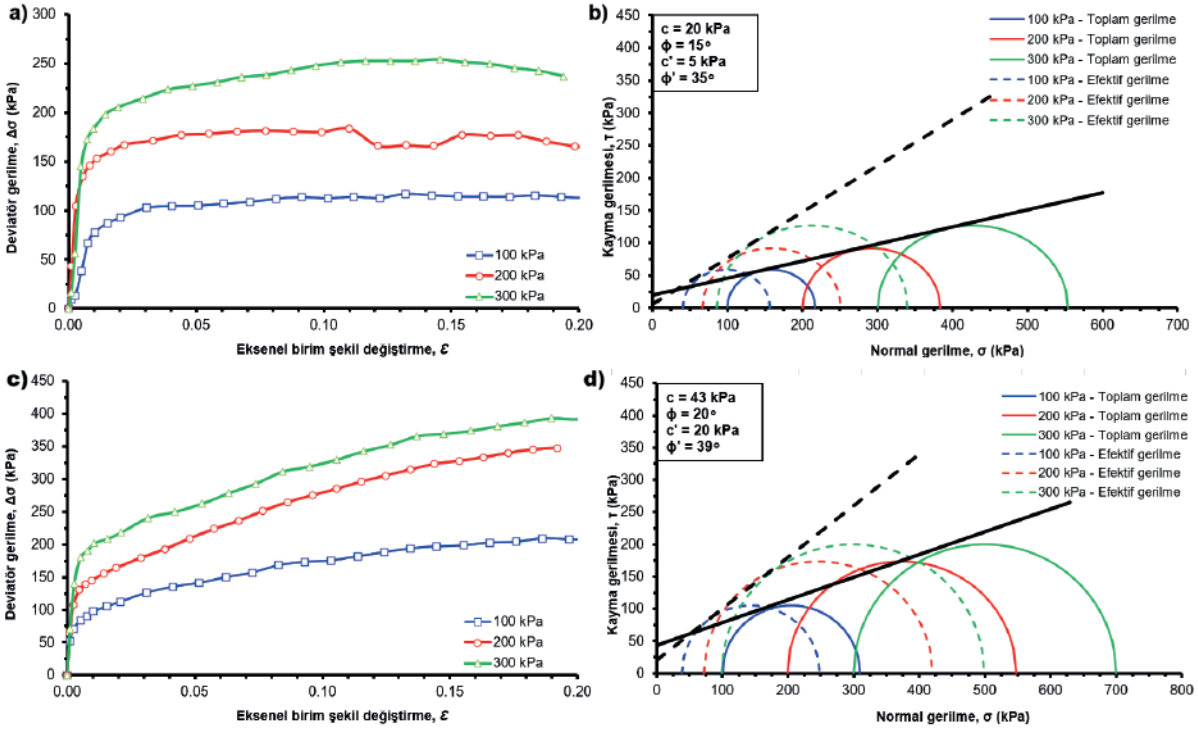
Ön konsolidasyonu tamamlanan tek tabakalı ve çift tabakalı zemin numuneleri konsolidasyonlu drenajsız (CU) üç eksenli basınç deneylerine tabi tutulmuştur. Deneyler, farklı efektif gerilme seviyelerinde zemin davranışının belirlenebilmesi amacıyla 100 kPa, 200 kPa ve 300 kPa hücre çevre basınçları altında gerçekleştirilmiştir. Her deneyde numuneler öncelikle ilgili hücre basıncı altında konsolide edilmiş, ardından drenaj kapatılarak drenajsız kesme aşamasına geçilmiştir. Kesme aşaması sabit deformasyon kontrollü olarak yürütülmüş ve eksenel yükleme hızı 0.2 mm/dk olarak uygulanmıştır. Deney süresince eksenel yük, deformasyon ve gerilme-şekil değiştirme ilişkileri sürekli olarak kaydedilmiştir. Bununla birlikte drenajsız yükleme sırasında gelişen aşırı boşluk suyu basınçlarının numune boyunca dağılımını belirleyebilmek amacıyla boşluk suyu basınçları numunenin hem altından hem de üstünden eş zamanlı olarak ölçülmüştür. Bu sayede tabaka düzeninin boşluk suyu basıncı gelişimi üzerindeki etkisi ayrıntılı biçimde değerlendirilmiştir.

BULGULAR VE TARTIŞMA

Konsolidasyonlu drenajsız (CU) üç eksenli deneyler sonucunda öncelikle tek tabakalı kil ve silt numunelerinin gerilme-şekil değiştirme davranışı ile toplam ve efektif gerilmeler cinsinden kayma dayanımı parametreleri belirlenmiştir. Elde edilen sonuçlar Şekil 2'de sunulmaktadır. Şekil 2a ve 2b sırasıyla kil numunesinin gerilme-şekil değiştirme ilişkisini ve yenilme zarfını, Şekil 2c ve 2d ise silt numunesine ait karşılık gelen sonuçları göstermektedir. Şekil 2a incelendiğinde, kil numunesinde deviatör gerilmenin eksenel şekil değiştirme ile birlikte başlangıçta hızlı bir artış gösterdiği, ardından belirli bir şekil değiştirme seviyesinden sonra yaklaşık sabit bir değere ulaştığı görülmektedir. Bu durum, killi zeminin belirgin bir dayanım tepe noktasından sonra plastik akma davranışı sergilediğini göstermektedir. Artan çevre basıncı ile birlikte maksimum deviatör gerilmenin yükseldiği ve numunenin daha yüksek gerilme seviyelerinde kesmeye karşı daha dirençli hale geldiği gözlenmiştir. Şekil 2b'de verilen yenilme zarfına göre kil numunesi için toplam gerilmeler cinsinden kohezyon değeri 20 kPa ve kayma direnci açısı 15° olarak belirlenirken, efektif gerilmeler cinsinden kohezyon 5 kPa ve içsel sürtünme açısı 35° olarak elde edilmiştir. Toplam ve efektif parametreler arasındaki bu fark, drenajsız kesme sırasında gelişen aşırı boşluk suyu basınçlarının efektif gerilmeyi azaltıcı etkisini açık biçimde ortaya koymaktadır. Silt numunesine ait gerilme-şekil değiştirme davranışı Şekil 2c'de verilmiştir. Kil numunesine kıyasla siltte deviatör gerilmenin şekil değiştirme ile birlikte daha sürekli ve belirgin bir artış eğilimi gösterdiği, belirgin bir tepe dayanımı oluşmadan sertleşme karakterine yakın bir davranış sergilendiği görülmektedir. Bu durum, daha düşük plastisiteli ve nispeten daha iri daneli yapıdaki siltin kesme sırasında daha kademeli bir dayanım gösterdiğini düşündürmektedir. Şekil 2d'de verilen yenilme zarfına göre silt numunesi için toplam gerilmeler cinsinden kohezyon 43 kPa ve içsel sürtünme açısı 20° olarak belirlenirken, efektif gerilmeler cinsinden kohezyon 20 kPa ve içsel

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sürtünme açısı 39° olarak elde edilmiştir. Silt numunesinin hem toplam hem de efektif gerilmeler altında kil numunesine göre daha yüksek sürtünme açısı değerleri göstermesi, daha iri dane oranı ve daha düşük plastisiteye bağlı olarak sürtünme bileşeninin daha baskın olduğunu göstermektedir.

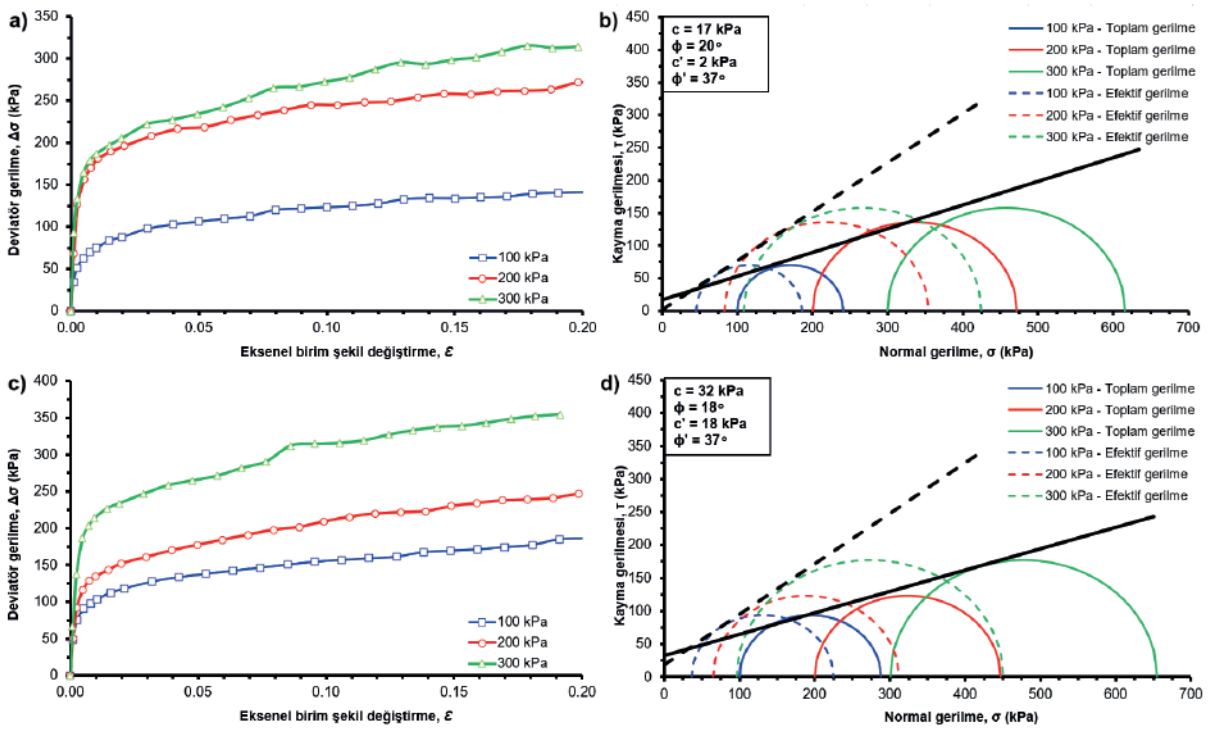


Şekil 2. Kil ve siltin CU deney sonuçları; **a)** Kil gerilme şekil değiştirme ilişkisi, **b)** Kil yenilme zarfı, **c)** Silt gerilme şekil değiştirme ilişkisi, **b)** Silt yenilme zarfı

Şekil 3'te katmanlı numunelere ait konsolidasyonlu drenajsız (CU) üç eksenli deney sonuçları sunulmaktadır. Şekil 3a ve b kilin üstte, siltin altta bulunduğu numuneye, Şekil 3c ve d ise siltin üstte, kilin altta bulunduğu numuneye ait gerilme-şekil değiştirme davranışı ve yenilme zarflarını göstermektedir. Şekil 3a incelendiğinde, kil (üstte)-silt (altta) düzeninde deviatör gerilmenin eksenel şekil değiştirme ile birlikte hızlı bir başlangıç artışı gösterdiği ve daha sonra kademeli olarak yükselmeye devam ettiği görülmektedir. Buna karşılık Şekil 3b'de verilen yenilme zarfına göre bu tabakalanmada toplam gerilmeler cinsinden kohezyon 17 kPa ve içsel sürtünme açısı 20°, efektif gerilmeler cinsinden ise kohezyon 2 kPa ve sürtünme açısı 37° olarak belirlenmiştir. Özellikle efektif kohezyonun oldukça düşük olması, kesme sırasında gelişen boşluk suyu basınçlarının efektif gerilme üzerindeki etkisinin belirgin olduğunu göstermektedir. Silt (üstte)-kil (altta) düzenine ait gerilme-şekil değiştirme davranışı (Şekil 3c), genel eğilim olarak daha yüksek deviatör gerilme seviyelerine ulaşıldığını göstermektedir. Aynı çevre basınçlarında elde edilen dayanım değerlerinin kil üstte-silt altta durumuna göre daha yüksek olduğu dikkat çekmektedir. Şekil 3d'de verilen yenilme zarfına göre bu tabakalanmada toplam gerilmeler cinsinden kohezyon 32 kPa, içsel sürtünme açısı 18°, efektif gerilmeler cinsinden ise kohezyon 18 kPa ve sürtünme açısı 37° olarak belirlenmiştir. Özellikle efektif kohezyonun belirgin şekilde artması, tabaka konumunun drenajsız dayanım bileşenlerini doğrudan

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etkilediğini göstermektedir. İki katmanlı sistemler karşılaştırıldığında, siltin üstte, kilin altta bulunduğu durumda daha yüksek dayanım ve daha büyük efektif kohezyon değerleri elde edilmiştir. Buna karşın kayma direnci açısının efektif gerilmeler cinsinden her iki tabakalanma düzeninde benzer mertebelerde olması, sürtünme bileşeninin zemin türünden çok gerilme yolu ve drenajsız koşullara bağlı olduğunu düşündürmektedir. Sonuçlar, tabaka konumunun drenajsız kesme davranışı üzerinde belirgin bir etkisi olduğunu ve özellikle dayanım parametrelerinin yalnızca zemin türüne değil, tabakalanma düzenine de bağlı olarak değiştiğini açıkça ortaya koymaktadır.

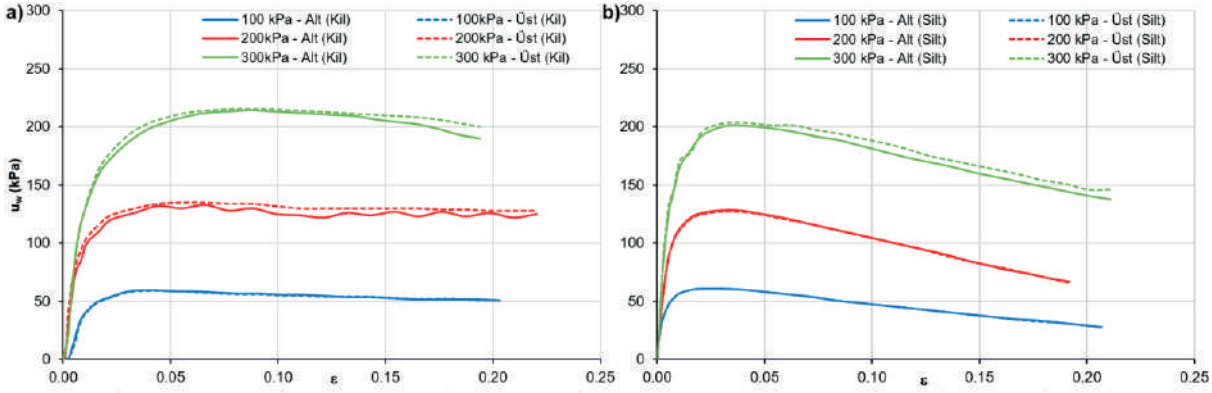


Şekil 3. Katmanlı numunelerin CU deney sonuçları; **a)** Kil-Silt numunesinin gerilme şekil değiştirme ilişkisi, **b)** Kil-Silt numunesinin yenilme zarfı, **c)** Silt-Kil numunesinin gerilme şekil değiştirme ilişkisi, **b)** Silt-Kil numunesinin yenilme zarfı

Şekil 4'te tek tabakalı kil ve silt numunelerinde drenajsız kesme sırasında gelişen aşırı boşluk suyu basınçlarının numunenin üst ve alt noktalarındaki değişimi gösterilmektedir. Şekil 4a kil, Şekil 4b ise silt numunesine ait sonuçları sunmaktadır. Şekil 4a incelendiğinde, kil numunesinde boşluk suyu basıncının kesmenin başlangıcında hızla arttığı, ardından belirli bir şekil değiştirme seviyesinden sonra yaklaşık sabit bir değere ulaştığı görülmektedir. Bu davranış, kilin düşük geçirgenliği nedeniyle kesme sırasında oluşan boşluk suyu basıncının numune içinde korunma eğiliminde olduğunu göstermektedir. Üst ve alt ölçüm noktalarından elde edilen değerlerin birbirine oldukça yakın olması, numune boyunca boşluk suyu basıncı dağılımının büyük ölçüde homojen olduğunu ve drenajsız koşullar altında suyun yeniden dağılımının sınırlı kaldığını göstermektedir. Çevre basıncının artmasıyla maksimum boşluk suyu basıncı değerlerinin de arttığı açıkça görülmektedir. Şekil 4b'de verilen silt numunesine ait

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

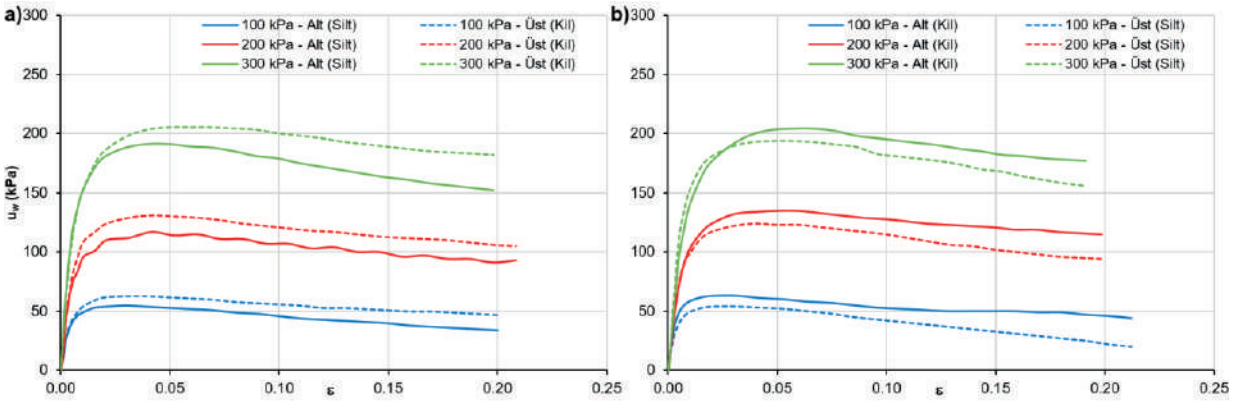
sonuçlar ise farklı bir eğilim ortaya koymaktadır. Siltte boşluk suyu basıncı kesmenin başlangıcında hızla artmakla birlikte, şekil değiştirme ilerledikçe belirgin bir azalma eğilimi göstermektedir. Bu durum, siltin kile kıyasla daha yüksek geçirgenliğe sahip olması nedeniyle kesme sırasında oluşan boşluk suyu basıncının zamanla yeniden dağıldığını ve kısmen sönümlendiğini göstermektedir. Ayrıca silt numunesinde üst ve alt ölçüm noktaları arasında kilden daha belirgin farklar gözlenmesi, boşluk suyu basıncının numune boyunca daha heterojen dağıldığını ve drenajsız koşulların yerel ölçekte farklı şekilde gelişebildiğini göstermektedir.



Şekil 4. Kil ve siltin boşluk suyu basıncı dağılımı; **a)** Kil, **b)** Silt

Şekil 5'te katmanlı numunelerde drenajsız kesme sırasında gelişen aşırı boşluk suyu basınçlarının numunenin üst ve alt noktalarındaki değişimi verilmiştir. Şekil 5a kilin üstte, siltin altta bulunduğu düzeni (kil-silt), Şekil 5b ise siltin üstte, kilin altta bulunduğu düzeni (sil-kil) göstermektedir. Şekil 5a incelendiğinde, üstte yer alan kil tabakasında ölçülen boşluk suyu basınçlarının alttaki silt tabakasına göre daha yüksek değerlerde kaldığı dikkat çekmektedir. Şekil değiştirme ilerledikçe alt tabakada boşluk suyu basıncının daha belirgin şekilde azalması, siltin drenaj eğiliminin daha yüksek olduğunu açıkça ortaya koymaktadır. Şekil 5b'de verilen silt üstte-kil altta düzeninde ise farklı bir dağılım gözlenmektedir. Kilin daha düşük geçirgenliğe sahip olması nedeniyle oluşan boşluk suyu basıncının alt tabakada daha fazla birikmesi ve daha yavaş sönümlenmesi beklenen bir durumdur. Buna karşılık üstteki silt tabakasında boşluk suyu basıncı daha erken azalma eğilimi göstermekte, bu da daha geçirgen yapıya bağlı olarak suyun daha kolay yeniden dağıldığını işaret etmektedir. İki katmanlı sistemler karşılaştırıldığında, boşluk suyu basıncının büyüklüğü ve dağılımının yalnızca gerilme seviyesine değil, tabaka konumuna ve zemin türlerinin geçirgenlik farkına güçlü biçimde bağlı olduğu açıkça görülmektedir. Katmanlı yapıda kil tabakasının silt ile birlikte bulunması nedeniyle kilde gelişen boşluk suyu basıncı bir miktar azalırken, silt tabakasında ise buna karşılık sınırlı bir artış gözlenmiştir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7



Şekil 5. Katmanlı numunelerin boşluk suyu basıncı dağılımı; **a)** Kil-Silt, **b)** Silt-Kil

SONUÇLAR

Bu çalışmada Adapazarı kili ve silti tek tabakalı ve çift tabakalı düzenlerde hazırlanarak konsolidasyonlu drenajsız (CU) üç eksenli deneylere tabi tutulmuş, gerilme-şekil değiştirme davranışı, kayma dayanımı parametreleri ve kesme sırasında numunenin üst ve alt noktalarında gelişen aşırı boşluk suyu basıncı değişimleri incelenmiştir. Elde edilen sonuçlar, tek tabakalı durumda kilin daha belirgin plastik akma davranışı ve homojen boşluk suyu basıncı dağılımı sergilediğini, siltin ise daha sürekli dayanım artışı ve zamanla azalan boşluk suyu basıncı ile daha geçirgen bir davranış gösterdiğini ortaya koymuştur. Katmanlı numunelerde ise tabaka konumunun hem drenajsız dayanım parametrelerini hem de boşluk suyu basıncı dağılımını doğrudan etkilediği belirlenmiştir. Siltin üstte, kilin altta bulunduğu düzen daha yüksek dayanım ve daha büyük efektif kohezyon değerleri vermiştir. Boşluk suyu basıncı dağılımı incelendiğinde düşük geçirgenliğe sahip kil tabakasının bulunduğu konumda basıncın daha fazla biriktiği, silt tabakasında ise daha hızlı sönümlendiği görülmüştür. Ayrıca katmanlı yapıda kilin silt ile birlikte bulunması kilde gelişen boşluk suyu basıncını bir miktar azaltırken, silt tabakasında sınırlı bir artışa neden olmuştur. Sonuç olarak zemin türü kadar tabaka konumunun da drenajsız kesme davranışı ve boşluk suyu basıncı gelişimi üzerinde belirleyici olduğu açıkça ortaya konmuştur.

REFERANSLAR

Ayoubi P, Pak A 2017. Liquefaction-induced settlement of shallow foundations on two-layered subsoil strata. Soil Dynamics and Earthquake Engineering, 94: 35-46.

Duncan JM, Wright SG, Brandon TL 2014. Soil strength and slope stability, 2nd ed. Hoboken: Wiley.

Mitchell JK, Soga K 2005. Fundamentals of soil behavior, 3rd ed. Hoboken: Wiley.

Özener TP, Özaydın K, Berilgen MM 2009. Investigation of liquefaction and pore water pressure development in layered sands. Bulletin of Earthquake Engineering, 7: 199-219.

Poulos HG, Davis EH 1974. Elastic solutions for soil and rock mechanics. New York: Wiley.

Pyrah IC 1996. One-dimensional consolidation of layered soils. Geotechnique, 46(3): 555–560.

Ronad H 2014. An experimental study on variation of shear strength for layered soils. International Journal of Research in Advent Technology, 2(5).

Schiffman RL, Stein JR 1970. One-dimensional consolidation of layered systems. Journal of Soil Mechanics and Foundations Division, ASCE.

Skempton AW 1954. The pore-pressure coefficients A and B. Geotechnique, 4(4): 143–147.

Terzaghi K 1943. Theoretical soil mechanics. New York: Wiley.

Türk Standardları Enstitüsü (TSE) 2006. TS 1900-1: İnşaat mühendisliğinde zemin laboratuvar deneyleri – Bölüm 1: Fiziksel özelliklerin tayini. Ankara: TSE.

Türk Standardları Enstitüsü (TSE) 2000. TS 1500: Zeminlerin sınıflandırılması. Ankara: TSE.

Wood DM 1990. Soil behaviour and critical state soil mechanics. Cambridge: Cambridge University Press.

Xie KH, Xia CQ, An R, Ying HW, Wu H 2016. A study on one-dimensional consolidation of layered structured soils. International Journal for Numerical and Analytical Methods in Geomechanics, 40(7): 1081–1098.

Zhang J, Shi D, Jin H, Li H, Jiang N, Ye Q 2022. Characteristics of cultivated layer soil shear strength for sloping farmland in response to soil erosion in the Three Gorges Reservoir Area, China. Catena, 215: 106304.

Zhou T, Zhang H, Zhang Z, Zhang L, Tan W 2023. Investigation of intralayer and interlayer shear properties of stabilized rammed earth by direct shear tests. Construction and Building Materials, 367: 130320.

Zhifu S, Qier X, Lingyu Z, Zhihua W, Hongmei G 2023. Experimental study on static triaxial shear behavior of artificially prepared interlayered soil. Chinese Journal of Geotechnical Engineering, 45(4): 840-846.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DEVELOPMENT OF A COMPOSITE PARTIALLY BIODEGRADABLE IMPLANT

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ABSTRACT

Segmental bone defects often require implant-assisted treatment, yet permanent metallic implants may lead to stress shielding and limited osseointegration. In this study, an implant design strategy was developed within a composite, partially biodegradable concept. This concept contains a load-bearing lattice framework combined with infiltrated graft and degradable phases. For diaphyseal segmental defect applications, the implant geometry was determined based on rat femur radiological images and femur dimensions reported in the literature. According to this knowledge a hollow cylindrical geometry was selected. To compare different lattice categories within the same geometry, four TPMS lattices (Gyroid, Lidinoid, SplitP, and Diamond), one strut-based lattice (Fluorite), and one stochastic lattice (Voronoi) were designed in nTop. These geometries designed according to two main restrictions: lower porosity at the bone-contact ends to support bone–implant interaction and higher porosity in the middle section to provide sufficient space for graft accommodation. Pore sizes were targeted within 300–600 μm to support osteoblast colonization and vascularization, and weight saving, mass, surface area, and pore-size metrics were calculated using nTop tools. Representative unit cells were generated, and homogenization analysis was performed to estimate effective elastic modulus values. All designs satisfied the targeted pore-size range and showed a graded pore distribution along the implant length. Smaller pores were placed at the bone-contact regions, and pore size increased toward the midsection. In the non-TPMS designs, the pore network was less uniform overall. Homogenization suggested that the lattice approach brought the effective elastic modulus down to about 9–16 GPa compared with bulk Ti-6Al-4V, which reduce stress shielding. Results from finite element analysis (FEA) pointed in the same direction: higher effective modulus generally went with higher strength, while lower-modulus designs carried less load. TPMS lattices also tended to distribute stress more evenly because their geometry is smooth and continuous; strut-based designs, by contrast, were more likely to show stress build-up around sharper transitions. Among the geometries evaluated, Gyroid, SplitP, and Diamond showed the best overall strength performance.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Composite implant; Pore size distribution; Homogenization; TPMS lattice; Finite element analysis (FEM)

EFFECT OF SHOT PEENING PRESSURE AND IMPINGEMENT ANGLE ON THE SURFACE ROUGHNESS OF AA7075-T6

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ABSTRACT

Shot peening is widely employed method to enhance the mechanical performance of engineering materials including aluminum alloys in the aerospace and defense industries. However, it inevitably leads to an increase in surface roughness. In this study, linear profilometry was used to quantify roughness via Ra (arithmetic mean height) and Rz (peak-to-valley height) in order to assess its dependence on process conditions. In a four-group experimental design, blasting pressure and impact angle were systematically varied, while velocity and shot size were held constant within each group. The findings indicate substantial increases in the Ra and Rz values compared to the untreated reference sample under all examined process conditions. Compared with the untreated condition (Ra=0.27 µm; Rz=2.58 µm), all shot-peened conditions exhibited pronounced roughness increases. The Ra values ranges 1.81 to 6.08 µm. The Rz values ranges from 11.11 to 29.82 µm. This indicates substantial degradation in surface finish. It was determined that this increase is associated with impact-induced crater formation and the accumulation of surrounding material. The investigation was carried out to determine the impact of various parameters. Comparisons revealed that an elevated pressure was the dominant variable, consistently raising roughness levels. Similarly, it was observed that crater depth and amplitude of peak or valley became particularly noticeable in the Rz parameter with increase in impact energy. The intergroup evaluation revealed that shot size is important, with larger diameters achieving higher roughness levels. Additionally, the roughness increases with pressure, even when the angle of attack is reduced. This indicates that surface topography exhibits higher sensitivity to pressure than to the angle of attack within the pressure-angle range examined in this work. This

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

underlines the importance of optimizing both pressure and shot size simultaneously in applications where roughness control is crucial.

Keywords: Shot Peening, Surface Roughness, AA7075-T6

Introduction

The most important feature expected from structural materials used in advanced engineering fields such as aerospace, defense, and automotive is their ability to offer both lightness and high mechanical performance. In this context, 7xxx series aluminum alloys stand out with their low density and superior strength values and finds frequent applications in industry.

Shot peening (SP) process stands out as a leading option among surface improvement techniques. This method involves repeatedly hitting the surface with shot to improve the material's mechanical properties. While an improvement in mechanical properties is expected as a result of the shot peening process, pits known as shot marks also form on the surface. These marks cause elastoplastic deformation in the material, resulting in residual compressive stresses and delaying crack propagation.

Considering the manufactured products and final outputs, the expectation of a perfect surface finish conflicts with the nature of this method. The shot pits that inevitably form on the surface cause a peaked-and-pitched surface morphology. Therefore, it is essential to measure surface roughness after shot peening. Surface roughness must be minimized, or appropriate process parameters must be selected to achieve the lowest possible roughness value. Which parameters affect surface roughness and the extent of this effect have become important topics of research.

Shot peening is primarily employed to introduce a compressive residual stress (CRS) layer that suppresses fatigue crack initiation and propagation while maintaining the surface roughness within acceptable limits (Wu, 2020). Although the process improves fatigue and wear performance, its influence on surface topography is strongly dependent on process parameters. Previous studies(Miao et al., 2010;Unal, 2016; Long et al., 2024; Wang et al., 2024; Zhao et al., 2024) consistently report that increasing shot diameter and shot velocity leads to higher surface roughness due to the formation of larger impact dimples (Sarveswara Reddy el al., 2024). In addition, roughness tends to increase with coverage, although it may approach a steady-state Ra value as processing time progresses (Bagherifard et al., 2012).

Similarly, Unal (2016) demonstrated that the simultaneous increase of peening duration and shot diameter causes a pronounced rise in surface roughness, whereas increasing only one parameter at a high level results in relatively limited roughness variation. From a microstructural perspective, shot peening is known to refine the surface grains down to the nanometer scale and to thicken the plastically deformed layer with increasing coverage. For instance, increasing coverage from 100% to 1000% was reported to increase the deformation layer thickness from approximately 7 μm to 17 μm (Qin et al., 2022). Interestingly, the same study indicated that under lower coverage levels (100–

300%), surface roughness may decrease compared to untreated specimens, highlighting the complex and non-linear nature of SP surface responses (Qin et al., 2022).

From an energy-based viewpoint, the effects of shot velocity, density, and diameter on CRS and surface roughness have been attributed to the increase in the total kinetic energy of the impacting shots. Higher kinetic energy levels generally produce higher compressive stresses but also lead to rougher surface morphologies (Cao, 2023). Consistent with this trend, Ravnikar (2023) reported that more intense shot peening conditions significantly increase surface roughness, with Ra rising up to 15.3 times at a working pressure of 8 bar.

In addition to pressure and shot characteristics, the impingement angle has also been identified as an influential parameter. Moradi (2022) showed that the shot impinging angle substantially affects residual stress, wear resistance, and surface hardness, contributing up to 59%, 64%, and 67%, respectively. These findings collectively indicate that SP surface integrity is governed by a complex interaction of impact energy components and process kinematics.

Despite the literature, the relative sensitivity of surface roughness to pressure and impingement angle, particularly for high-strength aluminum alloys such as AA7075-T6, remains insufficiently clarified. Therefore, a systematic experimental evaluation focusing on these parameters is still required. Dependent to this gap in the literature, this study systematically focus on the effect of various process parameters on surface roughness of AA7075-T6 aluminum alloy.

Materials

In this study, AA7075-T6 aluminium alloy was chosen as the material due to its high strength-to-weight ratio and chemical and mechanical properties, as shown in Table 1.

Table 2 Chemical Composition and Mechanical Properties of AA7075-T6 Base Material (Lofti et al.,2014)

Chemical Compositions (wt pct)								**Mechanical Properties**			
Cu	**Mg**	**Cr**	**Zn**	**Mn**	**Si**	**Fe**	**Al**	**Ultimate Tensile Strength (MPa)**	**Yield Strength (MPa)**	**Elongation (pct)**	**Microhardness (HV)**
1,7	2,43	0,2	5,64	0,08	0,04	0,11	balance	520	445	12	1,75

The strength of the AA7075 alloy can be improved using various heat treatments. One of the most important ways to improve the mechanical properties of this alloy is to apply a T6 heat treatment, which involves both solid solution heat treatment and artificial ageing (Tekeli et al., 2019). The

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

optimal heat treatment for the 7075 alloy is the T6 temper. This process involves heating the alloy to 480 °C for one hour, then quickly cooling it in water, and finally hardening it at 121 °C for 24 hours. The 7075-T6 is the strongest and most commonly used type of this alloy(Clark Jr. et al., 2005).

Methods

Before the shot peening procedure was carried out, the experimental design was developed using a methodical approach. Eight (1-8) distinct experimental conditions were obtained by dividing the four main groups (A,B,C,D) into two subgroups within the study's parameters. Clearly illustrating the relative effects of the parameters on surface roughness was the goal when designing the experiments.

The nozzle stand-off distance (340 mm ± 15 mm) and shot flow rate (7 kg/min ± 5%) were maintained constant throughout all experiments to guarantee experimental consistency during shot peening procedures. This was done to make sure that the chosen process parameters were directly responsible for any surface roughness changes that were noticed. The levels of the study's experimental parameters are listed below:

- **Pressure:** 1 bar, 1.5 bar
- **Impingement angle:** 45°, 60°, 75°, 90°
- **Shot size:** S70 (0.20 mm), S230 (0.60 mm)
- **Velocity:** 600, 800, 1000, 1200 mm/min

Although the shot size and velocity data remained consistent within each group, Table 2 given that the velocity and shot size varied across the sub-experimental set tests.

Table 3 Experimental Set Parameters

Group	Number of Experiment	Pressure (bar)	Angle (°)	Shot Size	Velocity (mm/min)
A	1	1	45	S70	600
	2	1,5	60	S70	600
B	3	1	75	S70	1000
	4	1,5	90	S70	1000
C	5	1	60	S230	800
	6	1,5	45	S230	800
D	7	1	90	S230	1200

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

	8	1,5	75	S230	1200

The samples' surface roughness was measured using the Mitutoyo Surftest SJ-301 linear profilometer after shot peening. Each sample was measured three times, and the results were evaluated using the arithmetic mean of the measurements. Untreated samples were also put through the same measurement procedure and used as a reference data set in order to improve measurement reliability and clearly illustrate the impact of the process.

In order to quantitatively and comparably assess the impact of shot peening process parameters on the surface roughness of the AA7075-T6 alloy, it's analysed the experimental data within this methodological framework.

Results

The surface roughness values obtained following shot peening applications are listed in Table 3. The table shows that the Ra and Rz parameters significantly increased under all process conditions when compared to the reference surface (untreated). Experiments with higher pressure and larger shot sizes showed the highest roughness values. These findings suggest that the surface morphology was considerably changed by the increase in impact energy.

Table 4 Experimental Surface Roughness Results

Group	**Number of Experiment**	**Velocity (mm/min)**	**Shot Size**	**Pressure (bar)**	**Angle (°)**	**Ra**	**Rz**
A	1	600	S70	1	45	2,06	12,91
	2			1,5	60	2,65	14,71
B	3	1000	S70	1	75	1,81	11,11
	4			1,5	90	2,08	12,15
C	5	800	S230	1	60	3,83	20,66
	6			1,5	45	5,63	28,48
D	7	1200	S230	1	90	3,5	20,74
	8			1,5	75	6,08	29,82
UNTREATED						***0,27***	***2,58***

According to experimental results, surface roughness considerably increased in comparison to the reference sample under all shot peening conditions studied. Ra was 0.27 µm and Rz was 2.58 µm for

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the untreated sample. The shot-peened samples, on the other hand, had Ra values between 1.81 and 6.08 µm and Rz values between 11.11 and 29.82 µm. These results suggest that the surface finish has significantly degraded.

As in the literature review, the roughness parameters Ra and Rz for the untreated 7075 aluminium alloy sample were measured at 0.47 µm and 4.60 µm, respectively (Zou et al., 2024). This represents an approximate tenfold increase, and the results are consistent with those of this study.

The highest roughness values were observed in combinations of high pressure and large shot diameter. Particularly in groups using S230 shot, deeper crater formation and surrounding material accumulation occurred due to the decrease in impact energy. The higher rate of growth of the Rz parameter compared to Ra indicates a significant increase in the peak-to-valley amplitude on the surface. SEM images were taken to more clearly observe the marks left by the dimples on the surface. Figure 1 below shows two shots taken at 250× magnification in topographic mode using an SEM microscope.

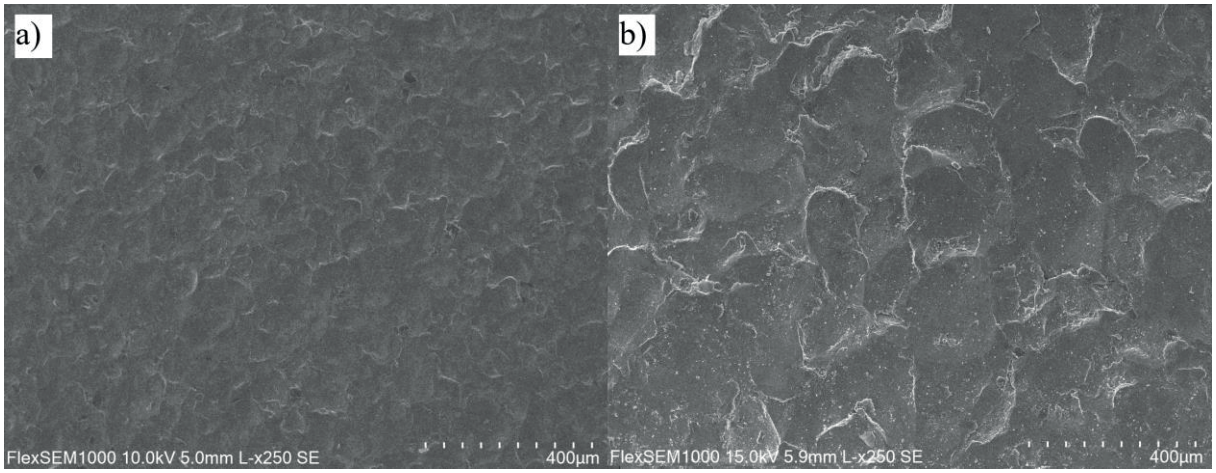


Figure 2. SEM: a) Experiment 3 (S70), b) Experiment 8 (S230).

Discussion

The findings obtained in this study clearly demonstrate that the effects of shot peening process parameters on surface roughness are directly related to impact energy components. Significant increases in Ra and Rz values were observed in all experimental conditions examined compared to the reference sample, which was attributed to impact-induced crater formation and surrounding material accumulation on the surface. In particular, the higher sensitivity of the Rz parameter indicates that the peak-to-valley amplitude on the surface responds strongly to impact intensity.

Comparisons within the group revealed that pressure is the most dominant parameter controlling surface roughness. Increasing the pressure from 1 bar to 1.5 bar consistently raised both Ra and Rz values in all experimental groups. Increased pressure raises the kinetic energy of the shots hitting the surface, leading to deeper crater formation and more pronounced plastic deformation. The

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ISBN: 978-9952-610-30-7

confirmation of this effect, particularly through significant increases in the Rz parameter, demonstrates that the increase in impact energy has strongly altered the surface topography.

It has been determined that shot size also plays an important role in intergroup evaluation. The use of larger shot sizes created wider and deeper craters on the surface due to higher momentum transfer, thereby significantly increasing roughness values. Compared to smaller diameters, the larger shot increased both the contact area and the deformation zone, which contributed particularly to the increase in peak-to-valley amplitude. This demonstrates that impact energy is strongly dependent not only on pressure but also on shot size.

In contrast, it was observed that the effect of speed on surface roughness remained limited within the examined parameter range. The fact that velocity variation within the same shot size did not create a significant upward trend in Ra and Rz may be related to the effective impact density per unit area. The relatively small decrease in coverage density at higher feed rates may have suppressed the increase in roughness. This finding indicates that the speed parameter should be evaluated in conjunction with other impact energy components rather than as a single determining factor.

The effect of the impact angle was found to be secondary compared to pressure within the examined range. Even if the angle decreases, the increase in pressure continues to raise roughness, indicating that the surface topography is more sensitive to impact energy than to the impact angle. However, it is considered that the change in angle may affect the crater geometry and the directionality of the surface morphology. In particular, an increase in the shear component at lower impingement angles may create asymmetric deformation traces on the surface; however, in the present study, this effect was not found to be dominant in terms of roughness magnitude.

Overall, it is understood that parameter interactions are critical in controlling surface roughness. While pressure is the primary determinant, shot size has emerged as the second important factor enhancing the effectiveness of impact energy. Velocity and impact angle, on the other hand, showed a secondary effect within the examined range. These findings are consistent with impact energy-based surface morphology changes reported in the literature (Li et al.,2023) and highlight the need for a balanced and integrated evaluation of parameters in process optimization.

Conclusion

This study experimentally examined the parameters of the shot peening process on surface roughness of AA7075-T6 alloy. It was found that impact-induced crater formation and plastic deformation caused surface roughness to increase significantly under all shot peening conditions.

Pressure was the most important factor influencing surface roughness, followed by shot size, which was the second most effective parameter when the relative effects of the parameters were assessed. Additionally, it was noted that, in comparison to Ra, the Rz parameter reacted to increasing impact energy more sensitively.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

As a result, it became clear that pressure and shot size must be combined to optimize surface and mechanical quality in engineering applications.

References

Bagherifard, S., Ghelichi, R., & Guagliano, M. (2012). Numerical and experimental analysis of surface roughness generated by shot peening. *Applied surface science*, *258*(18), 6831-6840.

Cao, Y., Niu, T., Gai, P., Chen, Y., Pang, J., & Xu, W. (2023). Numerical simulation for investigating the impact of shot peening process parameters via surface reconstruction. *The International Journal of Advanced Manufacturing Technology*, *129*(5), 2721-2734.

Clark Jr, R., Coughran, B., Traina, I., Hernandez, A., Scheck, T., Etuk, C., ... & Es-Said, O. S. (2005). On the correlation of mechanical and physical properties of 7075-T6 Al alloy. *Engineering Failure Analysis*, *12*(4), 520-526.

Jiuyue, Z. H. A. O., Jinyuan, T. A. N. G., Huaming, L. I. U., Xin, L. I., & Han, D. I. N. G. (2024). High-precision simulation and experimental verification of residual stress and surface topography of cylindrical surface shot peening. *Chinese Journal of Aeronautics*, *37*(9), 535-559.

Li, X., Gou, G., Jiang, C., & Xu, J. (2023). Simulation and Optimization of Shot Peening Process for CoCrFeNiAlx High-Entropy Alloy. *Metals*, *13*(9), 1537.

Long, Y., Jiang, W., Luo, J., Wei, J., Wang, X., Ji, N., ... & Liang, X. (2024). Effect of shot peening on surface characteristics and high-temperature corrosion behaviour of super 13Cr martensitic stainless steel. *Journal of Materials Research and Technology*, *32*, 802-816.

Lotfi, A. H., & Nourouzi, S. (2014). Effect of welding parameters on microstructure, thermal, and mechanical properties of friction-stir welded joints of AA7075-T6 aluminum alloy. *Metallurgical and Materials Transactions A*, *45*(6), 2792-2807.

Miao, H. Y., Larose, S., Perron, C., & Lévesque, M. (2010). An analytical approach to relate shot peening parameters to Almen intensity. *Surface and Coatings Technology*, *205*(7), 2055-2066. Moradi, A., Heidari, A., Amini, K., Aghadavoudi, F., & Abedinzadeh, R. (2022). Taguchi analysis of shot peening parameters for surface hardness, wear resistance, roughness, and residual stress in Ti-6Al-4V alloy. *Metallic Materials/Kovové Materiály*, *60*(4).

Ravnikar, D., Šturm, R., & Žagar, S. (2023). Effect of shot peening on the strength and corrosion properties of 6082-T651 aluminium alloy. *Materials*, *16*(14), 4976.

Sarveswara Reddy, S., Durga Rajesh, K., Maiti, A. K., & Janaki, D. V. (2024). Shot peening effects on Cr-Mo-V steel: a comprehensive study of microstructure, surface roughness, residual stress, and mechanical behavior. *Engineering Research Express*, *6*(3), 035564.

Tekeli, S., Simsek, I., Simsek, D., & Ozyurek, D. (2019). Effects of different solid solution temperatures on microstructure and mechanical properties of the AA7075 alloy after T6 heat treatment. *High Temperature Materials and Processes*, *38*(2019), 892-896.

Unal, O. (2016). Optimization of shot peening parameters by response surface methodology. *Surface and Coatings Technology*, *305*, 99-109.

Wang, C., & Kim, T. (2024). Optimization of parameters for the best shot peening effect based on surface response and neural network model. *Materials Research Express*, *11*(1), 016509.

Wu, J., Liu, H., Wei, P., Lin, Q., & Zhou, S. (2020). Effect of shot peening coverage on residual stress and surface roughness of 18CrNiMo7-6 steel. *International Journal of Mechanical Sciences*, *183*, 105785.

Zou, C., Jiang, Y., Yang, M., Guan, Q., Chen, P., & Nie, J. (2024). Effect of ultrasonic surface rolling process on the fatigue performance of the 7075 aluminum alloy. *Archives of Civil and Mechanical Engineering*, *25*(1), 10.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SYNTHESIS AND CHARACTERIZATION OF ULTRAFINE Fe_3O_4 SPIONS PREPARED BY CO-PRECIPITATION

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ABSTRACT

Superparamagnetic iron oxide nanoparticles (SPIONs, Fe_3O_4) were synthesized via a co-precipitation route and subsequently surface-modified with oleic acid to improve dispersibility and limit agglomeration. X-ray diffraction (XRD) confirmed the formation of the spinel Fe_3O_4 phase with no detectable secondary phases, and the average crystallite size was 8.02 nm. Transmission electron microscopy (TEM) showed predominantly quasi-spherical nanoparticles with an average particle size of 9.6 nm. FTIR spectra verified the presence of the iron–oxygen framework and the organic surface layer through characteristic Fe–O vibrations together with oleic-acid–related bands, indicating successful surface modification. Magnetic properties were evaluated by M–H measurements, revealing low coercivity and low remanence, consistent with superparamagnetic-like behavior at room temperature, with a saturation magnetization of M_s = 51.7 emu/g. These results demonstrate the successful preparation of ultrafine SPIONs with controlled size and magnetic properties, suitable for applications requiring stable, dispersible magnetic nanomaterials.

Keywords: Superparamagnetic, Iron oxide, Magnetic properties, Nanoparticle.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECTS OF THE ADSORBENT DOSAGE ON REMOVAL OF REACTIVE YELLOW 39 DYE VIA ADSORPTION

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ABSTRACT

This study investigates the effect of adsorbent dosage on the adsorption of Reactive Yellow 39 dye using BNAY as a polymeric adsorbent.Adsorption experiments were conducted at the previously optimized pH of 3 to ensure favorable electrostatic interactions. A calibration curve was established using UV–Vis spectrophotometry at the maximum absorbance wavelength of 402 nm. Dye solutions with an initial concentration of 250 ppm were treated with varying adsorbent amounts (10, 20, 30, 40, and 50 mg), and equilibrium was reached after 24 hours. Final dye concentrations were calculated using calibration data, and adsorption capacity (Q_e) and removal efficiency were determined.

Increasing the adsorbent dosage improved dye removal efficiency. The removal percentage rose from 10.23% at 10 mg to 95.91% at 50 mg, showing that more adsorption sites lead to greater dye removal. The adsorption capacity (q_e) increased from 25.57 mg g^{-1} at 10 mg to about 55 mg g^{-1} at 30–40 mg, then decreased to 47.96 mg g^{-1} at 50 mg. This decrease at higher dosages may be due to particle aggregation and overlapping of active sites, which reduce the effective surface area. These results suggest that although increasing the adsorbent amount improves removal efficiency, there is an optimal dosage beyond which further increases provide limited benefit.

Overall, the findings confirm that adsorbent dosage is a key parameter in adsorption systems and should be optimized to achieve high efficiency while minimizing material use in wastewater treatment.

Keywords: adsorption, Reactive Yellow 39, adsorbent dosage, dye removal, wastewater treatment

INTRODUCTION

Environmental pollution has increased significantly with the growth of industrialization. Water pollution is one of the most serious forms of environmental pollution because it affects natural ecosystems and limits the availability of clean water. Industrial wastewater is a major source of water pollution because it contains chemicals that are difficult to treat using conventional methods. For this

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reason, optimizing wastewater treatment methods has become an important environmental challenge.

Reactive dyes cause serious colour pollution in textile wastewater, as they are mainly used for dyeing cotton, which is widely used in the textile industry. [1] Reactive dyes have several negative effects on aquatic ecosystems. They can cause both short-term and long-term toxic effects on organisms, depending on dye concentration and exposure time. Reactive dyes can absorb or reflect sunlight, which reduces light penetration and obstructs the growth and activity of microorganisms in water bodies. Even at low concentrations, these dyes are highly visible and can cause unwanted coloration of water, making it visually unpleasant. They can also reduce dissolved oxygen levels and bind metal ions, leading to toxic effects on aquatic organisms. [2]

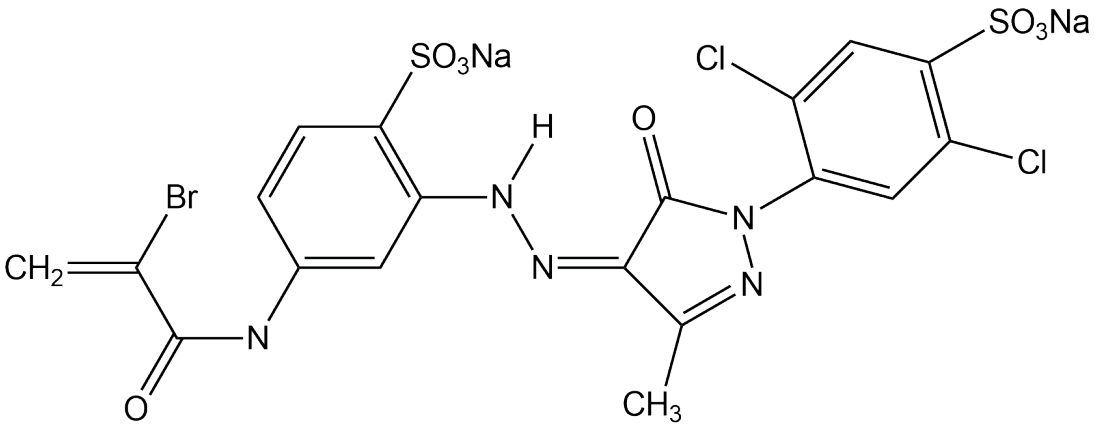
Reactive dyes are mainly used for dyeing cellulose fibers and characterised by azo bonds (–N=N–) that are responsible for their colour. Dye molecules are first absorbed onto the cellulose and then form a covalent bond with the fiber. This bond is more stable than the physical interactions formed by other types of dyes. Under alkaline conditions, the reactive groups of the dyes react with ionised hydroxyl groups on the cellulose. However, hydroxide ions in the dye bath can also react with the dyes, causing partial hydrolysis. As a result, 10–50% of the applied dye remains in the dye bath. Since most of the reactive dyes are chemically stable and poorly biodegradable, their presence in wastewater is an environmental concern. [3]

Various methods are used for dye removal from wastewater and these methods are generally classified as physical, chemical, and biological processes. Among these methods, adsorption is a process in which molecules from a liquid or gas phase attach to the surface of a solid material. The solid is called the adsorbent, while the substance being removed is known as the adsorbate. Adsorption is an equilibrium process in which the rates of adsorption and desorption are equal.

$k_{adsorption}$

Adsorbate + Surface site ⇌ Molecule adsorbed

$k_{desorption}$



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Figure 1. Molecular structure of Reactive Yellow 39 dye.

Adsorption can occur as physisorption or chemisorption. Physisorption involves weak intermolecular forces and is partially reversible, while chemisorption involves the formation of chemical bonds between the adsorbent and the adsorbate [4,5]. Adsorption is widely preferred for dye removal because of its high efficiency, simple operation, and absence of harmful by-products [6]. In addition, the possibility of adsorbent regeneration and reuse makes this method both economical and environmentally friendly.

The amount of adsorbent used in adsorption processes is a critical parameter because it directly affects treatment efficiency, cost, and the equilibrium adsorption capacity (Qe). In this study, the adsorption of Reactive Yellow 39 dye onto different amounts of a polymeric adsorbent (10, 20, 30, 40, and 50 mg) was investigated.

The adsorption capacity (Q_e) and removal percentage were calculated [7] to evaluate the effect of adsorbent amount on adsorption efficiency.

$$Adsorption\ Capacity\ (Q_e) = \frac{(C_0 - C_e)}{m} v \quad (1)$$

$$Removal\ Percentage\ = \frac{C_0 - C_e}{C_0} x100 \quad (2)$$

C_e : final concentration of dye in mg/L
C_0 : initial concentration of dye in mg/L
m: amount of polymer in g
V: volume of the solution in L

A similar study was carried out by Rao, L. N., Rohinikumar, P., & Rao, M. V. to examine the effect of adsorbent amount on the efficiency of dye removal. In this study, adsorption systems were prepared using 100 mL of dye solution and different amounts of adsorbent. Each sample was mixed at room temperature for the same contact time, and the final dye concentrations were measured using a UV–Vis spectrophotometer. The results showed that dye removal increased as the adsorbent amount increases. Removal percentage rised from about 40% to more than 90%, the dosage increased from 0.1 to 0.4 g. This increase was explained by the higher number of available adsorption sites at higher adsorbent amounts. Increasing the adsorbent dosage beyond this level caused only a slight increase in dye removal, and this value was selected as the optimum adsorbent amount. [2]

MATERIALS AND METHOD

pH=3 was determined as the optimal pH for adsorption of Reactive Yellow 39 on BNAY adsorbent. UV-Vis spectrophotometric measuerements were done and the maximum absorbence was obtained at

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ISBN: 978-9952-610-30-7

402 nm. Five solutions were prepared with different concentrations of dye in a range from 10 ppm to 50 ppm at pH=3 and adsorbance versus concentration curve was plotted as a calibration curve. This values were used in preparing the adsorption systems with different amounts of adsorbent while other conditions kept stable.

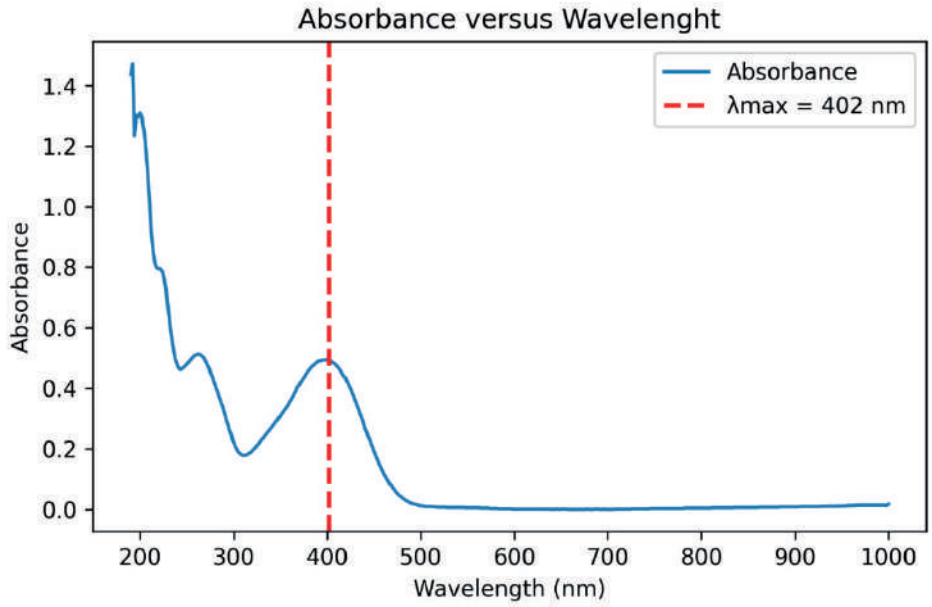


Figure 2. Absorbance values of a dye solutions with 25 ppm concentration at pH=5.

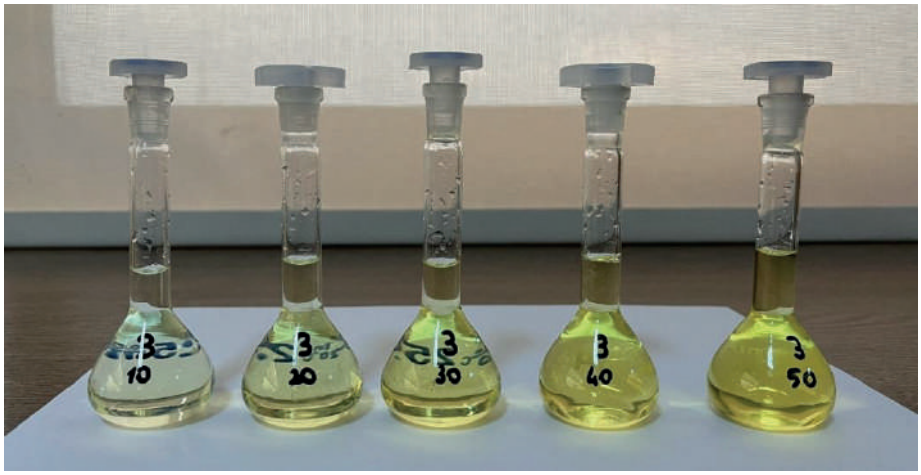


Figure 3. Calibration solutions with concentrations of 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm at pH=3.

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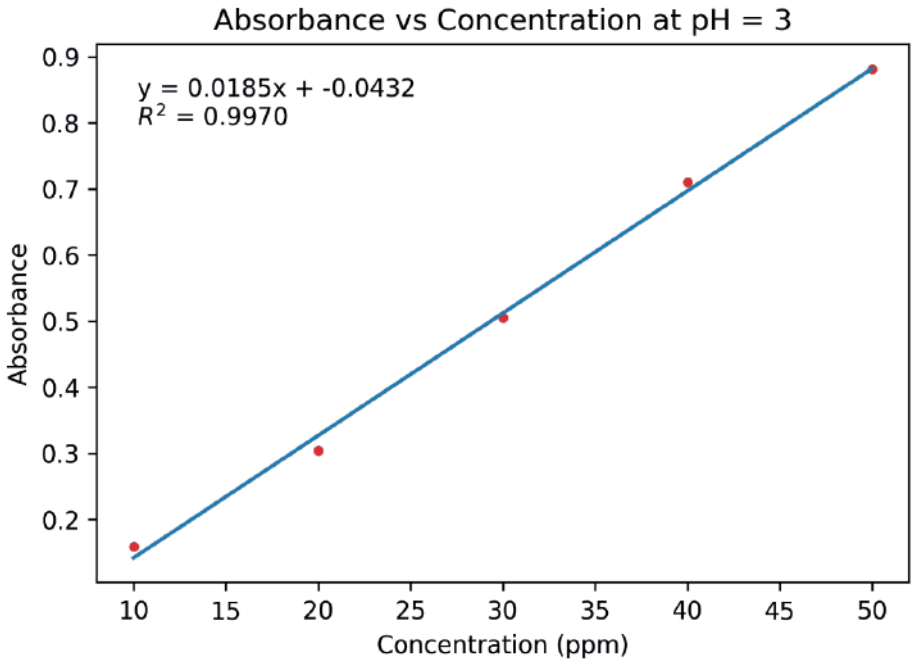


Figure 4. Calibration curve of absorbance versus concentration of Reactive Yellow 39 dye at pH=3.

10 mg, 20 mg, 30 mg, 40 mg and 50 mg polymeric adsorbent were added in dye solutions with 250 ppm concentration, the systems were allowed to reach equilibrium for 24 hours.

RESULTS

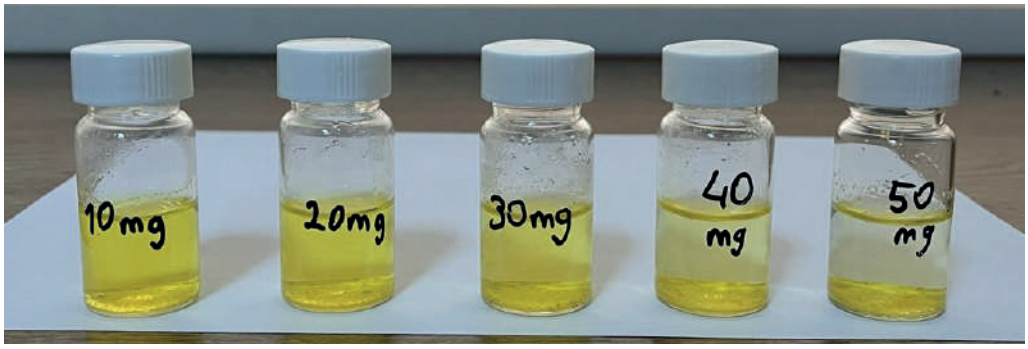


Figure 6. 24 hours after the adsorption systems reached equilibrium.

UV-Vis spectrophotomertic measurements were done for each solution. To reach more accurate results, 10 mg, 20 mg, 30 mg solutions were diluted by a factor of 10 before measuring the absorbance. Final concentrations were calculated by using the linear regression equation of the calibration curve. The adsorption capacity (Q_e) and removal percentages were plotted against the adsorbent dosage.

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Table 1. Absorbance values after 24 hours and calculated concentrations based on the calibration curves.

Amount of Adsorbent / mg	**10**	**20**	**30**	**40**	**50**
Absorbance	0.372	0.217	0.113	0.488	0.146
Dilution Factor	10	10	10	1	1
Calculated Final Concentration / ppm	224.432	140.649	84.432	28.714	10.227

Table 2. Calculated adsorption capacity and removal percentage at each dosage of adsorbent.

Amount of Adsorbent / mg	**10**	**20**	**30**	**40**	**50**
Q_e	25.568	54.676	55.189	55.322	47.955
Removal %	10.227	43.741	66.227	88.515	95.909

DISCUSSION

The results show that the amount of adsorbent has a significant effect on the adsorption of Reactive Yellow 39. As the adsorbent dosage increased from 10 mg to 40 mg, the removal percentage increased considerably, indicating that higher adsorbent amounts improve dye removal efficiency due to the increased number of available adsorption sites. A further increase in adsorbent dosage to 50 mg resulted in a smaller improvement in removal efficiency, suggesting that the system approached an optimum adsorbent amount.

The decrease in adsorption capacity (Qe) observed at higher adsorbent dosages can be attributed to the aggregation of adsorbent particles and the overlapping of active sites, which reduce the effective surface area available for adsorption. In addition, at higher adsorbent amounts, the amount of dye available per unit mass of adsorbent decreases, leading to lower Qe values. Overall, the results indicate that adsorbent dosage is a key parameter in adsorption processes and should be optimised to achieve efficient dye removal.

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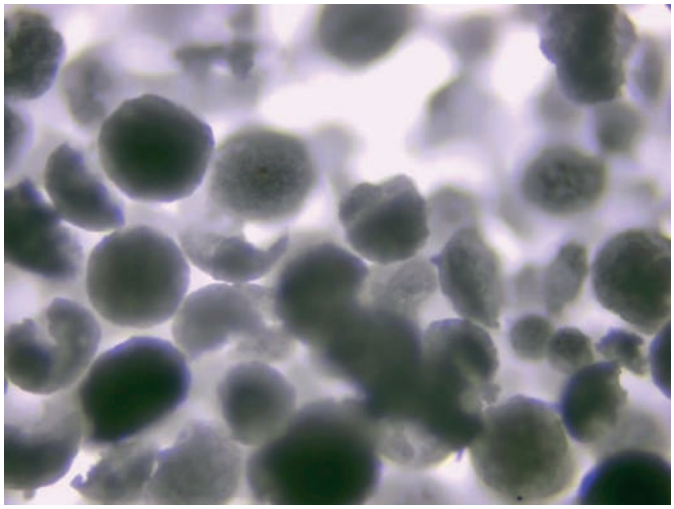


Figure 7. Polymeric adsorbent under optica B190TB mycroscope.

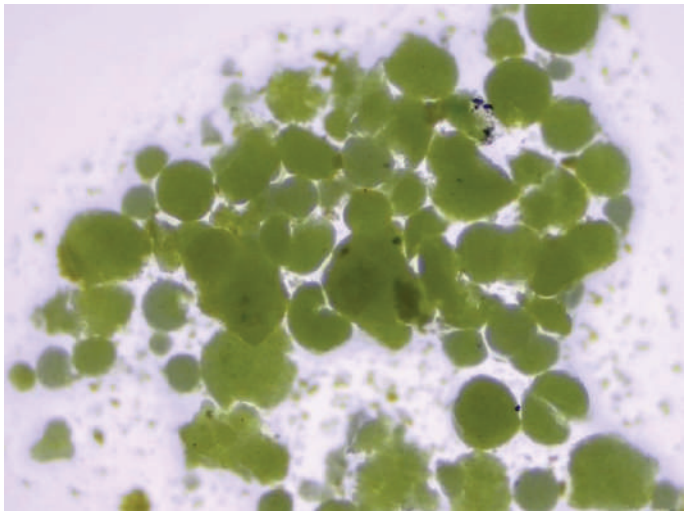


Figure 8. Polymeric adsorbent under optica B190TB mycroscope after the system which was prepared with 30 mg reaches equilibrium.

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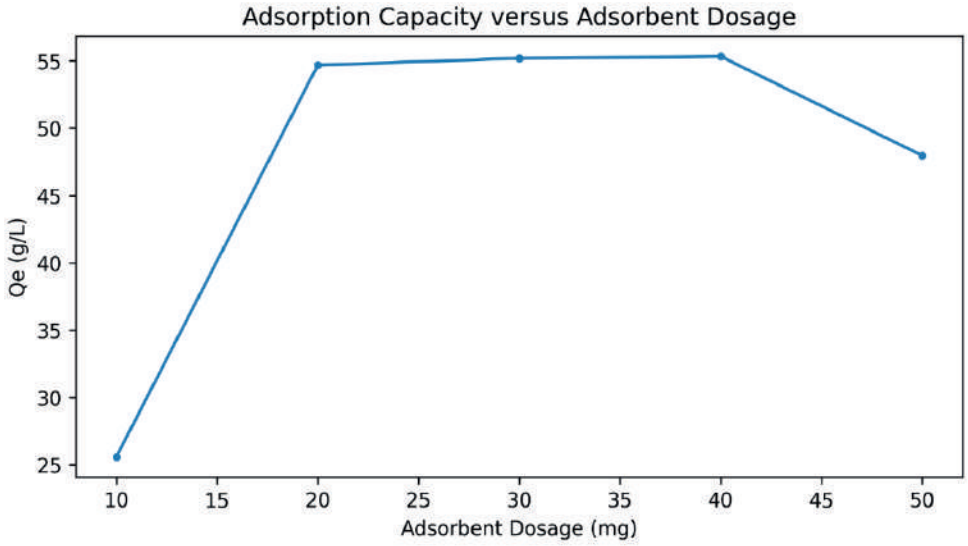


Figure 7. Adsorption capacity versus adsorbent dosage plot.

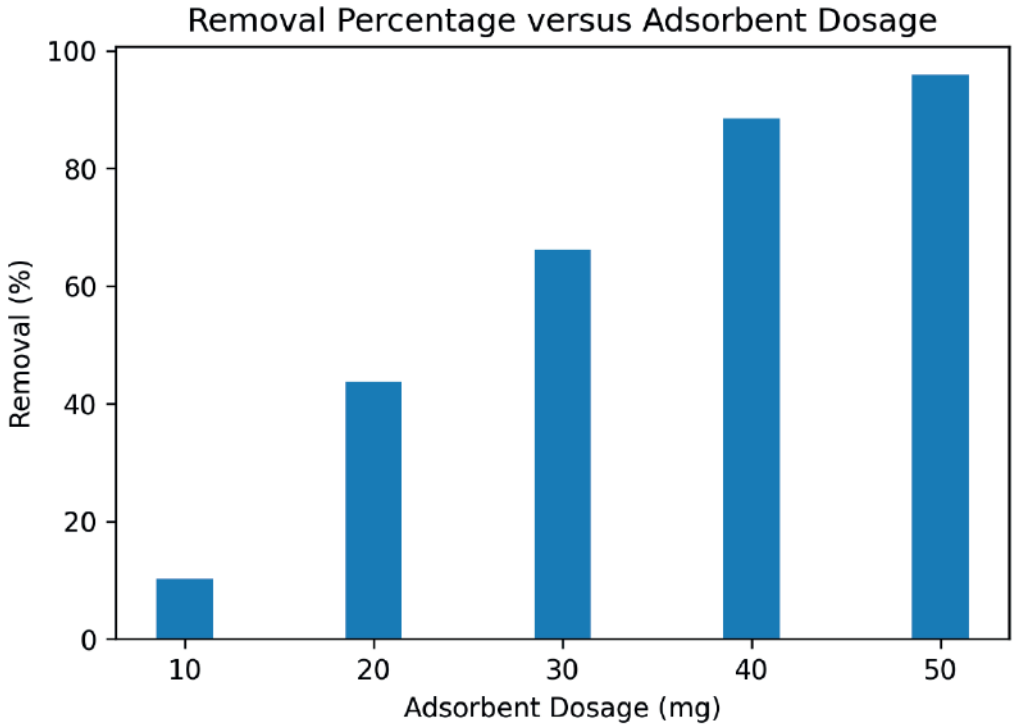


Figure 8. Removal percentage versus adsorbent dosage plot.

CONCLUSION

The results demonstrate that adsorbent dosage is a key parameter affecting the adsorption efficiency of Reactive Yellow 39. Increasing the adsorbent amount significantly increased the removal percentage due to the greater availability of active adsorption sites, and the highest removal was achieved at 50 mg. However, the decrease in adsorption capacity at higher dosages indicates the importance of

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determining an optimum adsorbent amount. Overall, optimizing adsorbent dosage is essential for achieving cost-effective dye removal in wastewater treatment applications.

REFERENCES

[1] Santhy, K., & Selvapathy, P. (2006). Removal of reactive dyes from wastewater by adsorption on coir pith activated carbon. Bioresource Technology, 97(11), 1329–1336.

[2] Rao, L. N., Rohinikumar, P., & Rao, M. V. (2015). Removal of Reactive Yellow 145 dyes from aqueous solution using adsorption technique. World Journal of Pharmaceutical Research, 4(3), 387–401.

[3] Al-Degs, Y. (2000). Effect of carbon surface chemistry on the removal of reactive dyes from textile effluent. Water Research, 34(3), 927–935. doi:10.1016/s0043-1354(99)00200-6

[4] Agarwala, R., & Mulky, L. (2023). Adsorption of dyes from wastewater: A comprehensive review. ChemBioEng Reviews, 10(3), 326–335. doi:10.1002/cben.202200011

[5] Atkins, P., & de Paula, J. (2014). Atkins' physical chemistry (10th ed.). Oxford University Press.

[6] Yagub, M. T., Sen, T. K., Afroze, S., & Ang, H. M. (2014). Dye and its removal from aqueous solution by adsorption: a review. Advances in Colloid and Interface Science, 209, 172–184. doi:10.1016/j.cis.2014.04.002

[7] Mutlu, G. K., Kara, A., Tekin, N., & Demirel, S. (2024). Synthesis and characterization of 1-vinyl-1,2,4-triazole, m-poly(EGDMA-VTA)-TiO2 polymer composite particles and the using of Reactive Orange 16 dye in adsorption and photocatalytic decolorization. Colloid and Polymer Science, 302(4), 623–642. doi:10.1007/s00396-023-05213-y

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECTS OF SOLUTION PH ON REMOVAL OF REACTIVE YELLOW 39 DYE VIA ADSORPTION

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ABSTRACT

In this study, the effect of solution pH on the adsorption of Reactive Yellow 39, an anionic azo dye, onto a polymeric adsorbent coded as BNAY, was investigated. Dye solutions with an initial concentration of 250 ppm were prepared at pH values of 3, 4, 5, 6, and 7. For each experiment, 10 mg of BNAY was contacted with 10 mL of dye solution and allowed to reach equilibrium for 24 hours at room temperature. Final dye concentrations were determined by UV-Vis spectrophotometry at 402 nm using calibration curves prepared at each pH. Adsorption capacity (Q_e) and removal percentage were calculated for each pH value. The results showed that adsorption efficiency was strongly dependent on solution pH. The highest adsorption capacity (123.41 mg/g) and removal percentage (49.36%) were achieved at pH 3, indicating that acidic conditions favour the adsorption process. This behaviour was attributed to the electrostatic interactions between the positively charged BNAY adsorbent surface and the anionic dye molecules under acidic conditions. As pH increased from 3 to 5, adsorption efficiency decreased, followed by a slight recovery at pH 6 and 7. These findings highlight the importance of pH optimization for enhancing the removal of reactive dyes from aqueous solutions.

Keywords: Polymeric adsorbent, pH, Reactive Yellow 39

INTRODUCTION

Environmental pollution is a global concern. Among all the aspects of environmental pollution, water resources have become one of the major priorities in environmental research. Water pollution results from various contaminants, including dyes. Dyes, when classified based on their chemical structure, have various types. Azo dyes which are identified by the presence of (-N=N-) bonds, are the most widely used dyes with a percentage of 65-70%[1]. The textile industry is one of the largest contributors to dye pollution and has an important role in increasing the amount of azo dyes in water bodies.

Azo dyes are considered pollutants due to different effects they have on the environment and the organisms that are exposed to them. One of the effects is reducing light transmission and limiting

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photosynthetic activities of aquatic organisms which results in ecological imbalance and increased toxicity. These dyes are absorbed by the skin and are associated with health effects such as allergic reactions, eye irritation and cancer.[2] Additionally, their presence in water bodies can cause mutagenic effects on organisms. [3] Since azo dyes are highly water soluble, their removal in wastewater requires specialized treatment methods. It becomes a priority to search for convenient removal techniques and improve those techniques to achieve highly efficient results. There are various methods of dye removal. These methods can be classified as i) physical, ii) chemical, iii) biological processes.

Theory

Adsorption is the process in which molecules from a gas or a liquid phase bind to the surface of a solid. The solid surface is referred to as the adsorbent and the substance being adsorbed is called the adsorbate. Adsorption is an equilibrium process in which the rate of adsorption equals the rate of desorption.

$$\text{Adsorbate} + \text{Surface site} \underset{k_{desorption}}{\overset{k_{adsorption}}{\rightleftharpoons}} \text{Molecule adsorbed}$$

Adsorption can be classified as two types: physisorption and chemisorption. In physisorption, only the weak intermolecular forces are involved between the adsorbate and the adsorbent. Due to these weak interactions, desorption of the adsorbate becomes easier which makes the process partially reversible. In contrast, chemisorption involves chemical bond formation between the adsorbent and the adsorbate. [4,5]

In dye removal treatment, adsorption method is commonly preferred because of its advantages such as high removal efficiency, simplicity of design, ease of operation and not producing harmful substances.[6] It can be applied to a wide range of contaminants and under different experimental conditions. Additionally, adsorbent regeneration and reuse are possible, making this method economically and environmentally advantageous.

To optimize this technique, it is essential to study different parameters affecting adsorption which some of them are pH, temperature, initial concentration of adsorbate, amount of adsorbent. The effects of solution pH on the adsorption of Reactive Yellow 39 on a polymeric adsorbent will be discussed in this work.

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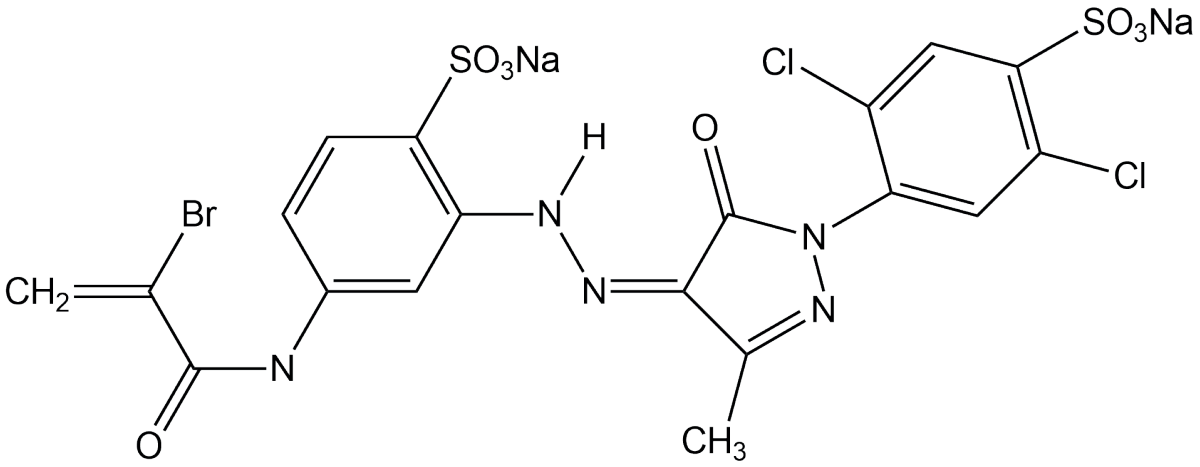


Figure 1. Molecular structure of Reactive Yellow 39 dye.

pH is one of the prior parameters which affects the capacity of adsorption. pH of the solution affects the degree of ionization of the dye and the surface properties of adsorbent. The pH at which the surface charge is zero is referred as the point of zero charge, pH_{pzc}. Theoretically, when $pH < pH_{pzc}$, surface of the adsorbent is positive and for an anionic dye, this condition makes the process more efficient.[6] Solutions with different pH values will be prepared and the efficiency of the process for each solution will be determined by calculating the removal percentage. Change in the adsorption capacity (Q_e) will be examined as pH changes while other conditions remain stable. Adsorption capacity and removal percentage will be calculated as follows[1]:

C_e: final concentration of dye in mg/L
C_0: initial concentration of dye in mg/L
m: amount of polymer in g
v: volume of the solution in L

$$Adsorption\ Capacity\ (Q_e) = \frac{(C_0 - C_e)}{m} v \quad (1)$$

$$Removal\ Percentage = \frac{C_0 - C_e}{C_0} x100 \quad (2)$$

Teli and Nadathur investigated removal of Acid Yellow 17, which is also an azo dye like Reactive Yellow 39, using the adsorption method. Their work showed that adsorption is strongly dependent on

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ISBN: 978-9952-610-30-7

solution pH. pH directly affects the strength of the electrostatic interactions between the negatively charged sulfonate groups of the dye and the positively charged adsorbent surface. In addition, adsorption of dye on unmodified silica was endothermic while adsorption on surface-modified adsorbent was exothermic. Overall, the work of Teli and Nadathur highlights the importance of studying the effects of pH and temperature on adsorption in order to optimize the removal of acid dyes from aqueous solutions. [7]

In a similar work, the effect of solution pH on dye adsorption was studied by changing the initial pH from 2 to 10 while keeping all other conditions constant. The results showed that solution pH strongly affected adsorption capacity because pH changes both the surface properties of the adsorbent and the ionisation state of the dye molecules. For some activated carbons, adsorption capacity decreased at low pH values and increased at higher pH values. In contrast, For another adsorbent, adsorption capacity increased gradually from acidic to basic conditions and reached a maximum in alkaline medium. Overall, dye adsorption was lower at acidic pH and higher at basic pH. This behaviour was explained by changes in surface charge and dye ionisation. Similar pH-dependent behaviour has also been reported in other dye adsorption studies. [8]

MATERIALS AND METHOD

The pH of the dye solutions was adjusted using 0.1 N NaOH, 0,01 N HCL and 0.1 N HCl solutions. The required pH values were obtained by careful addition of these solutions and measured using a pH meter.

Absorbance of a 25 ppm dye solution at pH=5 was taken as a reference to determine the wavelength at which the solution reaches the maximum absorbance. The results indicated that the maximum absorbance was reached at 402.0 nm with an absorbance value of 0.417 and this wavelength was used for all following UV–Vis spectrophotometric measurements (Figure 2.).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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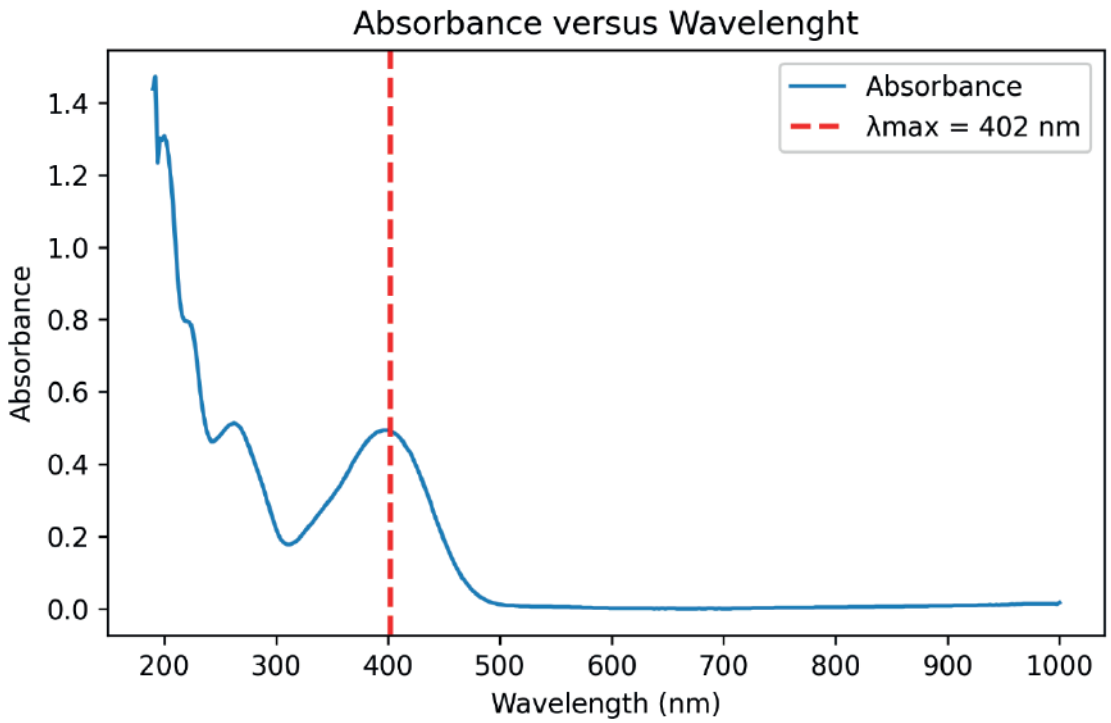


Figure 2. Absorbance values of a dye solutions with 25 ppm concentration at pH=5.

Dye solutions with an initial concentration of 250 ppm were prepared at pH values of 3, 4, 5, 6 and 7 (Figure 3.). For each experiment, 10 mg of coded as BNAY adsorbent was used for 10 mL of dye solution at each pH and the systems were allowed to reach equilibrium for 24 hours at room temperature.

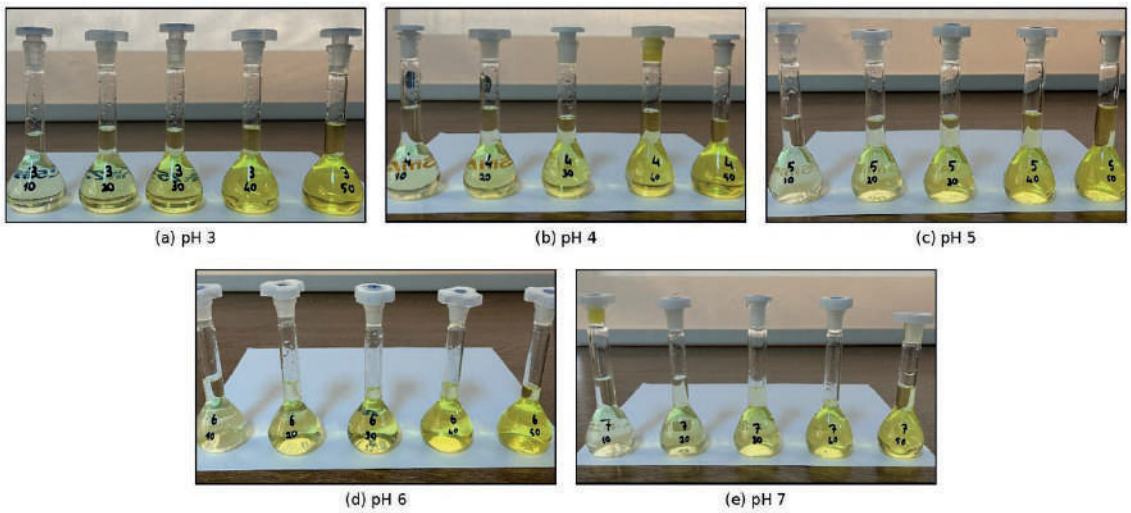


Figure 3. Photographs of calibration solutions (10–50 ppm) prepared at different pH values (pH 3–7): (a) pH 3, (b) pH 4, (c) pH 5, (d) pH 6, and (e) pH 7.

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After the equilibrium was reached, each solution was diluted by a factor of 10 prior to absorbance measurements in order to obtain more accurate and reliable absorbance values. To compare the adsorption capacities, calibration curves of absorbance versus concentration were plotted using solutions with concentrations 10 ppm, 20 ppm, 30 ppm, 40 ppm and 50 ppm at each pH. Based on these calibration curves (Figure 4.), final dye concentrations were determined from the linear regression equations using the absorbance values measured after 24 hours.

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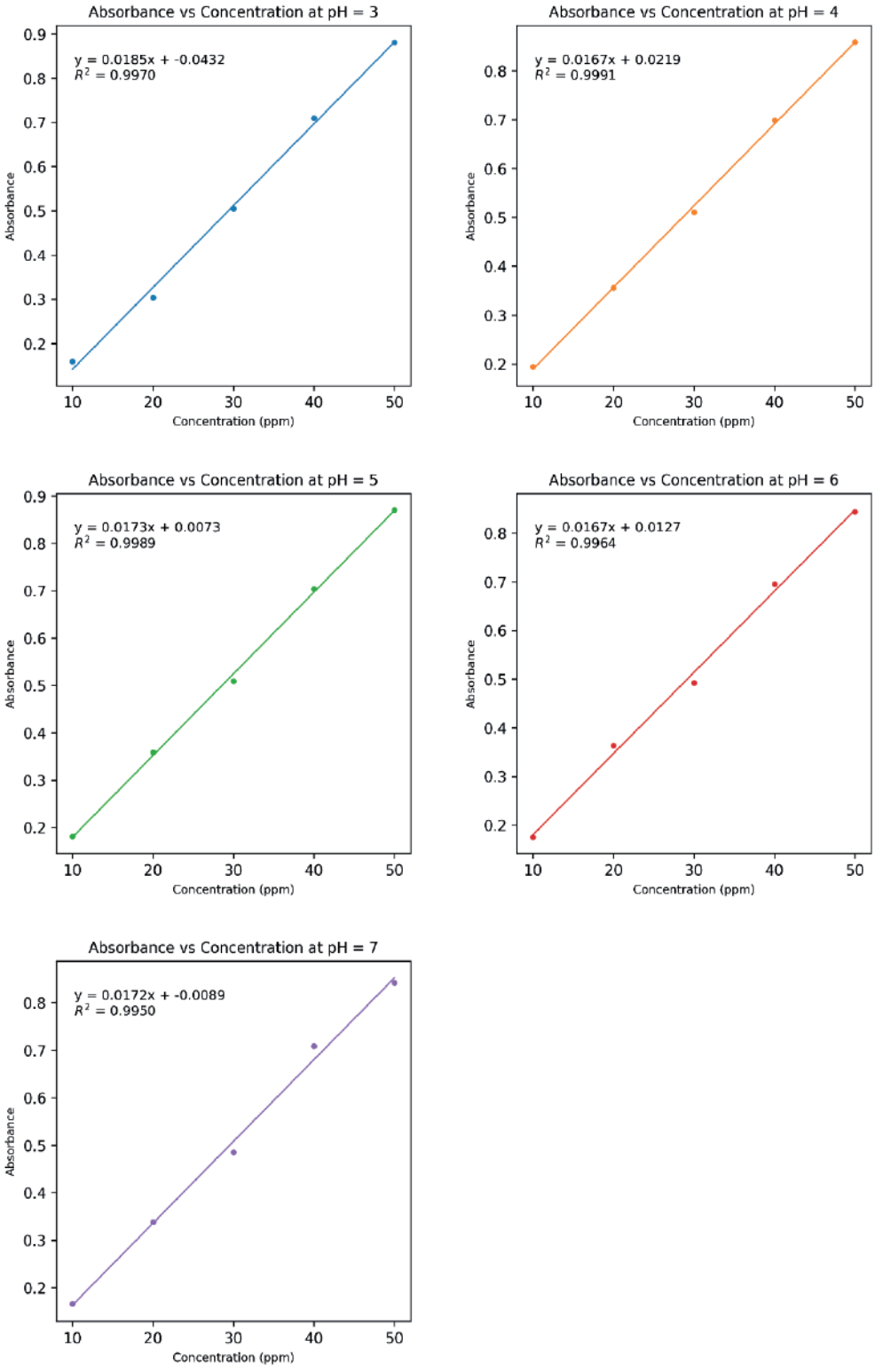


Figure 4. Calibration plots of absorbance versus concentration at different pH values.

Solution pH	3	4	5	6	7

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Absorbance	0.191	0.311	0.376	0.338	0.309
Calculated Concentration / ppm	12.66	19.93	22.16	21.00	18.48

RESULTS

Table 1. Absorbance values after 24 hours and calculated concentrations based on the calibration curves.

UV-Vis spectrophotometric measurements were taken (Table 1.) and final concentrations were calculated using calibration curves. Adsorption capacity and removal percentage were calculated(Table 2.). Results show that the adsorption of Reactive Yellow 39 dye is the most efficient at pH=3 with Q_e= 123.41 mg/g and % removal = 49.36 at room temperature.

Table 2. Calculated adsorption capacity and removal percentage at each pH.

Solution pH	**3**	**4**	**5**	**6**	**7**
Adsorption Capacity (Qe) / $mg.g^{-1}$	123.41	50.66	28.44	40.00	65.17
Removal Percentage	49.36	20.26	11.38	16.00	26.07

DISCUSSION

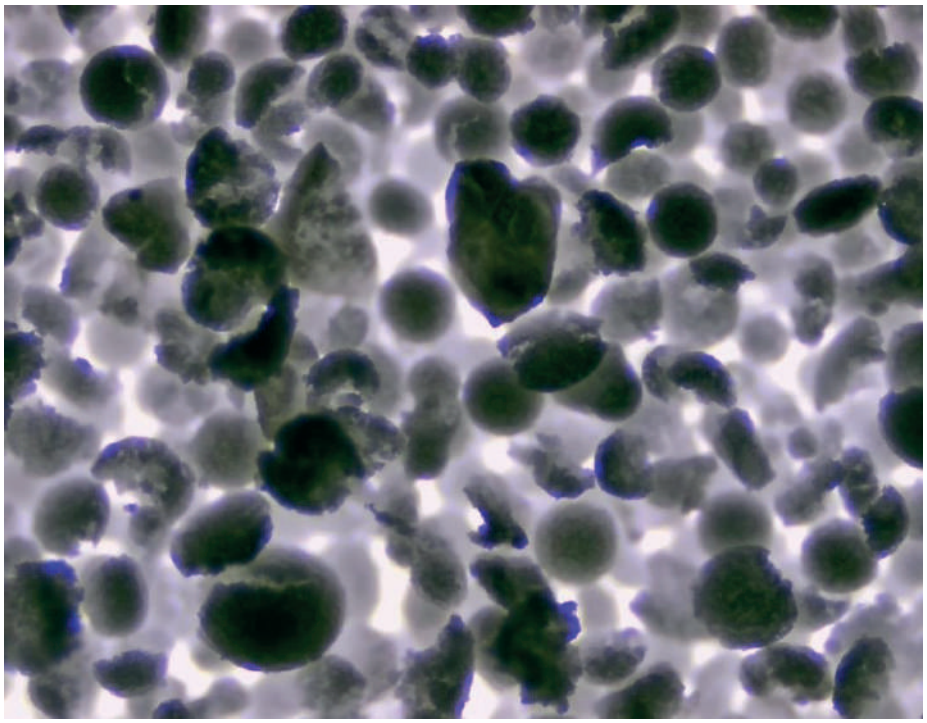
The results show that solution pH significantly affects the adsorption of Reactive Yellow 39 onto the polymeric adsorbent. The highest adsorption capacity and removal efficiency were obtained at pH 3(Figure 7 and 8.), which demonstrates that adsorption is more favourable under acidic conditions. As

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the pH increased from 3 to 5, adsorption efficiency decreased and a slight increase was observed at pH 6 and 7. This behaviour indicates that the efficiency of an adsorption process strongly depends on solution pH.

The higher adsorption efficiency at low pH values can be explained by the electrostatic interactions between the anionic dye molecules and the positively charged adsorbent surface under acidic conditions. The relatively lower removal percentages obtained in this study can be attributed to the high initial dye concentration, which is also a significant parameter affecting adsorption capacity, as the available adsorption sites are limited. Overall, the results confirm that pH is a key parameter in optimising the adsorption of Reactive Yellow 39.

Figure 5. Optical microscope image of the polymeric adsorbent after adsorption equilibrium was reached at pH 3, at 10× magnification (OPTIKA B-190TB)..



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Figure 6. Optical microscope image of the polymeric adsorbent after adsorption equilibrium was reached at pH 3, at 10× magnification (OPTIKA B-190TB).

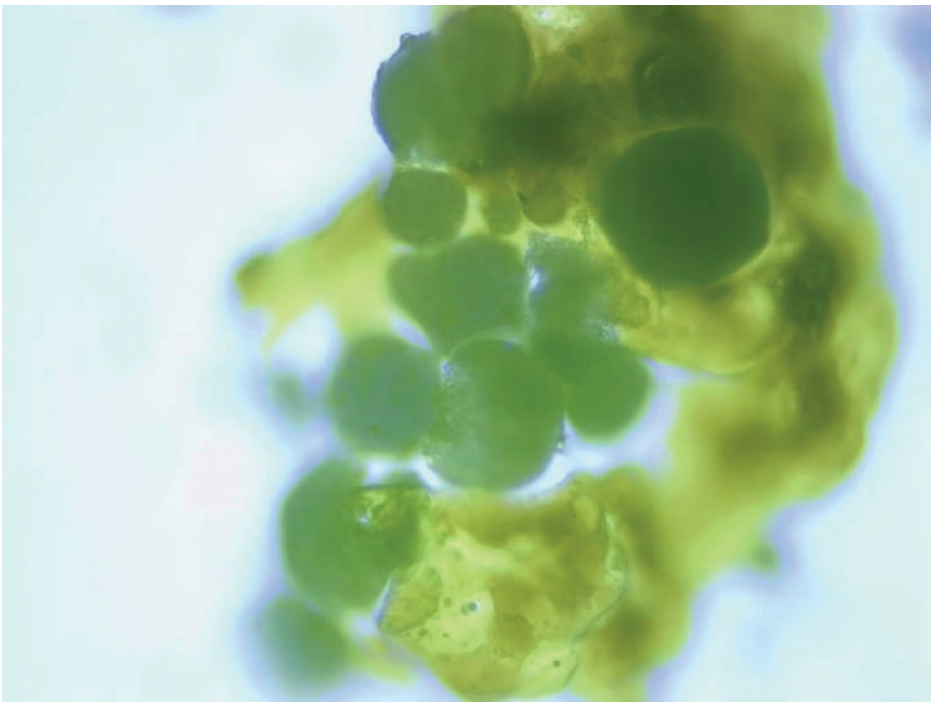
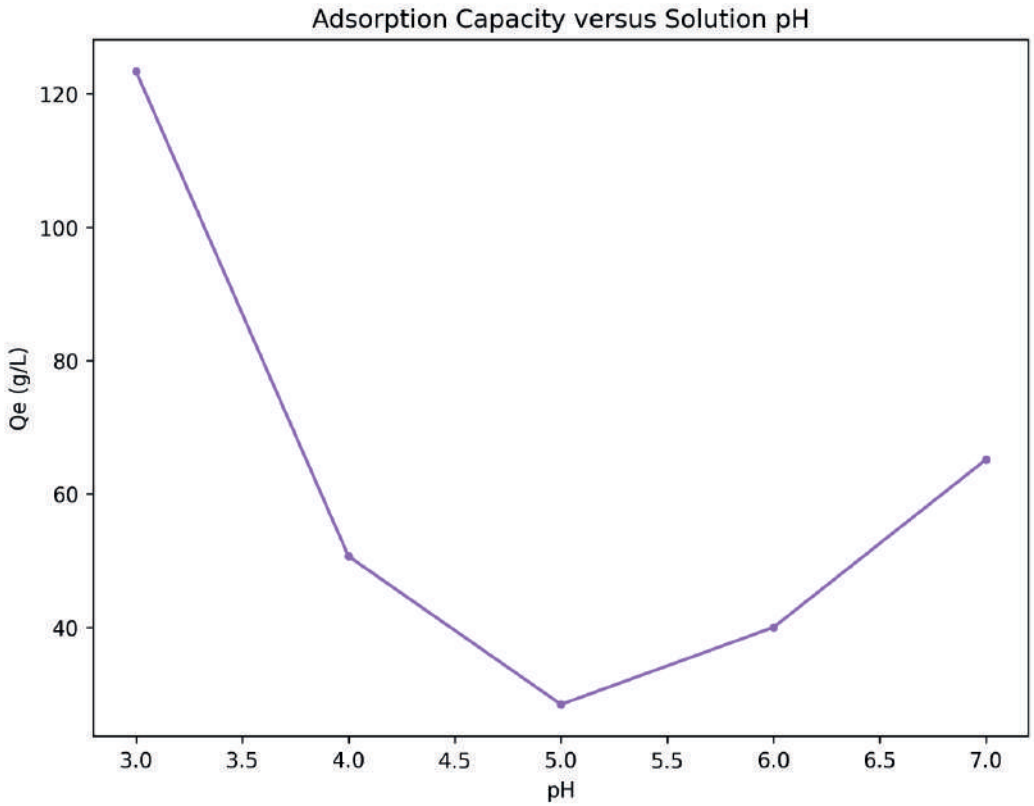
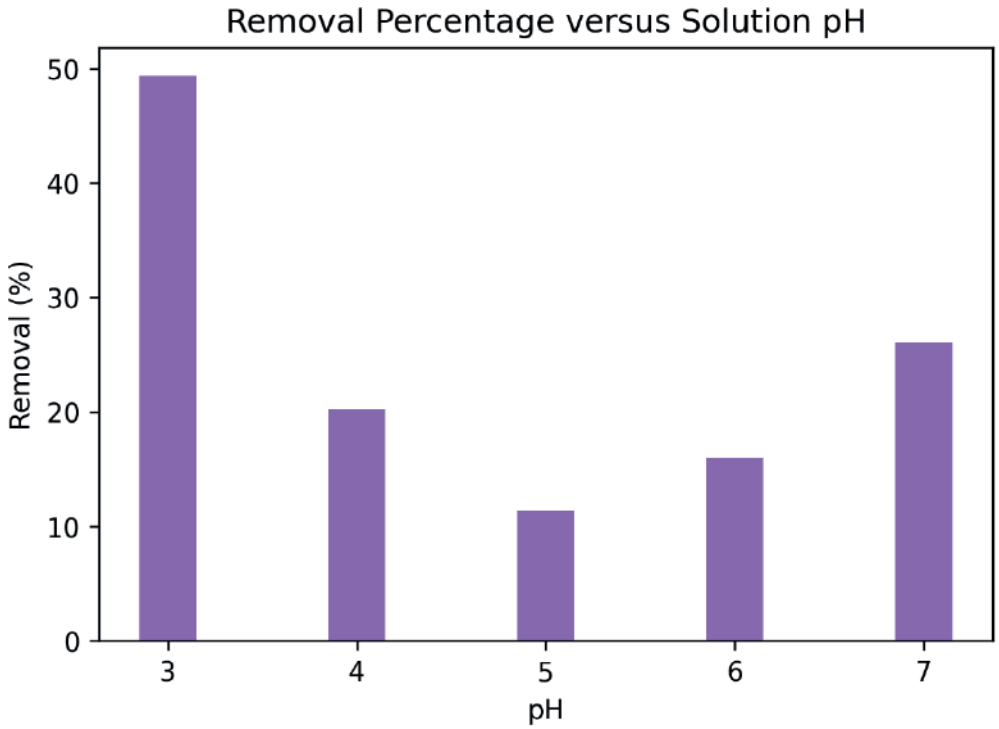


Figure 7. Adsorption capacity versus pH plot.



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Figure 8. Removal percentage versus pH plot



CONCLUSION

The results clearly demonstrate that solution pH is a crucial parameter in the adsorption of Reactive Yellow 39 onto the polymeric adsorbent. The highest adsorption capacity and removal efficiency were obtained under acidic conditions at pH=3, which highlights the strong influence of pH on electrostatic interactions. These findings show the importance of pH optimization for improving dye removal efficiency in wastewater treatment applications.

REFERENCES

[1] Gupta, V. K., & Suhas. (2009). Application of low-cost adsorbents for dye removal--a review. *Journal of Environmental Management*, *90*(8), 2313–2342. doi:10.1016/j.jenvman.2008.11.017

[2] Mutlu, G. K., Kara, A., Tekin, N., & Demirel, S. (2024). Synthesis and characterization of 1-vinyl-1,2,4-triazole, m-poly(EGDMA-VTA)-TiO2 polymer composite particles and the using of Reactive Orange 16 dye in adsorption and photocatalytic decolorization. *Colloid and Polymer Science*, *302*(4), 623–642. doi:10.1007/s00396-023-05213-y

[3] de Campos Ventura-Camargo, B., & Marin-Morales, M. A. (2013). Azo dyes: Characterization and toxicity-A review. *Textiles and Light Industrial Science and Technology*, *2*(2), 85–103. Retrieved from https://www.airitilibrary.com/Article/Detail/P20150611018-201304-201508180026-201508180026-85-103

[4] Agarwala, R., & Mulky, L. (2023). Adsorption of dyes from wastewater: A comprehensive review. *ChemBioEng Reviews*, *10*(3), 326–335. doi:10.1002/cben.202200011

[5] Atkins, P., & de Paula, J. (2014). *Atkins' physical chemistry* (10th ed.). Oxford University Press.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

[6] Yagub, M. T., Sen, T. K., Afroze, S., & Ang, H. M. (2014). Dye and its removal from aqueous solution by adsorption: a review. *Advances in Colloid and Interface Science*, *209*, 172–184. doi:10.1016/j.cis.2014.04.002

[7] Teli, M. D., & Nadathur, G. T. (2018). Adsorptive removal of acid yellow 17 (an anionic dye) from water by novel ionene chloride modified electrospun silica nanofibres. *Journal of Environmental Chemical Engineering*, *6*(6), 7257–7272. doi:10.1016/j.jece.2018.10.005

[8] Daoud, M., Benturki, O., Kecira, Z., Girods, P., & Donnot, A. (2017). Removal of reactive dye (BEZAKTIV Red S-MAX) from aqueous solution by adsorption onto activated carbons prepared from date palm rachis and jujube stones. Journal of Molecular Liquids, 243, 799–809. doi:10.1016/j.molliq.2017.08.093

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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İKLİM DEĞİŞİKLİĞİNİN ELEKTRİK DAĞITIM ŞİRKETLERİNİN ELEKTRİK KESİNTİ PERFORMANSI, YATIRIM STRATEJİLERİ VE BAKIM PLANLAMASI ÜZERİNDEKİ ETKİSİ

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ÖZET

Dünyadaki fosil yakıt kaynaklarının gün geçtikçe azalması ve iklim değişikliği, ülkeleri enerji güvenliğini sağlama konusunda çalışmalar yapmaya itmektedir. Buna bağlı olarak elektrik üretimi ve dağıtımı yapan firmaların sorumluluğu gittikçe artmaktadır. Elektrik dağıtım firmalarının hizmet kalitesi, sürekliliği ve şebeke güvenilirliği; farklı ülkelerde farklı parametreler kullanılarak ölçülmektedir. Bu göstergeler enerji üreten ve dağıtan sektör paydaşlarının şebeke yatırımlarının ve bakımlarının planlamasında da önemli bir yer tutmaktadır. Türkiye'de Enerji Piyasası Düzenleme Kurumu (EPDK) elektrik dağıtımı ve perakende satışına ilişkin hizmet kalitesi yönetmeliğinde kesinti süresi ve sıklık ölçümlerinde IEEE 1366-2022 Elektrik Enerjisi Dağıtım Güvenilirlik Endeksleri Kılavuzunda yer alan sistem ortalama kesinti süresi endeksi (OKSÜRE/SAIDI) ve sistem ortalama kesinti sıklığı endeksini (OKSIK/SAIFI) kullanmaktadır.

Özellikle küresel ısınmayla birlikte ülkemizde ve dünyada aşırı hava olaylarının gittikçe arttığı gözlenmektedir. Amerikan Ulusal Okyanus ve Atmosfer Dairesine (NOAA) göre 2024 yılı 1850 yılından beri kaydedilen en sıcak yıl olmuştur. Meteoroloji Genel Müdürlüğü tarafından yayınlanan aynı yıla ait iklim raporuna göre Türkiye'de 1257 tane aşırı hava olayı gerçekleşmiştir. Bu olağanüstü hidro-meteorolojik afetler belirli bölgelerde ve/veya zaman aralıklarında elektrik kesintisi sıklığını ve süresini ciddi olarak etkilemektedir. Bu hava olaylarının SAIDI ve SAIFI hesaplamalarından ayrıştırılmaması ülkemizdeki elektrik dağıtım şirketlerine ait olan şebekelerin gerçek işletme karakteristiğinin belirlenmesinde önemli sapmalara neden olabilmektedir. Bu çalışmada, Türkiye'deki elektrik dağıtım şirketlerinde; aşırı hava olaylarının ve istatistiksel yöntemlerle belirlenen olağanüstü koşulların SAIDI ve SAIFI hesaplamalarından ayrıştırılmasının önemi ve sağlayacağı faydalar değerlendirilmiştir. Şebeke güvenilirliğinin artırılması amacıyla, aşırı hava olaylarını dikkate alan,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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bölgeye ve mevsime özgü yatırım stratejileri ve optimize edilmiş bakım planlama yaklaşımları geliştirilmeli sonucuna varılmıştır.

Anahtar kelimeler: SAIDI, SAIFI, Küresel ısınma, Aşırı Hava Olayları, Elektrik Dağıtım Güvenliği

The Impact of Climate Change on the Power Outage Performance, Investment Strategies, and Maintenance Planning of Electricity Distribution Companies

ABSTRACT

The gradual depletion of fossil fuel resources worldwide and climate change are compelling countries to conduct studies on ensuring energy security. Accordingly, the responsibilities of companies that generate and distribute electricity are increasing. The service quality, continuity, and grid reliability of electricity distribution companies are measured using different parameters in different countries. These indicators also hold an important place in the planning of grid investments and maintenance by sector stakeholders who produce and distribute energy. In the regulation regarding service quality for electricity distribution and retail sales by the Energy Market Regulatory Authority (EMRA) in Turkey, the System Average Interruption Duration Index (OKSURE/SAIDI) and the System Average Interruption Frequency Index (OKSIK/SAIFI), which are included in the IEEE 1366-2022 Guide for Electric Power Distribution Reliability Indices, are used for interruption duration and frequency measurements.

Particularly with global warming, an increasing number of extreme weather events have been observed both in our country and around the world. According to the National Oceanic and Atmospheric Administration (NOAA), 2024 is the hottest year on record since 1850. According to the climate report for the same year published by the General Directorate of Meteorology, 1,257 extreme weather events occurred in Turkey. These extraordinary hydro-meteorological events significantly affect the frequency and duration of power outages. Failure to exclude these weather events from SAIDI and SAIFI calculations can lead to significant deviations in determining the actual operating characteristics of the grids belonging to electricity distribution companies in Turkey. In this study, the importance and the benefits of excluding extreme weather events and statistically determined extraordinary conditions from SAIDI and SAIFI calculations for electricity distribution companies have been evaluated. It has been concluded that, to enhance grid reliability, region- and season-specific investment strategies, along with optimized maintenance planning approaches that account for extreme weather events, should be developed.

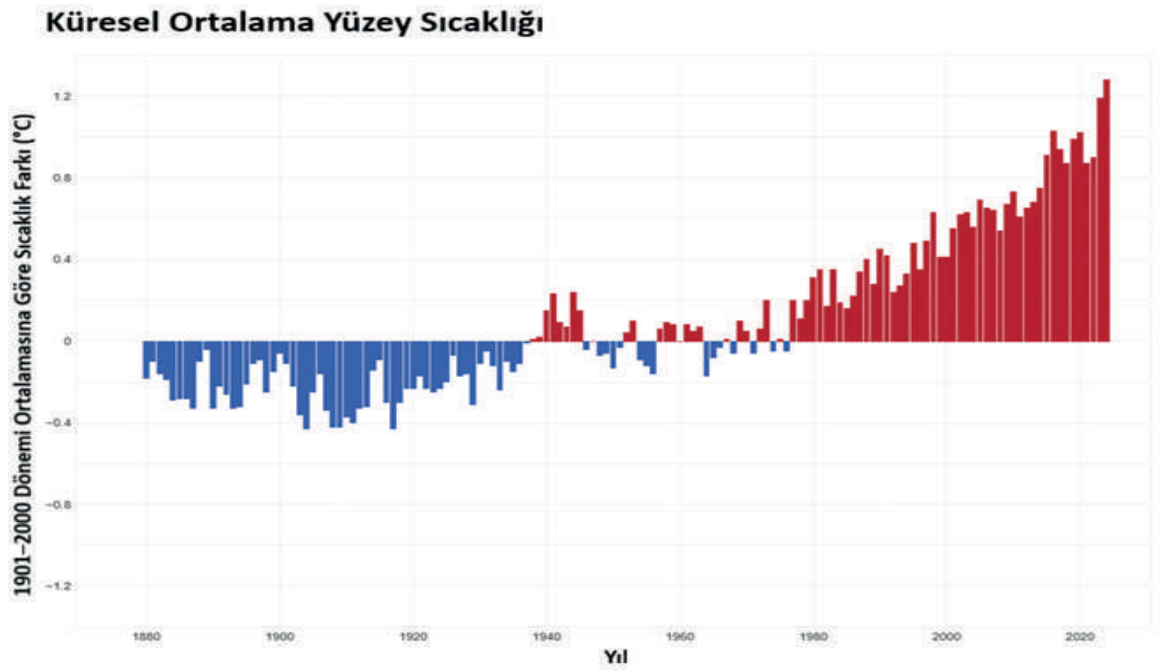
Keywords: SAIDI, SAIFI, Global Warming, Extreme Weather Event, Electricity Distribution Security

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GİRİŞ

İklim değişikliği, enerji altyapıları üzerinde giderek daha belirgin hale gelen yapısal riskler oluşturmaktadır. Küresel ölçekte gözlenen sıcaklık artışı ve aşırı hava olaylarındaki artış, elektrik dağıtım şebekelerinin işletme sürekliliğini ve güvenilirliğini doğrudan etkilemektedir. Bu durum, elektrik dağıtım hizmetlerinin planlanması ve performans değerlendirme süreçlerinde iklim kaynaklı etkilerin daha fazla dikkate alınmasını gerektirmektedir.

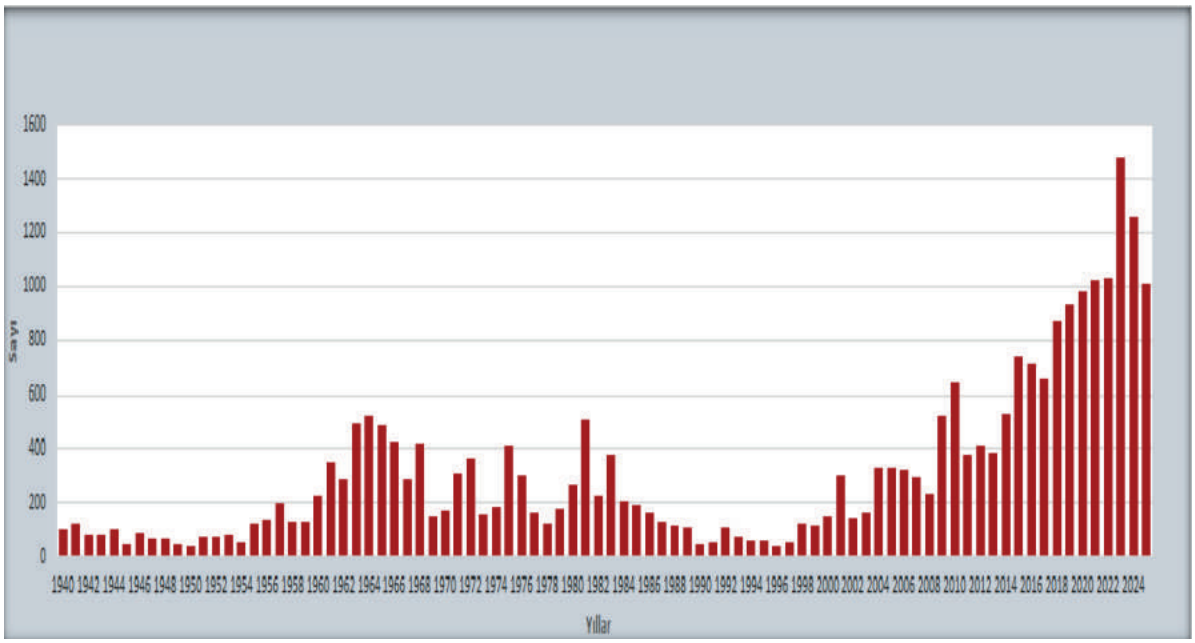
Şekil 1'de 1880 yılından günümüze kadar küresel ortalama yüzey sıcaklığı verileri gösterilmektedir. Uluslararası iklim gözlem verileri, küresel ortalama yüzey sıcaklıklarının uzun yıllar boyunca artış eğilimi gösterdiğini ortaya koymaktadır. Bu verilere bakıldığında en sıcak yılın 2024 olduğu görülmektedir. (NASA/GISS, 2026; NOAA, 2025)



Şekil 1. Küresel Ortalama Yüzey Sıcaklığı (NOAA, 2025)

Türkiye özelinde incelendiğinde, aşırı yağış, sıcak ve soğuk hava dalgaları gibi hidro-meteorolojik olayların (Çamalan, 2025) tüm dünyada olduğu gibi son yıllarda belirgin biçimde arttığı görülmektedir. Şekil 2'de Meteoroloji Genel Müdürlüğü 2025 yılı İklim Değerlendirme Raporu'ndan alınan 1940 yılından itibaren yıllık aşırı hava olaylarının sayıları gösterilmiştir. Aşırı hava olaylarının sürekli artış eğiliminde olduğu ve son 5 yılda bu sayının 1000'in üzerinde olduğu görülmektedir. (MGM, 2026)

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Şekil 2. Türkiye yıllık ekstrem olay sayıları (MGM, 2026)

Meteoroloji Genel Müdürlüğü tarafından yayımlanan iklim değerlendirme raporları, bu olayların yalnızca sayısal olarak değil, aynı zamanda daha geniş alanları etkilediğini göstermektedir. Coğrafi olarak geniş alanlara yayılmış ve büyük ölçüde açık alanlarda konumlanan elektrik dağıtım şebekeleri, bu süreçten doğrudan etkilenmektedir. Bu durum altyapı sistemleri üzerinde daha yüksek riskler oluşturmaktadır. Bu da elektrik dağıtım şebekelerinin fiziksel bütünlüğünü, işletme sürekliliğini ve güvenilirlik performansını doğrudan etkilemektedir. (Zabelin et al., 2024)

Elektrik dağıtım hizmet kalitesi, çoğu ülkede olduğu gibi Türkiye'de de Enerji Piyasası Düzenleme Kurumu (EPDK) tarafından kesinti süresi ve kesinti sıklığı göstergeleri aracılığıyla izlenmektedir. IEEE 1366-2022 standardında tanımlanmış OKSÜRE/SAIDI (Sistem Ortalama Kesinti Süresi) ve OKSIK/SAIFI (Sistem Ortalama Kesinti Sayısı) göstergeleri, elektrik dağıtım şebekelerinin güvenilirlik performansının izlenmesi ve karşılaştırılmasında uluslararası ölçekte kabul görmüş temel endekslerdir. (EPDK, 2020; IEEE, 2022)

SAIDI ve SAIFI göstergelerinin olağan işletme koşulları altında dağıtım şebekesi performansını temsil etmede etkindir. Ancak iklim değişikliğinin etkisiyle olağanüstü hava olaylarının daha sık ve etkili yaşanması, elektrik şebekesi performansının doğru biçimde değerlendirilmesini zorlaştırmaktadır. (Kukovič et al., 2015) Olağan işletme koşullarında meydana gelen kesintiler ile aşırı hava olayları kaynaklı kesintilerin ayrıştırılmadan ele alınması, dağıtım şebekelerinin gerçek performansının ortaya konulmasında belirsizliklere neden olabilmektedir. Bu çalışmada, mevcut literatürden hareketle, iklim değişikliği ve aşırı hava olaylarının elektrik dağıtım sistemlerinin güvenilirlik performans endekslerinden biri olan OKSÜRE/SAIDI göstergesi üzerindeki etkileri değerlendirilmiştir.

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MATERYAL VE YÖNTEM

Bu çalışmada 2024 yılı Nisan ayı için Aydın, Denizli ve Muğla illerinin içinde bulunduğu dağıtım bölgesine ait SAIDI hesaplamaları yapılacaktır. Türkiye'de elektrik dağıtım hizmet kalitesinin izlenmesi ve değerlendirilmesinde kullanılan OKSÜRE/SAIDI göstergesi için denklemler aşağıda verilmiştir.

OKSÜRE/SAIDI, müşteri başına düşen ortalama kesinti süresidir. Saat veya dakika cinsinden hesaplanmaktadır.

$$OKSÜRE/SAIDI = \Sigma(N_k \times T_k) / N_t \quad (1)$$ (IEEE, 2022)

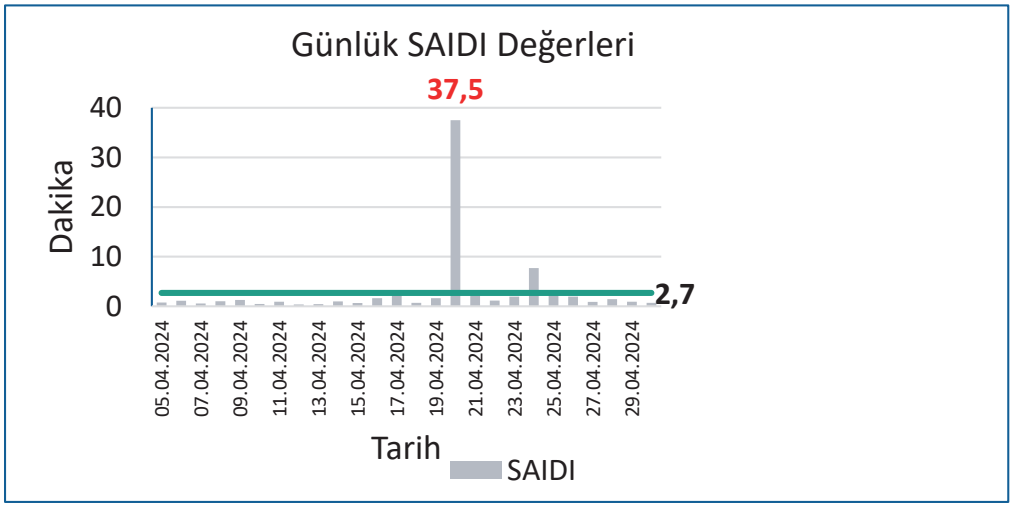
N_k = Kesintiden Etkilenen Abone Sayısı

T_k = Kesinti Süresi

N_t = Toplam Abone Sayısı

BULGULAR

Şekil-3'te Nisan 2024'te Aydın, Denizli ve Muğla illerinin içinde bulunduğu dağıtım bölgesine ait günlük SAIDI değerleri paylaşılmıştır. (Adm Elektrik, 2026) Aylık toplam OKSÜRE/SAIDI değeri yaklaşık 80 dakika, günlük ortalama OKSÜRE/SAIDI değeri ise 2,7 dakika olarak hesaplanmıştır. İlgili bölgede yaşanan aşırı hava olayları nedeniyle sadece tek bir günün OKSÜRE/SAIDI değerinin 37,5 dakikaya ulaştığı görülmektedir. Bu durum, bir aylık toplam kesinti süresinin yaklaşık yarısının sadece tek bir ekstrem günden kaynaklandığını göstermektedir. Eğer söz konusu gün, diğer olağan günler gibi normal seyretseydi; aylık OKSÜRE/SAIDI değeri 80 dakikadan 43 dakikaya, günlük ortalama OKSÜRE/SAIDI ise 2,7 dakikadan 1,4 dakikaya gerileyecekti.



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Şekil 3. Nisan 2024 OKSÜRE/SAIDI değerleri (Adm Elektrik, 2026)

SONUÇ ve TARTIŞMA

Bu çalışmada, aşırı hava olaylarının ve iklim değişikliği kaynaklı olağanüstü koşulların OKSÜRE/SAIDI göstergesi üzerindeki etkileri Nisan 2024'te Aydın, Denizli ve Muğla bölgelerini içeren dağıtım bölgesi üzerinden değerlendirilmiştir.

Elde edilen bulgular aşırı hava olaylarının SAIDI hesaplamalarından ayrıştırılması durumunda aylık ve günlük SAIDI değerlerinde %50'lik bir düşüşe neden olabileceğini göstermiştir. Bu nedenle, iklim değişikliğini ve aşırı hava olaylarını dikkate alan performans değerlendirme yaklaşımlarının geliştirilmesi; elektrik dağıtım sektöründe stratejik yatırım ve bakım planlaması, risk yönetimi, müşteri hizmetleri ve işgücü yönetimi gibi birçok alanda daha doğru ve verimli bir çalışma imkânı sağlayacaktır.

KAYNAKLAR

Adm Elektrik. (2026). Tedarik Sürekliliği Kalitesi Tabloları. https://www.admelektrik.com.tr/bilgi-merkezi/yasal-bildirimler/hizmet-kalitesi-gostergeleri/tedarik-surekliligi-kalitesi-tablolari

Çamalan, G. (2025). Fevkalade-Ekstrem Olay (FEVK) Kayıtları. *Meteoroloji Genel Müdürlüğü Araştırma Dairesi Başkanlığı*. https://www.mgm.gov.tr/FILES/genel/sunular/fevk2025.pdf

Enerji Piyasası Düzenleme Kurumu (EPDK). (2020). Elektrik Dağıtımı Ve Perakende Satışına İlişkin Hizmet Kalitesi Yönetmeliği. *29.12.2020 T.C. Resmi Gazete Sayısı: 31349, Türkiye*.

Institute of Electrical and Electronics Engineers (IEEE). (2022). IEEE Standard 1366-2022: IEEE Guide For Electric Power Distribution Reliability Indices. *IEEE Standards Association*.

Kukovič, D., Lerher, T., & Jereb, B. (2015). Natural Risks in Distribution Power System in Rs. Логистические системы в глобальной экономике, (5), 37-43.

Meteoroloji Genel Müdürlüğü (MGM). (2026). 2025 yılı Türkiye İklim Değerlendirme Raporu. *T.C. Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, Ankara*. https://www.mgm.gov.tr/FILES/iklim/yillikiklim/2025-iklim-raporu.pdf

NASA's Goddard Institute for Space Studies (NASA/GISS). (2026). Global Temperature - Earth Indicator https://science.nasa.gov/earth/explore/earth-indicators/globaltemperature/#:~:text=Since%20record%2Dkeeping%20began%20in,the%20latest%20available%2C%20updated%20annually.

National Oceanic and Atmospheric Administration (NOAA). (2025). Climate Change: Global Temperature. NOAA Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature

Zabelin, M. A., Klimenko, V. V., & Loktionov, O. A. (2024). Assessment of the operability and causes of accidents of electric grid facilities in the north of the European part of Russia. Izvestiâ Akademii nauk SSSR. Ènergetika, (3), 3-21.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

IMPLEMENTATION AND EXECUTION ISSUES OBSERVED IN CLASSICAL OTTOMAN MONUMENTAL STRUCTURES

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ABSTRACT

This study investigates the implementation issues observed in monumental structures of the Classical Ottoman Period, focusing on the technical challenges, design inconsistencies, and detailing problems encountered during that era. Within this scope, the Süleymaniye, Selimiye, and Sultanahmet mosques -the three most prominent monuments of Classical Ottoman architecture- were selected as case studies.

Research was conducted through on-site investigations, where data gathered via photographic documentation was critically analyzed based on predetermined observation parameters. The findings indicate that these structures were often constructed under time-constrained and accelerated schedules. This resulted in recurrent issues such as faulty connections at structural intersections, overlapping elements, poor workmanship, and a fragmented construction process. On the one hand, structural additions frequently result in technical defects; on the other hand, some of these elements are eventually removed, while others are adopted as permanent architectural features.

When analyzing the defects in these structures built in close succession, it is observed that improved conditions can become problematic again in later stages. This calls into question the idea of a continuous development in Classical Period architecture, suggesting instead that earlier implementations were often more refined.

Keywords: Classical Ottoman Architecture, implementation issues, design problems, technical challenges.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KARCIFANN YÖNTEMİ İLE KANSER TESPİTİ

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Özet

Kanser, dünyada ölümlere en çok sebep olan hastalıklardan biri olup sağlık açısından kritik bir sorun teşkil etmektedir. Kanserin erken evrede tespit edilmesi, tedavi sürecinin zamanında başlatılmasına olanak tanıyarak iyileşme sürecini önemli ölçüde hızlandırmaktadır. Bu bağlamda, kanser tespitine yönelik çalışmalar bilgisayar teknolojilerine olan ilgiyi artırmaktadır. Özellikle makine öğrenmesi yöntemleri, yüksek doğrulukta ve etkin tanı süreçlerinin geliştirilmesinde yaygın biçimde kullanılmaktadır.

Bu çalışmada, Wisconsin Üniversitesi tarafından hazırlanan Meme Kanseri (WDBC) veri setinin sınıflandırılması amacıyla SGD ve Karcı Kesir Dereceli Türev yaklaşımına dayanan KarcıFANN optimizasyon yöntemleri kullanılmıştır. Söz konusu optimizasyon yöntemleriyle tasarlanan modeller eğitilmiş, elde edilen performans çıktıları karşılaştırmalı olarak değerlendirilmiş ve ayrıca ağırlık sönümleme işleminin model başarımı üzerindeki etkileri analiz edilmiştir.

Elde edilen bulgular, KarcıFANN yönteminin SGD'ye benzer düzeyde performans sergilediğini; buna karşın ağırlık sönümleme işleminin modellerin başarımını anlamlı ölçüde iyileştirmediğini ortaya koymuştur. Sonuç olarak bu çalışma, KarcıFANN yönteminin hastalık tespiti ve biyomedikal sınıflandırma problemlerinde etkin biçimde kullanılabileceğini göstermesi bakımından literatüre özgün ve önemli bir katkı sunmaktadır.

Anahtar Kelimeler: Kanser, KarcıFANN, SGD, Sınıflandırma.

Cancer Diagnosis with KarcıFANN Method

Abstract

Cancer is one of the leading causes of mortality worldwide and constitutes a critical health concern. The early diagnosis of cancer enables the timely initiation of treatment, thereby substantially accelerating the recovery process. In this context, studies aimed at cancer diagnosis have significantly increased interest in computer technologies. In particular, machine learning methodologies are widely employed in the development of highly accurate and efficient diagnostic processes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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In this study, the Breast Cancer (WDBC) dataset prepared by the University of Wisconsin was classified using the SGD optimization method and the KarcıFANN optimization method based on the Karcı fractional-order derivative approach. The models designed using these optimization techniques were trained, their performance outcomes were comparatively evaluated, and the effects of weight decay on model performance were analyzed.

The findings indicate that the KarcıFANN method demonstrates a performance comparable to that of SGD; however, weight decay does not lead to a statistically significant improvement in model performance. Consequently, this study makes an original and significant contribution to the literature by demonstrating the effectiveness of the KarcıFANN approach in disease detection and biomedical classification tasks.

Keywords: Cancer, KarcıFANN, SGD, Classification.

1. Giriş

Kanser, biyolojik hücrelerin anormal bir şekilde çoğalmasıyla ortaya çıkan önemli bir sağlık problemidir. Meme, kolon, prostat ve akciğer kanserleri en sık rastlanan kanser türleri olmakla birlikte meme kanseri, kadınlarda en çok görülen kanser hastalıklarında birinci sıradadır (Meylem ve Çiçek, 2025). Kanser hastalığının vücutta ilerlemesiyle neden olacağı tahribat artışı doğru orantılıdır. Bu nedenle erken tanı, hastalığın iyileşme sürecini hızlandırarak ölüm riskini en aza indirmektedir.

Kanser görüntülerinin bilgisayar ortamında işlenmesi ve kanser tespiti yapılması amacıyla yapay zeka teknolojileri popüler olarak kullanılmaktadır. Özellikle makine öğrenmesi temelli yaklaşımlar kanser tespiti çalışmalarında başarılı sonuçlar üretmektedir.

Kullanılan optimizasyon yöntemleri, aktivasyon ve hata fonksiyonları gibi birçok hiperparametrenin değiştirilmesiyle çeşitli makine öğrenmesi yöntemleri geliştirilmektedir. Makine öğrenmesi yöntemleri kullanılarak meme kanseri tespiti amacıyla yapılan bir çalışmada, Karakurt ve İşeri (2022), Kaggle web sitesinden aldıkları meme patoloji görüntülerini sınıflandırmak amacıyla bir Evrişimsel Sinir Ağı (Convolutional Neural Network – CNN) modeli önermişlerdir. Yaptıkları deneyler sonucunda, 0.8775 doğruluk, 0.8238 F1 skoru, 0.8381 hassasiyet, ve 0.8762 hatırlama değerleri ile 0.1195 MSE ve 0.2497 MAE değerlerini elde ederek önerdikleri modelin başarısını ortaya koymuşlardır (Karakurt ve İşeri, 2022). Dandıl ve Serin (2020), meme histopatoloji görüntülerinden oluşan BreakHis veri setini sınıflandırma sürecinde DenseNet201, Inception V3, ResNet50 ve Xception derin öğrenme modellerini kullanmışlardır. Elde ettikleri bulgularda, Xception modelinin %98.01 doğruluk, %97.89 hassasiyet ve %97.47 hatırlama değerleri ile diğer yöntemlerden daha üstün performansa sahip olduğunu göstermişlerdir (Dandıl ve Serin, 2020). Meylem ve Çiçek (2025), Destek Vektör Makineleri, Rastgele Orman, Evrişimsel Sinir Ağları, Vision Transformer, Swin Transformer yöntemlerini kullanarak DDSM (Digital Database for Screening Mammography) veri setini sınıflandırmışlardır. İlgili çalışmada, Vision Transformer ve Swin Transformer hibrit mimarisinin

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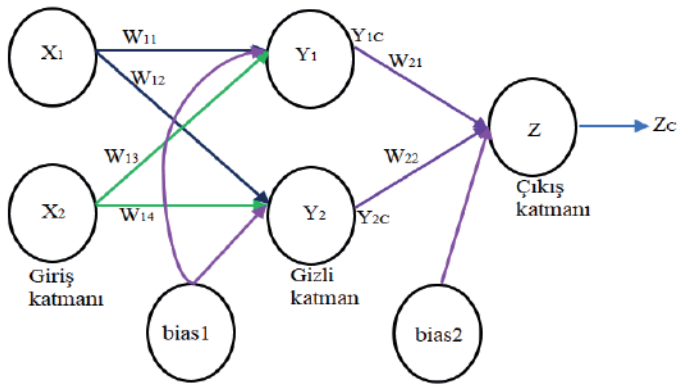
diğer yöntemlere göre daha başarılı olduğunu göstermişlerdir (Meylem ve Çiçek, 2025). Tangi ve Solmaz (2025), Kaliforniya Üniversitesi veri tabanından edindikleri meme kanseri veri setini sınıflandırmak amacıyla Naive Bayes, k – en yakın komşu (k-NN), J48 Karar Ağacı ve Destek Vektör Makineleri modellerini kullanmışlardır. Deneysel çalışmada Naive Bayes yönteminin en başarılı sonuçları ürettiğini raporlamışlardır (Tangi ve Solmaz, 2025). Uysal (2025), UCI Makine Öğrenmesi Deposundan aldığı Breast Cancer Wisconsin (Diagnostic) veri setini, Lojistik Regresyon, Rastgele Orman, Aşırı Gradyan Artırma (XGBoost), TabNet, Variational Quantum Classifier (VQC) ve Quantum Kernel Support Vector Classifier (QKSVC) modelleriyle sınıflandırmış ve bu modellerin çıktılarını yumuşak oylama (soft voting) yöntemiyle birleştirerek yeni bir hibrit model sunmuştur. Önerdiği hibrit modelin yaklaşık 0,995 ortalama AUC ve 0,98 doğruluk değerleri ürettiğini ve kuantum teknolojisinin biyomedikal verilerin sınıflandırılmasında uygulanabilirliğini göstermiştir (Uysal, 2025).

Bu çalışmada, gradyan (kısmi türev) tabanlı Stokastik Gradyan İniş (Stochastic Gradient Descent – SGD) ve Karcı Kesir Dereceli Yapay Sinir Ağı (Karcı Fractional Artificial Neural Network – KarcıFANN) optimizasyon yöntemleri kullanılarak Wisconsin Üniversitesi tarafından hazırlanan Meme Kanseri (Wisconsin Diagnostic Breast Cancer - WDBC) veri seti sınıflandırılmıştır.

2. Yöntem

Modellerin öğrenme sürecinde seçilen optimizasyon yöntemleri başarımı doğrudan etkilemektedir. Bu süreçte, modellerin ürettiği hataların kabul edilebilir bir değere düşürülmesini sağlamak amacıyla türevlenebilir yöntemler yaygın bir şekilde kullanılmaktadır. SGD, hataları en aza indirerek başarımı artırmayı hedefleyen yinelemeli ve türevlenebilir bir optimizasyon yöntemidir. Her eğitim adımında bir ya da birkaç veri örneğinin modele sunulmasıyla bu verilere ait ağırlık güncellemeleri yapılmakta ve böylece modelin öğrenmesi sağlanmaktadır.

Şekil 1 ile gösterilen 3 katmanlı bir yapay sinir ağı (YSA) modelinde $X = X_1, X_2$ giriş katmanı girdi değerleri, $Y = Y_1, Y_2$ gizli katman girdi değerleri, $W = W_{11}, W_{12}, W_{13}, W_{14}, W_{21}, W_{22}$ girdilere ait ağırlık değerleri ve Z_C modelin ürettiği çıktı değerini göstermektedir.



Şekil 1. Üç Katmanlı YSA Modeli

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Yukarıdaki modelde, W_{11} ağırlığının toplam hataya (H) etkisi, (1) denklemi ile hesaplanan Newton türevinin zincir kuralı kullanılmaktadır.

$$\frac{\partial_H}{\partial_{W_{11}}} = \frac{\partial_H}{\partial_{Z_C}} \cdot \frac{\partial_{Z_C}}{\partial_Z} \cdot \frac{\partial_Z}{\partial_{Y_{1C}}} \cdot \frac{\partial_{Y_{1C}}}{\partial_{Y_1}} \cdot \frac{\partial_{Y_1}}{\partial_{W_{11}}} \quad (1)$$

W_{11} ağırlığının herhangi bir *t+1* adımında güncellenmesi işlemi, $w_{11t+1} = w_{11t} - \alpha . \frac{\partial H}{\partial w_{11t}}$ denklemi ile ifade edilmektedir (LeCun ve diğ, 1998). Burada *α*, öğrenme katsayısını ifade etmektedir.

Karcı Kesir Dereceli Yapay Sinir Ağı (Karcı Fractional Artificial Neural Network – KarcıFANN), SGD yönteminde kullanılan öğrenme katsayısının neden olduğu problemleri çözmek amacıyla geliştirilen bir optimizasyon yöntemidir (Karakurt vd., 2022; Karakurt vd, 2024, 2025; Karakurt 2025a, 2025b; Saygılı vd., 2024, 2025a, 2025b). KarcıFANN yöntemi, Karcı (2013a, 2013b, 2015a, 2015b, 2015c, 2019, 2021) tarafından tanımlanan Karcı kesir dereceli türev matematiği ile hesaplanmaktadır. Bu sayede, ağırlık güncelleme sürecinde kesir dereceli türevler hesaplanarak modelin kendi içinde öğrenmesi sağlanmaktadır.

KarcıFANN yöntemi, (1) denkleminde gösterilen Newton türevine Karcı kesir dereceli türevi (D_α^K) tanımından gelen $\left(\frac{H}{W_{11}}\right)^{\alpha-1}$ çarpanının eklenmesiyle hesaplanmaktadır. Bu çarpan, her eğitim adımında hata ve ağırlık değerlerine göre değişmektedir (Karakurt vd., 2022; Karakurt vd, 2024, 2025; Karakurt 2025a, 2025b; Saygılı vd., 2024, 2025a, 2025b). KarcıFANN yönteminde, alfa (α) değeri, kesir derecesi olmak üzere Şekil 1'de sunulan w_{11} ağırlığının toplam hataya (H) etkisini hesaplamak amacıyla (2) denklemi kullanılmaktadır.

$$D_\alpha^K \frac{H}{W_{11}} = \left(\frac{H}{W_{11}}\right)^{\alpha-1} \cdot \frac{\partial_H}{\partial_{Z_C}} \cdot \frac{\partial_{Z_C}}{\partial_Z} \cdot \frac{\partial_Z}{\partial_{Y_{1C}}} \cdot \frac{\partial_{Y_{1C}}}{\partial_{Y_1}} \cdot \frac{\partial_{Y_1}}{\partial_{W_{11}}} \quad (2)$$

Hata değerinin hesaplanmasından sonra w_{11} ağırlığının herhangi bir $t+1$ adımında güncellenme denklemi, $w_{11t+1} = w_{11t} - D_\alpha^K \frac{H}{W_{11t}}$ şeklindedir.

Ağırlık sönümleme (weight decay) işlemi, ağırlıkların belli sınırlarda tutularak kararlı bir öğrenme sürecinin sağlanması amacıyla kullanılmaktadır (Karakurt, 2025). Ağırlık sönümleme katsayısı λ olmak üzere herhangi bir $t+1$ anında, KarcıFANN yönteminin ağırlık güncelleme bağıntısına (3) denklemindeki gibi eklenerek ağırlık sönümleme işlemi uygulanmaktadır.

$$w_{t+1} = w_t - D_\alpha^K . \left(\frac{H}{W_t} + \lambda . w_t\right) \quad (3)$$

KarcıFANN ve SGD yöntemlerinin performanslarının değerlendirilmesinde Ortalama Karesel Hata (Mean Squared Error – MSE) hata fonksiyonu ve doğruluk metrikleri kullanılmıştır. Z modelin ürettiği çıktı, R etiket bilgisi ve n örnek sayısı olmak üzere MSE değeri, $MSE = \frac{1}{n}\sum_{i=0}^{n}(R_i - Z_i)^2$ denklemi

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ile hesaplanmaktadır. Doğruluk değeri ise modelin doğru tahmin ettiği örnek sayısının tüm örnek sayısına oranı olarak tanımlanmaktadır (Christen vd., 2023).

3. Veri Seti Seçimi ve Deneysel Çalışmalar

Bu çalışmada kullanılan Meme Kanseri (Wisconsin Diagnostic Breast Cancer - WDBC) veri seti, biyopsi sonuçlarından elde edilen 30 tane hücresel özellik içermekte, iyi huylu (benign) ve kötü huylu (malign) tümör olarak iki sınıfa ayrılmaktadır (Tangi ve Solmaz, 2025). Veri setinde 357 adet iyi huylu ve 212 adet kötü huylu olmak üzere toplam 569 örnek bulunmaktadır. Veri setinin %60'ı eğitim verisi, %20'si doğrulama verisi ve %20'si test verisi olarak kullanılmıştır.

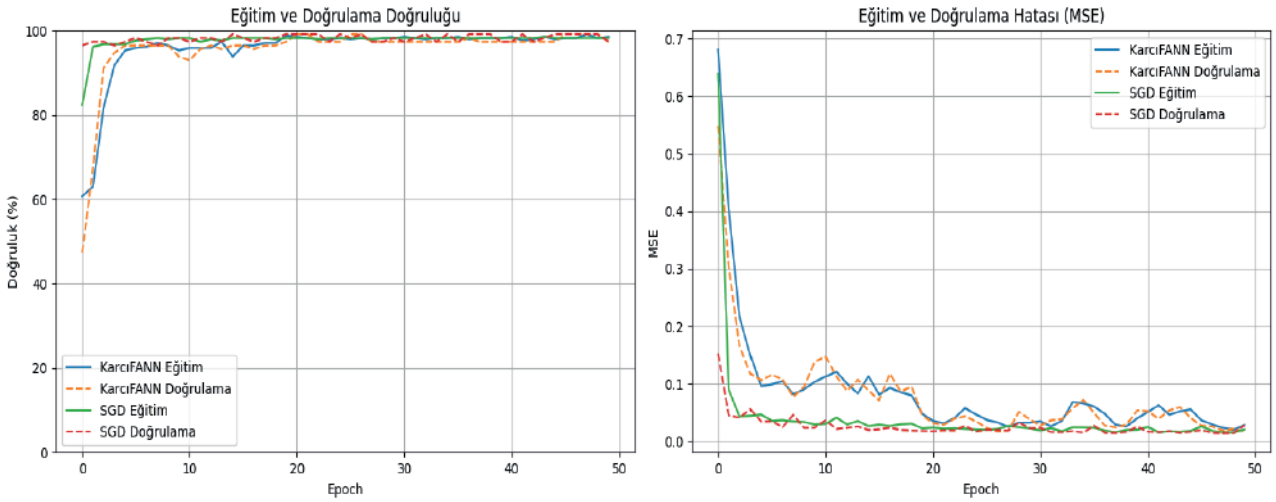
Deneysel çalışmalar Anaconda tümleşik geliştirme ortamının (IDE) Jupyter Notebook uygulamasında Python programlama dili kullanılarak gerçekleştirilmiştir. Ağırlık sönümleme işleminin uygulandığı modellerde $\lambda = 0.0005$ olarak belirlenmiştir. SGD yönteminde öğrenme katsayısı ve KarcıFANN yönteminde alfa kesir derecesine 0.85, 0.87 ve 0.9 rastgele değerleri verilerek elde edilen sonuçlar Tablo 1 ile gösterilmektedir.

Tablo 1. KarcıFANN ve SGD Yöntemlerinin Kullanılmasıyla Elde Edilen Doğruluk ve MSE Değerleri

Optimizasyon Yöntemi	**Alfa / Öğrenme Katsayısı**	**Eğitim**		**Doğrulama**		**Test**	
		Doğruluk	**MSE**	**Doğruluk**	**MSE**	**Doğruluk**	**MSE**
KarcıFANN	0.85	98.83	0.0541	97.37	0.0593	93.86	0.0732
	0.87	98.53	0.0282	97.37	0.0165	96.49	0.0325
	0.9	98.24	0.0534	99.12	0.0321	98.25	0.0492
SGD	0.85	98.24	0.0157	99.12	0.0140	98.25	0.0302
	0.87	98.24	0.0202	97.37	0.0277	95.61	0.0418
	0.9	97.95	0.0160	99.12	0.0145	98.25	0.0300
Ağırlık Sönümleme İşlemi:							
		Doğruluk	**MSE**	**Doğruluk**	**MSE**	**Doğruluk**	**MSE**
KarcıFANN	0.85	97.95	0.0719	97.37	0.0902	91.23	0.1032
	0.87	98.24	0.0335	99.12	0.0337	**97.37**	0.0536
	0.9	98.24	**0.0183**	98.25	**0.0146**	97.37	**0.0308**
SGD	0.85	**98.83**	0.0211	97.37	0.0165	97.37	0.0311
	0.87	98.24	**0.0153**	97.37	**0.0174**	**97.37**	**0.0317**
	0.9	**98.24**	**0.0159**	98.25	0.0200	97.37	0.0377

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Tablo 1 ile sonuçları gösterilen ve ağırlık sönümleme işleminin uygulanmadığı KarcıFANN ve SGD modellerinde, alfa ve öğrenme katsayısının 0.87 değeri için elde edilen doğruluk ve hata grafikleri Şekil 2 ile gösterilmektedir.



Şekil 2. KarcıFANN ve SGD Modellerinde, Alfa ve Öğrenme Katsayısının 0.87 Değeri için Elde Edilen Doğruluk ve Hata Grafikleri

4. Sonuçlar

Kanser hastalığının erken tespit edilmesi, hayati derecede önemlidir. Bu çalışmada, KarcıFANN ve SGD yöntemleri kullanılarak Wisconsin Üniversitesi tarafından hazırlanan Meme Kanseri (WDBC) veri seti sınıflandırılmıştır. Doğruluk değeri ve MSE fonksiyonu kullanılarak yapılan ölçümler sonucunda KarcıFANN yönteminin SGD yöntemiyle genel olarak benzer performansta olduğu görülmektedir.

Bu çalışma, KarcıFANN yönteminin medikal veri setlerinin sınıflandırılmasında başarılı bir şekilde kullanılabileceğini göstermektedir. İleriye yönelik çalışmalarda, farklı hiperparametrelerin kullanılmasıyla elde edilecek modellerde farklı veri setleri kullanılarak KarcıFANN yönteminin etkinliğinin artırılabileceği öngörülmektedir.

Kaynakça

Christen, P., Hand, D. J., & Kirielle, N. (2023). A review of the F-measure: its history, properties, criticism, and alternatives. ACM Computing Surveys, 56(3), 1-24.

Dandıl, E., & Serin, Z. (2020). Derin Sinir Ağları Kullanarak Histopatolojik Görüntülerde Meme Kanseri Tespiti. Avrupa Bilim ve Teknoloji Dergisi, 451-463.

Karcı, A. (2013a). "A New Approach for Fractional Order Derivative and Its Applications", Universal Journal of Engineering Sciences, Vol:1, pp: 110-117.

Karci, A. (2013b). Generalized fractional order derivatives, its properties and applications. arXiv preprint arXiv:1306.5672.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Karcı, A. (2015a). Kesir Dereceli Türevin Yeni Yaklaşımının Özellikleri. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, 30(3), 487-501.

Karcı, A. (2015b). "Properties of Fractional Order Derivatives for Groups of Relations/Functions", Universal Journal of Engineering Sciences, vol:3, pp:39-45.

Karci, A. (2015c). Chain rule for fractional order derivative. Science Innovation, Vol:3, pp:63-67.

Karcı, A. (2019). Properties of Karcı's Fractional Order Derivative. Universal Journal of Engineering Science, Vol:7, pp:32-38.

Karci, A. (2021). Fractional Order Integration: A New Perspective based on Karcı's Fractional Order Derivative. Computer Science , 6(2), 102-105.Koşan, M. A., Coşkun, A., & Karacan, H. (2019). Yapay zeka yöntemlerinde entropi. Journal of Information Systems and Management Research, 1(1), 15-22.

Karakurt, M., & İşeri, İ. (2022). Patoloji görüntülerinin derin öğrenme yöntemleri ile sınıflandırılması. Avrupa Bilim ve Teknoloji Dergisi, (33), 192-206.

Karakurt, M., Oymak, E.A., Hark, H., Erdoğan, M.C. & Karcı, A. (2022). Karcı Sinir Ağlarının Uygulaması ve Performans Analizi. Journal of Computer Science, 7(2), 68-80. DOI: 10.53070/bbd.1194017.

Karakurt, M., Saygılı, H. ve Karcı, A. (2024). Comparison of Activation Functions in the KarcıFANN Method. 8th International Artificial Intelligence and Data Processing Symposium (IDAP2024), IEEE, doi: 10.1109/IDAP64064.2024.10711149 . https://ieeexplore.ieee.org/document/10711149.

Karakurt, M., Saygılı, H. & Karcı, A. (2025). Karcı fractional artificial neural networks (KarcıFANN): a new artificial neural networks model without learning rate and its problems. Turkish Journal of Electrical Engineering and Computer Sciences, 33(3), 248-263. doi: 10.55730/1300-0632.4125.

Karakurt, M. (2025a). YSA'larda Kesir Dereceli Türev Kullanımının Öğrenmeye Etkisi. Computer Science, 10(2), 153-179. https://doi.org/10.53070/bbd.1808790

Karakurt, M. (2025b). KarcıFANN Yönteminde Ağırlık Sönümlemenin Etkisi. Computer Science, 10(2), 201-216. https://doi.org/10.53070/bbd.1809030

LeCun, Y., Bottou, L., Bengio, Y., & Haffner, P. (1998). Gradient-based learning applied to document recognition. Proceedings of the IEEE, 86(11), 2278-2324.

Meylem, H., & Cicek, G. (2025). Vision Transformer ve Swin Modelleri Kullanılarak Gelişmiş Mamografi Tabanlı Meme Kanseri Sınıflandırması DDSM Veri Seti Üzerine Bir Çalışma. Bilişim Teknolojileri Dergisi, 18(4), 319-333.

Saygılı, H., Karakurt, M. & Karcı, A. (2024). Comparison of Loss Functions in the KarcıFANN Method. In 2024 8th International Artificial Intelligence and Data Processing Symposium (IDAP), (pp. 1-5). IEEE.

Saygılı, H., Karakurt, M. & Karcı, A. (2025a). Karcı kesir dereceli yapay sinir ağı (KarcıFANN): öğrenme oranı, aşırı uyum ve yetersiz uyum sorunlarını çözme. Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi.

Saygılı, H., Karakurt, M. & Karcı, A. (2025b). KarcıFANN Yönteminin Yakınsama Kabiliyetinin Analiz Edilmesi. Fırat Üniversitesi Mühendislik Bilimleri Dergisi, 37(2), 897-907. https://doi.org/10.35234/fumbd.1661969.

Tangi, R., & Solmaz, R. (2025). Meme Kanseri Tanısında Wisconsin Veri Seti ile Makine Öğrenmesi Uygulamaları. Bilişim Teknolojileri Dergisi, 18(1), 29-43.

Uysal, İ. (2025). Açıklanabilir kuantum destekli hibrit öğrenme ile meme kanseri sınıflandırması. Gümüşhane Üniversitesi Fen Bilimleri Dergisi, 15(4), 910-927.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ESTABLISHMENT OF A NEW SETTLEMENT IN ANATOLIA AT THE EARLY 18TH CENTURY; MUŞKARA BECAME NEVŞEHİR

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ABSTRACT

As a result of urbanization caused by internal migration in our country, the population and area of metropolitan cities, as well as their problems, have grown excessively. The possibility of disaster has increased various efforts in metropolises, especially in renewal, in legal and practical terms. In order to solve increasing socio-economic problems, establishing new settlements and providing reverse internal migration to these places is an important alternative. In order to reveal the quality and quantity of this, examining old practices will be guiding. The process of Muşkara, which was a village with 18 households in the early 1700s, becoming Nevşehir with a population of 17 thousand is discussed with this understanding. The construction and development of Nevşehir was carried out by Damat İbrahim Pasha, the grand vizier of the Tulip Era. In addition to issues such as security, trade, settlement and taxes, the importance of the social complex structure becomes evident here. In the complex that regulates economic, social, cultural needs and relations; The unity and development of society takes place. In addition, the judge resided in Muşkara, no taxes were collected from the people, derbentçi was appointed here, and security was provided by repairing the castle in the center and sending soldiers. Fountains were built in the city for access to water, agricultural areas were allocated for viticulture, and tree cutting was limited. The ban on immigration to Istanbul with the sultan's decree and the efforts to settle different nomadic communities in Nevşehir aimed to increase the settlement. In Muşkara, which is an important example with its change in that period, there is a holistic approach with its incentives and rules. Today, due to the lack of identified centers in our cities, it is possible to examine and reconsider the function of the social complex here. In terms of urbanism, Muşkara is one of the remarkable places in history within the scope of the idea of establishing new settlements as a solution to dense cities.

Keywords: New Settlement, Reverse Migration, Complex, Nevşehir

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANADOLU'DA 18. YÜZYIL BAŞINDA YENİ BİR YERLEŞİM KURULMASI; MUŞKARA'NIN NEVŞEHİR OLMASI

ÖZET

Ülkemizde iç göç ile oluşan kentleşme sonucu, büyükşehirlerin nüfusu ve alanı gibi, sorunları da aşırı büyümüştür. Afet olasılığı, yenileme başta olmak üzere metropollerdeki çeşitli çabaları, yasal ve pratik anlamda çoğaltmıştır. Artan sosyo-ekonomik problemleri çözmek için ise, yeni yerleşimler kurulması ve buralara tersine iç göçün sağlanması önemli bir alternatiftir. Bunun niteliği ve niceliğini ortaya koymak konusunda, eski uygulamaları incelemek yönlendirici olacaktır. 1700'lerin başlarında 18 haneli bir köy olan Muşkara'nın, 17 bin nüfusa ulaşan Nevşehir haline gelme süreci, bu anlayışla ele alınmıştır. Nevşehir'in inşa ve imarı, Lale Devri sadrazamı olan Damat İbrahim Paşa tarafından gerçekleştirilmiştir. Güvenlik, ticaret, iskan, vergi gibi konuların yanı sıra, külliye yapısının buradaki önemi ortaya çıkmaktadır. Ekonomik, sosyal, kültürel ihtiyaçları ve ilişkileri düzenleyen külliyede; toplumun birlikteliği ve gelişimi gerçekleşmektedir. Ayrıca kadı Muşkara'da ikamet etmiş, halktan vergi alınmamış, buraya derbentçi tayin edilmiş ve merkezdeki kale onarılıp asker gönderilerek güvenlik sağlanmıştır. Suya erişim için şehirde çeşmeler yapılmış, bağcılık alanında tarım alanları tahsis edilmiş, ağaç kesilmesi sınırlandırılmıştır. Padişah fermanı ile İstanbul'a göç etmenin yasaklanması, farklı göçebe toplulukların Nevşehir'e yerleştirilmesi için çalışmaların olması ise iskanı artırmayı amaçlamıştır. O dönemdeki değişimiyle önemli bir örnek olan Muşkara'da, teşvik ve kurallarıyla bütüncül bir yaklaşım vardır. Günümüzde, şehirlerimizdeki kimlikli merkez eksikliği için, buradaki külliyenin işlevinin irdelenerek tekrar ele alınması mümkündür. Şehircilik açısından, yoğun kentlere bir çözüm olarak yeni yerleşimler kurma düşüncesi kapsamında Muşkara, tarihteki dikkate değer yerlerden birisidir.

Anahtar Kelimeler: Yeni Yerleşim, Tersine Göç, Külliye, Nevşehir

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EXPERIMENTAL INVESTIGATION OF SURFACE WETTABILITY IN GRAPHENE NANOPLATELETS-REINFORCED E-GLASS/CARBON-EPOXY HYBRID COMPOSITES

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Abstract

Surface wettability in fiber-reinforced hybrid composites is an important parameter in terms of coating compatibility, adhesion performance, and environmental interactions. In this study, the effect of adding 0.3 wt.% graphene nanoplatelets (GnP) on the surface behavior of E-glass/carbon–epoxy hybrid laminates were experimentally investigated. Plates with unidirectional $(0)_{12}$ and cross-layered $(0/90)_{3S}$ stacking patterns were produced using hand lay-up and vacuum bagging methods. Surface wettability was determined using the sessile drop method and contact angle measurements were performed using 20 µL of ASTM Type 1 pure water. According to the results, the average contact angle was determined to be 95.19° in the unmodified $(0)_{12}$ sample, indicating a hydrophobic surface character. With the addition of graphene, this value decreased to 78.90°, indicating that the surface exhibited hydrophilic behavior. Similarly, the contact angle of 88.11° in the unmodified $(0/90)_{3S}$ sample decreased to 80.81° with the addition of graphene. This decrease indicates that graphene reinforcement increases surface energy, thereby strengthening liquid–solid interaction. Furthermore, the fiber arrangement pattern was observed to affect surface homogeneity. The findings reveal that low-level graphene reinforcement induces a significant change in hybrid composites not only structurally but also in terms of surface engineering.

Keywords: Graphene nanoplatelet; Hybrid composite; Surface wettability; Contact angle

1. Introduction

Scientific and technological advances are accelerating innovation in the materials sector. Lightweight, durable, rigid, and aesthetically pleasing materials are used particularly in land, air, and sea transportation. Economic concerns highlight the importance of fuel economy in the transportation sector. While metal materials maintain their place in various sectors under all conditions, composite materials are becoming increasingly important. Composite materials, formed by the macro-level

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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combination of two or more components, provide many properties such as high strength, high rigidity, lightness, wear resistance, corrosion resistance, and surface resistance (wettability). Two components, such as fiber and matrix, give shape to the composite, and these components act as load-bearing and binding agents, respectively.

Composite materials are classified based on the structure of the fiber and matrix. Classification can be made depending on whether the fiber is continuous, discontinuous, chopped, or particle shaped. Similarly, the matrix is classified according to whether it is polymer, metal, or ceramic [1]. Continuous fiber-reinforced polymer matrix composites are used for applications where optimum strength and stiffness are required. Layered composites, especially in the specified form, are indispensable for many applications. Layered composites are formed by stacking fibers with a specific orientation angle [2]. In these applications, many polymers such as epoxy and polyester are studied with synthetic fibers such as glass, carbon, and aramid. Epoxy continues to serve as an excellent binder in joints due to its superior properties such as high chemical stability, heat resistance, and electrical insulation [3]. In recent years, hybrid structures using multiple fibers (glass/carbon, carbon/aramid, glass/basalt, etc.) have provided significant advantages in many areas.

Particles of nano or micro size are used as additives in many polymers. Many researchers have investigated the mechanical, thermal, electrical, physical, morphological, tribological, and surface properties (contact angle, etc.) of composite materials by incorporating these particles into polymer materials [4]. In these studies, many particles such as carbon nanotubes, nanoclay, graphene nanoplatelets, nanofiber, and boron nitride have been examined. Among these, graphene nanoplatelets stand out with their excellent thermal and mechanical properties, low density, and high aspect ratio [5].

In many applications, particularly in coatings, the hydrophobic or hydrophilic nature of surface properties is of great importance. There is a strong correlation between water contact angles and these surface properties. Contact angle measurements examine the interaction between a solid surface and liquid droplets [6]. Wettability, in particular, determines how fluids interact, thereby managing fluid saturation and production efficiency. Wettability is an important factor in numerous industrial sectors, such as food processing, painting, lubrication, coating, and inkjet printing. Regarding the concept of wettability, surfaces with contact angles smaller or larger than 90º are referred to as hydrophilic and hydrophobic, respectively [7].

The wettability behavior of composite and hybrid surfaces has been clearly demonstrated in the literature to be directly related to surface chemistry and morphology. In particular, it has been reported that plasma-based surface modifications significantly improve wettability. It has been demonstrated that after air plasma treatment, the contact angle of functionalized graphene-reinforced glass fiber/epoxy laminates decreased from approximately 67° to 14°, acquiring a super hydrophilic

character [8]. Similarly, DBD plasma treatments reduced the contact angle on glass fiber surfaces from 54° to 34° levels [9], while in GF/EP composites, this value decreased from 71° to approximately 37–38° and the total surface free energy increased from 48 mJ/m² to 67 mJ/m² [10]. It is emphasized that this transformation is related to the increased oxygen-containing polar functional groups on the surface and that chemical activation plays a decisive role in wettability.

Surface roughness also emerges as a critical parameter affecting wettability. Controlled sandblasting processes can reduce the contact angle to approximately 20°, whereas inappropriate mechanical treatments can increase the angle to 111°, resulting in hydrophobic behavior [11]. These results support the Wenzel model's description of the wettability-roughness relationship [11]. The addition of filler material has been reported to make the surface less wettable in most cases. It has been reported that in basalt/E-glass reinforced epoxy composites, the contact angle increased from 61.76° to 86.45° with increasing graphite content [12], while in bamboo fiber/epoxy systems containing graphite nanoparticles, it increased from 54.4° to 74.5° [13]. Parallel to this increase, a decrease in work adhesion energy has been observed, revealing that the filler ratio has a direct effect on surface energy. Environmental and chemical effects also significantly alter surface behavior. After accelerating aging, it has been reported that the contact angle in some biocomposites increased from 58.7° to 84.6°, and the surface became more hydrophobic [14]. Different behaviors were observed in impregnation processes: CuN application reduced surface energy and wettability on both wood and FRP surfaces, while CCA retention increased surface energy on wood surfaces but had the opposite effect on FRP surfaces [15]. This situation reveals that surface chemistry responds differently depending on the type of material. However, it is emphasized that peel ply modifications and nanofiber interlayers also significantly alter surface energy; morphological structure and chemical composition must be evaluated together [16,17].

In general, the literature indicates that the contact angle depends not only on surface roughness but also on chemical functional groups, filler content, processing parameters, and environmental conditions. Therefore, the sessile drop method is considered a fundamental and reliable tool for characterizing the wettability of composite surfaces [8–17].

Most existing studies have addressed wettability through individual parameters; however, research examining the interaction between hybrid fiber architecture and nano-additives has been limited. This study experimentally evaluates the effect of graphene nanoplate reinforcement on the surface behavior of hybrid glass/carbon fiber-reinforced epoxy laminates. The contact angle results obtained using the sessile drop method reveal the reflection of fiber–matrix–nano filler interaction on surface energy within a holistic framework. The findings aim to provide a data-driven perspective for engineering approaches to the controlled design of composite surfaces.

2. Materials and Methods

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

In this study, a layered composite material with a continuous fiber-reinforced polymer matrix was investigated. E-glass fiber, carbon fiber, epoxy resin, and graphene nanoplatelets were used in the material manufacturing process. The E-glass fiber and carbon fiber were sourced unidirectionally from Fibermak (Izmir) and have a weight of 300 g/m². The epoxy resin with code F1564 (1200-1400 mPa.s viscosity, 1.15 g/cm^3 density) and the hardener with code F3487 (30-70 mPa.s viscosity, 1 g/cm^3 density, 100:34 mixing ratio) were purchased from Fibermak (Izmir). The graphene nanoplatelets, with a size of 3 nm, a surface area of 800 m²/g, and a diameter of 1.5 µm, were obtained from Nanografi in Ankara. The graphene nanoplatelets were incorporated into the epoxy matrix at a single fixed concentration (0.3 wt.%).

The production of layered composites was carried out using hand lay-up and vacuum bagging methods. Composite plates were produced in two different stacking directions: unidirectional $(0°)_{12}$ and cross-laminated $(0°/90°)_{3S}$. Four plates were manufactured for each stacking direction, both with and without graphene nanoplatelets reinforcement. During the production preparation stage, graphene nanoplatelets were first incorporated into the epoxy matrix using a two-stage mixing procedure. This procedure involved the use of a magnetic stirrer (Thermomac TM12) + sonicator (Sonics Vibra Cell). Each mixer was operated for 30 minutes. Carbon and glass fibers, along with other production materials (peel ply, perforated nylon, vacuum blanket, and vacuum nylon), were cut to the desired dimensions. After each fiber layer, the epoxy + hardener system was applied with a brush. After all processes, the other layers were placed, the material was covered with vacuum nylon, and excess air was removed via the vacuum line, leaving it to cure at room temperature. The following codes were assigned to the samples obtained after production: Unmodified $(0)_{12}$, graphene-modified $(0)_{12}$, unmodified $(0/90)_{3S}$, and graphene-modified $(0/90)_{3S}$ were coded as A1, A2, B1, and B2, respectively.

Liquid contact angle measurements were performed using the sessile drop technique. For this purpose, 20 µL of fresh ASTM Type 1 pure water was dropped onto the sample surface placed on a flat surface, and the process was recorded on video using a microscope camera. The image obtained when a stable droplet was achieved was analyzed using the Drop Analysis LBADSA plugin in ImageJ software to calculate the contact angle of the droplet [18]. To ensure statistical reliability, measurements were taken from three different points on the surface of each sample.

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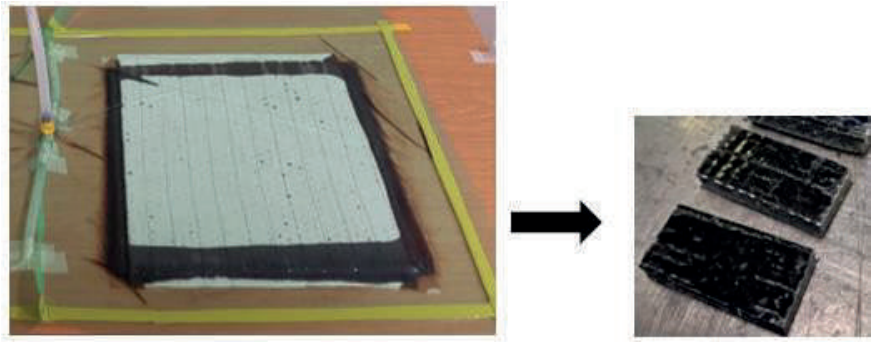


Figure 1. Manufacture of graphene-reinforced composite plates

3. Results and Discussion

The water contact angle results for graphene nanoplatelets-reinforced hybrid composite samples are presented in Table 1, while the droplet images are shown in Figure 2. The average contact angle values obtained indicate that the surface wettability behavior of the samples differs significantly.

Sample A1 exhibited hydrophobic character with an average contact angle value of 95.19°. This angle, measured above the 90° threshold value, indicates that the surface can hold water droplets in a more spherical form without spreading them. Furthermore, a low standard deviation value of 2.41% indicates that the measurements are quite stable and that the surface homogeneity is high. This suggests that the fiber–matrix–graphene interaction may have created a more balanced morphology on the surface. In sample A2, the average contact angle was measured as 78.90°, and the surface exhibited hydrophilic characteristics. A decrease of approximately 16° compared to A1 indicates an increase in surface energy and a stronger liquid–solid interaction. However, the standard deviation of 7.55% suggests that local roughness or differences in graphene distribution on the surface may be influential.

Sample B1 exhibited behavior quite close to the 90° threshold value with an average contact angle of 88.11°. This value indicates that the surface exhibits weak hydrophilic/borderline characteristics. The standard deviation of 4.54% shows that the surface properties are more balanced compared to A2. It can be said that fiber orientation and phase distribution within the hybrid structure have a limited effect on liquid spreading. In sample B2, the average contact angle was determined to be 80.81°, and hydrophilic behavior was observed. However, the standard deviation of 10.85% indicates a more heterogeneous surface structure compared to other samples. The droplet shape seen in Figure 2 (d) indicates irregularities in the contact line, which can be attributed to surface roughness and local microstructure differences.

In general, it is observed that graphene reinforcement and hybrid fiber architecture have a significant effect on surface wettability. In some configurations, the contact angle exceeds 90°, indicating a

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hydrophobic character, while in other structures, lower angles result in a dominant hydrophilic behavior. These results demonstrate that wettability depends not only on the presence of graphene but also on its distribution, fiber arrangement, and surface morphology.

Table 1. Contact angle properties of graphene-reinforced hybrid composites

Sample name	Sample no	Contact angle (degree)	Comment
A1	1	93.06	Hydrophobic
	2	97.81	
	3	94.72	
Mean		**95.19**	
Standard deviation (%)		**2.41**	
A2	1	78.19	Hydrophilic
	2	86.78	
	3	71.73	
Mean		**78.90**	
Standard deviation (%)		**7.55**	
B1	1	91.66	Hydrophilic
	2	89.68	
	3	82.99	
Mean	**88.11**		
Standard deviation (%)	**4.54**		
B2	1	87.36	Hydrophilic
	2	86.78	
	3	68.28	
Mean	**80.81**		
Standard deviation (%)	**10.85**		

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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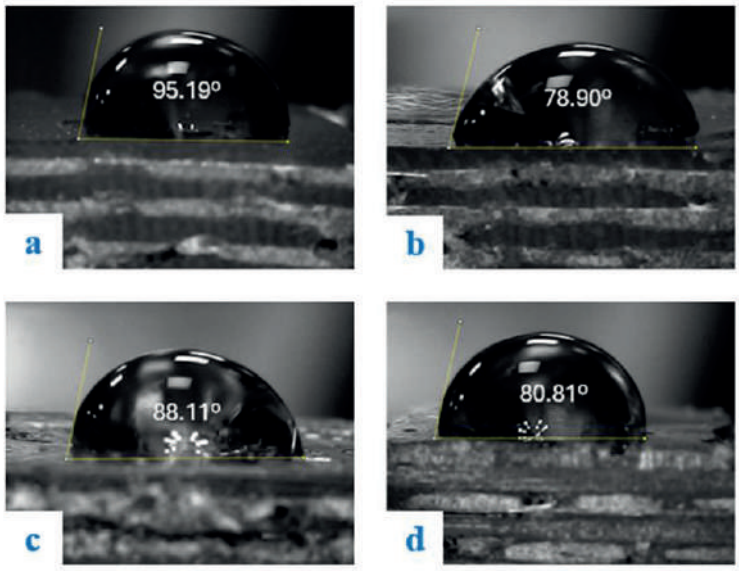


Figure 2. Contact angle measurements for samples coded A1, A2, B1, and B2

The contact angle results obtained are generally consistent with trends reported in the literature. In particular, previous studies have indicated that the addition of filler material can make the surface less wettable and increase the contact angle in some systems [12,13]. In this study, the value above 90° in sample A1 suggests that the graphene additive and hybrid architecture can reduce surface energy in a specific configuration. In contrast, the contact angle remaining below 90° in samples A2, B1, and B2 indicates that surface chemistry and morphological structure are jointly decisive. As emphasized in the literature, wettability depends not only on the type of additive but also on the distribution quality, fiber orientation, and surface roughness [11–14]. In this context, the findings reveal that the effect of graphene reinforcement is not unidirectional; different surface behaviors can emerge in hybrid composite systems depending on the structural configuration.

4. Conclusions

This study evaluated the effect of low-rate graphene nanoplatelets reinforcement on the surface wettability of hybrid E-glass/carbon-epoxy laminates. The results showed that graphene addition altered the surface behavior in both fiber arrangements, leading the system towards a more hydrophilic tendency. This indicates that the nano-reinforcement is decisive in terms of surface energy and liquid-solid interface interaction. Furthermore, the fiber arrangement was observed to affect surface homogeneity and measurement stability. These findings suggest that the relationship between morphology and surface behavior in hybrid composites should be evaluated together. It is considered that graphene reinforcement can contribute to the controlled design of surface properties in areas

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where interface performance is critical, such as adhesive joints, paint and protective coating applications, composite-metal hybrid junctions, and marine and aerospace structures.

Acknowledgements

We would like to thank the Çankırı Karatekin University Scientific Research Projects Coordination Unit for their support with project number MF080725B16.

References

[1] Sumithra, G., Reddy, R.N., Kumar, G.D., Ojha, S., Jayachandra, G., & Raghavendra, G. (2023). Review on composite classification, manufacturing, and applications. *Materials Today: Proceedings*.

[2] Khalid, S., Yazdani, M.H., Azad, M.M., Elahi, M.U., Raouf, I., & Kim, H.S. (2024). Advancements in physics-informed neural networks for laminated composites: a comprehensive review. *Mathematics, 13*(1), 17.

[3] Tang, Y., Zhang, X., Liu, X., Wei, W., & Li, X. (2024). Facile synthesis of hyperbranched epoxy resin for combined flame retarding and toughening modification of epoxy thermosets. *Chemical Engineering Journal, 482,* 148992.

[4] Mani, M., Murugaiyan, T., Shanmugam, V., & Karabulut, M. (2024). Mechanical and quasi-static puncture behavior of hybrid glass/Kevlar/carbon fiber laminate composites with graphene nanoparticles. *Mechanics of Advanced Materials and Structures, 31*(30), 13110-13120.

[5] Srivastava, A.K., Singh, A., & Verma, R.K. (2024). Production and mechanical characterization of Carbon fiber laminated composites modified by Graphene nano platelets (GnP) for high performance application. *Engineering Research Express, 6*(2), 025433.

[6] Danish, M. (2022). Contact angle studies of hydrophobic and hydrophilic surfaces. In *Handbook of magnetic hybrid nanoalloys and their nanocomposites* (pp. 1-22). Cham: Springer International Publishing.

[7] Razavifar, M., Abdi, A., Nikooee, E., Aghili, O., & Riazi, M. (2025). Quantifying the impact of surface roughness on contact angle dynamics under varying conditions. *Scientific Reports, 15*(1), 16611.

[8] Yousef, S., Subadra, S.P., Griškevičius, P., Varnagiris, S., Milčius, D., & Makarevičius, V. (2020). Superhydrophilic functionalized graphene/fiberglass/epoxy laminates with high mechanical, impact and thermal performance and treated by plasma. *Polymer Testing, 90*, 106701.

[9] Zhang, W., Yang, P., Cao, Y., Yu, P., Chen, M., & Zhou, X. (2020). Evaluation of fiber surface modification via air plasma on the interfacial behavior of glass fiber reinforced laminated veneer lumber composites. *Construction and Building Materials*, 233, 117315.

[10] Ayaz, A., Ozdemir, G.D., Ercan, U.K., & Sever, K. (2024). Influence of air DBD plasma treatment on the shear and flexural strength of adhesively bonded glass fiber reinforced epoxy composite joints. *Journal of Radiation Research and Applied Sciences*, *17*(2), 100929.

[11] Islam, M.S., Tong, L., & Falzon, P.J. (2014). Influence of metal surface preparation on its surface profile, contact angle, surface energy and adhesion with glass fibre prepreg. *International Journal of Adhesion and Adhesives*, *51*, 32-41.

[12] Atmakuri, A., Kolli, L., Palevicius, A., Urbaite, S., & Janusas, G. (2022). Influence of filler materials on wettability and mechanical properties of basalt/E-glass woven fabric–reinforced composites for microfluidics. *Micromachines, 13*(11), 1875.

[13] Pulikkalparambil, H., Saravana Kumar, M., Babu, A., Ayyappan, V., Tengsuthiwat, J., Rangappa, S.M., & Siengchin, S. (2024). Effect of graphite fillers on woven bamboo fiber-reinforced epoxy hybrid composites for semistructural applications: Fabrication and characterization. *Biomass Conversion and Biorefinery, 14*, 17761–17777.

[14] Kumar, S., & Bhowmik, S. (2025). Accelerated weathering with humidity effects on physical, surface interfacial and tribology behavior of kenaf–pineapple laminated biocomposite under different loading constraint. *Fibers and Polymers, 26*, 173–195.

[15] Taşçıoğlu, C., Goodell, B., Lopez-Anido, R., & Gardner, D. (2004). Surface energy characterization of preservative-treated wood and E-glass/phenolic composites. *Forest Products Journal, 54*(12), 262–268.

[16] Silva, B., Antunes, P., & Uribe, B. (2026). Effect of peel ply-induced surface roughness and wettability on the adhesive bonding of GFRP composites. *Journal of Manufacturing and Materials Processing, 10*(1), 20.

[17] Panduranga, R., Sharpe, M.M., & Shivakumar, K.N. (2012). Assessment of polymer nanofiber interleaving in composite laminates through simple tests. In *Proceedings of SAMPE Tech 2012 Conference and Exhibition* (pp. 1–20). Society for the Advancement of Material and Process Engineering.

[18] Stalder, A.F., Melchior, T., Müller, M., Sage, D., Blu, T. & Unser, M. (2010). Low-bond axisymmetric drop shape analysis for surface tension and contact angle measurements of sessile drops. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 364* (1–3): 72–81.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İQTİSADİYYATIN ƏSAS SAHƏLƏRİ ÜZRƏ MƏHSUL BURAXILIŞININ DİNAMİKASI VƏ STRUKTUR TƏHLİLİ (2018–2023-CÜ İLLƏR) (BALAKƏN RAYONU ÜZRƏ)

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Xülasə: *Məqalədə 2018–2023-cü illər üzrə iqtisadiyyatın əsas sahələri üzrə məhsul buraxılışının dinamikası və struktur xüsusiyyətləri təhlil edilmişdir. Aparılan təhlil göstərir ki, ümumi məhsul buraxılışında davamlı artım müşahidə olunur və bu artım əsasən istehsal və xidmət sahələrinin genişlənməsi hesabına formalaşır. Sənaye və kənd təsərrüfatı sahələri iqtisadiyyatın aparıcı istiqamətləri kimi çıxış edir. Xidmət sektorunda, xüsusilə ticarət, nəqliyyat və informasiya-rabitə sahələrində artım iqtisadi strukturun diversifikasiyasını əks etdirir. Hər nəfərə düşən məhsul buraxılışının yüksəlməsi isə sosial-iqtisadi inkişafın müsbət tendensiyalarını təsdiqləyir.*

Açar sözlər: *məhsul buraxılışı, iqtisadi sahələr, sənaye, kənd təsərrüfatı, xidmət sektoru, struktur təhlili, iqtisadi inkişaf, hər nəfərə düşən məhsul*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MƏHSUL BURAXILIŞI

İQTİSADİYYATIN ƏSAS SAHƏLƏRİ ÜZRƏ MƏHSUL BURAXILIŞI

min manatla

İllər	Əsas sahələrdə məhsul buraxılışı	O cümlədən							
		İstehsal sahələrin buraxılışı	ondan			Xidmət sahələrin buraxılışı	ondan		
			Sənaye	K/t, meşə təsərrüfatı və balıqçılıq	Tikinti quraşdırma işləri		Nəqliyyat və anbar təsərrüfatı	İnformasiya və rabitə	Ticarət və xidmətlər
2018	202228,8	123835,4	28914,1	73052,1	21869,2	78393,4	5198,9	723,8	72470,7
2019	225334,6	142633,3	48344,7	79077,3	15211,3	82701,3	5470,2	780,8	76450,3
2020	250381,8	170702,3	53865,3	83197,9	33639,1	79679,5	2947,4	838,6	75893,5
2021	244344,5	158597,8	58333,6	91820,0	8444,2	85746,7	4406,8	987,6	80352,3
2022	297811,3	198465,5	60944,2	115805,7	21715,6	99345,8	5946,9	1061,8	92337,1
2023	317616,4	209306,5	77919,2	128757,8	2629,5	108309,9	6184,3	1331,9	100793,7

HƏR NƏFƏRƏ DÜŞƏN MƏHSUL BURAXILIŞI

cari qiymətlərlə, manatla

2018	2019	2020	2021	2022	2023
2065,0	2312,1	2546,5	2466,2	2984,1	3162,1

Şəkildə 2018–2023-cü illər üzrə iqtisadiyyatın əsas sahələrində məhsul buraxılışı (min manatla) və hər nəfərə düşən məhsul buraxılışı göstəriciləri əks olunmuşdur. Cədvəl iqtisadi inkişafın sahələr üzrə strukturunu və zaman dinamikasını qiymətləndirməyə imkan verir.

1. Əsas sahələrdə məhsul buraxılışı

2018-ci ildə əsas sahələr üzrə məhsul buraxılışı 202 228,8 min manat olmuşdur. Bu göstərici 2023-cü ildə 317 616,4 min manata yüksəlmişdir. Bu artım iqtisadiyyatın ümumi həcminin genişləndiyini və istehsal potensialının gücləndiyini göstərir. Altı il ərzində müşahidə olunan davamlı artım iqtisadi sabitlik və istehsal imkanlarının genişlənməsi ilə xarakterizə olunur.

2. İstehsal sahələrinin rolu

İstehsal sahələrinin məhsul buraxılışı 2018-ci ildə 123 835,4 min manat, 2023-cü ildə isə 209 306,5 min manat təşkil etmişdir. Bu sahə ümumi məhsul buraxılışında əsas paya malikdir. İstehsal sahələrinin artımı ölkə iqtisadiyyatında real sektorun aparıcı rol oynadığını təsdiqləyir.

3. Sənaye sahəsi

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Sənaye məhsul buraxılışı 2018-ci ildə 28 914,1 iln manat, 2023-cü ildə isə 77 919,2 min manat olmuşdur. Bu, sənayenin sürətli inkişafını, xüsusilə emal və hasilat sahələrində istehsal həcminin artdığını göstərir. Sənaye artımı iqtisadiyyatın texnoloji səviyyəsinin yüksəlməsi ilə sıx bağlıdır.

4. Kənd, meşə təsərrüfatı və balıqçılıq

Bu sahədə məhsul buraxılışı 2018-ci ildə 73 052,1 min manat, 2023-cü ildə isə 128 757,8 min manat təşkil etmişdir. Kənd təsərrüfatında müşahidə olunan artım ərzaq təhlükəsizliyinin möhkəmləndirilməsi və aqrar sektorun iqtisadiyyatda strateji rolunun artması ilə izah olunur.

5. Tikinti sahəsi

Tikinti sahəsində məhsul buraxılışı illər üzrə qeyri-sabit dinamika nümayiş etdirmişdir. 2018-ci ildə 21 869,2 min manat, 2021-ci ildə minimum səviyyəyə – 8 444,2 min manat, 2023-cü ildə isə 26 129,5 min manat olmuşdur. Bu dalğalanmalar investisiya həcmləri və iqtisadi konjonktura ilə əlaqəlidir.

6. Xidmət sahələri

Xidmət sahələrinin məhsul buraxılışı 2018-ci ildə 78 393,4 min manat, 2023-cü ildə isə 108 309,9 min manat təşkil etmişdir. Xidmət sektorunun artımı iqtisadiyyatın strukturunda xidmət yönümlü inkişafın gücləndiyini göstərir.

Xidmət sahələrinin tərkibi:

Nəqliyyat və anbar təsərrüfatı: 2018–2023-cü illərdə sabit artım müşahidə olunur.

İnformasiya və rabitə: ən sürətli artan sahələrdən biridir (723,8 min manatdan 1 331,9 min manata).

Ticarət və xidmətlər: yüksək paya malik olmaqla 2023-cü ildə 100 793,7 min manat səviyyəsinə çatmışdır.

7. Hər nəfərə düşən məhsul buraxılışı

Hər nəfərə düşən məhsul buraxılışı 2018-ci ildə 2 065 manat, 2023-cü ildə isə 3 162,1 manat olmuşdur. Bu göstəricinin artması əhalinin iqtisadi rifah səviyyəsinin yüksəldiyini və istehsal artımının demoqrafik artımı üstələdiyini göstərir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ASSESSMENT OF HEAVY METAL CONTAMINATION IN COMMERCIAL FLOUR BRANDS FROM KADUNA METROPOLIS, NIGERIA: A HEALTH RISK ASSESSMENT STUDY

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Abstract

Background: Contamination of staple foods like flour with heavy metals poses a significant threat to public health. This study aimed to determine the concentration of heavy metals in selected commercial flour brands marketed in Kaduna Metropolis, Nigeria, and to assess the potential health risks associated with their consumption.

Methods: Seven different brands of flour (BUA, GDP, DNG, HYW, SPM, MAG, M&B) were collected from various markets. The concentrations of Cadmium (Cd), Chromium (Cr), Copper (Cu), and Lead (Pb) were determined using Atomic Absorption Spectrophotometry (AAS). A health risk assessment was conducted using USEPA models, calculating the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI), and Incremental Lifetime Cancer Risk (ILCR) for an average adult.

Results: The mean concentrations (mg/kg) of the metals were: Cd (0.00033), Cr (0.0369), Cu (0.0019), and Pb (0.0035). All values were below the WHO/FAO permissible limits. The THQ and HI values for all metals were significantly less than 1 (HI = 0.058), indicating no significant non-carcinogenic risk. The ILCR values for Cd (8.9×10^{-6}) and Cr (7.9×10^{-5}) fell within the acceptable range ($10^{-6} – 10^{-4}$), suggesting a low carcinogenic risk over a lifetime.

Conclusion: The study concludes that the levels of heavy metals in the analyzed flour samples do not pose an immediate significant health risk to consumers. However, the detectable levels of cumulative toxins like Lead and Chromium necessitate continuous monitoring and source identification to ensure long-term food safety.

Keywords: Heavy Metals, Flour, Health Risk Assessment, Carcinogenic Risk Atomic Absorption Spectrophotometry, Target Hazard Quotient.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Introduction

Food safety is a fundamental aspect of public health, and the contamination of staple foods with toxic heavy metals represents a pervasive global challenge (Islam et al., 2022). Heavy metals such as Cadmium (Cd), Chromium (Cr), and Lead (Pb) are non-essential elements with no known beneficial biological function; instead, they are notorious for their toxicity, persistence, and bioaccumulative nature in the food chain (Tchounwou et al., 2012). Chronic exposure to these metals, even at low concentrations, has been linked to a spectrum of adverse health effects, including renal dysfunction, neurodevelopmental disorders, cardiovascular diseases, and an increased risk of cancer (Jaishankar et al., 2014).

Flour, a primary ingredient in numerous diets worldwide, particularly in Nigeria, is a critical vehicle for such contaminants. The journey of flour from cultivation to processing exposes it to potential heavy metal contamination from various sources, including the use of phosphate fertilizers, contaminated irrigation water, industrial emissions, and the milling process itself (Arora et al., 2021). Monitoring the levels of these contaminants in flour is therefore essential for protecting consumer health.

In Nigeria, while studies have investigated heavy metals in water and vegetables, there is a relative paucity of data focusing on the safety of commercially packaged flour, a daily dietary staple for millions. Previous risk assessments in other regions have highlighted potential concerns, underscoring the need for localized studies (Cheng et al., 2021). Therefore, this study was designed to: (i) determine the concentrations of Cd, Cr, Cu, and Pb in selected commercial flour brands sold in Kaduna Metropolis, (ii) compare the findings with international safety standards set by the WHO/FAO, and (iii) conduct a quantitative health risk assessment to evaluate the potential non-carcinogenic and carcinogenic risks to adult consumers.

Methodology

The study was conducted across four (4) distinct areas within Kaduna Metropolis, Nigeria: Kawo, Rigasa, Sabo, Barnawa Kasu Barcci, Bakin Dogo and Central Market. These locations were selected to represent a variety of urban and suburban environments with differing population densities and potential anthropogenic influences. Three different types of commercially available flour, coded as BUA, GDP, DNG, HYW, SPM, MAG, M&B were sampled from each location. A total of (7) samples (7 Flour types from 7 locations) were collected. The samples were purchased from local retail outlets in their original, sealed packaging to ensure the integrity of the samples and to simulate real-world

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ISBN: 978-9952-610-30-7

consumption conditions. The samples were transported to the laboratory in insulated coolers to preserve their chemical stability and stored at 4°C prior to analysis.

Determination of Heavy Metal Concentrations

The concentrations of four heavy metals Manganese (Cu), Cadmium (Cd), Chromium (Cr), and Lead (Pb) were determined in the beverage samples.

Sample Preparation

The samples were prepared for analysis according to standard procedures. Any suspended solids were removed by filtration using a 0.45 µm membrane filter. The samples were then acidified with concentrated nitric acid (HNO_3) to a pH below 2 to prevent adsorption of metals onto container walls and to preserve the samples until analysis.

Instrumental Analysis

The quantification of heavy metals was performed using an Atomic Absorption Spectrophotometer (AAS), a highly sensitive and specific technique for metal analysis. The instrument was calibrated using standard solutions of known concentrations for each metal, prepared from certified stock solutions. Quality assurance and control measures were implemented, including the analysis of procedural blanks to account for any background contamination and the use of duplicate samples to ensure precision. The results for each sample are expressed as the mean concentration in milligrams per liter (mg/L) ± the standard deviation.

Health Risk Assessment

A health risk assessment was conducted to evaluate the potential non-carcinogenic risks to humans from the ingestion of the heavy metals present in the beverages. The assessment was performed for two demographic groups: adults and children.

Chronic Daily Intake (CDI)

The CDI, which represents the average daily dose of a contaminant ingested over a long-term period, was calculated using the following formula:

$$CDI\ (mg/kg\text{-}day) = (C \times IR) / BW$$

Where: C = Mean concentration of the heavy metal samples (mg/Kg), IR = Ingestion Rate (L/day). Conservative values of 2.0 L/day for adults and 1.0 L/day for children were used. BW = Body Weight (kg). Standard values of 70 kg for adults and 15 kg for children were applied.

Hazard Quotient (HQ) and Hazard Index (HI)

The non-carcinogenic risk for each metal was evaluated by calculating the Hazard Quotient (HQ), and the cumulative risk from all metals was assessed using the Hazard Index (HI).

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HQ = CDI / RfD and HI = Σ HQ (for all metals)

Where: RfD = Oral Reference Dose (mg/kg-day), representing a safe daily exposure level. The following RfD values were used in this study: Cadmium (Cd): 0.0005 mg/kg-day, Chromium (Cr): 0.003 mg/kg-day, Lead (Pb): 0.004 mg/kg-day and Cupper (Cu): 0.14 mg/kg-day.

An HQ or HI value of less than 1 (<1) indicates that no significant non-carcinogenic health effects are expected, while a value equal to or greater than 1 (≥1) suggests a potential for adverse health effects.

Data Analysis

The analytical results were systematically compiled, and descriptive statistics (mean and standard deviation) were calculated for the heavy metal concentrations in each sample type and location. The obtained metal concentrations were compared with the permissible limits set by the World Health Organization (WHO, 2024) for drinking water quality, which serves as a benchmark for beverage safety. The CDI, HQ, and HI were computed for each sample and for the maximum detected concentrations to present a conservative (worst-case) risk scenario. All data were tabulated for clear presentation and interpretation.

RESULTS

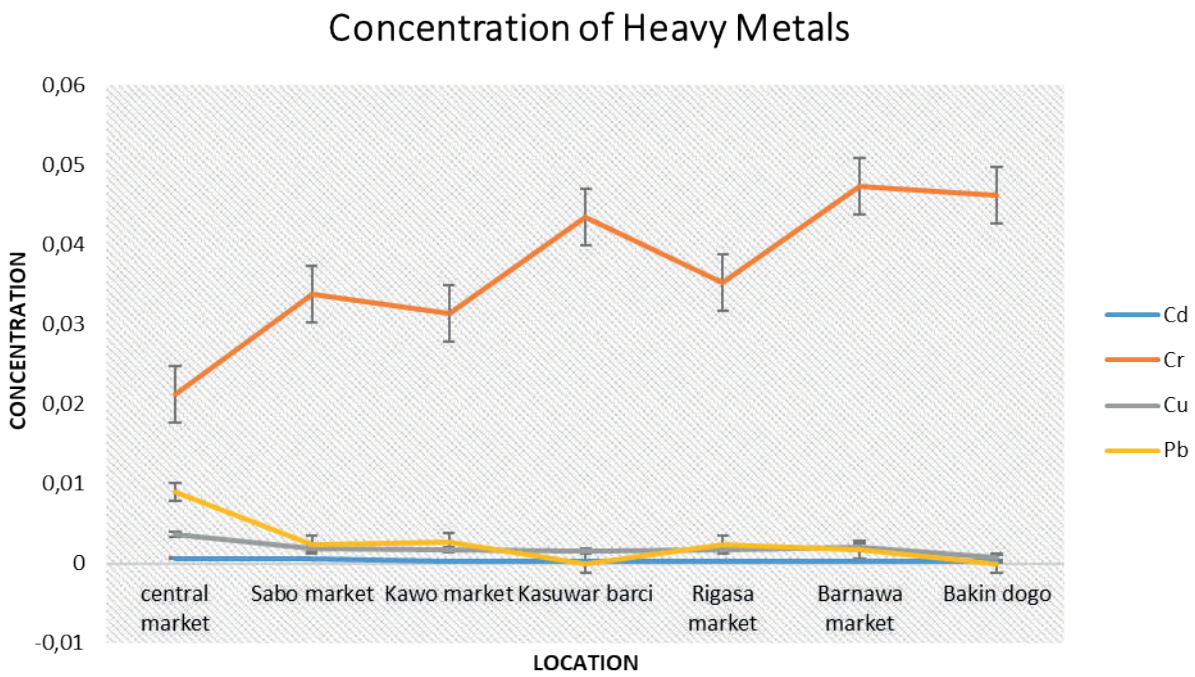


Figure 1: Concentration of Heavy Metals (mg/kg) in Various Flour Brands

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Table 2: Comparison with International Safety Standards with WHO/FAO Permissible Limits.

Heavy Metal	WHO/FAO Permissible Limit (mg/kg) (2024)	Concentration Range in Samples (mg/kg)	Compliance & Risk Status
Cadmium (Cd)	0.1	0.0002 - 0.0006	**Compliant.** Negligible Health Risk.
Chromium (Cr)	1.0	0.0212 - 0.0473	**Compliant.** Low Health Risk.
Copper (Cu)	10.0	0.0008 - 0.0037	**Compliant.** Negligible Health Risk.
Lead (Pb)	0.3	0.0017 - 0.0090	**Compliant.** Low to Moderate Risk due to its cumulative nature

Health Risk Assessment

A quantitative health risk assessment was performed using established USEPA models to evaluate both non-carcinogenic and carcinogenic risks. The calculation assumes an average adult body weight of 70 kg and a daily flour intake of 0.3 kg.

Table 3: Estimated Daily Intake (EDI) and Target Hazard Quotient – (THQ) (Non-Carcinogenic Risk).

Heavy Metal	Average Conc. (mg/kg)	EDI (mg/kg/day)	Reference Dose (RfD) (mg/kg/day)	THQ	Risk Level
Cadmium (Cd)	0.00033	1.41×10^{-6}	1.00×10^{-3}	0.0014	Negligible
Chromium (Cr)	0.0369	1.58×10^{-4}	3.00×10^{-3}	0.0527	Negligible
Copper (Cu)	0.0019	8.14×10^{-6}	4.00×10^{-2}	0.0002	Negligible
Lead (Pb)	0.0035*	1.50×10^{-5}	3.50×10^{-3}*	0.0043	Negligible

Table 4: Carcinogenic Risk Assessment (Incremental Lifetime Cancer Risk - ILCR)

Heavy Metal	Cancer Slope Factor (CSF) $(mg/kg/day)^{-1}$	ILCR	Risk Level
Cadmium (Cd)	6.30	8.90×10^{-6}	Acceptable

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Chromium (Cr)	0.50 (for Cr (VI)*	7.90×10^{-5}	Acceptable
Lead (Pb)	8.50×10^{-3}	1.28×10^{-7}	Negligible

*Calculation assumes a worst-case scenario where all Chromium is in the toxic Cr (VI) form. **Interpretation:** All ILCR values fall within the acceptable range (1×10^{-6} to 1×10^{-4}), indicating a **low carcinogenic risk** from a lifetime of exposure.

Hazard Index (HI) for Combined Metals:

HI = Σ THQ = 0.058

Interpretation: The HI is significantly less than 1, indicating no significant risk of non-cancer health effects from the combined exposure to these metals.

Table 5: Summary of Health Risk Indices.

Index	Value	Interpretation
Target Hazard Quotient (THQ)	All < 0.06	No individual metal poses a significant non-carcinogenic risk.
Hazard Index (HI)	0.058	The combined effect of all metals poses a negligible non-carcinogenic risk.
Incremental Lifetime Cancer Risk (ILCR)	Cd: 8.9E-6; Cr: 7.9E-5	The carcinogenic risk is within the acceptable range.

Discussion

The findings of this study reveal that while heavy metals are present in all the analyzed flour samples, their concentrations are within the permissible limits established by the WHO/FAO (2024). This general compliance is reassuring and suggests that, from a regulatory standpoint, the flours are safe for consumption. The levels of Cd and Cu were particularly low, presenting negligible risk, a finding consistent with studies on other food staples in controlled agricultural environments (Li et al., 2020).

However, the detection of Cr and Pb, even at "compliant" levels, warrants a more nuanced discussion. The mean concentration of Lead (0.0035 mg/kg), while below the WHO/FAO limit of 0.3 mg/kg, is notable because Pb is a potent cumulative neurotoxin with no safe exposure threshold (USEPA, 2022). Its consistent presence across most brands indicates a persistent contamination pathway, possibly from environmental pollution or processing equipment, which aligns with concerns raised by Arora et al. (2021) regarding post-harvest contamination of food grains.

The most significant potential risk identified in this assessment stems from Chromium. The health risk calculation for Cr was based on a worst-case scenario where all chromium is assumed to be in the

toxic and carcinogenic hexavalent form [Cr(VI)]. This is a conservative assumption, as chromium in food can also exist in the less harmful trivalent form [Cr(III)]. Our calculated ILCR for Cr (7.9×10^{-5}) was the highest among the metals and sits at the higher end of the acceptable range (1×10^{-6} to 1×10^{-4}). This echoes the findings of Cheng et al. (2021), who identified Cr as a primary contributor to cancer risk in cereal-based diets in industrially impacted areas. The inability of this study to speciate chromium is a limitation, and the results highlight an urgent need for future research to determine the Cr(VI)/Cr(III) ratio in Nigerian food products to enable a more accurate risk characterization.

The cumulative non-carcinogenic risk, expressed by the Hazard Index (HI = 0.058), was well below the safety threshold of 1. This indicates that the combined effect of these four metals is unlikely to cause systemic toxicity. This low HI value is comparable to studies on similar foodstuffs in regions with minimal industrial activity but is lower than values reported from highly polluted or mining-affected areas (Osma et al., 2022).

Conclusion

This study provides a systematic evaluation of heavy metal levels and associated health risks in commercial flour brands from Kaduna Metropolis. The results demonstrate that the concentrations of Cadmium, Chromium, Copper, and Lead are within internationally accepted limits. The health risk assessment models further confirm that the current exposure levels pose no significant non-carcinogenic health threat, and the carcinogenic risk is within the acceptable range for a lifetime of exposure. Therefore, the consumption of these flour brands does not present an immediate public health concern.

Recommendations

- Regulatory bodies such as the National Agency for Food and Drug Administration and Control (NAFDAC) should institutionalize continuous and widespread monitoring of heavy metals in flour and other staple foods to ensure ongoing compliance.
- Studies should be conducted to trace the specific sources of Lead and Chromium contamination within the flour supply chain, from farming practices (soil, fertilizer, water) to processing, packaging, and transportation.
- Future research must prioritize the chemical speciation of Chromium in these products to distinguish between the toxic Cr(VI) and the essential Cr(III). This will allow for a precise and realistic carcinogenic risk assessment.

References

Arora, M., Kiran, B., & Rani, S. (2021). Heavy metal contamination in agricultural soil and crops: A review. *Journal of Environmental Management, 285*, 112174.

Cheng, Z., Chen, L., Li, H., & Yan, X. (2021). Health risk assessment of heavy metals in cereals and vegetables from a typical industrial area in China. *Human and Ecological Risk Assessment: An International Journal, 27*(3), 624-641.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Islam, M. S., Ahmed, M. K., & Al-Mamun, M. H. (2022). Heavy metal pollution in surface water and sediment: A comprehensive assessment. *Environmental Science and Pollution Research, 29*(12), 16817-16831.

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology, 7*(2), 60–72.

Li, Z., Ma, Z., van der Kuijp, T. J., Yuan, Z., & Huang, L. (2020). A review of soil heavy metal pollution from mines in China: Pollution and health risk assessment. *Science of The Total Environment, 468*, 843-853.

Osma, E., Ilhan, V., & Yaman, M. (2022). Evaluation of heavy metal health risks in endemic plants and their soils from a mining region. *Chemistry and Ecology, 38*(4), 343-359.

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. *Molecular, Clinical and Environmental Toxicology, 101*, 133-164.

USEPA (United States Environmental Protection Agency). (2022). *Integrated Risk Information System (IRIS)*. Retrieved from https://www.epa.gov/iris

WHO/FAO (World Health Organization/Food and Agriculture Organization of the United Nations). (2024). *Codex Alimentarius: General Standard for Contaminants and Toxins in Food and Feed*. (CXS 193-1995).

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ARTIFICIAL INTELLIGENCE AND HUMAN RESOURCE MANAGEMENT: TRANSFORMING THE FUTURE OF WORK

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Abstract

The integration of Artificial Intelligence (AI) into Human Resource Management (HRM) represents a transformative paradigm shift in organizational practices. This research paper examines the multifaceted applications of AI in HRM, including recruitment, talent management, employee engagement, performance evaluation, and retention strategies. Through comprehensive analysis of current research and industry practices, this paper demonstrates that AI technologies including machine learning, predictive analytics, and sentiment analysis enhance HR decision-making, improve operational efficiency, and personalize employee experiences. However, significant challenges including algorithmic bias, data privacy concerns, and the need for workforce upskilling persist. The findings indicate that successful AI adoption in HRM requires strategic integration of automation with human oversight, ethical frameworks, and inclusive practices that balance technological advancement with employee-centric approaches.

Keywords: *Artificial Intelligence, Machine Learning, Human Resource Management, Talent Acquisition, Employee Engagement, Predictive Analytics, Performance Management*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

RIGID HIERARCHIES TO DYNAMIC, HUMAN-AI SYMBIOTIC FRAMEWORKS

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ABSTRACT

The new era of management philosophy heralds a paradigm shift from rigid hierarchies to dynamic, human-AI symbiotic frameworks, driven by digital transformation and ethical imperatives. In 2026, core tenets emphasize agile adaptability, where leaders harness AI for predictive decision-making while prioritizing empathy and inclusivity amid hybrid work models. Sustainability integrates ESG principles into strategic cores, balancing profit with planetary stewardship through data-driven accountability. This philosophy reimagines the manager as a "superagency" orchestrator, blending emotional intelligence with generative AI to foster innovation and resilience. Purpose-driven cultures empower distributed leadership, continuous learning, and ethical automation, mitigating biases in HR and operations echoing your AI-HRM research interests. Challenges like technological disruption demand resilient upskilling, ensuring organizations thrive in volatility. Ultimately, this evolution promises equitable growth, where technology amplifies human potential for holistic success.

Keywords: AI, Human Resource Management, ESG

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PROXIMATE AND HEAVY METALS DETERMINATION OF GOAT ORGANS SOLD IN ZANGO ABATTOIR MARKET KADUNA, NIGERIA

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Abstract

This study investigated the proximate composition and heavy metal concentrations in selected goat organs (liver, lung, skin, and intestine) sold at Zango Abattoir Market in Kaduna, Nigeria. Fresh samples were collected from multiple vendors and analyzed using standard AOAC methods for proximate parameters and X-ray Fluorescence (XRF) spectrometry for elemental analysis. The proximate results revealed varying nutritional compositions across the organs. Moisture content was highest in the lung (85.27±5.45%) and lowest in the skin (75.89±6.25%). Crude protein was significantly high in the liver (25.58±1.15%) and intestine (18.11±2.52%), while the skin recorded the lowest protein content (6.32±2.68%). Crude fat ranged from 0.85±0.08% in skin to 7.12±0.15% in intestine. Ash content, indicating mineral richness, was highest in the liver (1.72±0.04%) and lowest in the intestine (0.81±0.45%). Carbohydrate content ranged between 0.40±0.01% in liver and 22.80±2.67% in skin. Elemental analysis detected essential minerals, with iron concentration highest in the intestine (5.39±0.25 mg/kg) and liver (4.251±0.25 mg/kg), while zinc was highest in the intestine (0.63±0.72 mg/kg) and lowest in the skin (0.137±0.015 mg/kg). Importantly, toxic heavy metals (lead) were below detectable limits in all samples, indicating minimal contamination. The study concludes that goat organs from Zango Market are nutritionally valuable, particularly liver and intestine as rich protein and mineral sources, and are currently safe from heavy metal toxicity. Regular monitoring and improved market hygiene are recommended to maintain food safety standards.

KEY WORDS: Heavy metal, Zango Market, X-ray Fluorescence and Goat organ

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GREEN SYNTHESIS AND CHARACTERIZATION OF NANO FERTILIZER USING DAMAGI PLANT EXTRACT (*Chrozophora Senegalensis*)

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ABSTRACT

This study developed and characterized a nanofertilizer through a green synthesis route using an aqueous extract of *Chrozophora senegalensis* (Damagi). The objective was to create an environmentally sustainable production method, leveraging the plant's inherent phytochemicals as both reducing and stabilizing agents. The synthesis procedure involved boiling plant material in distilled water, followed by centrifugation to obtain a purified extract for nanoparticle formation. The resulting nanoparticles underwent comprehensive characterization using Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM), and Energy Dispersive X-ray Spectroscopy (EDX). FTIR analysis identified key functional groups (O-H, C-H, C=N, NO_2, C-X) instrumental in the reduction and capping mechanisms. EDX quantification showed the nanoparticles were predominantly composed of iron (46.18% by weight) and carbon (12.37%), alongside beneficial trace micronutrients including zinc, manganese, copper, and silver. XRD patterns confirmed the crystalline structure, with crystallite sizes determined by the Debye-Scherrer equation ranging from approximately 1.36 nm to 52.16 nm, a result corroborated by Williamson-Hall analysis. SEM imaging revealed the nanoparticles to be spherical and uniformly dispersed. The findings confirm the efficacy of *Chrozophora senegalensis* extract in producing stable, nano-scale particles. This synthesis method is straightforward, economical, and avoids toxic chemicals, aligning with the principles of green chemistry. The produced nanofertilizer exhibits favorable properties for improving nutrient-use efficiency, presenting a sustainable and eco-friendly alternative to conventional fertilization approaches in agriculture

KEY WORDS: *Chrozophora senegalensis,* X-ray Diffraction, Nanofertilizer and FTIR

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYSIS OF WOOD/PLYWOOD JOINTS IN LARGE PALLETS USING NUMERICAL FINITE ELEMENT ANALYSIS

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ABSTRACT

The global packaging industry has evolved toward more sustainable and efficient solutions, particularly in logistics and goods transportation. Wooden pallets remain dominant in freight handling due to their structural simplicity, low cost, and compatibility with various transport systems. However, industry trends demand optimization of these structures for sustainability, cost-effectiveness, and adaptability to custom sizes. This is particularly relevant for companies like NEFAB Portugal, which provide industrial packaging solutions for sectors such as automotive and telecommunications. As the demand for customized pallet sizes grows, there is an increasing need to analyse the mechanical performance of large dimensions pallets created by joining wooden beams. Actually, the use of adhesives and mechanical joints in pallet construction raises key questions regarding strength, cost, and durability under real-world loading conditions, which emphasis the need for structural verification.

The primary aim of this work is to study and compare seven different joint geometries for wooden beams used in pallet structures. These configurations were tested experimentally and simulated using Finite Element Analysis (FEA) to identify the best performing design. The research involved material characterization, manufacturing of joint specimens, quasi-static mechanical testing, and validation through numerical models. The joints were also assessed based on fabrication complexity, environmental sustainability, and cost-effectiveness. This comprehensive study supports NEFAB Portugal in optimizing future pallet designs, contributing to a more sustainable and efficient packaging strategy.

The results show that specific joint geometries, particularly those combining adhesives with mechanical reinforcements, provide superior load-bearing capacity and cost efficiency compared to conventional methods.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KEYWORDS: Pallet, Wood joint, Sustainability, Finite Element Analysis, Packaging solutions, Adhesives.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EXISTENCE OF NONNEGATIVE SOLUTIONS FOR A CLASS OF SEMIPOSITONE PROBLEMS IN A BALL

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ABSTRACT

in our article, we study the existence of radial nonnegative solutions for the boundary-value problem

$$-\Delta u(x) = \lambda f(u(x)), \quad x \in \Omega, \; u(x) = 0, \qquad x \in \partial\Omega, \quad (1)$$

where Δ is the Laplace operator, Ω is the unit ball of R^N, $N \geq 2$ and $\lambda > 0$ is a parameter. Where the main objective is to prove the existence of nonnegative solutions to (1) when the function f has more than one zero, is not entirely increasing on $[0, +\infty)$ and has more than one zero.

Keywords: Nonlinear boundary value problems, radial positive solution, nonpositone problem.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

LUBRICATION EFFICIENCY ASSESSMENT IN AUTOMATED AUTOMOTIVE COMPONENT FABRICATION

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ABSTRACT

Control cables, essential components in vehicles, require optimized manufacturing processes due to their low added value margin. Proper lubrication of these cables is fundamental to minimize friction, reduce noise, and extend their service life. Issues within lubrication systems can lead to significant grease waste, making the improvement of these systems critical for optimizing production and reducing waste.

This work aimed to address a need identified by an automotive components company, related to improving the efficiency of the control cable lubrication process. To this end, the entire lubrication process at the company was analysed to identify the problems compromising the effectiveness of the process. The process involves two main devices: the grease extraction device and the grease injection device. The observed inefficiency was attributed to high grease waste and the presence of air bubbles during the injection of grease into the control cables. Several improvements were suggested for each of the identified problems in each device and subsequently selected for development. These improvements were implemented in the existing devices through the construction of prototypes to validate the proposed solutions and ensure they met the established objectives. The implementation of these improvements resulted in a significant increase in efficiency, particularly concerning waste reduction. A 94.15% reduction in waste was observed for the extraction device, corresponding to an annual saving of 6,876.20 €. For the grease injection device, waste was reduced by 99.00%, resulting in an annual saving of 210.78 €.

Keywords: Automotive industry; Control cables; Grease; Lubrication process; Grease waste; Efficiency.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

NUMERICAL MODELLING OF A ROBUST STEEL PALLET FOR OVERSIZED SHAFT TRANSPORT

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ABSTRACT

The increasing demand for safer, more sustainable, and more efficient transport solutions is driving innovation in the packaging industry, particularly in the context of heavy and voluminous cargo. Despite the standardisation of pallets, discrepancies persist in the protection of large equipment, necessitating the development of more robust and adaptable structures. This work focuses on developing and optimising a heavy-duty steel packaging structure for the safe and efficient transportation of heavy and oversized shafts. The project addresses critical challenges relating to load securing, operational safety, and logistical efficiency. The research methodology is based on a structured approach incorporating a literature review, design synthesis and validation, and iterative structural optimisation using Finite Element Analysis (FEA). Design Science Research (DSR) was adopted to ensure a systematic, application-oriented design process. Ashby's method was used to select structural solutions that focus on strength, durability, and manufacturability. Several design iterations were developed to accommodate various handling and transport conditions, such as lifting, stacking, and forklift compatibility. The final packaging solution incorporates functional elements such as adjustable axial brakes, lashing points, forklift entry channels, and stackable elements to improve usability and adaptability. FEA simulations confirmed compliance with mechanical resistance criteria, particularly von Mises stress limits, thereby ensuring the structural integrity of the solution. Furthermore, the packaging design contributes to sustainability goals by reducing long-term costs and minimising environmental impact through extending the product's life and increasing its potential for reuse.

Keywords: Pallet; Heavy-Duty Steel Packaging Structure; Stacking system; Lashing solutions; Structure design iterations; Heavy shaft;CAD.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYSIS OF FUZZY PREEMPTIVE REPEAT PRIORITY QUEUE WITH RESAMPLING

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Abstract:

In this paper, we analyze a discrete-time fuzzy preemptive repeat priority queue with resampling. High-priority packets have preemptive repeat priority, and interrupted low-priority packets are subjected to independent retransmission attempts. Both classes contain packets with generally distributed transmission times. We show that the use of generating functions is beneficial for analyzing the system contents and packet delay of both classes. The influence of the priority scheduling on the performance measures is illustrated by some numerical examples.

Keywords: fuzzy Priority scheduling, Repeat priority, Discrete-time, Resampling, Measures

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SIMULATION ON FUZZY M/M/1 QUEUEING MODELS IN FUZZY ENVIRONMENT

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Abstract:

In this paper, we analyze the application of Simulations in fuzzy M/M/1 Queueing model are discussed by Fuzzy approach. We visualize the activities of each lane is discussed. The main aim of this paper is, the management can easily find which system are busy and which system is ideal and the movement of each type of vehicles in each lane is simulated by the arrival and departure time. The numerical studies for various aspects are discussed.

Keywords: Fuzzy M/M/1 Queueing model, Simulation, Probability distribution, Fuzzy ranking, Measures

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FUZZY ANALYSIS IN INTERVAL DATA BASED GAME THEORETICAL PROBLEM

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Abstract:

In a real world environment, the payoffs of a matrix game are varying between two fixed values because of uncertainty. This type of payoffs may not be defined as a crisp numbers. In order to model such uncertainty, the payoffs can be represented as interval numbers. A matrix game with payoffs of such interval numbers are called interval data based matrix game. This work takes an initiative to solve the interval data based matrix game in an uncertain environment. In order to find the optimum solution of the interval matrix game without the knowledge of interval arithmetic, the fuzzy set theory is used in various symmetric environments. Finally the analysis is made on the solutions obtained through various symmetric fuzzy environments with the help of different shapes of fuzzy numbers.

Key words: Interval Number; Symmetric Fuzzy Number; Matrix Game; Fuzzification; Defuzzification.

1. INTRODUCTION

The problems of optimization under uncertainty are appearing in many areas of application and present many interesting challenges in concept and computation. The key step of optimization is the exact formulation of real word problems. But in an uncertain environment, modelling of variables and their values of optimization problems are difficult in a precise manner. Stochastic and fuzzy valued variables are extensively used to model such uncertainties in optimization theories by the experts in their fields. However, the variables of interval number are also utilized for modelling the same. Although, the optimization models with random and fuzzy variables are widely used in many areas such as planning and scheduling of production, transportation etc. under uncertainty, the fuzzy mathematical formulation of the real world problems is familiar in recent years in an uncertain

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

context. Moreover, on nowadays, many authors are involving themselves to solve such fuzzy optimization problems using fuzzy arithmetic and defuzzification techniques for finding its optimum solutions. As per the objective of this study, here, we have made a sample survey of recent works on fuzzy game theoretical problems, a familiar problem in optimization theory, to get the idea about the current trend in this field.

In 2012 [3], Deng-Feng Li and Feng-Xuan Hong developed and effective methodology for solving constrained matrix games with payoff of triangular fuzzy number. Mijanur et al. in 2015 [15] have proposed a ranking function to solve bi-matrix games with payoffs of triangular intuitionistic fuzzy numbers and also proved that generalization of fuzzy non-linear programming problem is non-linear intuitionistic fuzzy programming problem. Subsequently, Senthil Kumar & Kumaraghuru [20] and Stalin & Thirucheran [21] proposed a methodology for two person matrix games in which all elements of pay-off matrix are considered as fuzzy numbers and used a method of defuzzification to convert it into crisp game matrix in the same year. In 2016, hexagonal fuzzy number based Two Person Zero Sum Game was solved using ranking function proposed by Jon Arockiaraj and Sivasankari [9]. In 2017, Namarta and others introduced two person zero sum game with its payoff matrix are represented by dodecagonal fuzzy numbers and solve the same with the help of defuzzification technique. Subsequently in the same year, Arindam Chaudhuri solved the fuzzy game problem using minimax-maximin in which payoff matrices are represented by interval and LR trapezoidal fuzzy numbers, Iden Hassen and Zainab Saad [6] proposed new ranking function algorithm for solving Fuzzy Game problems to get the best gains, Monisha and Sangeetha [16] solved the fuzzy game problem in which all elements of payoffs are considered as pentagonal fuzzy numbers based on ranking function and discussed its solution with saddle point by using minimax – maximin, Thirucheran and others [23] has solved two person zero sum game with payoff matrices of triangular fuzzy numbers without converting it into crisp problem, Dinagar and Narayanan [22] solved fuzzy game problem with hexagonal fuzzy number as elements of its payoff matrix using minimax – maximini method, Konstantin[11] proposed an algorithm to formulate and construct a Nash equilibrium in a bimatrix game. In 2018, Dong Qiu [4] and others presented Bi-matrix game model with crisp payoffs is presented using ranking function method and hence its equilibrium solution is converted into optimal solution of non-linear programming problem. Subsequently in the same year Jishu Jana [8] proposed the method to solve fuzzy matrix game using linear ranking function to reduce its computational complexity, Krishnaveni and Ganesan [13] introduce an algorithm to find the optimal solution of fuzzy game without conversion of classical form using new ranking function, Iden [7] utilized three different ranking algorithms for solving fuzzy trapezoidal payoffs problem to get the best gains by its comparison. In 2019, Brikaa et al. [2] developed fuzzy multi-objective programming algorithm to solve fuzzy numbers based constrained matrix game and finally the comparison is made through numerical illustration between the results of proposed method and GAMS software. Successively

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Karthi and Selvakumari [10] introduced symmetric pentagonal and constant pentagonal fuzzy matrices in Game Theory to study the existence of Nash equilibrium in pure and mixed strategies; Namarta et al. [18] introduced a new procedure to convert the fuzzy game problems with payoff of octagonal fuzzy numbers into crisp game problems for finding its optimum solution using any one of the traditional method, Krishnapriya and Senbagam [12] also converted the fuzzy game problems with payoff of pentagonal and hexagonal fuzzy numbers into crisp game problems using ranking function to find its solution, Maheswari and Vijaya [14] introduced an algorithm to solve two person zero-sum matrix game problem in an uncertain environment using incenter of centroids based ranking function of generalized trapezoidal fuzzy numbers,

Recently in 2020, Yang and Song [24] proposed a method to solve matrix game in which payoffs are considered as triangular dual hesitant fuzzy numbers. Afterwards Seikh et al. [19] used lexicographic method to solve two non-linear programming problems with triangular fuzzy numbers in order to solve matrix games of with payoffs of triangular hesitant fuzzy elements by transforming two non-linear programming problems with triangular hesitant fuzzy elements formulated from the payoff matrix.

As per the above survey, most probably, the authors are used fuzzy set theory to model the game theoretical problems in the environment with uncertainty. But in 2011, Handan Akyar and Emrah Akyar used interval valued matrix to model such uncertainties [5]. Moreover, they used interval arithmetic to find its optimum solution using graphical method. In this work, we present an algorithm to solve the interval data based game theoretical problem using fuzzy set theory and classical methods of game theory. The speciality of the proposed algorithm is to analyse the optimum solution of interval matrix game based on various forms of symmetric fuzzy quantities under fuzzy environment.

The organization of this paper is given as follows: In section 2, we provide some basic ideas namely interval number, fuzzy set, various forms of fuzzy numbers and fuzzification of interval number. In Section 3, we introduce a new ranking function for ordering generalized trapezoidal, pentagonal and hexagonal fuzzy numbers based on its new centroids. Section 4 proposes an algorithm for solving interval data based Two Person Zero Sum Matrix Game under various symmetric fuzzy environments and also introduces its mathematical formulation. In Section 5, three numerical illustrations are given in order to analyse the optimum solutions of Interval Matrix Game under three symmetric fuzzy environments. The research work ends with conclusion in Section 6.

2. PRELIMINARIES

Fuzzy Set: A Fuzzy Set $\widetilde{A} = \{(x, \mu_A(x)); x \in U\}$ is convinced by a membership function μ_A mapping from elements of a universe of discourse U to the unit interval [0,1].

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(i,e) μ_A: U $\rightarrow$[0,1] is a mapping called the degree of membership function of the fuzzy set $\tilde{A}$ and μ_A(x)is called the membership value of x Є U in the fuzzy set $\tilde{A}$.

Triangular Fuzzy Number: A Triangular Fuzzy Number $\tilde{A}$(x) is represented by

$\tilde{A}(a_1, a_2, a_3)$ with the membership function $\mu_A(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1 \quad , & x = a_2 \\ \frac{x-a_3}{a_2-a_3}, & a_2 \le x \le a_3 \\ 0, otherwise \end{cases}$

Trapezoidal Fuzzy Number: A Trapezoidal Fuzzy Number $\tilde{A}$(x) is represented by

$\tilde{A}(a_1, a_2, a_3, a_4)$ with the membership function $\mu_A(x) = \begin{cases} \frac{x-a_1}{a_2-a_1}, & a_1 \le x \le a_2 \\ 1 \quad , & a_2 \le x \le a_3 \\ \frac{x-a_4}{a_3-a_4}, & a_3 \le x \le a_4 \\ 0, otherwise \end{cases}$

Interval Number: A number is said to be an interval number if it is a subset of the real line R with the following form:

$[a,b] = \{x \in \mathrm{R} \mid a \le x \le b\}$

Fuzzification: In most of the real life situations, the observation of data is the numbers around some real value. In order to solve the problems of optimization, this type of data has to be represented in the standard form of numbers of mathematical theory. In 1965, Professor L.A. Zadeh [25] introduced fuzzy set theory to represent such vague information in some standard form of fuzzy numbers. In this section, we have introduced new approaches to fuzzify such vague information in the standard form of fuzzy numbers.

Let us consider the vague information as$[a_L, a_U]$. This is called interval number. The collection of such interval numbers is called interval data. The interval can be fuzzified different symmetric forms of standard fuzzy numbers in the following way.

The different symmetric forms of some standard fuzzy numbers for interval number are taken as follows:

Fuzzification of the interval number $[a_L, a_U]$ in the three different symmetric forms of trapezoidal fuzzy number as

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$$(1) \qquad [a_L, a_U] \Rightarrow \begin{cases} (a_L, a_L + d, a_L + 2d, a_U) & \text{with } d = (a_U - a_L)/3 \\ (a_L, a_L + d, a_L + 3d, a_U) & \text{with } d = (a_U - a_L)/4 \\ (a_L, a_L + 2d, a_L + 3d, a_U) & \text{with } d = (a_U - a_L)/5 \end{cases}$$

Fuzzification of the interval number $[a_L, a_U]$ in the three different symmetric forms of pentagonal fuzzy number as

$$(2) \qquad [a_L, a_U] \Rightarrow \begin{cases} (a_L, a_L + d, a_L + 2d, a_L + 3d, a_U) & \text{with } d = (a_U - a_L)/4 \\ (a_L, a_L + d, a_L + 3d, a_L + 5d, a_U) & \text{with } d = (a_U - a_L)/6 \\ (a_L, a_L + 2d, a_L + 3d, a_L + 4d, a_U) & \text{with } d = (a_U - a_L)/6 \end{cases}$$

Fuzzification of the interval number $[a_L, a_U]$ in the three different symmetric forms of hexagonal fuzzy number as

$$(3) \qquad [a_L, a_U] \Rightarrow \begin{cases} (a_L, a_L + d, a_L + 2d, a_L + 3d, a_L + 4d, a_U) & \text{with } d = (a_U - a_L)/5 \\ (a_L, a_L + d, a_L + 3d, a_L + 5d, a_L + 7d, a_U) & \text{with } d = (a_U - a_L)/8 \\ (a_L, a_L + 2d, a_L + 3d, a_L + 4d, a_L + 5d, a_U) & \text{with } d = (a_U - a_L)/7 \end{cases}$$

3. Ranking Function

Ranking function is a mapping which maps the set of all fuzzy numbers of various shapes into real numbers. Most probably, these types of ranking functions are based on centroids of fuzzy quantities. The set of real values arrived from Centroid based ranking function for various fuzzy quantities using Euclidean distance formula does not satisfy the total ordering. But in many fuzzy optimization problems, the fuzzy quantities have to be converted into real quantities and that should be satisfied by the total ordering properties. In order to overcome this problem we introduce the new centroid based ranking function using Euclidean distance formula.

$$(7) \qquad R(\tilde{A}) = \begin{cases} S(\tilde{A}) & \text{if } x_c \text{ is positive} \\ -S(\tilde{A}) & \text{if } x_c \text{ is negative} \end{cases}$$

Where (x_c, y_c) is the centroid of fuzzy number $\tilde{A}$ and $S(\tilde{A}) = \sqrt{(x_c)^2 + (y_c)^2}$

4. INTERVAL DATA BASED GAME THEORETICAL PROBLEM

4.1. Mathematical Formulation of Interval Data based Two-Person Zero-Sum Matrix Games

In game theoretical problems, the payoffs of matrix games are not observed in the form of crisp values in an uncertain context. But such values are mostly observed by the decision makers in the form of linguistic terms or interval values. The game theoretical problems with payoffs of interval values are called Interval Matrix Games or Interval data based Matrix Games. Here we introduce the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

mathematical form of interval data based two person zero sum matrix games in order to have an effective study under uncertainty.

Now we assume that $I_1, I_2 \ldots I_m$ are m strategies for Player I and $II_1, II_2 \ldots II_n$ are n strategies for Player II. In a Game Matrix with or without saddle point, that is, pure or mixed strategies, we assume that each player will have their own choices. Let $A = \left(\left[a_{ij}^L, a_{ij}^U \right] \right)_{m \times n}$ be an interval data based matrix game where $\left[a_{ij}^L, a_{ij}^U \right]$ is the payoff of interval number. Here player I gains from player II if strategy I_i and II_j are chosen by Players I and II respectively. The matrix with payoff of interval number is explicitly represented as follows:

$$\begin{array}{c} \\ \text{Player A} \end{array} \begin{array}{c} \text{Player B} \\ \begin{bmatrix} \left[a_{11}^l, a_{11}^u\right] & \left[a_{12}^l, a_{12}^u\right] & .... & .... & \left[a_{1n}^l, a_{1n}^u\right] \\ \left[a_{21}^l, a_{21}^u\right] & \left[a_{22}^l, a_{22}^u\right] & .... & .... & \left[a_{2n}^l, a_{2n}^u\right] \\ .... & .... & .... & .... & .... \\ .... & .... & .... & .... & .... \\ \left[a_{m1}^l, a_{m1}^u\right] & \left[a_{m2}^l, a_{m2}^u\right] & .... & .... & \left[a_{mn}^l, a_{mn}^u\right] \end{bmatrix} \end{array}$$

5. NUMERICAL ILLUSTRATION

Solve the game with payoff matrix is given by

$$\begin{array}{c} \\ \text{Player P} \end{array} \begin{array}{c} \text{Player Q} \\ \begin{array}{ccc} Q_1 & Q_2 & Q_3 \end{array} \\ \begin{array}{c} P_1 \\ P_2 \\ P_3 \end{array} \begin{bmatrix} [0,2] & [2,4] & [0.5,1.5] \\ [-2,2] & [-6,-2] & [-4,-2] \\ [-2,4] & [1,9] & [-3,1] \end{bmatrix} \end{array}$$

Solution

As per the proposed algorithm, we wish to solve the given game with interval data based payoff matrix in the three different symmetric fuzzy environments with the help of their proposed fuzzification formulae.

First let us solve the game in symmetric trapezoidal fuzzy environment.

In order to find its solution, the interval data based payoff matrix is converted into three fuzzy data based payoff matrices using eq. (1).

The fuzzy data based payoff matrices are

$$\begin{bmatrix} (0,0.67,1.33,2) & (2,2.67,3.33,4) & (0.5,0.83,1.17,1.5) \\ (-2,-0.67,0.67,2) & (-6,-4.67,-3.33,-2) & (-4,-3.33,-2.67,-2) \\ (-2,0,2,4) & (1,3.67,6.33,9) & (-3,-1.67,-0.33,1) \end{bmatrix}$$

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

$$\begin{bmatrix} (0,0.5,1.5,2) & (2,2.5,3.5,4) & (0.5,0.75,1.25,1.5) \\ (-2,-1,1,2) & (-6,-5,-3,-2) & (-4,-3.5,-2.5,-2) \\ (-2,-0.5,2.5,4) & (1,3,7,9) & (-3,-2,0,1) \end{bmatrix}$$

$$\begin{bmatrix} (0,0.8,1.2,2) & (2,2.8,3.2,4) & (0.5,0.9,1.1,1.5) \\ (-2,-0.4,0.4,2) & (-6,-4.4,-3.6,-2) & (-4,-3.2,-2.8,-2) \\ (-2,0.4,1.6,4) & (1,4.2,5.8,9) & (-3,-1.4,-0.6,1) \end{bmatrix}$$

The above fuzzy payoff matrices are converted into crisp payoff matrices using the ranking function (7) of proposed centroid (4)

$$\begin{bmatrix} 1.0985 & 3.0260 & 1.0879 \\ -0.4821 & -4.0531 & -3.0508 \\ 1.0766 & 4.9737 & -1.1320 \end{bmatrix} \quad \begin{bmatrix} 1.1099 & 3.0384 & 1.1099 \\ -0.4815 & -4.0289 & -3.0384 \\ 1.1099 & 5.0231 & -1.1099 \end{bmatrix}$$

$$\begin{bmatrix} 1.0899 & 3.0165 & 1.0700 \\ -0.4835 & -4.0730 & -3.0603 \\ 1.0502 & 4.9347 & -1.1501 \end{bmatrix}$$

The maximin value and minimax values are coincided for the above three problems. So the problems have the saddle point.

The maximin and minimax values are marked by (*) and (+) respectively as shown below:

$$\begin{bmatrix} 1.0985^{*+} & 3.0260 & 1.1043^{+} \\ -0.4821 & -4.0531^{*} & -3.0508 \\ 1.0766 & 4.9737^{+} & -1.1320^{*} \end{bmatrix} \quad \begin{bmatrix} 1.1099^{*+} & 3.0384 & 1.1099^{*+} \\ -0.4815 & -4.0289^{*} & -3.0384 \\ 1.1099^{+} & 5.0231^{+} & -1.1099^{*} \end{bmatrix}$$

$$\begin{bmatrix} 1.0899^{*+} & 3.0165 & 1.0999^{+} \\ -0.4835 & -4.0730^{*} & -3.0603 \\ 1.0502 & 4.9347^{+} & -1.1501^{*} \end{bmatrix}$$

We observed the following things from the above three problems.

In problem I, that there exist one saddle point at the position (1, 3). In problem II, there exist two saddle points at positions (1, 1) and (1, 3). Finally in problem III, that there exist one saddle point at the position (1, 1).

Thus the solutions to the crisp data based above problems are given by

Problem solved under Trapezoidal Fuzzy Environment				
Problems	Optimum Strategy		Value of the Game	
	Player P	Player Q	Player P	Player Q

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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I	P_1	Q_1	1.0985	-1.0985
II	P_1	Q_1& Q_3	1.1099	-1.1099
III	P_1	Q_1	1.0899	-1.0899

Now the given game is solved in symmetric pentagonal fuzzy environment.

Similarly, the payoff matrix for the given game is converted in to three fuzzy payoff matrices using (2)

The fuzzy data based payoff matrices are

$$\begin{bmatrix} (0,0.5,1,1.5,2) & (2,2.5,3,3.5,4) & (0.5,0.75,1,1.25,1.5) \\ (-2,-1,0,1,2) & (-6,-5,-4,-3,-2) & (-4,-3.5,-3,-2.5,-2) \\ (-2,-0.5,1,2.5,4) & (1,3,5,7,9) & (-3,-2,-1,0,1) \end{bmatrix}$$

$$\begin{bmatrix} (0,0.33,1,1.67,2) & (2,2.33,3,3.67,4) & (0.5,0.67,1,1.33,1.5) \\ (-2,-1.33,0,1.33,2) & (-6,-5.33,-4,-2.67,-2) & (-4,-3.67,-3,-2.33,-2) \\ (-2,-1,1,3,4) & (1,2.33,5,7.67,9) & (-3,-2.33,-1,0.33,1) \end{bmatrix}$$

$$\begin{bmatrix} (0,0.67,1,1.33,2) & (2,2.67,3,3.33,4) & (0.5,0.83,1,1.17,1.5) \\ (-2,-0.67,0,0.67,2) & (-6,-4.67,-4,-3.33,-2) & (-4,-3.33,-3,-2.67,-2) \\ (-2,0,1,2,4) & (1,3.67,5,6.33,9) & (-3,-1.67,-1,-0.33,1) \end{bmatrix}$$

The above fuzzy payoff matrices are converted into crisp payoff matrices using the ranking function (7) of proposed centroid (5)

$$\begin{bmatrix} 1.0981 & 3.0341 & 1.0981 \\ -0.4537 & -4.0256 & -3.0341 \\ 1.0981 & 5.0205 & -1.0981 \end{bmatrix} \quad \begin{bmatrix} 1.1037 & 3.0402 & 1.1009 \\ -0.4539 & -4.0134 & -3.0280 \\ 1.1150 & 5.0451 & -1.0869 \end{bmatrix}$$

$$\begin{bmatrix} 1.0925 & 3.0280 & 1.0953 \\ -0.4539 & -4.0379 & -3.0402 \\ 1.0813 & 4.9960 & -1.1094 \end{bmatrix}$$

The maximin value and minimax values are coincided for the above three problems. So the problems have the saddle point.

The maximin and minimax values are marked by (*) and (+) respectively as shown below:

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ISBN: 978-9952-610-30-7

$$\begin{bmatrix} 1.0981^{*+} & 3.0341 & 1.0981^{*+} \\ -0.4537 & -4.0256^{*} & -3.0341 \\ 1.0981^{+} & 5.0205^{+} & -1.0981^{*} \end{bmatrix} \begin{bmatrix} 1.1037 & 3.0402 & 1.1009^{*+} \\ -0.4539 & -4.0134^{*} & -3.0280 \\ 1.1150^{+} & 5.0451^{+} & -1.0869^{*} \end{bmatrix}$$

$$\begin{bmatrix} 1.0925^{*+} & 3.0280 & 1.0953^{+} \\ -0.4539 & -4.0379^{*} & -3.0402 \\ 1.0813 & 4.9960^{+} & -1.1094^{*} \end{bmatrix}$$

We observed the following things from the above three problems.

In problem I, that there exist two saddle points at the positions (1, 1) and (1, 3). In problem II, there exists one saddle point at the position (1, 3). Finally in problem III, that there exist one saddle point at the position (1, 1).

Thus the solutions to the crisp data based above problems are given by

Problem solved under Pentagonal Fuzzy Environment				
Problems	Optimum Strategy		Value of the Game	
	Player P	Player Q	Player P	Player Q
I	P_1	Q_1 & Q_3	1.0981	-1.0981
II	P_1	Q_3	1.1009	-1.1009
III	P_1	Q_1	1.0925	-1.0925

Now the given game is solved in symmetric hexagonal fuzzy environment.

Similarly, the payoff matrix for the give game is converted in to three fuzzy payoff matrices using eq. (3).

The fuzzy data based payoff matrices are

$$\begin{bmatrix} (0,0.4,0.8,1.2,1.6,2) & (2,2.4,2.8,3.2,3.6,4) & (0.5,0.7,0.9,1.1,1.3,1.5) \\ (-2,-1.2,-0.4,0.4,1.2,2) & (-6,-5.2,-4.4,-3.6,-2.8,-2) & (-4,-3.6,-3.2,-2.8,-2.4,-2) \\ (-2,-0.8,0.4,1.6,2.8,4) & (1,2.6,4.2,5.8,7.4,9) & (-3,-2.2,-1.4,-0.6,0.2,1) \end{bmatrix}$$

$$\begin{bmatrix} (0,0.25,0.75,1.25,1.75,2) & (2,2.25,2.75,3.25,,3.75,4) & (0.5,0.625,0.875,1.125,1.375,1.5) \\ (-2,-1.5,-0.5,0.5,1.5,2) & (-6,-5.5,-4.5,-3.5,-2.5,-2) & (-4,-3.75,-3.25,-2.75.-2.25,-2) \\ (-2,-1.25,0.25,1.75,3.25,4) & (1,2,4,6,8,9) & (-3,-2.5,-1.5,-0.5,0.5,1) \end{bmatrix}$$

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ISBN: 978-9952-610-30-7

$$\begin{bmatrix} (0,0.57,0.86,1.14,1.43,2) & (2,2.57,2.86,3.14,3.43,4) & (0.5,0.79,0.93,1.07,1.21,1.5) \\ (-2,-0.86,-0.29,0.29,0.86,2) & (-6,-4.86,-4.29,-3.71,-3.14,-2) & (-4,-3.43,-3.14,-2.86,-2.57,-2) \\ (-2,-0.29,0.57,1.43,2.29,4) & (1,3.29,4.43,5.57,6.71,9) & (-3,-1.86,-1.29,-0.71,-0.14,1) \end{bmatrix}$$

The above fuzzy payoff matrices are converted into crisp payoff matrices using the ranking function (7) of proposed centroid (6)

$$\begin{bmatrix} 1.1139 & 3.0399 & 1.1139 \\ -0.4907 & -4.0300 & -3.0399 \\ 1.1139 & 5.0240 & -1.1139 \end{bmatrix} \quad \begin{bmatrix} 1.1181 & 3.0444 & 1.1160 \\ -0.4908 & -4.0208 & -3.0353 \\ 1.1264 & 5.0425 & -1.1056 \end{bmatrix}$$

$$\begin{bmatrix} 1.1092 & 3.0347 & 1.1115 \\ -0.4909 & -4.0405 & -3.0451 \\ 1.0997 & 5.0030 & -1.1234 \end{bmatrix}$$

The maximin value and minimax values are coincided for the above three problems. So the problems have the saddle point.

The maximin and minimax values are marked by (*) and (+) respectively as shown below:

$$\begin{bmatrix} 1.1139^{*+} & 3.0399 & 1.1139^{*+} \\ -0.4907 & -4.0300^{*} & -3.0399 \\ 1.1139^{+} & 5.0240^{+} & -1.1139^{*} \end{bmatrix} \quad \begin{bmatrix} 1.1181 & 3.0444 & 1.1160^{*+} \\ -0.4908 & -4.0208^{*} & -3.0353 \\ 1.1264^{+} & 5.0425^{+} & -1.1056^{*} \end{bmatrix}$$

$$\begin{bmatrix} 1.1092^{*+} & 3.0347 & 1.1115^{+} \\ -0.4909 & -4.0405^{*} & -3.0451 \\ 1.0997 & 5.0030^{+} & -1.1234^{*} \end{bmatrix}$$

We observed the following things from the above three problems.

In problem I, that there exist one saddle point at the position (1, 3). In problem II, there exist two saddle points at positions (1, 1) and (1, 3). Finally in problem III, that there exist one saddle point at the position (1, 1).

Thus the solutions to the crisp data based above problems are given by

Problem solved under Hexagonal Fuzzy Environment				
Problems	Optimum Strategy		Value of the Game	
	Player P	Player Q	Player P	Player Q
I	P_1	Q_1 &Q_3		-1.1139
II	P_1	Q_3		-1.1160

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

III	P_1	Q_1		-1.1092

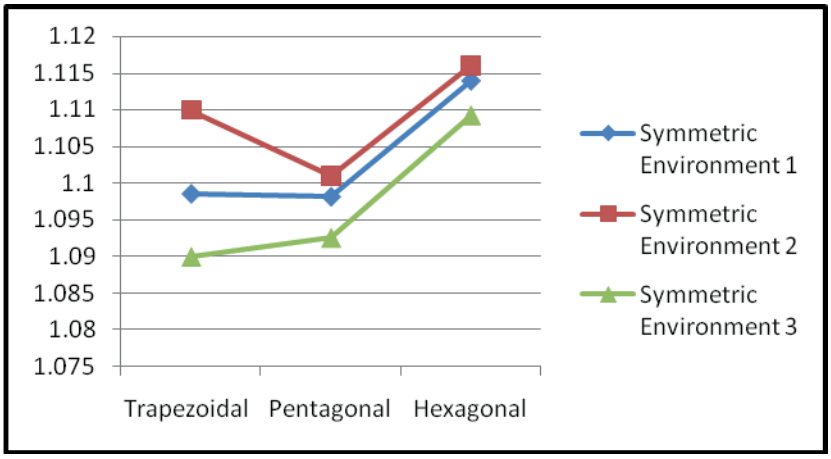


FIGURE 5.Values of the Game for IDBGTP

Therefore, the Value of the Game for given IDGTP = Max { Max {1.0985, 1.1099, 1.0899}, Max {1.0981, 1.1009, 1.0925}, Max {1.1139, 1.1160, 1.1092} } = Max {1.1099, 1.1009, 1.1160} = 1.1160.

It is observed from the above illustration for pure and mixed strategies that we can get maximum gain for player I and minimum loss for player II in the 2nd symmetric fuzzy environment with regard to the three different shapes of fuzzy numbers taken in this study as per the utilization of its new centroids for defuzzification. Hence the study suggests that if we solve the matrix game with payoffs of interval number in the second symmetric fuzzy environment with regard to any shape of fuzzy number, it will give the effective optimum solution as per the proposed ranking function of new centroids of trapezoidal, pentagonal and hexagonal fuzzy numbers.

6. CONCLUSİON

The matrix games with fuzzy payoffs have been widely studied in the literature. But, very few of the researchers have used interval numbers for representing the payoffs in game theory studied under uncertainty. Moreover, in finding the solution of interval data based game theoretical problems, they used interval arithmetic for its calculation based on traditional methods. In recent years, fuzzy set theory has got the recognition among many researchers for solving the optimization problems with imprecise information. The reason for utilizing this theory is that it has different shapes of membership functions for representing the vagueness. But some particular shape of membership functions only are being used by the researchers in frequent manner. Considering these things in our mind, we have proposed a new algorithm through connecting interval number with fuzzy number of its different shapes in order to find the effective solution of game theoretical problems which is the one of the special theory of optimization that deals the competitive situation with general features. Furthermore,

the study has made an attempt to analyse the solutions of interval matrix games under various symmetric fuzzy environment with the help of various forms of fuzzy number.

REFERENCES

Arindam Chaudhuri, Solving rectangular fuzzy games through, Open Computing Science 7 (2017) 26 – 50.

M.G. Brikaa, Zhoushun Zheng and El-Saeed Ammar, Fuzzy multi-objective programming approach for constrained matrix games with payoff of fuzzy rough numbers, Symmetry11 (2019) 2 – 26.

Deng-Feng and Fang-Xuan Hong, Solving constrained matrix games with payoffs of triangular fuzzy numbers, Computers and Mathematics with Applications64 (2012) 432 – 446.

Dong Qiu, Yumei Xing and Shuqiao Chen, Solving fuzzy matrix games through a ranking value function, Journal of Mathematics and Computer Science18 (2018) 175 – 183.

Handan Akyar and Emrah Akyar, A graphical method for solving interval matrix games, Abstract and Applied Analysis 2011 (2011) 1 – 17.

Iden Hassan Hussein and Zainab Saad Abood, A new proposed ranking function for solving fuzzy games problems, International Journal of Mathematics and statistics Studies5 (2017) 34 – 40.

Iden Hasan Hussein and Zainab Saas Abood, Solving fuzzy games problems by using ranking function, Baghdad Science Journal15 (2018) 98 – 101.

Jishu Jana and Sankar Kumar Roy, Solution of matrix games with generalized trapezoidal fuzzy payoffs, Fuzzy Information and Engineering 10 (2018) 213 – 224.

J. Jon Arockiarajand N. Sivasankari, Solution of fuzzy game problem using hexagonal fuzzy numbers, International Journal of Mathematics and its Applications4 (2016) 381 – 387.

C. Karthiand K. Selvakumari, Refinements of nash equilibrium in a pentagonal fuzzy bimatrix game, IOP Publishing: Journal of Physics1362 (2019) 1 – 11.

Konstantin N. Kudryavtsev, Irina S. Stabulit and Viktor I. Ukhobotov, A bimatrix game with fuzzy payoffs and crisp game, Proceedings of OPTIMA(2017) 343 – 349.

B. Krishnapriya and K. Senbagam., Solving fuzzy game problems using pentagonal and hexagonal fuzzy numbers, International Journal of Scientific Research and Review 8 (2019) 1409 – 1420.

G. Krishnaveni and K. Ganesan, A new approach for the solution of fuzzy games, IOP Publishing Conference Series: Journal of Physics1000 (2018) 1 – 7.

P. Maheswari and M. Vijaya, On solving two-person zero-sum matrix games with payoff of generalized trapezoidal fuzzy numbers based on fuzzy ranking values using incenter of centroids, Advances and Applications in Mathematical science18 (2019) 1245 – 1260.

Mijanur Rahaman Seikh, Prasun Kumar Nayak and Madhumangal pal, Solving bi-matrix games with pay-offs of triangular intuitionistic fuzzy numbers, European Journal of Pure and Applied Mathematics 8 (2015) 153 – 171.

R. Monisha and K. Sangeetha, To solve fuzzy game problem using pentagonal fuzzy numbers, International Journal for Modern Trends in Science and Technology3 (2017) 152 – 154.

Namarta, Umesh Chandra Gupta and Neha Ishesh Thakur, Solution of fuzzy game problem by using dodecagonal fuzzy numbers, International Journal of Scientific & Engineering Research 8 (2017) 1 – 8.

Namarta, Umesh Chandra Gupta and Neha Ishesh Thakur, Applications of game problem in fuzzy environment, International Journal for Research in Engineering Application & Management 4 (2019) 228 – 232.

M.R. Seikh, S. Karmakar and M. Xia, Solving matrix games with hesitant fuzzy pay-offs, Iranian Journal of Fuzzy Systems 17 (2020) 25 – 40.

R. Senthil Kumar and S. Kumaraghuru, Solution of fuzzy game problem using triangular fuzzy number, International Journal of Innovative Science, Engineering & Technology2 (2015) 497 – 502.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

T. Stalinand M. Thirucheran, Solving fuzzy matrix game defuzzificated by trapezoidal parabolic fuzzy numbers, International Journal for Scientific Research & Development 3 (2015) 1006 – 1010.

D. Stephen Dinagar and U. Hari Narayanan, Solving fuzzy matrix problem involving hexagonal fuzzy numbers, Bulletin of Mathematics and Statistics Research5 (2017) 119 – 130.

M. Thirucheran, E.R. Meena Kumari, and S. Lavanya, A new approach for solving fuzzy game problem, International Journal of Pure and Applied Mathematics114 (2017) 67 – 75.

Z. Yang and Y. Song, Matrix game with payoffs represented by triangular dual hesitant fuzzy numbers, International Journal of Computers Communications & control15 (2020) 1 – 11.

L.A. Zadeh, Fuzzy Sets, Information and Control8 (1965), 338 – 353.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COP 29 (TƏRƏFLƏRİN KONFRANSI)

İlqar V.Əliyev

Azərbaycan Univeristeti politolgiya

COP 29, BMT-nin İqlim Dəyişmələri üzrə Çərçivə Konvensiyasının (UNFCCC) illik görüşlərinin bir hissəsidir və 2024-cü ilin sonunda Birləşmiş Ərəb Əmirliklərinin Dubay şəhərində keçiriləcək. Bu konfrans iqlim dəyişikliyi ilə mübarizə məqsədilə ölkələri bir araya gətirən ən əhəmiyyətli qlobal platformalardan biridir. COP görüşləri Paris Sazişinin icrasını təmin etmək, emissiyaların azaldılması və adaptasiya tədbirlərinin müzakirəsi üçün imkan yaradır.

COP 29-un əsas mövzuları arasında iqlim maliyyələşdirilməsi, karbon emissiyalarının azaldılması, yenilənə bilən enerji mənbələrinin təşviqi və inkişaf etməkdə olan ölkələrə texniki dəstək dayanır. Bu görüşdə əsas diqqət "qayıdış məqsədli mexanizmlər" və "itki və zərərin kompensasiya fondu" kimi kritik məsələlərə yönəldiləcəkdir.

Bu tədbirdə müxtəlif hökumətlər, qeyri-hökumət təşkilatları, elm adamları və iş adamları iştirak edəcək. COP 29 qlobal istiləşməni 1,5°C ilə məhdudlaşdırmaq məqsədilə ölkələrdən daha ambisiyalı hədəflər və konkret tədbirlər tələb edir. Konfransın uğuru, beynəlxalq əməkdaşlığın gücləndirilməsi və ekoloji tarazlığın qorunması baxımından böyük əhəmiyyət daşıyır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TITLE: HEAT TRANSFER IN MICROPOLAR CASSON NANOFLUIDS CONTAINING CU NANOPARTICLES OF DIFFERENT GEOMETRIES IN THE PRESENCE OF TRANSVERSE MAGNETIC FIELD

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ABSTRACT

Sodium alginate (SA)-based nanofluids offer a novel approach to investigating heat transfer phenomena. Due to their diminutive size, these nanofluids exhibit distinct physical properties compared to conventional fluids. This study examines the influence of particle shape on the non-Newtonian micropolar Casson Cu-nanofluid formulated with SA. The behavior of the fluid is analyzed under the influence of a magnetic field, which causes the sheet to stretch or shrink. The Cu-nanofluid comprises nanoparticles of various geometries, including bricks, cylinders, platelets, and blades, in a solution with a Prandtl number of Pr = 6.45. Utilizing the Tiwari-Das nanofluid model, a mathematical framework was developed. Necessary transformations were applied to convert the non-linear partial differential equations (PDEs) into a system of non-linear ordinary differential equations (ODEs), which were then solved numerically with appropriate boundary conditions. The Runge-Kutta-Fehlberg (RKF) method was employed to obtain numerical solutions for the transformed equations. This approach allows for the exploration of various parameters, as well as the analysis of velocity and temperature fields. The findings reveal that blade-shaped nanoparticles exhibit the highest temperatures, while platelet-shaped Cu-nanoparticles demonstrate greater velocities compared to bricks and cylinders. Additionally, it was found that SA maintains a higher temperature than kerosene.

Keywords: Nanofluid; magnetic field; heat transfer; micro-rotation

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE IMPACT OF VARIATION OF CHANNEL DOPING CONCENTRATION ON SHORT CHANNEL EFFECTS IN NANOSCALE DOUBLE GATE FINFETS: A COMPARATIVE STUDY

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ABSTRACT

The impact of varying channel doping concentration on short channel effects (SCEs) in nanoscale double gate FinFETs using Gallium Arsenide (GaAs), Gallium Antimonide (GaSb), Gallium Nitride (GaN) and Silicon (Si) as channel materials is investigated. The analysis is carried out in the PADRE simulator environment. We examine critical parameters such as Drain Induced Barrier Lowering (DIBL), Subthreshold Swing (SS), Threshold Voltage Roll-off, On-current and Transconductance. The results reveal that GaAs-FinFET showed exceptional on-current, DIBL characteristics and subthreshold swing. Meanwhile, GaSb-FinFET demonstrated better threshold voltage characteristics. On the other hand, GaN-FinFET demonstrated superior transconductance. These findings are critical to the advancement of semiconductor technology, the enhancement of device performance, and the resolution of issues related to the continuous scaling of electronic devices. Studies like these provide insights that aid in the development of transistor technologies that are more reliable and efficient.

KEYWORDS

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CHANNEL DOPING CONCENTRATION, CHARACTERISTIC, FINFETS, ON-CURRENT, PADRE, SEMICONDUCTOR, TRANSCONDUCTANCE GENETIC FACTORS IN HUMAN OBESITY

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Key words: disorders, obesity, mutations, homeostasis, gene

Obesity is a major health problem worldwide. It is more common in established countries but is on the increase in developing countries. The worldwide prevalence of obesity [body mass index (BMI) ≥ 30 kg m^2] has doubled between 1980 and 2008, with a prevalence of 13% in the adult population reported in 2014. In 2013, there were 42 million obese children below the age of five years. BMI, according to the World Health Organization (WHO), is classified in adults as overweight at 25–29.9 kg/m^2, obese at 30–39 kg/m^2, and morbidly obese at 40 kg/m^2 and above [1-3].

Obesity is a complex multifactorial disorder with genetic and environmental factors. The increased prevalence of obesity is impacted by the environment as high caloric food sources with a sedentary lifestyle has decreased energy expenditure. Twin and family studies have documented the role of genetic factors in obesity, with the risk of childhood obesity increasing with a positive family history of obesity. There is a high concordance rate for obesity in monozygotic twins vs dizygotic twins and an estimated heritability for obesity at between 40% and 75% in twin studies [4].

New advances in genetic evaluation and analysis have led to the identification of obesity-related genes [5].

The past decade has been a remarkable time for the genetic study of human obesity. We have seen the first definitive descriptions of genetic mutations leading to obesity in man, the identification of a subtype of genetic obesity that is dramatically responsive to mechanism-based therapy, the discovery of a monogenic form of obesity that is one of the commonest single-gene disorders in humans, and the first convincing reports of the identification of common genetic variants predisposing to obesity in the wider population [6,7].

We have learned that genes can powerfully influence human eating behaviour and that obesity, at least in part, is a genetically determined disorder of appetitive behaviour.

The pace of discovery is escalating and human genetics will play a crucial role in improving our understanding of basic energy regulation, in aiding the discovery of new effective drugs and optimizing their use, and in targeting behavioural strategies to those who will benefit most from them. Any scientific strategy designed to understand and combat human obesity will need to have firmly embedded at its core a deep understanding of, and engagement with, human genetics.

Our studies have demonstrated that MRAP2 variants associated with human obesity impair multiple aspects of MC4R signaling. Consistent with previous studies we showed that wild-type MRAP2 enhances MC4R coupling to Gs and increases cAMP signaling and demonstrated that most obesity-associated MRAP2 variants impair cAMP signaling. However, some variants did not affect cAMP signaling which is consistent with previous studies of obesity-associated MC4R mutations. All MRAP2 variants that were identified in at least one overweight or obese individual also impaired MC4R-mediated IP3 signaling.

MRAP2 had no effect on the overall cell surface expression of MC4R in our studies, and we did not detect any differences in MC4R expression in the presence of MRAP2 mutant proteins. This is consistent with previous studies that similarly reported that MRAP2 does not affect MC4R surface expression. However, some studies have suggested MRAP2 can reduce or increase MC4R cell surface expression, while investigations in inner medullary collecting duct (IMCD3) cells have shown that MRAP2 enhances MC4R expression at primary cilia, an organelle that is known to be important in energy homeostasis and weight control.

REFERENCES

1.Kaur Y., de Souza R.J., Gibson W.T., Meyre D. A systematic review of genetic syndromes with obesity. Obes. Rev. 2017;18:603–634. doi: 10.1111/obr.12531. [DOI] [PubMed] [Google Scholar]

2.Purnell J.Q. Definitions, Classification, and Epidemiology of Obesity. In: Feingold K.R., Anawalt B., Boyce A., Chrousos G., de Herder W.W., Dhatariya K., Dungan K., Hershman J.M., Hofland J., Kalra S., et al., editors. Endotext. MDText.com, Inc.; South Dartmouth, MA, USA: 2000. [PubMed] [Google Scholar]

3.Wardle J., Carnell S., Haworth C.M., Plomin R. Evidence for a strong genetic influence on childhood adiposity despite the force of the obesogenic environment. Am. J. Clin. Nutr. 2008;87:398–404. doi: 10.1093/ajcn/87.2.398. [DOI] [PubMed] [Google Scholar]

4.Singh R.K., Kumar P., Mahalingam K. Molecular genetics of human obesity: A comprehensive review. Comptes Rendus Biol. 2017;340:87–108. doi: 10.1016/j.crvi.2016.11.007. [DOI] [PubMed] [Google Scholar]

5.Duis J., Butler M.G. Syndromic and Nonsyndromic Obesity: Underlying Genetic Causes in Humans. Adv. Biol. 2022:e2101154. doi: 10.1002/adbi.202101154. [DOI] [PubMed] [Google Scholar]

6.Butler M.G. Single Gene and Syndromic Causes of Obesity: Illustrative Examples. Prog. Mol. Biol. Transl. Sci. 2016;140:1–45. doi: 10.1016/bs.pmbts.2015.12.003. [DOI] [PMC free article] [PubMed] [Google Scholar]

7.Farooqi I.S. Genetic and hereditary aspects of childhood obesity. Best Pract. Res. Clin. Endocrinol. Metab. 2005;19:359–374. doi: 10.1016/j.beem.2005.04.004. [DOI] [PubMed] [Google Scholar]

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

IMPORTANCE OF GENETIC COUNSELING FOR PATIENTS WITH GM1 GANGLIOSIDOSIS

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Key words: GM1 gangliosidosis, beta galactosidase, enzyme deficiency, chromosome disorders.

GM1 gangliosidosis is a lysosomal disease characterized by the accumulation of GM1 ganglioside, both in the visceral and central nervous system, due to a deficiency of the enzyme beta galactosidase. It is a rare recessive genetic disorder that affects the *GLB1* gene located on chromosome 3. Its incidence is estimated to be 1:100,000-200,000 live births. It mainly affects the CNS and viscera, in addition to producing important skeletal abnormalities. It often occurs with the presence of vacuolated lymphocytes in the peripheral blood or bone marrow sample. It has three forms of presentation, which makes its identification even more challenging due to the wide clinical spectrum [1-3].

The disease is divided into three types, and the severity of the phenotype is associated with the degree of enzyme deficiency. The infantile form (type I) is the most severe; establishes in the first 6 months of life with generalized CNS involvement, hypotonia, delay in neuropsychomotor development, apathy, weak sucking, subnormal weight gain, hepatosplenomegaly, facial dysmorphism, macular cherry-red spot, skeletal dysplasia, repeated respiratory infections, and early death [4].

The early and extensive involvement of the CNS leads to a marked delay in neuropsychomotor development, which gradually progresses to generalized hypotonia and seizures. Cardiomyopathy and cardiac hypertrophy are less frequent findings.

The juvenile form (type II) develops between 7 months and 3 years of age, with a slower course. It has generalized CNS involvement with psychomotor deterioration, seizures, and localized skeletal involvement. With this form, the child usually survives only until childhood, since convulsive conditions and recurrent infections, especially pneumonia, are usually the causes of death [5].

The adult form (type III) manifests from 3 to 30 years of age; the involvement of the CNS is more localized, presenting with dystonia, speech and gait disorders. The progression of symptoms is slow, but the intellectual disability is accentuated [6].

So far, there is no effective treatment for GM1 gangliosidosis, that is, patients with the disease receive symptomatic and palliative measures. Some new therapeutic strategies have been explored, mainly in animals, such as bone marrow transplantation, gene therapies, and substrate reduction therapies.

However, these approaches are still far from reaching a viable clinical application. Thus, the early diagnosis of the disease is extremely important, as its only form of prevention, at the moment, is through genetic counseling.

References

1.Cabral A, Tasso T, Eusébio F, et al. Gangliosidose GM1, tipo I, infantil — a propósito de 8 casos. Acta Pediatr Port. 2001; 32(2): 293–99.

2.Khatiwada B, Pokharel A. Lysosomal storage disease. JNMA J Nepal Med Assoc. 2009; 48(175): 242–45.

3.Padhi TR, Pattnaik S, Kesarwani S, Das T. Macular cherry-red spot helps diagnose rare storage disorder in an infant with repeated respiratory tract infections: case report. Semin Ophthalmol. 2015; 30(3): 224–26. doi:10.3109/08820538.2013.835848.
» https://doi.org/10.3109/08820538.2013.835848

4.Kivlin JD, Sanborn GE, Myers GG. The cherry-red spot in Tay-Sachs and other storage diseases. Ann Neurol. 1985; 17(4): 356–60. doi:10.1002/ana.410170409.
» https://doi.org/10.1002/ana.410170409

5.Erol I, Alehan F, Ali Pourbagher M, Canan O, Vefa Yildirim S. Neuroimaging findings in infantile GM1 gangliosidosis. Eur J Paediatr Neurol. 2006; 10(5-6): 245–48. doi:10.1016/j.ejpn.2006.08.005.
» https://doi.org/10.1016/j.ejpn.2006.08.005

6.Autti T, Joensuu R, Åberg L. Decreased T2 signal in the thalami may be a sign of lysosomal storage disease. Neuroradiology. 2007; 49(7): 571–78. doi:10.1007/s00234-007-0220-6.
» https://doi.org/10.1007/s00234-007-0220-6

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GENETIC DIAGNOSIS OF MONOGENIC DIABETES

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Key words: Diabetes, mutation, diseases, insulin, treatment

Monogenic diabetes is caused by a single defect in one of over 40 genes (1, 2).

Since maturity-onset diabetes of the young (MODY) was named by Fajans for the type 2 diabetes–like presentation in young people with an autosomal dominant pattern of inheritance our understanding of phenotypic and genetic heterogeneity in monogenic diabetes has increased. The major monogenic diabetes categories are MODY, neonatal diabetes mellitus (NDM), and syndromic diabetes (5). Misdiagnosis is frequent because of overlapping of phenotypes with type 1 diabetes (T1D), such as young onset and leanness, and with type 2 diabetes (T2D), such as preserved β cell function and family history. Tailored treatment of some monogenic diabetes depends on the disease's underlying etiology (3, 4).

We will describe monogenic diabetes types, etiologies, diagnosis, management, and strategies to improve diagnosis.

Type 2 diabetes (T2D) has been reproducibly clustered into five subtypes based on six-clinical variables; age at diabetes onset, body mass index (BMI), Glutamic acid decarboxylase autoantibodies (GADA), glycated hemoglobin (HbA1c) and insulin secretion and resistance estimated as HOMA2B and HOMA2IR derived from fasting glucose and Cpeptide. These subtypes have different disease progression and risk of complications. The newly defined subtypes are called Severe Autoimmune Diabetes (SAID), Severe Insulin Deficient Diabetes (SIDD), Severe InsulinResistant Diabetes (SIRD), Mild Obesity-related Diabetes (MOD), and Mild Age-Related Diabetes (MARD) (5-7).

The main aim of the thesis was to characterize the subtypes using genetics and biomarkers to investigate potential etiological differences, identify subtype-specific genetic associations and determine the underlying mechanisms of kidney complications in the subtypes. In Paper the proteomic profiles of the subtypes were studied using biomarkers measured on Olink panels. Machine learning algorithms were applied to prioritize biomarkers, followed by Menedelian Randomization (8).

The variant near the LRMDA gene was uniquely associated with MOD. In the CTNNA2 gene at near genomewide significance, but was not associated in any of the other subtypes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The newly defined subtypes are partially distinct with genetically different backgrounds and SIRD is suggested to have more beta-cell independent pathogenesis. There is some suggestive support for different genetic backgrounds of DKD in diabetes subtypes. Biomarkers could be valuable for better discrimination of subtypes and cross cohort comparisons in larger datasets. The diabetes subclassification approach paves the way for individualized patient management and the development of new therapeutic targets (9).

References

1.Hattersley AT, et al. ISPAD clinical practice consensus guidelines 2018: the diagnosis and management of monogenic diabetes in children and adolescents. *Pediatr Diabetes*. 2018;19(suppl 27):47–63.

2.American Diabetes Association. 2. Classification and diagnosis of diabetes: *Standards of Medical Care in Diabetes—2020*. *Diabetes Care*. 2020;43(suppl 1):S14–S31.

3.Tattersall RB. Mild familial diabetes with dominant inheritance. *Q J Med*. 1974;43(170):339–357.

4.Fajans SS, et al. The Banting Memorial Lecture 1978. Clinical and etiologic heterogeneity of idiopathic diabetes mellitus. *Diabetes*. 1978;27(11):1112–1125.

5.Laver TW, et al. The common p.R114W HNF4A mutation causes a distinct clinical subtype of monogenic diabetes. *Diabetes*. 2016;65(10):3212–3217.

6.Sigma Type 2 Diabetes Consortium, et al. Association of a low-frequency variant in HNF1A with type 2 diabetes in a Latino population. *JAMA*. 2014;311(22):2305–2314.

7.Lango Allen H, et al. Polygenic risk variants for type 2 diabetes susceptibility modify age at diagnosis in monogenic HNF1A diabetes. *Diabetes*. 2010;59(1):266–271.

8.Kleinberger JW, et al. Monogenic diabetes in overweight and obese youth diagnosed with type 2 diabetes: the TODAY clinical trial. *Genet Med*. 2018;20(6):583–590.

9.Patel KA, et al. Heterozygous RFX6 protein truncating variants are associated with MODY with reduced penetrance. *Nat Commun*. 2017;8(1):888.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FREQUENCY OF THE G6PD-DEFICIENT IN AZERBAIJAN POPULATION.

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Keywords: G6PD deficient, mutations, chromosome, public health, prenatal diagnosis

Abstract

Newborn G6PD deficiency screening has been recognized as an essential component of public health care in most developed and some Mediterranean countries. However, such screening is yet to be widely embraced in Azerbaijan. The aim of the present study was to determine the normal values of G6PD and deficiency prevalence of this enzyme in different age groups of people living in the western region of Azerbaijan and accordingly inform and educate about favism to those asymptomatic carriers who usually are not aware of their G6PD deficient status.

Introduction

The diagnosis of G6PD deficiency is made by a quantitative spectrophotometric analysis or, more commonly, by a rapid fluorescent spot test detecting the generation of NADPH from NADP. The test is positive if the blood spot fails to fluoresce under ultraviolet light. In field research, where quick screening of a large number of patients is needed, other tests have been used; however, they require definitive testing to confirm an abnormal result. Tests based on polymerase chain reaction detect specific mutations and are used for population screening, family studies, or prenatal diagnosis [1-4].

In patients with acute hemolysis, testing for G6PD deficiency may be falsely negative because older erythrocytes with a higher enzyme deficiency have been hemolyzed. Young erythrocytes and reticulocytes have normal or near-normal enzyme activity. Female heterozygotes may be hard to diagnose because of X-chromosome mosaicism leading to a partial deficiency that will not be detected reliably with screening tests [5-7].

G6PD deficiency is one of a group of congenital hemolytic anemias, and its diagnosis should be considered in children with a family history of jaundice, anemia, splenomegaly, or cholelithiasis, especially in those of Mediterranean or African ancestry [8,9].

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Testing should be considered in children and with an acute hemolytic reaction caused by infection, exposure to a known oxidative drug, or ingestion of fava beans.

Although rare, G6PD deficiency should be considered as a cause of any chronic nonspherocytic hemolytic anemia across all population groups [10, 11].

G6PD deficiency occurs with increased frequency throughout Africa, Asia, the Mediterranean, and the Middle East. In the United States, black males are most commonly affected, with a prevalence of approximately 10 percent. Prevalence of the deficiency is correlated with the geographic distribution of malaria, which has led to the theory that carriers of G6PD deficiency may incur partial protection against malarial infection. Cases of sporadic gene mutation occur in all populations [12-16].

Materials and methods

The gene mutations affecting encoding of G6PD are found on the distal long arm of the X chromosome. More than 400 mutations have been identified, most being missense mutations. Most of the variants occur sporadically, although the G6PD Mediterranean and the G6PD A–variants occur with increased frequency in certain populations. clinical presentation and laboratory investigations including the complete blood count, red blood cells morphology, liver and renal functions and quantitative assay of G6PD enzyme activity by spectrophotometric method. Mutations were analyzed with LighCycler 5.1 real-time PCR melting-curve analysis.

Results

There is no significant statistical difference of G6PD activity between males and females, although frequency of the G6PD-deficient phenotype is relatively high in Azerbaijan. The results emphasize a need for screening for G6PD deficiency before therapy in this region of Azerbaijan. Normal mean values of G6PD in healthy males were 9.95 +/- 9.65 IU/g Hb, in females were 9.15 +/- 4.70 IU/g Hb. The frequencies of severe and mild G6PD deficiencies were 0.37% and 7.07% in females, respectively, whereas in males it was 8.27%. Overall frequency of the G6PD-deficient phenotype was detected as 7.8%.

References:

1. Luzzatto L., Seneca E. G6PD deficiency: A classic example of pharmacogenetics with on-going clinical implications. *Br. J. Haematol.* 2014;164:469–480.

2. Piomelli S., Corash L.M., Davenport D.D., Miraglia J., Amorosi E.L. In vivo lability of glucose-6-phosphate dehydrogenase in GdA- and GdMediterranean deficiency. *J. Clin. Investig.* 1968;47:940–948.

3. Garcia J., Han D., Sancheti H., Yap L.P., Kaplowitz N., Cadenas E. Regulation of mitochondrial glutathione redox status and protein glutathionylation by respiratory substrates. *J. Biol. Chem.* 2010;285:39646–39654.

4.Huseynova L.S. Methods for extracting genomic DNA from whole blood samples. 9th International Congress on Medicine, Nursing and Health Sciences in a Changing World. Turkey, Germany.2023. p.182-187

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

5.Huseynova L.S.,Ansarova A.H. Application of Sanger sequence technology in the study of CFTR, MEFV, GALT, PAH, BCKDHB and DBT gene mutations in the population Azerbaijan. International journal of online and biomedical engineering. Vol. 19, No. 01, Austria. 2023. P. 153-161

6.Aghayeva S.A., Huseynova L.S., Kichibekov B.R. , Aliyeva K.A., Khalilov R.I. Inherited metabolic disease phenylketonuriya and deficiency of G6PD enzim in a family study. Germany. German Herald Science N2/2018., p 34-36

7. Nakamura T., Yoshimoto K., Aoyama K., Ichihara A. Hormonal regulations of glucose-6-phosphate dehydrogenase and lipogenesis in primary cultures of rat hepatocytes. *J. Biochem.* 1982;91:681–693.

8. Manos P., Nakayama R., Holten D. Regulation of glucose-6-phosphate dehydrogenase synthesis and mRNA abundance in cultured rat hepatocytes. Pt 1*Biochem. J.* 1991;276:245–250.

9. He C., Yang J., Ding J.W., Li S., Wu H., Xiong Y., Zhou F., Jiang Y.R., Teng L., Yang J. Downregulation of glucose-6-phosphate dehydrogenase by microRNA-1 inhibits the growth of pituitary tumor cells. *Oncol. Rep.* 2018;40:3533–3542. 10. Barajas J.M., Reyes R., Guerrero M.J., Jacob S.T., Motiwala T., Ghoshal K. The role of miR-122 in the dysregulation of glucose-6-phosphate dehydrogenase (G6PD) expression in hepatocellular cancer. *Sci. Rep.* 2018;8:9105.

11. Pes G.M., Parodi G., Dore M.P. Glucose-6-phosphate dehydrogenase deficiency and risk of cardiovascular disease: A propensity score-matched study. *Atherosclerosis.* 2019;282:148–153.

12. Thomas J.E., Kang S., Wyatt C.J., Kim F.S., Mangelsdorff A.D., Weigel F.K. Glucose-6-Phosphate Dehydrogenase Deficiency is Associated with Cardiovascular Disease in U.S. Military Centers. *Tex. Heart Inst. J.* 2018;45:144–150.

13. Fois A., Dore M.P., Manca A., Scano V., Pirina P., Pes G.M. Association between Glucose-6-Phosphate Dehydrogenase Deficiency and Asthma. *J. Clin. Med.* 2021;10:5639.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

İDENTIFICATION OF D442G MUTATION IN THE *CETP* GENE

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Key words: CETP* gene, *D442G mutation, cholesterol, disease, lipoprotein,

Epidemiologic studies have shown that high density lipoprotein (HDL) cholesterol is a strong negative risk factor for atherosclerotic vascular disease. The metabolism of HDL is complex and regulated by its apolipoprotein synthesis and catabolism, lipoprotein lipase, hepatic lipase activities, plasma lecithin cholesteryl acyltransferase activity and plasma cholesteryl ester transfer protein (*CETP*) (1).

CETP functions to transfer cholesteryl ester from HDL to triglyceride-rich lipoproteins and regulates plasma HDL cholesterol level. The human CETP gene consists of 16 exons encompassing 25,000 bases on chromosome 16q13 (2,3).

A number of mutations in the *CETP* gene have been described since the first report in 1990 (4,5).

D442G mutation results in plasma *CETP* deficiency and increased plasma HDL cholesterol level (6).

Plasma HDL cholesterol level in women is affected by hormonal status. Hormone replacement therapy (HRT) apparently increases plasma HDL cholesterol level, even though the most recent studies did not resolve the question of whether HRT will prevent coronary heart disease (7-10).

To date, several common polymorphisms have been reported in the *CETP* gene. Most are located within intronic regions and do not appear to affect either the secretion or the function of *CETP*. In addition, there are no data available regarding children with these mutations, who seem to be less affected by environmental factors than subjects reported previously. As a first step to clarify the relation between *CETP* gene mutations and HDL, in the present study we characterized children with the D442G gene mutation (10,11).

In this preliminary study, we found that in dialysis patients with submedian HDL-C levels, the D442G mutation in the *CETP* gene may be an independent risk factor for VD. Subjects with the *CETP* mutation have been shown to have qualitative defects in the ability of HDL to participate in reverse cholesterol transport, that is, an increase in the number of abnormal HDL-2 particles that has less antiatherogenic effects and a deficiency of smaller HDL species that are involved in cellular cholesterol efflux. These qualitative defects may predominate when the mutation carriers had a considerable decrease in HDL particle number, for example, low HDL-C levels of less than 45 mg/dl. Thus, in the low–HDL-C subgroup of this study, group M (+) patients may have lower activity of

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

reverse cholesterol transport or less antiatherogenic effects and more susceptibility to atherosclerotic complications than group M (-) patients, although HDL-C levels were comparable between the two groups. However, there could be unknown genes or other clinical factors influencing VD and associated with the *CETP* mutation.

We presented another finding that atherogenic lipid profiles combined with low HDL-C levels may be positively related with VD in group M (+) but negatively related in group M (-).

This finding may reflect a lower activity of reverse cholesterol transport in group M (+) patients with low HDL-C levels. We may need to pay more attention to lipid profiles, especially in dialysis patients with the *CETP* mutation.

References

1.Gordon DJ, Probstifield JL, Garrison RJ, Neaton JD, Castelli WP, Knoke JD, Jacobs DR, Jr, Bangdiwala S, Tyroler HA. High-density lipoprotein cholesterol and cardiovascular disease. Four prospective American studies. Circulation. 1989;79:8–15. doi: 10.1161/01.cir.79.1.8. [DOI] [PubMed] [Google Scholar]

2.Gordon DJ, Rifkind BM. High density lipoprotein. The clinical implications of recent studies. N Engl J Med. 1989;321:1311–6. doi: 10.1056/NEJM198911093211907. [DOI] [PubMed] [Google Scholar]

3.Agellon LB, Quinet EM, Gillette TG, Drayna DT, Brown ML, Tall AR. Organization of the human cholesteryl ester transfer protein gene. Biochemistry. 1990;29:1372–6. doi: 10.1021/bi00458a004. [DOI] [PubMed] [Google Scholar]

4.Inazu A, Brown ML, Hesler CB, Agellon LB, Koizumi J, Takata K, Maruhama Y, Mabuchi H, Tall AR. Increased high-density lipoprotein levels caused by a common cholesteryl-ester transfer protein gene mutation. N Engl J Med. 1990;323:1234–8. doi: 10.1056/NEJM199011013231803. [DOI] [PubMed] [Google Scholar]

5.Hill SA, McQueen MJ. Reverse cholesterol transport – A review of the process and its clinical implication. Clinical Biochemistry. 1997;30:517–25. doi: 10.1016/s0009-9120(97)00098-2. [DOI] [PubMed] [Google Scholar]

6.Tamminen M, Kakko S, Kesänienmi A, Savolainen MJ. A polymorphic site in the 3′ untranslated region of the cholesterly ester transfer protein (CETP) gene is associated with low CETP activity. Atherosclerosis. 1996;124:237–47. doi: 10.1016/0021-9150(96)05833-9. [DOI] [PubMed] [Google Scholar]

7.Hill SA, Thomson C, McQueen MJ. Cholesteryl ester transfer protein mutations, protein activity and HDL cholesterol concentration. Clin Chem Lab Med. 1998;36:629–32. doi: 10.1515/CCLM.1998.110. [DOI] [PubMed] [Google Scholar]

8.Inazu A, Jiang X-C, Haraki T, Yagi K, Kamon N, Koizumi K, Mabuchi H, Taketa R, Takata K, Moriyama Y, Tall AR. Genetic cholesteryl ester transfer protein deficiency caused by two prevalent mutations as a major determinant of increased levels of high density lipoprotein cholesterol. J Clin Invest. 1994;94:1872–82. doi: 10.1172/JCI117537. [DOI] [PMC free article] [PubMed] [Google Scholar]

9.Akita H, Chiba H, Tsuchihashi K, Tsuji M, Kumagai M, Matsuno K, Kobayashi K. Cholesteryl ester transfer protein gene: two common mutations and their effect on plasma high-density lipoprotein cholesterol content. J Clin Endocrinol Metab. 1994;79:1615–18. doi: 10.1210/jcem.79.6.7989465. [DOI] [PubMed] [Google Scholar]

10.Wring Group for PEPI Trial Effects of estrogen or estrogen/progestin regimens on heart disease risk factors in postmenopausal women: The Postmenopausal Estrogen/Progestin Interventions (PEPI) Trial. JAMA. 1995;273:199–208. [PubMed] [Google Scholar]

11.Friedwald WT, Levy RL, Frederickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma without use of the preparative ultracentrifuge. Clin Chem. 1972;18:499–502. [PubMed] [Google Scholar]

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FUZZY ORDERING APPROACH FOR QUEUEING MODEL WITH SERVER BREAKDOWNS, REPAIRS, VACATIONS, AND BACKUP SERVER

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Abstract:

This paper analyzes with Fuzzy Ordering approach for Queueing models wherein having a backup server during the absences (caused by vacations and breakdowns) of the main server have found many applications in practice. Such services offered by a backup server can be viewed as the (main) server working during a vacation or during a breakdown period. A backup server offering services can be thought of as the main server working (at a reduced rate) on vacations/repairs. Using Fuzzy ordering approach for the arrivals and modeling the service times with phase type distributions, we propose a model that generalizes some of the previously published ones on working-vacation-breakdown-repair queues. We carry out the steady-state analysis and report interesting illustrative numerical examples. We also prove decomposition results for the rate matrix and the mean number in the system under some special cases.

Keywords: Queueing Model, Fuzzy Numbers, Fuzzy Ordering, Performances,

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ISBN: 978-9952-610-30-7

FUZZY QUEUEING SYSTEM WITH SERVER BREAK DOWNS AND INDIVIDUAL CUSTOMER DUMPING

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Abstract:

We consider an M/M/1 queueing system with a finite capacity buffer in which the server is subject to breakdowns and repairs with Fuzzy Ordering approach. At the time of a breakdown, the customers, if any, present in the system will either decide to stay or abandon according to a probabilistic mechanism. This decision is made by every customer present in the system independent of the others. We assume that the arrivals of customers occur according to a Markovian arrival process. The shocks that create breakdowns of the servers are also assumed to follow a MAP independent of the other MAP. The service and the repair times of the server are assumed to follow (possibly) different phase type (PH) distributions. An arriving customer finding the buffer full will be lost. Further, an arriving customer finding the server under repair may decide to balk or join the queue at that instant. This queueing system, which generalizes some of the well-known queueing models in the literature, is studied as a GI/ M/ 1- type with a finite state space. The model is analyzed in steady-state and illustrative numerical examples including an optimization problem of interest are presented.

Keywords: Fuzzy Queue, Server Break down, Fuzzy Ordering, Performances.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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FUZZY VACATION QUEUING POLICY CONSIDERING SERVER'S DETERIORATION AND RECOVERY

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Abstract:

In this paper, we present a Fuzzy vacation queue model in which the service rate of the server deteriorates during the service period (e.g., due to the fatigue of a human server or the wear and ageing of machinery) and recovers during the vacation period (e.g., following a recuperation period for a human sever or the servicing of a machine). During the recuperation period, the main server is replaced with a temporary server with inferior capabilities. Using the Fuzzy Ordering approach, we analyze the effects of different vacation policies on the target function and focus on the scheduling of the vacation period as a function of the deterioration and recovery rates. It is shown that the use of vacations to allow the server to rest and regain efficiency has a strong and valuable effect on the mean customer waiting time, to the extent that switching servers may be beneficial for the system, even when implemented at a point in time when the main server's service rate is still much higher than that of the temporary server.

Keywords: Fuzzy Queueing Model, Vacation Policy, Deterioration and Recovery, Performances.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ADVANCING SUSTAINABLE ENERGY: A COMPREHENSIVE REVIEW OF RENEWABLE ENERGY SOURCES, TECHNOLOGIES, AND PUBLIC PERCEPTIONS.

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ABSTRACT

Renewable energy sources, such as solar, wind, and biomass, provide sustainable solutions to the world's growing energy demands without depleting their availability. Solar energy, as an abundant and consistent resource, continues to play a crucial role in addressing global energy challenges. This review examines global energy requirements, the advancements in renewable energy technologies for domestic applications, and the impact of public perception on their adoption. A systematic review of literature spanning 2006 to 2023 was conducted, involving the classification of over 270 studies and a detailed analysis of 50 selected papers.The findings reveal that despite considerable efforts to transition from fossil fuels, these sources accounted for 70% of global electricity production as of 2023, while renewable sources contributed approximately 30%. A significant barrier to the broader adoption of renewable energy technologies remains the lack of public awareness and understanding. This study highlights the necessity of integrating renewable energy sources into power generation systems to mitigate ongoing energy crises.Moreover, the review emphasizes the importance of public perception in shaping energy policies and demonstrates the utility of real-time opinion analysis, such as tweet analytic, to guide research and policy formulation. By addressing public attitudes and fostering engagement, this review provides valuable insights for researchers, policy-makers, and industries aiming to accelerate the development and acceptance of renewable energy technologies.

KEYWORDS Energy policy, public perception, renewable energy technologies (RETs), solar power, wind power, sustainable energy solutions

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AZƏRBAYCAN-TÜRKİYƏ MÜNASİBƏTLƏRİNƏ İQTİSADİ ƏLAQƏLƏR ÇƏRÇİVƏSİNDƏ BAXIŞ

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Açar sözlər: İqtisadi əlaqələr, qeyri neft sektoru, strateji əməkdaşlıq

Xülasə

Azərbaycanla Türkiyə arasındakı ikitərəfli iqtisadi əlaqələr son 20 ildə digər qonşu ölkələr üçün nümunə və model ola biləcək keyfiyyət və dinamika səviyyəsinə yüksəlib. 1991-ci il noyabrın 9-da Türkiyə Azərbaycanın müstəqilliyini tanıyıb, diplomatik əlaqələr isə 1992-ci il yanvarın 14-dən qurulub. Türkiyə Azərbaycanın dövlət müstəqilliyini tanıyan ilk dövlətdir. Türkiyə-Azərbaycan münasibətlərində müstəqilliyin ilk illərində olduğu kimi son dövrlərdə də maraqlı yeniliklər yaşanır. İlk növbədə Strateji Əməkdaşlıq Şurasının yaradılmasını qeyd etmək lazımdır. Eyni zamanda, enerji sahəsi başda olmaqla iqtisadiyyatın bütün sahələrində əməkdaşlıq yeni səviyyəyə çatıb. Qarşılıqlı rəsmi səfərlərin intensivliyi xeyli artıb.

Giriş

Azərbaycanın sosial-iqtisadi inkişafında əvəzsiz rolu olan türk şirkətlərinin sayı 1000-dən artıqdır ölkədə neft və qeyri-neft sektoruna qoyduğu investisiyaların ümumi həcmi 6 milyard dollardan çoxdur. Bunun yarısı qeyrineft sektorunun payına düşür ki, son məlumatlara əsasən, bu rəqəm 3 milyard dollardan artıqdır. Türkiyə sərmayəli şirkətlərdə ümumilikdə 50.000 işçi çalışır. Azərbaycanda fəaliyyət göstərən Türkiyə şirkətlərini digər ölkələrin şirkətlərindən fərqləndirən əsas cəhət odur ki, bu şirkətlər iqtisadiyyatın, demək olar ki, bütün sektorlarında fəaliyyət göstərir. Türkiyə şirkətləri qeyrineft sektorunun inkişafında xüsusi rol oynayır. Türkiyə şirkətlərinin inşaat, xidmət, kənd təsərrüfatı və qida sektoru, bank və sığorta sahəsi, tekstil və yüngül sənayedə mövqeləri kifayət qədər güclüdür. Son zamanlar yerli Azərbaycan şirkətləri idarəetməyə türkiyəli menecerləri geniş şəkildə cəlb etməkdədirlər ki, bu da ölkələrimiz arasında sosial-iqtisadi əlaqələrin inkişafına müsbət töhfə verir. Son illərin mühüm tendensiyalarından biri də ondan ibarətdir ki, Azərbaycan əsas etibarilə Dövlət Neft Şirkətinin (ARDNŞ/SOCAR) timsalında Türkiyəyə dəyəri milyard dollarla ölçülən sərmayələr yatırır. Daha da konkretləşdirsək, hazırda Türkiyədə 850 Azərbaycan şirkəti fəaliyyət göstərir və son illər həmin şirkətlər Türkiyə iqtisadiyyatına 4.5 milyard dollar investisiya qoyub.Türkiyə ilə Azərbaycan arasındakı iqtisadi əlaqələrin hüquqi çərçivəsini təşkil edən “Türkiyə ilə

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Azərbaycan arasında ticarət və iqtisadi əməkdaşlıq haqqında" Saziş 1992-ci ildə, "Türkiyə ilə Azərbaycan arasında investisiyaların qarşılıqlı təşviqi və qorunması haqqında" Saziş ilə "Türkiyə ilə Azərbaycan arasında ikiqat vergitutmanın qarşısının alınması haqqında" Saziş isə müvafiq olaraq 1994 və 1997-ci illərdə imzalanıb və bununla da hüquqi bazanın qurulması önəmli ölçüdə tamamlanıb. 2010-cu il avqustun 16-da Bakı şəhərində imzalanmış "Azərbaycan Respublikası ilə Türkiyə Respublikası arasında strateji tərəfdaşlıq və qarşılıqlı yardım haqqında" müqavilədə tərəflər ölkələrində və üçüncü dövlətlərdə karbohidrogen ehtiyatlarının inkişaf etdirilməsi, daşınması və satışının təmin edilməsi üçün müştərək investisiya layihələri həyata keçirmək məqsədilə Enerji sahəsində birgə komissiya formalaşdırmaq barədə ilkin razılığa gəliblər.

2007-ci il noyabrın 6-da Bakı şəhərində imzalanmış "Azərbaycan Respublikası ilə Türkiyə Respublikası arasında uzunmüddətli "İqtisadi əməkdaşlıq proqramı və İcra planı"na əsasən isə tərəflər iqtisadi əməkdaşlıqda 8 prioritet sahə müəyyən ediblər ki, bunlar da aşağıdakılardır: ticarət, azad iqtisadi zona, sənayə, energetika, nəqliyyat, rabitə, turizm və kənd təsərrüfatı. Sənədə əsasən, Azərbaycan-Türkiyə azad iqtisadi zonasının yaradılması imkanlarının araşdırılması məqsədilə müzakirələr başlanmalı və müzakirələr nəticəsində tərtib olunacaq hesabat azad iqtisadi zona layihəsinin hazırlanması və həyata keçirilməsi ilə məşğul olan təşkilat və firmalara təqdim edilməlidir. Azərbaycanda azad iqtisadi zonanın yaradılması zamanı lazım olan təlim dəstəyi və texniki yardımları Türkiyə təmin edəcək. 2010-cu il sentyabrın 15-də İstanbul şəhərində "Azərbaycan Respublikası ilə Türkiyə Respublikası arasında yüksək səviyyəli strateji əməkdaşlıq şurasının yaradılması haqqında" birgə bəyannamə imzalanıb. Bəyannaməyə əsasən, "Şura Azərbaycan və Türkiyə arasında mövcud olan siyasi, hərbi, iqtisadi, ticarət, energetika, nəqliyyat, mədəniyyət, elm və humanitar sahələrdə həyata keçirilən əlaqələrin strategiyasını müəyyən edəcək, bu strategiyanın əsasında əməkdaşlıq layihələrinin inkişafını və həmin layihələrin icra olunmasını təşviq edəcək. Azərbaycan Respublikasının Prezidenti və Türkiyə Respublikasının Baş naziri Şuranın həmsədrləri vəzifəsini üzərlərinə götürürlər. Şuranın iclaslarında, gündəlikdə olan mövzulara uyğun olaraq Azərbaycan və Türkiyə Respublikası hökumətlərinin üzvləri iştirak edəcəklər. Şuranın iclasları tərəflərin razılığı ilə mütəmadi keçiriləcək. Hökumət üzvləri şuranın qərarlarının həyata keçirilməsi üçün məsuliyyət daşıyacaqlar. Şuranın bazasında, siyasi mövzularda iki ölkə arasındakı əlaqələrin və əməkdaşlığın daha da inkişaf etdirilməsi, ikitərəfli, regional və qlobal mövzularda siyasi fikir mübadiləsinin aparılması və əməkdaşlığın prioritet sahələrinin və layihələrinin müəyyən edilməsi məqsədilə birgə strateji planlaşdırma qrupu təsis ediləcək. Qrupun iclasları il ərzində ən azı bir dəfə, xarici işlər nazirlərinin həmsədrliyi ilə keçiriləcək. Birgə Strateji Planlaşdırma qrupu lazım olduğu təqdirdə müşavir müşavirin müavini və nazir müavini səviyyəsində və aidiyyəti digər qurum nümayəndələrinin iştirakı ilə əlavə iclaslar təşkil edə bilər. Qrup iclasların nəticəsi haqqında Şuraya məlumat verəcək.

İqtisadi və ticarət məsələlərində iqtisadi əməkdaşlıq üzrə Birgə Hökumətlərarası Komissiya əsas mexanizm rolunu oynamağa davam edəcək. Komissiya iclasların nəticələri haqqında Şuraya məlumat

verəcək. Enerji təminatı, nəqli və təhlükəsizliyi sahəsində birgə layihələrin işlənilib- hazırlanması və tətbiq olunması məqsədilə iki ölkənin əlaqədar orqan və təşkilat nümayəndələrinin iştirakı ilə təsis ediləcək Birgə Energetika Komissiyası energetika sahəsində əməkdaşlığın gücləndirilməsi məsələsində əsas mexanizm rolunu oynayacaq. Komissiya il ərzində ən azı bir dəfə yığılacaq və fəaliyyətinin nəticələrini Şuraya təqdim edəcək.

İki ölkənin xalqları arasında mövcud olan çoxyönlü və hərtərəfli əlaqələr çərçivəsində dialoq kanallarının səmərəliliyini daha da artırmaq, eyni zamanda vətəndaş cəmiyyəti təşkilatlarının əməkdaşlığını gücləndirmək və şaxələndirmək məqsədi ilə Vətəndaş Cəmiyyəti forumu təsis ediləcək. Foruma biznes dairələri, təlimçilər, diaspor təşkilatlarının da daxil olduğu müxtəlif qeyri-hökumət təşkilatlarının nümayəndələri, sənətçilər, elm xadimləri, mətbuat orqanlarının nümayəndələri də daxil olmaqla cəmiyyətin bütün təbəqələri töhfəsini verə biləcək. Forum iclasları Şura iclaslarından əvvəl və ya eyni vaxtda, Şura iclasının təşkil olunacağı şəhərdə keçiriləcək. Əslində, bu yeni institusional mexanizm rəsmilərin daha intensiv görüşməsinə və cari məsələlərə daha operativ münasibətinə təkan verəcək. ARDNŞ-in Türkiyədə investisiya yatırımlarının intensivliyini artırması, iki ölkənin neft-kimya komplekslərini inteqrasiya etmək niyyətini açıqlaması gələcəkdə mühüm nəticələrə gətirib çıxara bilər. Bu inteqrasiya iki qardaş ölkə iqtisadiyyatlarının ümumi bir vəhdət halında çalışması istiqamətində ciddi bir addım olacaq. Bütün bunlar göstərir ki, artıq ölkələrimiz arasında investisiya axınları qarşılıqlı xarakter alır. Əgər bir neçə il bundan əvvələ qədər, adətən, Türkiyənin Azərbaycana investisiya qoyuluşlarından danışılırdısa, artıq Azərbaycan da Türkiyəyə irihəcmli investisiya qoyuluşları həyata keçirməyə başlayıb. Türkiyənin hazırda Azərbaycan iqtisadiyyatına sərmayəsinin həcmi 10 milyard dollara yaxınlaşmaqdadır. Türkiyə, həmçinin, Azərbaycanın qeyri-neft sektoruna investisiyaların həcminə görə liderliyini qoruyur. Azərbaycandakı 1000dən çox türk şirkətinin (Azərbaycandakı bütün xarici sərmayəli şirkətlərin üçdə biri) ümumi sərmayəsi Türk petrolları anonim ortaqlığının (TPAO) enerji sektoruna sərmayələri daxil olmaqla 6 milyard dollar həcmindədir. Türk şirkətlərinin (əsasən tikinti sektorunda) 2010-cu ilin əvvəlinə Azərbaycanda üzərlərinə götürdükləri 198 layihənin ümumi dəyəri 3.3 milyard dolları ötüb. Hazırda Azərbaycanda türk kapitalı ilə 5 bank da fəaliyyət göstərir.

2010-cu ildə Türkiyədə əcnəbilərin təsis etdiyi 2 min 479 şirkətdən 136-sı Azərbaycan iş adamlarına məxsus olub. Azərbaycanlılar Türkiyədə şirkət quran əcnəbilərin siyahısında 4-cü sıraya yüksəlib. Bu ilin ilk 5 ayının rəqəmlərinə əsasən, Türkiyədə xarici ölkə vətəndaşları tərəfindən 401 şirkət yaradılıb ki, bunun da 86-sı azərbaycanlıların payına düşür. Türkiyədə Azərbaycan kapitalının iştirakı ilə qeydə alınan şirkətlərin 74-ü İstanbulda yaradılıb. 2010- cu ildə Azərbaycan kapitalının iştirakı ilə 6 səhmdar cəmiyyət və 130 məhdud məsuliyyətli cəmiyyət yaradılıb. Azərbaycan kapitalının iştirak etdiyi şirkətlərin çoxu tikinti sektorunda fəaliyyət göstərir. 2010-cu ildə Türkiyədə xarici iştirakla yaradılan məhdud məsuliyyətli cəmiyyətlər arasında Azərbaycan dördüncü, səhmdar cəmiyyətlər arasında isə 14-cü yerdədir". Azərbaycan tərəfi də son illər Türkiyədə birgə müəssisələr yaratmaqla yeni-yeni

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sərmayə qoyuluşları həyata keçirməkdə maraqlıdır. 2008-ci ildə ARDNŞ-in SOCAR & TURCAS Enerji A.Ş. (STEAŞ) alyansı "PETKİM" kimya konserninin 51 faizlik səhm paketinin satışı üzrə tenderin qalibi olub və bunun üçün 2,04 milyard dollar vəsait ödənilib. PETKİM Petrokimya Holdinq plastik qablaşdırma, parça, yuyucu vasitələr və s istehsal edir və Türkiyədə bu cür məhsulun yeganə istehsalçısıdır. 2011-ci ildə ARDNŞ ümumi kapitalı 2010-cu ilin əvvəlində 3.4 milyard dollar olan "SOCAR- TURCAS" birgə müəssisəsində payını artırdığını da bildirib. Türkiyənin Aksoy şirkəti ("SOCAR-TURCAS"ın təmsilçisi) ilə yeni sazişdən sonra birgə müəssisənin nizamnamə kapitalında ARDNŞ-in payı 51%-dən 74,98%-ədək artıb.

Habelə, ARDNŞ İstanbul və Ankaranın qazpaylayıcı şəbəkələrinin özəlləşdirilməsində iştirak etmək istəyir. Beləliklə, 2012-ci ildə ARDNŞ "PETKİM"-in fəaliyyətindən artıq gəlir gözləyir. 2010-cu ildə ARDNŞin gəlirləri Türkiyədə 1.6 milyard manat təşkil edib". Onu da qeyd edək ki, son illər aktiv şəkildə fəaliyyətini genişləndirən ARDNŞ- in təsis etdiyi "SOCAR-TURCAS" şirkəti Türkiyənin daxili bazarında təbii qazın topdan ticarəti hüququnu əldə edib. Türkiyənin Enerji bazarını Tənzimləmə qurumu "SOCAR-TURCAS Petrokimya"

şirkətinə bu ölkədə təbii qazın topdan satışı üçün 30 illik lisenziya verib. "SOCAR-TURCAS"-1 ARDNŞ idarə edir və o, Azərbaycanın ən vacib xarici aktividir. ARDNŞ 2011-ci ildən Türkiyənin daxili bazarında 1,2 milyard kubmetr qaz satmağı planlaşdırır. Bu həcmin böyük hissəsi Petkim Holdingə, qalanı istilik elektrik stansiyalarına veriləcək.

2011-ci il oktyabrın 25-də hər iki ölkənin dövlət və hökumət başçılarının iştirakı ilə İzmirdə "SOCAR"-ın sərmayəsi ilə tikiləcək yeni neft-kimya kompleksinin təməlinin qoyulması ikitərəfli iqtisadi əlaqələrdə yeni mərhələnin simvoluna çevrilib. "Star Rafinerisi" adlanan kompleksi "SOCAR-TURCAS" birgə müəssisəsi müştərək inşa edir və bu layihəyə qoyulacaq

sərmayələr 5.5 mlrd. dollardır. "SOCAR" və "TURCAS" şirkətlərinin sahibi olduqları "PETKİM" şirkətinə məxsus ərazidə inşa ediləcək "STAR" neft-kimya kompleksinə yönəldilən sərmayə Türkiyə özəl sektorunun tarixində tək nöqtəyə yatırılan ən böyük investisiyadır. 2015-ci ildə ilk qurğuları işə düşəcək neft-kimya kompleksində ildə 1 milyon 600 min ton nafta istehsal ediləcəkdir ki, bu da "Petkim" şirkətinin bu məhsula olan tələbatını tam ödəyəcək və onun hazırda bu məhsul üzrə idxaldan 80%-lik asılılığını sıfıra endirəcək. İllik emal gücü 10 milyon ton olan zavodda "PETKİM" şirkətinin ana xam maddəsi nafta ilə yanaşı, təxminən 6 milyon ton aşağı kükürdlü motorin, 500 min ton aviasiya yanacağı, 500 ton reformat, 630 min ton petrokok və s. məhsullar istehsal ediləcəkdir ki, bunların da nəticəsində Türkiyənin illik xarici ticarət kəsiri taxminan 2 milyard dollar azalacaq. Kompleksin inşası zamanı 10 min nəfər fəaliyy zamanı isə min nəfər işçi çalışacaq. Kompleksin tikintisi nəticəsinda Petkim kompleksi xammalla təmin olunmalı, ARDNŞ dizel yanacağı, aviasiya kerosini və kimya sənayesi üçün xammalla Aralıq dənizi bazanına cıxmalıdır. Bütövlükdə, "SOCAR-TURCAS" birgə müəssisəsi "Petkims 2023-cü ilə qədər 10 mimet bu qoymağı planlaşdır ATİB-in

fəxri sədri Ahmet Erentok bu layihə ilə bağlı bildirib ki, münasibətlərinin Türkiyə və Azərbaycan arasında sarsılmaz qardaşlıq simvollarından olacaq "STAR" neft-kimya kompleksi ölkələrimiz arasındakı strateji müttəfiqliyi daha da gücləndirəcək: "25 oktyabr Azərbaycan və Türkiyə üçün tarixi nefti artiq xammal əlavə dəyər yaradılaraq yarımfabrikatlar və hazır məhsul üçün ölkələrə ixrac edilecek. Eyni zamanda, istehsal edilən məhsullar Türkiyənin daxili tələbatını ödəməklə yanaşı, idxalı əhəmiyyətli dərəcədə azaldacaq. Həmçinin, hər iki ölkə iqtisadiyyatlarının əsas sektorlarından azaldacaftkimya komplekslərinin inteqrasiyası digər sektorlar üçün multiplikator effekti rolunu oynayaraq onların da inteqrasiyasına gətirə Çıxara bilər. Hazırkı Avropa Birliyinin əsasında Avropa kömür və polad birliyi dayanır. Azərbaycan və Türkiyənin neft-kimya komplekslərinin inteqrasiyasının regionda analoji nəticəyə gətirib çıxaracağı iddiasından uzağam. Amma bu inteqrasiya iki qardaş ölkə iqtisadiyyatlarının ümumi bir vəhdət halında çalışması istiqamətində ciddi addım olacaq. Bir sözlə, Türkiyə və Azərbaycanın strateji gücünü artıracaq bu layihə ölkələrimizin regiondakı və dünyadakı mövqelərini daha da Son on ildə iki ölkə arasında mal dövriyyəsi, demək olar ki, 10 dəfə artıb və hazırda ildə 2,5 milyard dollar təşkil edir. 2010-cu ildə Türkiyə və Azərbaycan arasında mal dövriyyəsi 12,2 faiz artıb. 2010-cu ildə Azərbaycana Türkiyədən 771.2 milyon dollarlıq mal idxal edilib ki, bu da idxal üzrə əsas tərəfdaş ölkələr arasında Rusiyadan sonra 2-ci mövqedir. Azərbaycanın əsas idxal tərəfdaşları arasında Türkiyənin mövqeyi (Rusiyadan sonra 2-ci yer) son dörd ildə dəyişmədən stabil qalır. 2010-cu ildə Türkiyəyə 170.8 milyon dollarlıq mal ixrac olunub. Bu göstəriciyə görə, Türkiyə Azərbaycanın ixrac üzrə əsas tərəfdaşları sırasında hətta Tailanddan da geridə qalır. İdxal-ixrac üzrə Türkiyə və Azərbaycanın rəsmi statistik mənbələri, aşağıdakı cədvəldən də göründüyü kimi, fərqli məlumatlar verir. Birgə iqtisadi əməkdaşlıq proqramı və onun icra planına əsasən Azərbaycan və Türkiyənin qurum və firmalarının hər iki ölkədəki investisiya, sənaye istehsalı və modernləşdirmə fəaliyyətlərində iştirakları təşviq ediləcək. Bu çərçivədə, xüsusilə kiçik və orta sahibkarlıq subyektləri arasındakı əməkdaşlığın inkişafını təmin etmək məqsədilə kiçik və orta sahibkarlıq üçün məlumat bazalarının qarşılıqlı tətbiqi, məlumat və təcrübə mübadiləsinin aparılması, mütəxəssis mübadiləsinin həyata keçirilməsi kimi tədbirlər həyata keçiriləcək. Sənaye sahəsindəki əməkdaşlığın inkişafını təmin etmək üçün hər iki ölkənin investisiya proqramları və prioritet sektorları haqqında mütəmadi qaydada məlumat mübadiləsi aparılacaq. 20 Kənd təsərrüfatı sahəsində əməkdaşlığın inkişafı istiqamətində isə işlər Azərbaycan-Türkiyə kənd təsərrüfatı İcra Komitəsinin fəaliyyətləri çərçivəsində həyata keçiriləcək, mövcud saziş və protokollarda nəzərdə tutulan əməkdaşlıq sahələri ilə yanaşı, yeni əməkdaşlıq sahələrinin müəyyən edilməsinə dair fikir mübadiləsi aparılacaq. Azərbaycanın və Türkiyənin turizm potensialının hər iki ölkə vətəndaşlarına yüksək səviyyədə tanıdılması məqsədilə əməkdaşlıq davam etdiriləcək, hər iki ölkənin dövlət qurumları və özəl şirkətləri arasında əlaqələr genişləndiriləcək, Azərbaycandakı turizm infrastrukturunun yenilənməsi və ya inkişafı istiqamətindəki işlərdə əməkdaşlıq imkanları müzakirə ediləcək. Bununla əlaqədar, bu proqramın və İcra planının qüvvəyə minmə tarixindən etibarən altı ay ərzində bir tədqiqat tipli hesabat hazırlanacaq və hər iki ölkənin müvafiq qurum və təşkilatlarına təqdim olunacaq.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Müştərək turizm layihələrinin həyata keçirilməsi sahəsində hər iki ölkənin investorlarının təşviq edilməsi istiqamətində işlər görüləcək. Türkiyənin müvafiq təhsil qurumları ilə Azərbaycanda yeni yaradılmış Azərbaycan Turizm İnstitutu arasında əlaqələr yaradılacaq və Türkiyədən mütəxəssislər dəvət ediləcək. Tikintisinə 2008-ci ildə start verilən və 2012-ci ildə başa çatdırılması planlaşdırılan Bakı-Tbilisi-Qars dəmiryolu xəttinin işə düşməsi ilə Azərbaycanla Türkiyə arasında qurulması nəzərdə tutulan strateji infrastruktur xətləri böyük ölçüdə başa çatacaq ki, bu da hər iki ölkənin regiondakı strateji, geosiyasi və geoiqtisadi nüfuzunun daha da güclənməsini şərtləndirəcək. Azərbaycan, həmçinin, Qarsdan Naxçıvana dəmiryolunun tikintisi ilə Naxçıvanla birbaşa dəmiryolu əlaqəsinin qurulmasına nail olacaq. Qars-Axalkalaki (Gürcüstan) arasında 98 kilometrlik yeni bir dəmiryolunun tikintisi, Gürcüstanda isə 160 kilometrlik mövcud dəmiryolunun modernləşdirilməsi ilə birlikdə Türkiyə-Gürcüstan- Azərbaycan dəmiryolu şəbəkələrinin birbaşa birləşdirilməsini nəzərdə tutan "Bakı-Tbilisi-Qars" dəmiryolu layihəsinin 2012-ci ildə tam reallaşdırılması da planlaşdırılır. Bundan başqa, Türkiyə Dövlət Dəmiryolları İşlətməsi ilə Azərbaycan Dövlət Dəmiryolu İdarəsi arasındakı institusional əməkdaşlığın inkişaf etdirilməsi, strateji əməkdaşlığın daha da gücləndirilməsi məqsədilə Xəzər və Qara dəniz hövzələrində multimodal yükdaşımaların inkişafı nəzərdə tutulur.

İki ölkə arasında qaz sahəsində əməkdaşlığın perspektivləri çox əhatəlidir. Azərbaycan 2011-ci ildə Bakı-Tbilisi-Qars dəmir yolu layihəsi üçün əlavə vəsait ayırıb. Həmçinin elektrik enerjisi sahəsində əməkdaşlıq, xüsusən Türkiyə, Gürcüstan və Azərbaycanın elektrik ötürücü xətlərinin birləşdirilməsi, habelə Türkiyəyə elektrik enerjisi ixracı da rəsmi gündəmdədir.

Enerji sahəsində iki ölkə arasında uzun müddət müzakirə predmeti olan təbii qazın nəqli qiymətlərində yeni formul artıq razılaşdırılıb. Bununla da həm "Şahdənız" yatağı üzrə 1-ci fazada Türkiyəyə satılmış qazın yeni qiymətləndirilməsindən sonra həmin ölkənin qaz borcu problemi, həm də 2-ci faza üzrə yeni nəql həcmi və qiyməti problemi xeyli dərəcədə həllini tapıb. 2010-cu il dekabrın sonunda Türkiyə "Şahdəniz" səhmdarlarına qaza görə borcunu da ödəməyə başlayıb. 2010-cu ilin iyununda rəsmi Bakı və Ankara Türkiyə bazarında qazın qiyməti və "Şahdəniz 2" layihəsi çərçivəsində Azərbaycan qazının həcmi üzrə razılıq əldə edib.

Nəticə:

"Şahdəniz"ın işlənməsinin 2-ci mərhələsindən Türkiyəyə ildə 6 mlrd. kubmetr və Türkiyədən tranzitlə Avropaya 10 mlrd. kubmetr qaz göndərilməsi realdır. "Mərhələ 2" layihəsi çərçivəsində boru kəmərinin tikintisi də daxil $25-30 milyard investisiya qoyulacaq. "Şahdəniz" qazının osas alıcısı olan Türkiyə daim alış həcmini azaldır. Əgər 2008-ci ildə bu ölkə Azərbaycandan 5,3 milyard kubmetr qaz almışdısa, 2009-cu ildə 5,1 milyard kubmetr, ötən il cəmi 4,9 milyard kubmetr qaz alıb. 2011-ci ildə həmin göstəricinin 4,75 milyard kubmetrə düşəcəyi gözlənilir. 2011-ci ilin oktyabrında iki ölkə arasında Türkiyənin Azərbaycandan qaz almasına və Azərbaycan qazının Türkiyə ərazisindən Avropaya tranzitinə imkan verən bir sıra mühüm qaz ixracı sazişləri imzalanıb. Bu sənədlərə

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Azərbaycan hökuməti ilə Türkiyə hökuməti arasında hökumətlərarası saziş, ARDNŞ və "BOTAŞ" arasında, eləcə də Azərbaycan Qaz Təchizatı Şirkəti ilə “BOTAŞ” İnterşnal Limitid arasında qaz satışı sazişləri, ARDNŞ və “BOTAŞ” arasında qaz tranziti sazişi və Azərbaycan mənşəli qazın Türkiyə ərazisi vasitəsilə tranziti üçün şərt və qaydaları müəyyən edən çərçivə sazişi daxildir. Sazişlərə uyğun olaraq Türkiyədən tranzit ya "BOTAŞ"-ın mövcud ötürmə şəbəkəsinin modernləşdirilməsi, ya da Türkiyə ərazisində yeni bir boru kəmərinin yaradılması yolu ilə həyata keçiriləcək. Bu sənədlər "Şahdəniz" yatağının tammiqyaslı işlənməsi Üçün və Azərbaycanın Xəzərdəki bu nəhəng qaz yatağından "Mərhələ-2" qazını Türkiyəyə və Avropa bazarlarına çıxarmaq üçün imkanlar açır. "Şahdəniz" yatağının işlənilməsinin 2-ci mərhələsi Azərbaycan qazını Avropaya və Türkiyəyə çatdıracaq nəhəng bir layihədir. Bu layihə yeni "Cənub qaz dəhlizi" vasitəsilə Avropa bazarlarına qaz təchizatını və enerji təhlükəsizliyini artıracaq. Layihənin 1-ci mərhələsində hasil olunan ildə təqribən 9 milyard kubmetr qaza ildə 16 milyard kubmetr qaz əlavə ediləcəyi gözlənilir. Bu, dünyada ən böyük qaz işlənməsi layihələrindən biridir.

Ədəbiyyat siyahısı:

1.http://mfa.gov.az/images/stories/Ikiterefli%20munasibetler/Avropa/Turkiye.pdf

2.http://www.atib.az (2011)

3.http://abc.az/news_28_11_2011_59965.html

4.http://e-qanun.az/print.php?internal=view&target=1&docid= 21158&doctype=0 (2011)

5.http://eqanun.az/print.php?internal=view&target=1&docid= 13851&doctype=0 (2011)

6.http://e-qanun.az/print.php?internal=view&target=1&docid= 21161&doctype=0 (2011)

7.http://www.gun.az/interview/15000 (2011)

8.http://www.mfa.gov.tr/turkiye-azerbaycanekonomik-iliskileri.tr.mfa

9.Azərbaycan Respublikası ilə Türkiyə Respublikası arasında uzunmüddətli iqtisadi əməkdaşlıq Proqramı və İcra Planı (1 fevral 2008-ci il) http://www.e-qanun.az (2008)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AI FOR OSINT: CHALLENGES, OPPORTUNITIES, AND FUTURE DIRECTIONS

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Keywords: Open Source Intelligence, Artificial Intelligence, Data Analysis.

ABSTRACT

This paper discusses the critical role that Open Source Intelligence (OSINT) is playing in the modern information age characterized by unprecedented volumes and speeds of data flow. OSINT entails the gathering and analysis of publicly available information to support decision-making across government, private industry, academia, and civil society. Artificial Intelligence integrated into the OSINT process has hugely increased the efficiency and accuracy of data gathering, analysis, and synthesis. Meanwhile, OSINT still grapples with a whole gamut of issues-data privacy and security, biased data, and ethical and legal problems. This work identified that addressing these challenges requires increased improvement in AI technologies, substantial ethical and legal frameworks, and more interdisciplinary collaboration to improve OSINT capabilities. The possible role of AI in OSINT was discussed in this context-not only from a technical viewpoint but also from ethical and social perspectives. Further, the need for interdisciplinary collaborations for wider dissemination of OSINT and integration with AI is highlighted. This paper concludes by suggesting that future research must aim at reducing biases and increasing the reliability and effectiveness of OSINT processes.

Introduction

Open Source Intelligence (OSINT) refers to the process of collecting, analyzing, and utilizing information that is publicly available from sources such as news articles, social media, academic publications, public records, and websites (Böhm and Lolagar, 2021). According to Lowenthal, OSINT is "the use of publicly available information and its analysis to inform decision-making processes." The U.S. Director of National Intelligence defines OSINT as "intelligence produced from publicly available information that is collected, exploited, and disseminated in a timely manner to an appropriate audience for the purposeof addressing a specific intelligence requirement.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Definition and Sources of OSINT

There are various definitions of OSINT, but common elements include the emphasis on publicly accessible information and its strategic use (Oelmaier et al., 2023). The U.S. Director of National Intelligence defines OSINT as "intelligence produced from publicly available information that is collected, exploited, and disseminated in a timely manner to an appropriate audience for the purpose of addressing a specific intelligence requirement". Similarly, NATO describes OSINT as information derived from "publicly available sources that are exploited in a systematic manner".

For this analysis, the definition by the U.S. Director of National Intelligence will be the primary reference, emphasizing the collection, exploitation, and dissemination of publicly available information for intelligence purposes.

History of OSINT

OSINT, or Open Source Intelligence, isn't a new idea. It started in the early 1900s, during World War I, when countries started to look at public information like newspapers and radio shows to learn things. During World War II, OSINT became more official with groups like the Foreign Broadcast Information Service (FBIS) set up by the United States to watch and understand foreign radio shows. Now, with the internet, there's a lot more information that's easy to get, so OSINT is very important for today'sintelligence work.

Relationship Between OSINT and AI

The integration of AI with OSINT represents a significant advancement in the field of intelligence gathering and analysis (Oelmaier et al., 2023). AI technologies, particularly machine learning and natural language processing, enhance the ability to process and analyze vast amounts of open-source data efficiently. For instance, AI can automate the collection of information from various online sources, filter out irrelevant data, and identify patterns and trends that would be difficult for human analysts to detect manually. This synergy between OSINT and AI enables more accurate and timely intelligence, supporting decision-makers in various sectors, including national security, business, and public policy. In the last three years, artificial intelligence (AI) has greatly improved Open Source Intelligence (OSINT) by making data collection and processing automatic, helping to analyze big sets of data better, and making intelligence insights more accurate. Important examples of how AI is used in OSINT include using natural language processing (NLP) to understand text from places like social media, news, and forums to find out what's popular and how people feel, using machine learning to spot and guess where cybersecurity problems might happen, and using image recognition to get information from pictures and videos, like those from satellites. All these uses have made gathering intelligence quicker, more correct, and more complete, which helps with making decisions in things like keeping the country safe, stopping terrorism, and understanding business competition.

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ISBN: 978-9952-610-30-7

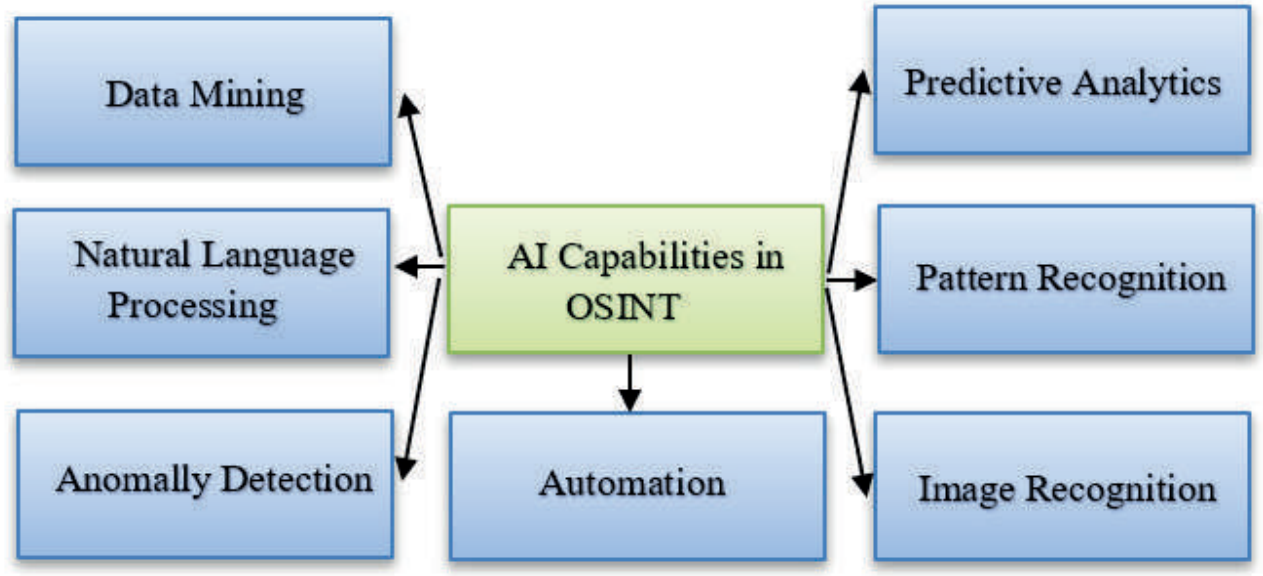


Fig 1. AI Capabilities in OSINT

Literature review

Article DOI	Brief Explanation of the Study	Findings	Identified Challenges	Future Direction Suggestions
https://doi.org/10.17234/INFUTURE.2019.23	This study examines the use of big data analytics in digital forensics and its integration with OSINT.	Big data analytics increases efficiency and speeds up processes in digital forensics.	Challenges include data privacy and security issues, data accuracy, and reliability.	Suggestions include developing new technologies for data security and improving methods to enhance data accuracy.
https://doi.org/10.1007/s00146-023-01628-x	This article focuses on the use of AI and OSINT for automatic fake news detection and analysis.	AI models achieve high accuracy rates in detecting fake news.	Challenges include biases in AI models and ethical concerns, as well as imbalanced datasets.	Recommendations include developing guidelines for the fair and ethical use of AI models and diversifying datasets.

https://doi.org/10.1007/s10207-024-00868-2	This paper explorestheAI and OSINT in cyber security applications.	AI enhances the ability todetectand respond to cyber threats.	Issues involve algorithm security and sys tem integrity in theuse of AI for cybersecurity.	Future directions suggest developing more robust AI algorithms for cyber security and strategies to maintain system integrity.

Applications of OSINT

Text Generation

AI plays a significant role in reporting and summarizing information, utilizing advanced language models like GPT-4 to analyze vast amounts of text data and produce detailed reports and summaries. This capability significantly reduces the time and effort required by analysts, enhancing the extraction of meaningful insights from extensive datasets. The text generation process in models such as GPT-4 is built upon the transformer architecture, which leverages self-attention mechanisms to process input sequences in parallel. Mathematically, the generation process can be described by a sequence-to-sequence (Seq2Seq) framework where the input sequence ($x_1, x_2, \ldots, x_T$) is encoded into a context vector ccc (Yang et al., 2024). The decoder then generates the output sequence $(y_1, y_2, \ldots, y'_T)$ using the context vector and the previously generated tokens . The self-attention mechanism within transformers calculates the attention score between words i and j using the formula:

$$Attention\ (Q, K, V) = softmax\left(\frac{QK^T}{\sqrt{d_k}}\right)V \qquad (1)$$

where Q (queries), K (keys), and V (values) are matrices derived from the input embeddings, and d_k is the dimension of the key vectors. During text generation, the model predicts the next token y_t based on the previously generated tokens and the context vector, using:

$$P(y_t|y_{<t}, c) = \text{softmax}(W_s s_t) \qquad (2)$$

In this formula, $P(y_t|y_{<t}, c)$ represents the probability distribution of the next token y_t given the previously generated tokens $y_{<t}$ and the context vector c. This probability distribution is calculated by applying the softmax function to the linear transformation $W_s s_t$, where W_s is the weight matrix and s_t

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

is the hidden state of the decoder at time step t. The softmax function ensures the output probabilities sum to 1, providing a normalized distribution over possible next tokens.

Image and Video Analysis

AI has centrally revolutionized image and video data analysis, enabling face recognition, object detection, and motion analysis to be performed at unprecedented speeds and accuracy levels (Dong et al., 2024). These capabilities thus make possible the handling of huge volumes of video and image data in an expeditious and effective manner, as is required by many applications in the fields of security, surveillance, and intelligence gathering. Companies like Palantir and Clearview AI are at the forefront of the considerable advantage offered by AI-powered solutions over traditional methods for such analyses.

Similarly, facial recognition algorithms utilize deep learning models in identifying and verifying individuals in images and videos. These models are trained on very large datasets containing millions of images of faces, learning to recognize facial features and patterns. This involves a series of steps: face detection, alignment, feature extraction, and comparison with a database of known faces.

Object detection is another important area where artificial intelligence shows outstanding capabilities. Convolutional Neural Networks (CNNs), particularly architectures like YOLO (You Only Look Once) and Faster R-CNN, are commonly used for this purpose (Xie et al., 2024). These models have the capability to locate and classify multiple objects in one image or video frame in real time, making them indispensable in surveillance and analysis of complex environments.

Motion analysis refers to observing the movement of entities or individuals in video frames from one frame to another. Artificial intelligence algorithms analyze temporal and spatial relationships between consecutive frames to understand motion patterns for better situational awareness, thereby feeding the decision-making process.

Mathematically, object detection can be illustrated using the following formula in the context of a CNN-based model (Ghanimi et al., 2024). Suppose an image I is input into the network, which outputs a feature map F. The object detection task can be formulated as finding bounding boxes B and class labels C for the objects in the image. The prediction ismade by applying a function f over the feature map:

$$(B,C)=f(F(I)) \quad (3)$$

Where I is the input image, $F(I)$ is the future map extracted by the CNN, f is a function that predicts bounding boxes and class labels from the feature map.

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ISBN: 978-9952-610-30-7

For example, in the YOLO algorithm, the image is divided into a grid, and each grid cell predicts bounding boxes and their corresponding confidence scores (Bagherzadeh et al., 2024). The model optimizes a loss function that balances localization accuracy and classification confidence, ensuring that the detected objects are both accurately localized and correctly classified.

AI-driven image and video analysis leverages advanced algorithms and deep learning techniques to perform complex tasks such as facial recognition, object detection, and motion analysis (Kang and Kim, 2023). These capabilities enable the efficient handling of large-scale visual data, providing substantial benefits in security and intelligence operations. The mathematical foundations, exemplified by models like CNNs, illustrate the sophisticated processes underlying these powerful AI applications (Ghanimi et al., 2024).

Data Synthesis

AI plays a crucial role in creating and testing new datasets through techniques like Generative Adversarial Networks (GANs), which can generate realistic synthetic datasets (Wang et al., 2023) [13]. These datasets are invaluable for training and testing machine learning models, especially when real data is scarce or expensive to obtain. Companies such as NVIDIA and OpenAI have developed prominent applications in data synthesis, including NVIDIA's GAN models and OpenAI's DALL-E.

GANs consist of two neural networks, the generator and the discriminator, which are trained together through an adversarial process. The generator creates synthetic data samples, while the discriminator evaluates their authenticity. The goal is for the generator to produce samples that are indistinguishable from real data, and for the discriminator to correctly identify whether a sample is real or synthetic. The generator tries to create realistic data, while the discriminator tries to tell the difference between real and fake data.

Prominent applications of GANs include NVIDIA's StyleGAN, which generates highly realistic images, and OpenAI's DALL-E, which creates images from textual descriptions. These applications demonstrate the power of GANs in generating diverse and realistic synthetic data (Wang et al., 2022).

Synthetic data generated by GANs is particularly valuable in scenarios where real data is limited, enhancing model performance and robustness (Sharma et al., 2024). By augmenting existing datasets with synthetic data, machine learning models can be trained more effectively, improving their accuracy and generalization. Additionally, synthetic data helps maintain privacy by allowing models to be trained on realistic but non-sensitive data, reducing risks associated with using real private data.

Data synthesis through AI, particularly using GANs, addresses the challenges of limited data availability (Li et al., 2024). By generating realistic synthetic datasets, GANs enable more robust training and testing of machine learning models, driving advancements in various applications and ensuring data privacy.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Challenges in Using AI for OSINT

Accuracy and Reliability

One of the primary concerns in utilizing AI for OSINT is ensuring the accuracy and reliability of the generated outputs. AI models, especially those based on machine learning, can produce false positives or negatives due to limitations in their training data or algorithms. This can lead to incorrect conclusions or missed critical information,undermining the credibility of intelligence reports. For instance, language models might misinterpret context or produce plausible yet inaccurate summaries, while image recognition algorithms might fail to accurately identify objects or faces in diverse and complex environments.

Ethical and Legal Issues

AI applications in OSINT often raise significant ethical and legal concerns. The collection and analysis of data from open sources can sometimes infringe on privacy rights and lead to unauthorized surveillance. Additionally, the use of AI in identifying individuals or predicting behaviors can result in ethical dilemmas, such as profiling and discrimination. Legal frameworks around data protection, like GDPR in Europe,impose strict regulations that must be adhered to, complicating the deployment of AI in OSINT. Ethical considerations also include the responsible use of AI, ensuring that it is not used to propagate misinformation or infringe on individuals' rights.

Security Concerns

Security is a major issue when deploying AI in OSINT. AI systems can be vulnerable to adversarial attacks, where malicious actors manipulate input data to deceive the model and produce erroneous outputs (Yadav et al., 2023). Furthermore, the vast amount of data processed by AI for OSINT purposes can be a target for cyberattacks, aiming to steal sensitive information or disrupt operations (Riebe et al., 2024). Ensuring the robustness and security of AI models and the data they handle is crucial, requiring continuous monitoring, regular updates, and the implementation of strong cybersecurity measures to protect against potential threats.

Bias and Fairness

AI systems are susceptible to biases present in their training data, which can lead to unfair or discriminatory outcomes. In the context of OSINT, biased AI models might disproportionately affect certain groups or misrepresent situations based on skewed data. This can result in flawed intelligence assessments and decision-making processes. Addressing these biases requires careful selection and preprocessing of training data, as well as ongoing evaluations to ensure that AI models operate fairly and equitably (Karakikes et al., 2024). Developers must strive to create transparent AI systems and implement bias mitigation techniques to enhance the fairness of AI-driven OSINT applications.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Opportunities Presented by AI in OSINT

Enhanced Analysis Capabilities

AI significantly enhances the analytical capabilities of OSINT operations. Advanced machine learning algorithms can process and analyze vast amounts of unstructured data from various sources, including social media, news articles, and public records. This allows for deeper insights and more accurate predictions. For example, natural language processing (NLP) can identify patterns and trends in text data, while computer vision can analyze visual data to detect specific objects or activities (Hupkes et al., 2023). These capabilities enable analysts to uncover hidden connections and generate actionable intelligence more efficiently than traditional methods.

Scalability

AI enables the processing and analysis of large datasets at scale, which is crucial for OSINT operations. Traditional analysis methods struggle with the sheer volume of data available from open sources, but AI can handle this data deluge effectively. Machine learning models can continuously ingest and analyze data in real-time, providing timely insights and updates. This scalability ensures that intelligence operations can keep pace with the rapidly changing information landscape, making it possible to monitor vast amounts of data from multiple sources simultaneously and identify relevant information without human intervention.

Cost Efficiency

Implementing AI in OSINT can lead to significant cost savings. Automated data collection and analysis reduce the need for large teams of analysts, allowing organizations to reallocate resources to other critical areas. AI-driven tools can perform repetitive and time-consuming tasks faster and more accurately than humans, lowering operational costs. Additionally, the ability to quickly derive insights from large datasets can prevent costly errors and improve decision-making processes. By enhancing efficiency and reducing labor costs, AI helps organizations maximize their return on investment in OSINT operations.

Future Directions

Technological Advancements

Future advancements in AI and OSINT are set to enhance data analytics and machine learning, enabling faster and more accurate analysis of large datasets. Innovations in natural language processing and computer vision will improve the analysis of textual and visual data, while AI's self-learning capabilities will make intelligence processes more adaptive and responsive to emerging threats.

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Policy and Regulation

The integration of AI in OSINT necessitates robust policy and regulatory frameworks to address ethical, legal, and security concerns. Future directions in this area will involve the establishment of international standards and guidelines to ensure the responsible use of AI in intelligence gathering. Policymakers will need to focus on data privacy, consent, and the potential misuse of AI technologies. Additionally, regulations must evolve to keep pace with technological advancements, ensuring that they provide adequate oversight while not stifling innovation. Collaboration between governments, private sectors, and international bodies will be crucial to developing comprehensive regulatory frameworks.

Interdisciplinary Approaches

The future of AI in OSINT will benefit greatly from interdisciplinary approaches, involving collaboration between various fields such as computer science, sociology, law, and political science. This collaborative effort will foster the development of more holistic and effective AI solutions for intelligence gathering. By integrating insights from different disciplines, it will be possible to address the complex challenges associated with AI and OSINT, such as bias in AI models and the ethical implications of AI-driven intelligence. Interdisciplinary research and partnerships will drive innovation, ensuring that AI technologies are developed and applied in a manner that is both effective and ethically sound.

Conclusion

This study examines the integration of AI in Open Source Intelligence (OSINT), emphasizing its advancements, challenges, and opportunities. AI significantly enhances OSINT through improved data analysis, synthesis, and scalability. However, challenges such as accuracy, reliability, ethical and legal issues, security concerns, and biases in AI models persist. Despite these obstacles, AI offers substantial benefits, including advanced analytics, cost efficiency, and the ability to process vast datasets.

The findings have practical and theoretical implications. Practically, AI integration in OSINT can streamline intelligence processes, enabling faster, more accurate decisions. Theoretically, the study contributes to understanding AI's role in intelligence gathering and underscores the need for ethical and legal frameworks for responsible AI use.

Recommendations for future efforts include enhancing AI systems' accuracy and reliability, establishing robust regulatory frameworks, promoting interdisciplinary collaboration, and addressing biases in AI models. These steps will maximize AI's potential in OSINT, fostering effective and responsible intelligence practices.

References

Bagherzadeh, S., Daryanavard, H. & Semati, M.R. A novel multiplier-less convolution core for YOLO CNN ASIC implementation. *J Real-Time Image Proc* 21, 45 (2024). https://doi.org/10.1007/s11554-024-01419-7

Böhm, I., Lolagar, S. Open source intelligence. *Int. Cybersecur. Law Rev.* 2, 317– 337 (2021). https://doi.org/10.1365/s43439-021-00042-7

Dong, X., Jiang, L., Li, W. *et al.* Let's Talk about AI: Talking about AI is Posi tively Associated with AI Crafting. *Asia Pac J Manag* (2024). https://doi.org/10.1007/s10490-024-09975-z

Ghanimi, H.M.A., Sengan, S., Sadu, V.B. *et al.* An open-source MP + CNN + BiLSTM model-based hybrid model for recognizing sign language on smartphones. *Int J Syst Assur Eng Manag* 15, 3794–3806 (2024). https://doi.org/10.1007/s13198-024-02376-x

Hupkes, D., Giulianelli, M., Dankers, V. *et al.* A taxonomy and review of general-ization research in NLP. *Nat Mach Intell* 5, 1161–1174 (2023). https://doi.org/10.1038/s42256-023-00729-y

Kang, C.H., Kim, S.Y. Real-time object detection and segmentation technology: an analysis of the YOLO algorithm. *JMST Adv.* 5, 69–76 (2023). https://doi.org/10.1007/s42791-023-00049-7

Karakikes, A., Alexiadis, P. & Kotis, K. Bias in X (Twitter) and Telegram Based Intelligence Analysis: Exploring Challenges and Potential Mitigating Roles of AI. *SN COMPUT. SCI.* 5, 574 (2024). https://doi.org/10.1007/s42979-024-02935-w

Li, B., Yang, P., Sun, Y. *et al.* Advances and challenges in artificial intelligence text generation. *Front Inform Technol Electron Eng* 25, 64–83 (2024). https://doi.org/10.1631/FITEE.2300410

Oelmaier, F., Knebelsberger, U., Naefe, A. (2023). Open Source Intelligence (OSINT). In: Krisenfall Ransomware. Edition. Springer Vieweg, Wiesbaden.https://doi.org/10.1007/978-3-658-41614-0_7

Riebe, T., Bäumler, J., Kaufhold, MA. *et al.* Values and Value Conflicts in the Context of OSINT Technologies for Cybersecurity Incident Response: A Value Sensitive Design Perspective. *Comput Supported Coop Work* 33, 205–251 (2024).https://doi.org/10.1007/s10606-022-09453-4

Sharma, P., Kumar, M., Sharma, H.K. *et al.* Generative adversarial networks (GANs): Introduction, Taxonomy, Variants, Limitations, and Applications. *Mul-timed Tools Appl* (2024). https://doi.org/10.1007/s11042-024-18767-y

Wang, T., Shen, B., Zhang, J. *et al.* Improving PLMs for Graph-to-Text Generation by Relational Orientation Attention. *Neural Process Lett* 55, 7967–7983 (2023). https://doi.org/10.1007/s11063-023-11292-3

Wang, Z., Zhang, Z., Feng, Y. *et al.* Generation of synthetic ground glass nodules using generative adversarial networks (GANs). *Eur Radiol Exp* 6, 59 (2022). https://doi.org/10.1186/s41747-022-00311-y

Xie, X., Cheng, G., Wang, J. *et al.* Oriented R-CNN and Beyond. *Int J Comput Vis* 132, 2420–2442 (2024). https://doi.org/10.1007/s11263-024-01989-w

Yadav, A., Kumar, A. & Singh, V. Open-source intelligence: a comprehensive re- view of the current state, applications and future perspectives in cyber security. *Artif Intell Rev* 56, 12407–12438 (2023). https://doi.org/10.1007/s10462-023-10454-y

Yang, L., Wei, C., Yang, J. *et al.* Seq2Seq-AFL: Fuzzing via sequence-to-sequence model. *Int. J. Mach. Learn. & Cyber.* (2024). https://doi.org/10.1007/s13042-024-02153-z

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BIOLOGICAL ACTIVITIES AND CHEMICAL CHARACTERIZATION OF PROPOLIS MINI- REVIEW

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Abstract:

The aim of the study, mini- review to the biological activities and chemical characterization of propolis. The present mini- review gave a important information for propolis, the propolis used for treating diseases. The rediscovering of this propolis is highly needed with contribution of overseas pharmaceuticals companies as natural products have less side effects than industrial drugs. The physico-chemical characteristics and the natural properties of various kinds of propolis have been studied for the past decade. The bioactive compounds in propolis promote wound healing and exhibit analgesic effects, primarily attributed to its rich content of bioflavonoids, vitamins, and minerals. Published research has indicated that propolis and its derivatives has many natural antimicrobial compounds with a broad spectrum against different types of bacteria and fangi and that it enhanced the efficacy of conventional antibiotics. Propolis, a resinous substance used for construction and maintenance within the hive, which possesses anti-inflammatory, antioxidant, antibacterial, antimycotic, antifungal, antiulcer, anticancer, and immunomodulatory properties. Propolis has been used to treat various medical conditions, including those affecting the gastrointestinal tract, gynaecological health, neoplastic conditions, skin, and oral health.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MARIGOLD'S ESSENCE: EXPLORING MEDIA NARRATIVES AND THEIR IMPACT ON BEAUTY, HEALTH, AND CULTURAL HERITAGE PRESERVATION

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Abstract:

The marigold flower, celebrated for its vibrant hues and rich cultural heritage, offers a wealth of beauty and health benefits that extend far beyond its aesthetic appeal. This research investigates the role of media in promoting marigold's applications in skincare, holistic health, and traditional medicine. By analysing diverse media representations, this paper examines how the marigold is portrayed as a symbol of natural wellness, uniting ancient traditions with contemporary scientific insights. The study further explores the implications of media narratives on public perceptions, commercialization, and the preservation of cultural heritage.

Keywords: Marigold flower, beauty benefits, health benefits, media narratives, natural wellness, traditional medicine.

1. Introduction:

The marigold (Tagetes spp.), renowned for its radiant orange and yellow blossoms, is more than an ornamental plant. Across various cultures, it holds deep symbolic and therapeutic significance. The petals of marigold are rich in bioactive compounds such as lutein, flavonoids, and essential oils, which have positioned it as a cornerstone in traditional medicine and modern wellness industries.

In many cultures, marigold is intertwined with rituals and festivals. For instance, in Indian traditions, it symbolizes auspiciousness and purity, while in Latin America, it is integral to Dia de los Muertos ceremonies as a symbol of remembrance. Beyond its cultural roles, the marigold's health properties—including antioxidant, anti-inflammatory, and antimicrobial effects—have been embraced in contemporary applications such as skincare, teas, and dietary supplements.

This paper explores how media narratives have shaped the perception of marigold, highlighting its transition from a traditional emblem to a modern wellness symbol. It investigates the interplay

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

between cultural heritage, scientific validation, and media's role in disseminating information, while addressing concerns about commercialization and the dilution of traditional knowledge.

The Marigold: A Universal Symbol of Life, Healing, and Spirituality

The marigold, known for its radiant hues and versatile applications, has been cherished across cultures and eras. Its symbolism, cultural relevance, and medicinal properties vary from region to region, reflecting its adaptability and deep connection to human traditions. This account delves into its importance in India, Latin America, and Europe, with added insights into its ecological role, horticultural value, and contemporary relevance.

India: A Symbol of Prosperity, Devotion, and Healing

Cultural and Religious Significance

Marigolds hold a sacred position in Indian culture, where they symbolize auspiciousness, energy, and vitality. Their vibrant orange and yellow shades mirror the sun's life-giving force, making them indispensable in religious and social ceremonies.

- **Hindu Festivals:** During Diwali, Durga Puja, and Ganesh Chaturthi, marigolds adorn temples, homes, and public spaces. Garlands made of marigold flowers are offered to deities as a symbol of devotion and protection.
- **Weddings:** Indian weddings prominently feature marigolds in decorative motifs, garlands for the bride and groom, and ceremonial arrangements. The flower signifies prosperity and the sanctity of marital union.
- **Ritual Protection:** Believed to ward off negative energies, marigold garlands are often hung at entrances to homes and temples.

Medicinal and Ecological Contributions

In Indian traditional medicine, marigolds—particularly the calendula variety—have been treasured for their healing properties.

- **Ayurvedic Use:** Marigolds are used to prepare herbal infusions and oils to treat cuts, burns, rashes, and skin infections. They are known for their anti-inflammatory, antimicrobial, and detoxifying effects.
- **Pollinator Attraction:** Beyond cultural uses, marigolds are an integral part of Indian agriculture. Farmers plant them as companion crops to repel pests and attract pollinators, ensuring ecological balance.

Latin America: The Sacred Flower of the Dead

Spiritual and Cultural Symbolism

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ISBN: 978-9952-610-30-7

In Latin America, particularly in Mexico, marigolds—known as *cempasúchil*—are central to the celebration of Día de los Muertos (Day of the Dead).

- **Connection to the Afterlife:** According to tradition, the bright orange hue and pungent aroma of *cempasúchil* flowers guide the spirits of deceased loved ones back to the world of the living. This belief underscores their use in altars (*ofrendas*) and pathways.
- **Altars and Offerings:** Intricate arrangements of marigold petals on altars honor the dead and create a welcoming environment for their spirits. Pathways of petals lead from the altar to gravesites.

Historical Roots

The reverence for marigolds dates back to pre-Hispanic civilizations like the Aztecs, who considered the flower sacred.

- **Aztec Rituals:** Marigolds were associated with Tonatiuh, the sun god. They were used in rituals, medicinal preparations, and as a natural dye for fabrics.
- **Healing Properties:** The Aztecs used marigold infusions to treat digestive ailments and wounds, a tradition that persists in modern herbal medicine in the region.

Europe: A Medicinal Treasure and Christian Symbol

Therapeutic Uses

Marigolds have long been valued in European herbal medicine, particularly the species *Calendula officinalis*.

- **Wound Healing:** In medieval times, marigold poultices and salves were common remedies for cuts, ulcers, and inflammation. Its antiseptic properties made it a staple in battlefield medicine.
- **Skin Care:** Calendula-infused oils and creams were used to soothe eczema, acne, and burns. Today, calendula is a key ingredient in many skincare and cosmetic products.

Christian and Cultural Symbolism

Marigolds were often referred to as “Mary’s gold” in medieval Europe, symbolizing the Virgin Mary’s purity and sanctity.

- **Religious Ceremonies:** The flowers were planted in monastery gardens and used in processions and offerings to represent devotion and reverence.
- **Folk Traditions:** In rural Europe, marigolds were believed to repel evil spirits and were often planted near homes for protection.

Contemporary Relevance: Bridging Tradition and Innovation

Horticultural Value

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Marigolds remain a favorite among gardeners worldwide for their beauty, resilience, and ecological benefits.

- **Pest Control:** Marigolds are widely used in companion planting to deter nematodes and other pests.
- **Pollinator Support:** Their bright colors attract bees and butterflies, enhancing biodiversity in gardens.

Modern Medicine and Industry

The bioactive compounds in marigolds continue to inspire innovations in medicine, cosmetics, and agriculture.

- **Pharmaceutical Applications:** Research into marigold-derived compounds like lutein and calendulin has shown promise for anti-cancer, anti-inflammatory, and eye health treatments.
- **Cosmetics:** Calendula extracts are prevalent in skincare products, prized for their soothing and regenerative properties.

Cultural Renaissance

The marigold's role in festivals, art, and storytelling continues to evolve.

- **Global Celebrations:** Festivals like India's Diwali and Mexico's Día de los Muertos have brought the marigold to global prominence, inspiring interest in its history and uses.
- **Art and Literature:** The flower frequently appears in poetry, painting, and folk tales as a symbol of life, resilience, and beauty.

The marigold's enduring significance across continents is a testament to its versatility and profound connection to human culture. Whether symbolizing devotion in India, guiding spirits in Mexico, or healing wounds in Europe, the marigold continues to bridge the natural and spiritual worlds, enriching lives with its vibrant presence.

Bioactive Properties and Modern Applications of Marigold (Calendula officinalis)

Marigold (Calendula officinalis) has been historically valued for its medicinal properties, and modern scientific research has confirmed many of its health benefits. The plant contains several bioactive compounds responsible for its therapeutic effects, including lutein, flavonoids, and essential oils. Below is a detailed exploration of these compounds and their modern applications.

1. Lutein:

Lutein is a carotenoid with strong antioxidant properties, primarily found in the flowers of marigold. This compound is known for its health benefits, particularly in eye health.

Health Benefits:

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- **Eye Health:** Lutein is one of the main antioxidants found in the macula of the eye, helping to filter blue light and protect against oxidative stress. It has been shown to reduce the risk of age-related macular degeneration (AMD) and cataracts, both of which are major causes of vision impairment in older adults. Lutein also supports retinal health and can improve visual function, especially in low-light conditions.

- **Skin Protection:** Lutein's antioxidant properties also help protect the skin from ultraviolet (UV) radiation. By neutralizing free radicals generated by UV exposure, lutein can help reduce the risk of sunburn, premature aging, and the development of skin cancer.

Modern Applications:

- **Dietary Supplements:** Lutein-rich supplements are popular for promoting eye health and preventing macular degeneration. These supplements are often combined with other antioxidants such as zeaxanthin to provide comprehensive eye protection.

- **Skincare:** Lutein is increasingly incorporated into skincare products due to its ability to neutralize the damaging effects of UV radiation, preventing sun damage and maintaining healthy, youthful skin.

2. Flavonoids:

Flavonoids are a group of polyphenolic compounds found in marigold, known for their powerful antioxidant, anti-inflammatory, and antimicrobial effects.

Health Benefits:

- **Antioxidant Activity:** Flavonoids scavenge free radicals, helping to protect the body from oxidative stress. This action can slow the aging process and reduce the risk of chronic diseases such as cancer, heart disease, and neurodegenerative disorders.

- **Anti-inflammatory Effects:** Flavonoids in marigold help modulate inflammatory pathways in the body. They have been shown to reduce inflammation, which is linked to various conditions such as arthritis, asthma, and cardiovascular disease.

- **Antimicrobial Action:** Certain flavonoids have antimicrobial properties, which make them effective in treating minor infections. They can be used in topical treatments to promote healing in wounds and prevent infections.

Modern Applications:

- **Skincare:** Due to their anti-inflammatory and antioxidant properties, marigold extracts rich in flavonoids are widely used in skincare. They help soothe irritated skin, reduce redness, and prevent premature aging by protecting the skin from free radical damage.

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- **Therapeutic Use:** Flavonoids are incorporated into dietary supplements to support overall health, particularly in boosting immune function and combating inflammation. They are also used in traditional medicine to treat digestive issues, coughs, and colds.

3. Essential Oils:

Marigold essential oils are derived from the flowers of the plant and contain compounds like terpenes and alcohols that have significant medicinal properties.

Health Benefits:

- **Antimicrobial and Antifungal:** The essential oils of marigold have demonstrated antimicrobial and antifungal properties, making them effective in preventing infections, particularly in minor cuts, burns, and skin abrasions. They are also used to treat fungal infections like athlete's foot and ringworm.
- **Skin Healing and Soothing:** Marigold oil is often used for its skin-healing properties, particularly in treating dry skin, eczema, and psoriasis. The oil helps to soothe inflammation, promote tissue regeneration, and reduce scarring in wound healing.
- **Pain Relief:** Marigold essential oils can have mild analgesic effects, which make them useful in reducing pain and inflammation associated with conditions like arthritis and muscle strains.

Modern Applications:

- **Skincare:** Marigold essential oils are incorporated into creams, lotions, and balms for their soothing, moisturizing, and healing properties. They are often used in formulations designed to treat sensitive or irritated skin.
- **Aromatherapy:** Marigold oil is used in aromatherapy to relieve stress and promote relaxation. It is believed to have calming effects on the nervous system, helping to reduce anxiety and improve mood.
- **Topical Treatments:** Due to their antimicrobial properties, marigold essential oils are included in ointments and creams that help treat minor skin infections and promote faster wound healing.

Applications of Marigold in Modern Practices:

1. **Skincare:**

   - Marigold extracts are widely used in modern skincare for their anti-aging, soothing, and anti-inflammatory properties. They are found in creams, lotions, serums, and masks aimed at moisturizing the skin, reducing the appearance of wrinkles, and calming skin irritations such as acne, rosacea, and eczema.

- The plant's compounds also help in protecting the skin from UV damage and pollution, making marigold-based skincare products an essential part of anti-aging regimens.

2. **Dietary Supplements:**

- Lutein-rich marigold supplements are marketed as a natural way to support eye health and prevent conditions like macular degeneration. These supplements are often combined with other nutrients like vitamin E, vitamin C, and omega-3 fatty acids to promote overall health.

- Flavonoids, with their antioxidant and anti-inflammatory benefits, are also included in supplements that support immune health, cardiovascular health, and reduce inflammation.

3. **Traditional Medicine:**

Marigold has a long history of use in traditional medicine. It has been used in poultices, teas, and tinctures for a variety of ailments such as digestive issues, menstrual cramps, and wound healing.

It is also commonly used in herbal remedies for detoxification and as a mild sedative to calm the nervous system.

The modern applications of marigold are vast and continue to grow as more is discovered about its bioactive compounds. Lutein, flavonoids, and essential oils play a significant role in the therapeutic benefits of this plant. From skincare to eye health, marigold's bioactive components offer a natural, scientifically-backed solution to a range of health concerns.

Media Narratives and Public Perception: The Marigold's Journey from Tradition to Modern Wellness Icon

The marigold (Calendula officinalis), a flower historically associated with healing and various folk remedies, has undergone a significant transformation in its public image over recent years. Through the influence of media platforms, it has evolved from a traditional botanical remedy to a modern wellness icon. This change, however, comes with both positive and negative consequences, especially when considering the interplay between commercial interests, traditional knowledge, and scientific validation.

1. Social Media: Wellness Influencers and the Appeal of "Natural" Products

Social media has played a pivotal role in reshaping public perception of marigold, particularly in the wellness and beauty industries. Influencers, bloggers, and content creators, often focusing on organic, eco-friendly, and natural products, have popularized marigold-infused goods.

- **Promotion of Marigold Products:** Wellness influencers frequently highlight marigold-based skincare, supplements, and cosmetics, emphasizing their "natural" and "sustainable" qualities. By framing marigold as a plant with healing properties, influencers have made it an attractive option for consumers seeking alternative, plant-based solutions to skin care and health.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

- **Aesthetic and Green Consumerism:** The association of marigold with nature, health, and sustainability taps into the growing trend of eco-conscious consumers. Hashtags like #NaturalSkincare and #GreenBeauty frequently feature marigold as a key ingredient in their content, thus making it a sought-after component of beauty regimens that promise wellness without harming the environment.

- **Viral Content and Trend Cycles:** Through Instagram, YouTube, and TikTok, marigold has been incorporated into "wellness trends" that emphasize ingredients that are seen as both effective and environmentally friendly. Products such as marigold-based facial oils, creams, and teas, often boasting anti-aging and anti-inflammatory properties, are showcased by influencers, thereby boosting their popularity.

2. Advertisements: Highlighting Therapeutic Properties and Eco-Conscious Messaging

Advertising campaigns have capitalized on marigold's increasing visibility as a natural ingredient with therapeutic benefits, often linking the plant to broader societal trends related to health, eco-consciousness, and sustainability.

- **Therapeutic Messaging:** In ads, marigold is frequently marketed as an effective ingredient for skincare, pain relief, and inflammation reduction. Beauty brands position marigold as a key player in their "clean beauty" lines, often emphasizing its anti-aging, healing, and soothing effects. For example, marigold-based creams may be advertised as suitable for sensitive skin, with claims that the plant helps to heal and calm irritated skin, making it an appealing option for consumers with conditions like eczema or rosacea.

- **Targeting Eco-Conscious Consumers:** Advertisements also play into the growing demand for products that are not only effective but also environmentally responsible. Marigold is frequently portrayed as a "sustainable" and "eco-friendly" ingredient, especially when sourced organically or from fair-trade suppliers. This appeals to a segment of consumers who prioritize ethical sourcing, transparency in production, and a commitment to reducing environmental impact.

- **Brand Identity and Cultural Values:** Many brands use marigold as part of a narrative that promotes values such as sustainability, natural health, and personal wellness. These advertisements often tap into the broader wellness movement, where marigold is presented not just as a plant, but as a symbol of a holistic lifestyle that connects the individual to nature.

3. Scientific Publications: Bridging Cultural Practices with Modern Research

While the media plays a significant role in shaping the public perception of marigold, scientific research has also validated many of the plant's traditional uses, lending credibility to its therapeutic properties.

- **Validation of Traditional Uses:** Numerous studies have confirmed that marigold contains bioactive compounds such as lutein, flavonoids, and essential oils, which have antioxidant, anti-

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ISBN: 978-9952-610-30-7

inflammatory, antimicrobial, and skin-healing effects. Scientific publications validate marigold's traditional use in herbal medicine, creating a bridge between folk knowledge and modern scientific understanding.

- **Incorporation into Modern Wellness Discourses:** As a result of such studies, marigold is increasingly featured in academic papers, health publications, and clinical studies. The plant's therapeutic potential is highlighted in scientific journals, thus contributing to a more mainstream acceptance of marigold-based products in healthcare and wellness industries. Researchers also discuss its role in reducing oxidative stress, alleviating pain, and protecting against UV damage, aligning the traditional uses of marigold with current health and wellness trends.

- **Cultural Relevance and Bridging the Gap:** Publications often highlight the deep cultural roots of marigold in various global traditions. For example, its use in Ayurvedic, Chinese, and European herbal medicine provides context to its modern-day applications, making it an important example of how indigenous knowledge can be integrated into modern health practices.

4. The Risks of Overshadowing Traditional Knowledge

While the rise of marigold in modern media is largely positive, it also comes with the risk of overshadowing indigenous practices and traditional knowledge.

- **Commercialization of Traditional Remedies:** The commercialization of marigold-based products often focuses on its appeal to consumers seeking "natural" solutions, but this narrative may obscure the plant's historical and cultural significance. Traditional uses of marigold, such as in poultices, tinctures, and teas for wound healing or digestive health, may be marginalized in favor of a more profit-driven, sanitized version of its benefits.

- **Loss of Cultural Context:** When marigold is marketed primarily for its aesthetic or therapeutic qualities in the context of global wellness trends, it risks being disconnected from the cultural and indigenous practices that have sustained its use for centuries. For example, in some cultures, marigold is not just a product but also a symbol in rituals and healing practices. The widespread commercialization of marigold might unintentionally reduce the plant to a mere commodity, stripping away its deeper cultural significance.

- **Risk of Appropriation:** As global interest in "natural" remedies rises, there is a danger that the wisdom of indigenous communities, who have used marigold for centuries, may not be properly acknowledged. The exploitation of marigold for commercial purposes by larger companies may not always fairly compensate or credit the communities whose knowledge has contributed to its popularity. This reflects a broader issue of cultural appropriation in the wellness industry, where traditional knowledge is repackaged for a global market without recognition of its roots.

5. Conclusion: The Double-Edged Sword of Media Influence

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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The media's influence on marigold's transformation from a traditional medicinal herb to a modern wellness product has been transformative. Social media influencers, advertising campaigns, and scientific validation have all contributed to elevating the plant's status in the contemporary wellness landscape. However, this shift comes with concerns about the commercialization of traditional knowledge and the risk of erasing the cultural context in which marigold has been used for generations.

As marigold becomes increasingly recognized for its therapeutic properties, there is a growing need for a balanced narrative that acknowledges both its scientific validation and its deep roots in indigenous practices. For marigold to maintain its integrity in the modern wellness market, it is crucial to bridge the gap between tradition and modernity, ensuring that the value of cultural wisdom is recognized and respected alongside the benefits it offers in contemporary health and beauty industries.

Successful Case Study Campaign: The Marigold Flower in the Wellness and Beauty Industry

One of the most successful campaigns involving the marigold flower (Calendula officinalis) is the **"Calendula Skincare Line"** launched by **Weleda**, a well-known global natural cosmetics brand. This case study highlights how marigold's historical uses and modern wellness trends were effectively leveraged in a multi-dimensional marketing strategy, creating both brand growth and consumer loyalty.

1. Background of Weleda's Calendula Campaign

Weleda, founded in 1921, has long been known for producing natural and organic products, with a strong commitment to sustainability and ethical sourcing. The company introduced its **Calendula Baby Care Range** in 1959, capitalizing on marigold's well-established reputation for its soothing and healing properties. Over the decades, Weleda has continued to build on this heritage, leveraging marigold in various skincare and baby care products. The company's branding and marketing strategies have been instrumental in highlighting marigold's benefits, connecting its historical use to modern wellness and beauty trends.

2. Key Components of the Campaign

a. Emphasis on Natural Ingredients and Sustainability

- **Natural and Organic Focus:** Weleda's marketing campaign centers on marigold's natural healing qualities, focusing on its reputation as a soothing, anti-inflammatory, and anti-aging ingredient. In an era when consumers are more conscious about the ingredients in their products, Weleda's message emphasizes that marigold is sustainably grown, free from synthetic chemicals, and suitable for sensitive skin. This messaging aligns with a growing global demand for natural and cruelty-free products.

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- **Sustainability Efforts:** Weleda's campaign emphasizes the sustainability of its marigold flowers. The company uses organically farmed marigold, grown in its own biodynamic gardens, ensuring that both the environment and the local farming communities benefit. This commitment to sustainability is key in resonating with eco-conscious consumers.

b. Multi-Platform Media Strategy

- **Social Media Influencers and User-Generated Content:** Weleda effectively used social media to promote its Calendula line. Wellness influencers and beauty bloggers, particularly those focused on clean beauty and organic skincare, featured Weleda's Calendula products in sponsored posts, often highlighting the brand's environmentally conscious production process. The hashtag #CalendulaCare gained traction as users shared personal stories and before-and-after photos of their experience using the products, adding authenticity and creating trust with potential buyers.

- **Targeted Advertisements:** Weleda used both traditional and digital media platforms to target specific demographics, such as parents seeking gentle skincare products for their babies and individuals with sensitive skin. Through online ads and magazine placements, the campaign highlighted marigold's therapeutic and gentle properties, making it an attractive choice for a wide range of consumers.

- **Content Marketing:** The company also used blog posts, videos, and articles to educate consumers on marigold's benefits, both from a skincare and health perspective. By producing educational content, Weleda positioned itself as a trusted source of knowledge, further enhancing its credibility in the wellness space.

c. Scientific Backing and Traditional Knowledge

- **Scientific Validation:** Weleda's campaign incorporated scientific research that supports the therapeutic claims associated with marigold. The brand cited studies showing the plant's anti-inflammatory, antimicrobial, and skin-healing effects. This scientific backing enhanced the brand's authority and appeal to consumers who are increasingly interested in the health benefits of natural ingredients.

- **Cultural Connection:** The campaign did not just focus on marigold as a modern wellness product; it also emphasized its historical and cultural relevance. By linking marigold's use in traditional medicine to its modern-day applications, Weleda successfully bridged the gap between indigenous knowledge and contemporary beauty practices. This approach helped foster a sense of authenticity around the product and built an emotional connection with consumers.

d. The Launch of Marigold-Based Product Lines

Weleda's Calendula products include **Calendula Baby Cream**, **Calendula Body Lotion**, and **Calendula Face Cream**, all of which use marigold extracts as the main active ingredient. The product

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launch was accompanied by a clear narrative about the flower's beneficial effects on skin, particularly for sensitive or irritated skin, which is why it became a top choice for baby care.

- **Calendula Baby Care:** The Calendula Baby Care Range has been one of Weleda's flagship product lines, with the marigold-based baby creams and oils positioning the brand as a leader in gentle, non-irritating skincare for infants. The products were marketed not only for their healing properties but also for being free from synthetic fragrances, dyes, and preservatives, appealing to the growing demand for chemical-free baby products.
- **Calendula as a Therapeutic Ingredient:** Weleda also marketed Calendula as a therapeutic skincare ingredient for adults, especially for conditions like dry skin, eczema, and minor cuts and bruises. The soothing, skin-healing properties of marigold were highlighted in multiple product lines targeting adults, including their popular **Calendula Oil** and **Calendula Hand Cream**.

3. Results and Impact of the Campaign

The **Calendula Baby Care Range** has been a major success for Weleda, contributing significantly to the brand's global growth. Here are the key outcomes from the campaign:

- **Increased Brand Awareness:** Weleda successfully expanded its customer base by tapping into the growing demand for natural skincare. Their Calendula line has been consistently featured in top wellness and beauty media outlets, raising awareness among both new and loyal customers.
- **Market Leadership in Organic Skincare:** By positioning marigold as a primary ingredient in their products and effectively marketing its therapeutic properties, Weleda has become a recognized leader in the organic skincare market. This campaign has helped strengthen the company's position within the eco-conscious, natural beauty segment.
- **Sales Growth:** Weleda's Calendula-based products, particularly in the baby care category, have seen sustained growth, with the brand reporting increased sales year after year in markets such as the U.S. and Europe. Consumers have responded well to the therapeutic benefits of marigold, as well as the brand's commitment to sustainability and ethical sourcing.
- **Consumer Loyalty:** The campaign has helped foster a loyal customer base, particularly among parents and individuals seeking reliable, natural skincare products. Testimonials and user-generated content on social media have further strengthened brand trust, allowing Weleda to engage with its audience directly.

4. Lessons Learned and Future Considerations

- **Highlighting Ethical Practices:** Weleda's success underscores the importance of combining natural product benefits with a commitment to sustainability and ethical practices. The brand's focus on organic marigold cultivation and its biodynamic farming methods have made the product line more attractive to eco-conscious consumers.

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- **Leveraging Scientific Research:** The use of scientific backing in the campaign helped bridge the gap between traditional knowledge and modern consumers' desire for evidence-based health benefits. This combination of scientific validation with cultural authenticity was key in building trust.
- **Digital Marketing and Social Media:** The success of social media influencers and user-generated content has become an essential part of modern marketing. Weleda's ability to tap into these platforms helped them reach a wider, more engaged audience, particularly younger, health-conscious consumers.

Weleda's Calendula campaign is a prime example of how a traditional ingredient like marigold can be successfully marketed in the modern wellness and beauty industry. By combining natural benefits, sustainability messaging, scientific validation, and a strong digital presence, Weleda has created a product line that resonates with today's consumers while honoring the long history and cultural significance of the marigold flower. This case study illustrates how traditional knowledge can be successfully integrated into contemporary branding and marketing strategies, ensuring that both the plant's heritage and modern wellness trends are respected and promoted.

Challenges in Representation of Marigold in Media

As marigold (Calendula officinalis) has gained prominence in the wellness, beauty, and healthcare industries, the media has played a crucial role in shaping public perception. However, with its rise as a sought-after ingredient, several challenges have emerged regarding how marigold is represented and marketed. These challenges can dilute the true cultural significance of the plant, distort the understanding of its benefits, and marginalize the communities that have historically used it.

1. Commercialization: Dilution of Cultural Significance

One of the most significant challenges in the media's portrayal of marigold is its **commercialization**, which often leads to a commodification of the plant. As marigold becomes increasingly popular in the wellness and beauty sectors, it is frequently marketed as just another "superflower" or trendy ingredient, stripped of its deeper cultural and medicinal roots.

a. Loss of Traditional Context

- **Cultural Roots Neglected:** Marigold has a long history of use in various cultures, including traditional medicine systems like Ayurveda, Chinese medicine, and European folk remedies. In these systems, marigold was revered not only for its physical healing properties but also as a symbol of life, vitality, and well-being. However, in the commercial landscape, marigold is often reduced to a mere ingredient for skin creams or dietary supplements, disconnected from its rich cultural heritage. The deeper spiritual, cultural, and ritualistic aspects of marigold's use are often overlooked, with little emphasis placed on the knowledge systems that have preserved its value for generations.

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- **Cultural Appropriation Risks:** The global demand for marigold-based products sometimes leads to the **appropriation of indigenous knowledge**. Many traditional uses of marigold have been passed down through generations within indigenous and local communities. When large commercial companies capitalize on marigold's healing properties, they often fail to acknowledge or compensate these communities for their centuries-old knowledge. This creates a power imbalance where the benefits of marigold are extracted for profit, but the cultures responsible for its preservation are not appropriately recognized.

b. The Loss of Marigold's Spiritual Significance

- In many cultures, marigold is not just a medicinal plant but also has spiritual significance. For example, in Indian culture, marigold flowers are used in religious rituals, weddings, and festivals as symbols of prosperity and divine protection. However, in media portrayals aimed at selling products, this sacred cultural significance is often overshadowed by commercial interests. Marigold is frequently marketed as just another "beauty herb," losing the deep symbolic meaning it holds for many people.

2. Overhyping Benefits: Exaggerated Claims and the Risk of Skepticism

With marigold's increased popularity, the wellness and beauty industries have been quick to emphasize its supposed benefits. While marigold does indeed have many therapeutic properties, there is a risk of **exaggerated claims** that can backfire, creating consumer skepticism and undermining trust in its genuine health benefits.

a. Unrealistic Expectations

- **Overpromising Results:** Marketing campaigns often present marigold products as a "miracle cure" for a wide range of skin and health issues, from curing acne and wrinkles to preventing UV damage and reducing stress. Such exaggerated claims can set unrealistic expectations for consumers, leading them to believe that marigold will provide quick and dramatic results. When the benefits do not meet these inflated expectations, consumers may become disillusioned and lose trust in marigold-based products altogether.

- **The "Superfood" Trend:** Similar to other plants that have been thrust into the spotlight as "superfoods," marigold is sometimes advertised as a panacea for all skin-related issues or an elixir for overall health. However, while marigold does have proven antioxidant, anti-inflammatory, and antimicrobial properties, it is not a cure-all. By focusing on such exaggerated health claims, brands risk misrepresenting the plant's true effects and creating a backlash when the results don't match the hype.

b. Backlash and Consumer Distrust

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- **Skepticism about Natural Products:** The trend toward "natural" beauty and wellness products can sometimes lead to **greenwashing**, where companies claim their products are completely natural or organic without fully substantiating these claims. When marigold products are marketed with exaggerated promises and little scientific backing, consumers may begin to view them with skepticism. They may question the authenticity of the claims and, as a result, begin to distrust not just marigold-based products but natural and organic beauty products in general.

- **Regulatory Oversight:** The lack of regulation in the natural product sector often allows companies to make exaggerated health claims without rigorous scientific validation. This further undermines consumer trust and complicates the perception of marigold as a reliable, scientifically-backed ingredient.

3. Exclusion of Indigenous Voices: Marginalizing Traditional Knowledge

While marigold's healing properties have been validated through modern scientific research, the **traditional knowledge** that has been passed down through indigenous communities is often not sufficiently acknowledged. The media, particularly in commercial campaigns, tend to focus on the plant's benefits through a Western scientific lens, neglecting the voices of the cultures and communities that have used marigold for centuries.

a. Erasure of Cultural Significance

- **Lack of Credit to Indigenous Communities:** In many cases, media campaigns focus on marigold's benefits as a "new" or "innovative" discovery, even though the plant's use has been deeply embedded in various cultures for generations. The traditional knowledge about marigold's medicinal uses, particularly in wound healing, skin care, and digestive health, is often **marginalized** in favor of scientific validation, which often prioritizes Western-based research. This erasure of the plant's indigenous cultural significance contributes to a broader pattern of cultural appropriation in the wellness and beauty industries.

- **Failure to Support Indigenous Knowledge Holders:** Many indigenous communities in countries like India, Mexico, and parts of Africa have long used marigold as part of their holistic health practices. However, these communities are often excluded from the commercial benefits derived from the plant. Companies rarely acknowledge the traditional knowledge that these communities hold, nor do they provide fair compensation or recognition for their contributions. As a result, the commercialization of marigold risks reinforcing the **economic and cultural marginalization** of these communities.

b. Disconnection from Traditional Uses

- **Simplification of Traditional Practices:** Media often distills marigold's uses into a simplified, consumer-friendly narrative—such as "soothing for skin" or "anti-aging"—without

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acknowledging the more complex, holistic approaches that indigenous cultures take toward using the plant. In traditional practices, marigold is often combined with other herbs or used in specific rituals, emphasizing a deep connection between the plant, health, and spirituality. When the plant is reduced to a commercial product, this intricate web of traditional knowledge is overlooked.

- **The Role of Indigenous Healers:** In many cultures, marigold is administered by traditional healers or herbalists, who understand the plant's full range of uses within the context of local ecosystems and health practices. However, the media often overlooks these healers, and their contributions to the wellness industry are rarely recognized. This leads to an oversimplified and Westernized view of marigold that misses the depth of indigenous knowledge.

Balancing Commercial Success with Cultural Respect

The media's representation of marigold in modern wellness campaigns has certainly elevated the plant's profile, bringing attention to its valuable health benefits. However, several significant challenges remain. **Commercialization** has led to the commodification of marigold, potentially diluting its cultural significance and marginalizing the communities that have preserved its uses. The trend of **overhyping benefits** can undermine trust in the plant's real therapeutic value, and the **exclusion of indigenous voices** risks further erasure of traditional knowledge systems.

To create a more balanced and respectful representation of marigold, it is essential for the media and wellness brands to acknowledge the plant's cultural roots, avoid over-promising benefits, and engage with indigenous communities. By doing so, marigold can be celebrated not just as a product but as a symbol of cultural heritage and modern wellness, maintaining its authenticity while thriving in the global marketplace.

Bridging Tradition and Modernity: The Role of Media in Representing Marigold's Value

In the modern age, **media** has become a powerful tool in shaping public perception, especially when it comes to wellness and beauty trends. The growing popularity of **marigold** (Calendula officinalis) in the global market presents a unique opportunity for media platforms to bridge the gap between **traditional wisdom** and **scientific innovation**. Marigold, a flower rich in historical significance and modern-day health benefits, offers a compelling case for how media can respect cultural heritage while promoting scientific progress. By crafting **balanced narratives**, the media can serve as a crucial vehicle to educate consumers, preserve the cultural heritage associated with marigold, and promote inclusivity by amplifying indigenous voices.

1. Educating Consumers: Fostering a Comprehensive Understanding of Marigold

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Media plays a vital role in **educating consumers** about the full scope of marigold's benefits, both from a **scientific** and **cultural** perspective. As wellness and beauty consumers increasingly seek out natural products, media can bridge the gap by providing nuanced and accurate information.

a. Scientific Education: Unveiling the Active Compounds

- **Validating Health Claims:** Scientific studies have identified many of marigold's active compounds, such as **lutein**, **flavonoids**, and **essential oils**, which contribute to its therapeutic effects. Media can highlight these discoveries through articles, documentaries, and interviews with **scientists** and **dermatologists**, thus emphasizing marigold's **scientifically proven benefits** for skin care, eye health, and inflammation reduction.

- **Discussing Mechanisms of Action:** By explaining how marigold works biologically—such as how its compounds counteract oxidative stress, promote collagen production, and reduce irritation—media platforms can demystify the science behind marigold's effectiveness. This helps build consumer trust in its actual health benefits, going beyond the buzzwords of "natural" and "organic" to demonstrate **evidence-based results**.

b. Cultural Education: Connecting to Ancient Practices

- **Honoring Traditional Uses:** Marigold has a rich history of use in various traditional medicinal systems, including **Ayurveda**, **Traditional Chinese Medicine (TCM)**, and **European folk medicine**. Media platforms can serve as a conduit for educating consumers about the flower's deep cultural roots. For instance, sharing **oral histories**, **folklore**, and **ritual practices** can help consumers connect with marigold on a deeper level, understanding it not just as a modern commodity but as a plant with centuries of cultural significance.

- **Highlighting Cultural Rituals:** In countries like India, marigold is often used in religious ceremonies, festivals, and weddings, symbolizing prosperity, good fortune, and protection. By showcasing these cultural practices, media can reinforce marigold's importance beyond its health benefits, fostering a more holistic understanding of its role in **spiritual** and **social** contexts.

2. Preserving Heritage: Showcasing Traditional Uses of Marigold

As marigold becomes increasingly commercialized, it is crucial to **preserve its cultural heritage**. The media has a responsibility to present marigold's traditional uses and respect the **cultural wisdom** that has been passed down through generations.

a. Documenting and Celebrating Indigenous Knowledge

- **Interviews with Traditional Healers:** Media outlets can feature **interviews** with **indigenous healers**, **herbalists**, and **community elders** who have long utilized marigold in natural medicine. By amplifying the voices of these practitioners, the media can create a platform for traditional knowledge

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to be respected and shared globally. These stories provide a counter-narrative to the commercialized, Westernized portrayal of marigold and encourage a deeper respect for indigenous cultures.

- **Storytelling and Documentary Projects:** Documentaries, short films, and digital content can showcase how marigold has been used in **family remedies**, **local healing practices**, and **cultural rituals**. This type of content offers viewers insight into the plant's broader role within specific cultural landscapes, helping to preserve its rich legacy for future generations. Additionally, through storytelling, the media can reveal the **ethical practices** of cultivating marigold and the sustainable farming techniques that many indigenous communities use.

b. Respecting Cultural Significance in Marketing

- **Ethical Marketing:** Media can help advocate for ethical practices in the commercialization of marigold-based products. By encouraging brands to acknowledge and respect the plant's cultural roots in their marketing, the media can push for a more **respectful representation** of marigold in the global marketplace. This includes ensuring that indigenous communities receive **recognition** and **fair compensation** for the knowledge and sustainable farming practices they provide.

- **Cultural Sensitivity in Advertising:** Advertising campaigns that include marigold as an ingredient should aim for cultural sensitivity, ensuring that the plant's deep spiritual and cultural significance is respected. Media can hold brands accountable for using marigold not just as a marketing tool but as a symbol of cultural respect.

3. Promoting Inclusivity: Amplifying Indigenous Voices and Practices

A significant challenge in modern media is the **underrepresentation** of **indigenous voices**. In the case of marigold, media can play a vital role in promoting inclusivity by ensuring that the voices of those who have used and preserved the plant for generations are heard and valued.

a. Platforms for Indigenous Voices

- **Media Advocacy and Representation:** Media outlets should proactively seek out indigenous practitioners, **traditional healers**, and **community leaders** to speak about their knowledge of marigold. By creating platforms for these voices to share their experiences, media can help shift the conversation away from **appropriation** and toward **acknowledgment**. This would help reduce the risk of cultural erasure and bring attention to the important work of indigenous communities.

- **Collaborative Projects:** Partnerships between wellness brands and indigenous communities can be highlighted in the media, showcasing **fair trade initiatives**, **sustainable farming practices**, and **community-led conservation efforts**. These collaborations can be presented as models for how the wellness industry can operate ethically and inclusively.

b. Promoting Diversity in Scientific Research

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- **Highlighting Indigenous Knowledge in Modern Science:** As modern science continues to explore the health benefits of marigold, media can encourage collaboration between scientists and indigenous communities. **Ethnobotanists**, for instance, often work with indigenous people to understand traditional plant uses, and media platforms can feature these collaborations, demonstrating the synergy between **traditional ecological knowledge** and **modern scientific practices**.

- **Ethical Research Practices:** The media can also raise awareness about the importance of **ethical research** in which indigenous knowledge is credited and respected. This ensures that scientific innovations do not occur at the expense of indigenous communities but instead create pathways for shared learning and collaboration.

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4. Case Studies of Media Bridging Tradition and Modernity

a. "Calendula: The Healing Flower" Documentary

A documentary that explores the history, cultural significance, and modern applications of marigold could be a powerful tool for bridging tradition and modernity. This project could feature **traditional healers**, **scientists**, **farmers**, and **wellness experts**, offering viewers a comprehensive understanding of marigold's role in both ancient and modern contexts.

b. Social Media Campaigns Celebrating Marigold's Origins

Brands could partner with **local communities** and **indigenous influencers** to promote marigold-based products while also sharing the history and cultural stories behind the flower. This **multi-channel campaign** could include social media posts, blog articles, and videos that honor marigold's roots in both science and culture, giving **credit** to its traditional uses and the people who have preserved this knowledge.

A Path Forward for Media's Role in Marigold's Narrative

As marigold continues to thrive as a commercial and wellness ingredient, the media has an opportunity to bridge the gap between **traditional wisdom** and **modern scientific discoveries**. By educating consumers, preserving cultural heritage, and promoting inclusivity, media platforms can provide a balanced, respectful narrative that honors marigold's rich history while celebrating its potential in contemporary health and beauty practices. Ultimately, by fostering a deeper understanding of both the **scientific benefits** and **cultural significance** of marigold, the media can ensure that this remarkable plant is celebrated for all its diverse values, supporting a future where tradition and innovation coexist harmoniously.

Methodology: Analyzing Media Representations of Marigold

This study adopts a **mixed-methods approach** to analyze the media representations of marigold, examining the intersection of its portrayal in **advertisements**, **social media**, **scientific articles**, and **cultural practices**. By integrating **qualitative** and **quantitative** research methods, the study seeks to provide a comprehensive understanding of how marigold is presented in modern media and how these representations shape public perception. The mixed-methods framework includes **content analysis**, **expert interviews**, and **case studies**, each of which offers unique insights into different aspects of marigold's media portrayal.

1. Content Analysis: Analyzing Media Texts

The first component of the methodology is **content analysis**, which involves systematically analyzing media texts to uncover patterns and trends in the representation of marigold. This process provides an

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objective way to assess how marigold is depicted across different media platforms, such as advertisements, social media, and scientific articles.

a. Selection of Media Types

The study focuses on three key media types where marigold is commonly represented:

- **Advertisements**: Commercials, print ads, and digital marketing campaigns that feature marigold as an ingredient in skincare, wellness, and beauty products.
- **Social Media**: Influencer posts, brand promotions, and user-generated content across platforms like Instagram, TikTok, Facebook, and YouTube. Social media is particularly influential in shaping modern consumer perceptions.
- **Scientific Articles**: Peer-reviewed studies and health articles published in academic journals, health magazines, and medical websites, which validate or critique the plant's therapeutic properties.

b. Coding and Categorization

The content analysis involves **coding** the texts for various themes, such as:

- **Key Messages**: What benefits of marigold are emphasized (e.g., skin healing, anti-aging, antimicrobial properties)?
- **Representation of Science and Tradition**: Is there a balance between highlighting marigold's traditional uses and scientific validation? Are traditional cultural uses mentioned, or is the focus solely on modern, scientifically backed applications?
- **Commercial Focus**: How are marigold's benefits framed—primarily as a selling point, or is there an educational approach regarding its cultural significance and health benefits?

The results of this content analysis will provide a quantitative snapshot of how marigold is being represented across media channels, allowing the researcher to identify recurring trends, potential exaggerations, or gaps in representation.

2. Expert Interviews: Gathering Insights from Professionals

The second component of the study involves **expert interviews** to gain in-depth insights from key stakeholders with specialized knowledge on marigold. These interviews help provide context and further qualitative understanding of the media portrayal of marigold from the perspectives of professionals in relevant fields.

a. Selection of Experts

The study will include interviews with professionals from three primary domains:

- **Botanists**: Experts in plant sciences and ethnobotany who can speak to the **natural history** and **cultivation** of marigold, as well as its traditional uses in various cultures.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

- **Dermatologists**: Medical professionals with expertise in skin care and cosmetic dermatology who can provide insights into the **scientific evidence** supporting marigold's use in modern skincare products.

- **Media Professionals**: Individuals involved in marketing, advertising, or media production, particularly those who have worked on campaigns promoting marigold-based products. These experts can share insights into how media representations of marigold are constructed and the commercial motivations behind them.

b. Interview Methodology

The interviews will be semi-structured, allowing for both guided questions and open-ended responses. The key areas of focus will include:

- **Perceptions of Marigold**: How do experts view the plant's medicinal and cultural significance? Do they believe it is being portrayed accurately in the media?

- **Media Representation**: What are the challenges and benefits of promoting marigold through media? Are there ethical considerations regarding cultural appropriation or exaggerated health claims?

- **Consumer Impact**: How do experts believe media representations of marigold influence consumer behavior and perceptions of natural or "alternative" products?

By gathering these diverse perspectives, the study will provide a more comprehensive understanding of how marigold is represented across professional and cultural spheres.

3. Case Studies: Investigating Specific Campaigns and Cultural Practices

The third method involves **case studies**, which will allow the study to explore specific instances where marigold has been prominently featured in media campaigns or cultural practices. Case studies provide a detailed examination of how marigold is used in real-world scenarios, and they offer insight into both its modern commercial applications and its traditional cultural significance.

a. Selection of Case Studies

The study will focus on three types of case studies:

- **Commercial Campaigns**: Specific media campaigns that prominently feature marigold-based products, such as skincare lines or wellness supplements. These campaigns will be analyzed to understand how the brand positions marigold as a wellness or beauty ingredient and whether they acknowledge the plant's cultural and scientific origins.

- **Traditional Cultural Practices**: Case studies that explore the traditional uses of marigold in specific communities or regions. For example, marigold's role in religious ceremonies, healing rituals, or herbal medicine will be explored through ethnographic sources or media representations of these practices.

- **Indigenous Collaborations**: Case studies where wellness brands or media outlets have collaborated with indigenous communities to highlight marigold's role in cultural practices. These cases will be examined to assess how the partnerships address the ethical considerations of **cultural representation** and **fair compensation** for indigenous knowledge.

b. Methodology for Case Study Analysis

Each case study will be analyzed using the following approach:

- **Media Representation**: What messages and themes are present in the campaign or portrayal of marigold in the media? How is the plant framed in terms of **authenticity**, **efficacy**, and **cultural value**?

- **Cultural Sensitivity**: Does the campaign or cultural practice acknowledge and respect marigold's cultural significance, or does it simplify or commodify its meaning for commercial purposes?

- **Impact on Public Perception**: How have these case studies influenced public perception of marigold, both in terms of its **health benefits** and **cultural value**? Are consumers more likely to see marigold as a genuine wellness product, or are they viewing it through the lens of appropriation and commercialization?

4. Data Integration and Analysis

Once data has been collected through content analysis, expert interviews, and case studies, the study will integrate the findings to draw comprehensive conclusions about how marigold is represented in media. The analysis will:

- **Identify Themes and Patterns**: Using qualitative analysis tools, themes and patterns will be identified across different media types (e.g., **cultural erasure**, **scientific validation**, **over-commercialization**).

- **Evaluate Ethical Implications**: The study will examine the ethical implications of the commercialization of marigold and the possible effects of misrepresentation or lack of cultural sensitivity.

- **Provide Recommendations**: Based on the findings, the study will propose recommendations for media campaigns, brands, and consumers to ensure that marigold is represented with respect to both its scientific properties and cultural origins.

By employing a mixed-methods approach that integrates content analysis, expert interviews, and case studies, this study will offer a **comprehensive evaluation** of how marigold is represented in modern media. The findings will provide valuable insights into the **intersection of tradition and modernity** in the media landscape, highlighting both the **commercial opportunities** and **ethical challenges** that

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

arise when marketing a plant with deep cultural and medicinal significance. Ultimately, this methodology will help foster a more informed, respectful, and inclusive representation of marigold, ensuring that its potential benefits are understood and appreciated across diverse audiences.

Findings and Discussion: Media Representations of Marigold

The analysis of media representations of marigold through content analysis, expert interviews, and case studies has provided several key insights into how marigold is portrayed in modern media. The findings reveal a complex intersection of **media amplification**, **cultural dilution**, and **consumer trends**, which influence how marigold is perceived and consumed. The study underscores both the potential benefits and ethical challenges associated with marigold's growing popularity in the wellness and beauty industries.

1. Media Amplification: Raising Awareness and Aligning with Modern Consumer Demands

One of the most significant findings of this study is the **amplification of marigold's benefits** through modern media platforms. Media outlets, including **advertisements**, **social media**, and **scientific publications**, have played a pivotal role in raising consumer awareness of marigold's health benefits, aligning traditional knowledge with contemporary wellness and beauty trends.

a. Increased Visibility

Media has significantly increased the visibility of marigold, transitioning it from a lesser-known plant to a widely recognized ingredient in **skincare**, **wellness supplements**, and **herbal remedies**. Advertisements and social media campaigns, often led by **wellness influencers** and **beauty brands**, emphasize marigold's **anti-inflammatory**, **antioxidant**, and **antimicrobial properties**. These campaigns have made marigold a central figure in the narrative of natural beauty and health, positioning it as a go-to ingredient for **moisturizing**, **soothing**, and **healing** purposes.

b. Aligning with Consumer Preferences

The growing interest in **natural** and **organic** products has further fueled the demand for marigold-based goods. With increasing consumer concerns over the **harmful effects of synthetic chemicals** in skincare and wellness products, marigold's status as a **natural** and **plant-based** remedy makes it a desirable ingredient for eco-conscious buyers. Media platforms have been effective in aligning marigold's health benefits with modern consumer values, including **sustainability**, **transparency**, and **ethical sourcing**.

c. Bridging Tradition and Modernity

Through **scientific publications** and **academic research**, media has also played a key role in **validating traditional uses** of marigold. Studies on marigold's bioactive compounds, such as **lutein** (for eye health) and **flavonoids** (for their antioxidant properties), have bridged the gap between ancient practices and modern scientific validation. These findings have empowered media outlets to

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

tell a more comprehensive story of marigold's efficacy, which resonates with both **traditional knowledge** and **scientific communities**.

2. Cultural Dilution: The Commodification of Marigold

Despite the many benefits of media amplification, the analysis reveals a troubling trend toward **cultural dilution**. As marigold gains popularity in mainstream wellness and beauty industries, its **traditional significance** and **cultural roots** are often overshadowed or commodified.

a. From Ritual to Commodity

In many media representations, marigold is presented primarily as a **commodity**—a product to be marketed, sold, and consumed. This reduction of the plant to a mere commercial product neglects its rich **cultural heritage**. In indigenous cultures, marigold is used in **religious rituals**, **spiritual ceremonies**, and **folk medicine**. It holds **symbolic meaning** in many parts of the world, particularly in countries like **India**, where marigold flowers are integral to festivals, weddings, and other cultural events. However, mainstream media often fails to acknowledge or celebrate these cultural contexts, instead focusing on its **functional benefits** in skincare and wellness routines.

b. Exaggerated Commercial Narratives

In the race to capitalize on marigold's rising popularity, many commercial narratives tend to **over-simplify** or **exaggerate** the plant's benefits. This over-commercialization leads to **hyperbolic claims** about its efficacy, such as "miracle skincare" or "cure-all properties," which often **overshadow** its more **modest and culturally embedded** uses. This not only distorts public perceptions but also risks marginalizing the communities who have historically preserved and used marigold for **healing** and **spiritual purposes**.

c. Loss of Context

While marigold's scientific and cosmetic benefits are celebrated, its **cultural and spiritual significance** is often left out of the narrative. By focusing only on marigold's practical applications in beauty products, media risk erasing the **multifaceted value** of the plant, which encompasses its **symbolic** and **spiritual roles** in various cultures. This cultural erasure diminishes the opportunity for consumers to understand the full significance of marigold, reducing it to a trend or a marketing buzzword.

3. Consumer Trends: Ethical Sourcing and Growing Demand for Natural Products

The growing demand for **natural** and **sustainable** products has undoubtedly boosted marigold's popularity, but this trend also raises important concerns about **ethical sourcing** and the **impact of commercialization** on indigenous communities and local ecosystems.

a. Natural and Sustainable Appeal

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

As more consumers seek out products that are **natural** and **eco-friendly**, marigold has become a go-to ingredient for wellness and beauty brands. This demand is driven by consumers' increasing awareness of the negative environmental and health impacts of synthetic chemicals, as well as their desire to support companies that align with **sustainable practices**. Media campaigns often emphasize the natural origins of marigold, positioning it as a safe, effective, and **planet-friendly** alternative to synthetic products. This has contributed to the flower's growing presence in **skincare**, **haircare**, and **dietary supplements**.

b. Ethical Sourcing Concerns

However, the rising demand for marigold also brings up important concerns about its **ethical sourcing**. As marigold becomes a commercial commodity, the risk of **exploitation** of **indigenous knowledge** and **local farming practices** increases. Indigenous communities who have traditionally cultivated marigold often face challenges in **protecting their intellectual property**, especially when their knowledge is commercialized without fair compensation. Moreover, there are concerns about the environmental impact of large-scale cultivation of marigold, including potential **monoculture farming practices**, which could deplete soil health and disrupt local ecosystems.

c. Calls for Ethical Consumerism

Media plays a critical role in **educating consumers** about these ethical concerns. By advocating for **fair trade practices**, **sustainable sourcing**, and **community empowerment**, media platforms can encourage consumers to make informed choices. Campaigns that highlight the stories of indigenous communities, their sustainable farming practices, and their involvement in the commercial process can help bridge the gap between consumer demand for natural products and the need for **ethical responsibility** in sourcing.

Conclusion: A Complex Landscape

The findings of this study reveal a complex landscape in the media representations of marigold, highlighting both its potential for empowering modern consumers and the risks of cultural dilution and exploitation. While media has played a crucial role in amplifying the awareness of marigold's benefits and aligning it with **contemporary trends** in natural and sustainable products, it has also contributed to the **commodification** and **oversimplification** of its cultural and medicinal significance.

The growing popularity of marigold in the global market necessitates a more **balanced narrative**—one that honors its **cultural roots**, **scientific validation**, and **ethical sourcing**. By ensuring that **indigenous voices** are included and that **traditional knowledge** is respected, the media can help preserve the full value of marigold as both a **cultural treasure** and a **modern wellness icon**. This approach will foster a more **inclusive** and **ethical** market, ensuring that marigold's rise to prominence benefits not only consumers but also the communities that have long cared for and cultivated this remarkable plant.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Conclusion and Recommendations: Preserving Marigold's Legacy through Ethical Representation

The marigold stands as a symbol of the harmony between **nature**, **culture**, and **science**. Its historical significance in **traditional medicine** and **cultural rituals**, combined with its contemporary use in **wellness products** and **scientific research**, underscores its versatile role in both past and present societies. The media has played an essential role in amplifying the awareness of marigold's benefits, positioning it as a natural, sustainable solution in beauty and health markets. However, this increased visibility also raises critical concerns about the **authenticity of its representation**, the **commodification** of its cultural significance, and the need for **ethical practices** in its commercialization.

As marigold continues to capture the public's imagination and expand in commercial use, it is crucial to maintain a **balance** between **preserving its cultural heritage** and embracing **modern scientific advancements**. This balance can ensure that marigold's representation remains **respectful**, **accurate**, and **inclusive**, fostering a deeper understanding of the plant's multifaceted value. The following recommendations are proposed to guide future media narratives, commercial practices, and consumer behavior in ways that support the long-term sustainability of marigold's legacy.

1. Ethical Storytelling: Honoring Marigold's Cultural Heritage

As media platforms continue to promote marigold-based products, it is vital that **ethical storytelling** becomes a cornerstone of these representations. This involves portraying marigold not just as a **modern wellness ingredient** but also as a **cultural symbol** with deep historical and spiritual significance.

Recommendations for Ethical Storytelling:

- **Incorporate Cultural Context**: Advertisements, social media campaigns, and product descriptions should acknowledge marigold's traditional uses in different cultures. Whether in **religious ceremonies**, **healing rituals**, or **local medicine**, these narratives should honor marigold's **cultural origins** and its integral role in various societies.
- **Avoid Commercialization of Sacred Practices**: Brands should avoid exploiting sacred rituals or indigenous knowledge solely for commercial purposes. When referencing traditional uses, it is crucial to do so with respect and accuracy, ensuring that the narrative does not trivialize the cultural significance of marigold.
- **Promote a Balanced Narrative**: By combining modern scientific findings with cultural stories, media can highlight the **interplay between tradition and innovation**, offering consumers a more complete and authentic understanding of marigold's full potential.

2. Inclusive Practices: Collaborating with Indigenous Communities

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Indigenous communities have long been the stewards of marigold, preserving its cultural, medicinal, and ecological significance. As marigold becomes a global commodity, it is essential to ensure that these communities are **acknowledged** and **fairly compensated** for their knowledge and contributions.

Recommendations for Inclusive Practices:

- **Partnerships with Indigenous Communities**: Media outlets, wellness brands, and researchers should **actively collaborate with indigenous communities** to promote marigold in ways that respect their traditions. This could involve partnerships in which indigenous knowledge and practices are shared, ensuring these communities receive **fair compensation** and **recognition** for their contributions.

- **Cultural Representation in Media**: When marigold is featured in media campaigns, it is essential to **include indigenous voices** and feature their perspectives on marigold's importance. Collaborating with community leaders and experts can create a more inclusive and **representative narrative** that amplifies indigenous culture and knowledge.

- **Empowerment through Fair Trade**: Brands should consider implementing **fair trade** practices to support sustainable farming and ensure that indigenous farmers have access to the **economic benefits** of growing marigold. This could be achieved by engaging with **certified fair-trade organizations** and fostering direct trade relationships with indigenous groups.

3. Consumer Education: Promoting Informed Consumption

As marigold continues to gain popularity in the wellness and beauty industries, **consumer education** becomes critical. Empowering consumers with the knowledge of marigold's **genuine benefits**, **origins**, and **ethical considerations** can foster more **responsible consumption** and ensure that demand is met in ways that support sustainability and cultural integrity.

Recommendations for Consumer Education:

- **Transparency about Sourcing and Benefits**: Media platforms should prioritize **educating consumers** about the **scientific evidence** behind marigold's therapeutic properties (e.g., its **antioxidant**, **anti-inflammatory**, and **antimicrobial** effects) and **sourcing practices**. This can include detailed information on the **growing conditions**, **supply chain transparency**, and **sustainability efforts** undertaken by brands.

- **Highlighting Marigold's Cultural Significance**: In addition to its health benefits, consumers should be educated about the **cultural roots** of marigold, its **symbolic meanings**, and how it has been used in **traditional medicine**. This will help foster a deeper appreciation for marigold beyond its marketable qualities, allowing consumers to make more conscious decisions about the products they purchase.

- **Ethical Consumerism Campaigns**: Media campaigns should encourage consumers to think critically about the ethical implications of purchasing marigold-based products. This includes educating the public on **ethical sourcing**, **fair trade**, and **sustainability** in marigold cultivation. Brands that align with these values should be highlighted to inspire consumers to make more informed, **ethical purchasing decisions**.

4. Preserving and Celebrating the Legacy of Marigold

Marigold's rise in popularity is a testament to its diverse and enduring relevance across cultures and industries. To ensure its legacy is preserved for future generations, it is crucial to **celebrate** and **respect** both its cultural significance and modern applications.

Recommendations for Preserving Marigold's Legacy:

- **Cross-Disciplinary Research**: Ongoing **scientific research** should continue to explore marigold's potential health benefits while also documenting its cultural and ecological significance. This can help bridge the gap between traditional knowledge and modern science, ensuring that marigold's value is celebrated across **disciplines**.

- **Cultural Preservation Initiatives**: Media, academic institutions, and cultural organizations should work together to **preserve marigold's cultural heritage**. This could involve documenting its use in **ethnobotanical studies**, organizing **cultural exhibitions**, and promoting **traditional festivals** where marigold plays an important role.

- **Sustainable Agricultural Practices**: To ensure that marigold remains a **sustainable** and **ethically sourced** resource, it is important to promote **ecologically sound farming practices** that respect the land, the farmers, and the communities involved in marigold cultivation.

Marigold exemplifies the intersection of **nature**, **culture**, and **science**, serving as both a **natural remedy** and a **symbol of cultural richness**. As it continues to grow in popularity through media platforms, it is essential to ensure that its representation remains **authentic**, **inclusive**, and **ethically responsible**. By implementing the recommendations outlined above, media, brands, and consumers can work together to foster a future where marigold is celebrated not only for its **modern applications** but also for its **cultural heritage** and **sustainable cultivation**. Through **ethical storytelling**, **inclusive practices**, and **consumer education**, the legacy of marigold can be preserved and celebrated for generations to come, ensuring that it remains a **powerful symbol of harmony between tradition and modernity**.

References:

Patel, S., & Yadav, S. (2021). "Phytochemical Composition and Biological Activities of Marigold Extracts." *Phytotherapy Research*.

Kumar, R., & Sharma, S. (2020). "Anti-inflammatory and Antioxidant Properties of Tagetes Erecta: A Review." *Journal of Medicinal Plants*.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Alvarez, D., & Santos, M. (2022). "The Role of Marigold Extracts in Wound Healing: An Insight into Mechanisms." *International Journal of Molecular Sciences*.

Reddy, M., & Sriram, P. (2023). "Marigold in Traditional and Modern Medicine: A Review of its Therapeutic Potential." *Journal of Ethnopharmacology*.

Singh, G., & Mishra, R. (2021). "Tagetes Erecta: A Valuable Herb with Multi-Dimensional Benefits." *Journal of Herbal Medicine*.

Sharma, V., & Sharma, P. (2020). "Biological Activities and Phytochemistry of Tagetes spp.: A Comprehensive Review." *Phytochemistry Reviews*.

Mohanty, A., & Das, M. (2022). "Chemical Profiling and Anticancer Potential of Marigold Extracts." *Anticancer Research*.

Kaur, P., & Singh, D. (2023). "Marigold-Based Cosmetics: An Emerging Trend in Skincare." *Cosmetic Dermatology Journal*.

Zhang, X., & Liu, Y. (2021). "Tagetes Erecta: A Natural Source of Bioactive Compounds." *Journal of Natural Products*.

Ibrahim, A., & Ali, H. (2022). "The Effect of Marigold Extract on Immune Modulation and Cancer Therapy." *Immunopharmacology and Immunotoxicology*.

Srinivasan, K., & Mehta, M. (2020). "The Role of Tagetes Erecta in Skin Health: A Systematic Review." *Journal of Dermatology*.

Ghosh, S., & Singh, P. (2022). "Marigold Flower Extracts: Promising Applications in Traditional and Modern Medicine." *International Journal of Phytomedicine*.

Pandey, S., & Kumar, A. (2023). "Antioxidant and Antimicrobial Activities of Marigold Extracts." *Molecules*.

Patel, R., & Desai, K. (2020). "Pharmacological Properties of Marigold: A Focus on its Anti-inflammatory Potential." *Pharmacognosy Reviews*.

Zhao, X., & Xu, W. (2021). "Marigold (Tagetes spp.) and Its Bioactive Compounds: A Review on Applications in Food and Medicine." *Food Research International*.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DAY-AHEAD FORECASTING OF HUMIDITY WITH TIME SERIES AND MACHINE LEARNING MODELS

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Abstract

Humidity plays a critical role in influencing weather patterns, agricultural productivity, and disaster management, making accurate humidity forecasting essential. This study's objectives are to use time series analysis and machine learning approaches to create predictive models for daily humidity forecasts and to examine and comprehend the patterns of daily humidity in different districts of Khyber Pakhtunkhwa, Pakistan. The study also contrasts the prediction accuracy of other models, including Vector Auto-Regressive (VAR) and Auto-Regressive Integrated Moving Average (ARIMA). In this study, four-time series models are used such as Exponential Smoothing (SES), ARIMA, and ARNN are used to estimate the day-ahead humidity in Pakistan's Kohat and Karak areas. Root Mean Squared Error (RMSE) was used to evaluate the models. With an RMSE of 1275.27 for Karak SES and 1184.59 for Kohat SES, the results demonstrated that the SES models for both districts had significant RMSE values. Additionally, the ARIMA models outperformed SES; Kohat ARIMA's RMSE was 28.04 and Karak ARIMA's was 25.92. The VAR model also demonstrated competitive accuracy with an RMSE of 18.43. With Karak ARNN obtaining the lowest RMSE of 7.34 and Kohat ARNN producing 7.89, the ARNN models, however, better than both SES and ARIMA. These results demonstrate that ARNN models provide outstanding predictive accuracy in day-ahead humidity forecasts for both districts. This breakthrough technology puts ARNN in a position to transform climate adaptation techniques and improve regional meteorological accuracy. By enabling more intelligent decision-making in environmental planning, agriculture, and disaster management, this work highlights the revolutionary potential of cutting-edge computational methods in effectively and precisely addressing current climate issues.

Keywords: (ARIMA, VAR, ARNN, RMSE)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE IMPACT OF ENERGY AND WATER USE EFFICIENCY ON SUSTAINABLE AGRICULTURE IN SOUTH ASIA; 2000 TO 2023

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Abstract

This study examines the impact of energy and water use efficiency on sustainable agriculture in South Asia from 2000 to 2023, a region grappling with the dual challenges of resource constraints and increasing food demand. For this study a Panel Autoregressive Distributed Lag (ARDL) model and a double log model has been used, the research investigates the effects of energy efficiency (EE) and water use efficiency (WE) on sustainable agriculture (SA), while control variables such as agricultural capital (AC), agricultural labor (AL), research and development expenditure (RD), capital use in agriculture (K), and pesticides in agriculture (AP). For this study, a comprehensive sustainable agriculture index was constructed, incorporating social, economic, and environmental dimensions.

The findings reveal that energy efficiency has a significant positive impact on sustainable agriculture. Similarly, water use efficiency also positively influences sustainable agriculture. By analyzing data across selected countries within South Asia, this study seeks to answer two pivotal questions: 1) what is the effect of energy efficiency on sustainable agriculture in south Asia? and 2) How does water use efficiency influence sustainable agriculture? The findings aim to provide actionable insights for policymakers and stakeholders to enhance sustainable agricultural practices, ensuring food security and environmental sustainability in South Asia.

Key words: Sustainable agriculture (SA) , Energy efficiency (EE), Water use efficiency (WUE), South Asia, Panel ARDL (PARDL)

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MSI2 EXPRESSION IN LGMDD2: EFFECTS OF DIFFERENTIATION AND CELL SEEDING DENSITY

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ABSTRACT

Limb-girdle muscular dystrophy D2 (LGMDD2) is a rare autosomal dominant genetic disorder caused by a point mutation in the *TNPO3* gene, which disrupts its stop codon and results in an extended protein with impaired importin function and altered cellular localization. Patients experience progressive atrophy, contractures, and skeletal deformities, often leading to wheelchair dependence. Severe cases may involve respiratory failure. Preliminary studies suggest Musashi-2 (MSI2), an RNA-binding protein involved in oncogenesis, is upregulated in other muscular dystrophies such as Myotonic Dystrophy Type 1 (DM1). Reducing MSI2 expression can suppress excessive autophagy and rescue atrophic markers. A potential strategy for achieving this is the use of gapmers, antisense oligonucleotides designed to trigger RNase H-mediated degradation of target mRNA.

Laboratory experiments showed that MSI2 is upregulated in LGMDD2 patient-derived myotubes but not in myoblasts. Additionally, treatment with gapmer GT44 reduced the relative expression of *MSI2* in LGMDD2 cells, with higher oligo concentrations leading to greater decreases. In this study, patient-derived myotubes were treated with increasing concentrations of the gapmer GT44 to evaluate dose-dependent effects of proteinic expression derived from the RNA decrease. Experiments were conducted under varying seeding densities and surface area conditions, with comparisons to untransfected myotubes and healthy controls. Results revealed that MSI2 expression varied based on surface area and seeding density. Higher seeding concentrations resulted in increased MSI2 expression.

These findings support the hypothesis that cell concentration and distribution affect MSI2 expression, likely due to distinct stages of differentiation. Collectively, these results emphasize the importance of optimized protocols and the impact of experimental parameters when studying cell cycle-regulated genes like *MSI2*.

Keywords: Rare disease, LGMDD2, MSI2, gapmers

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INNOVATIVE APPROACH TO TEACHING: PROBLEM-BASED LEARNING IN MATHEMATICS

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ABSTRACT

Problem-based learning (PBL) occupies a unique place among the educational methods of the 21st century, and its application in mathematics lessons is considered an effective approach to improving students' critical thinking, problem-solving, and collaboration skills. This method allows students to apply their theoretical knowledge practically by working on real-life problems and significantly increases their interest in learning.

The PBL method does not stop at just transferring knowledge but also transforms the learning process into an active, interactive, and student-centered environment. The application of PBL in mathematics lessons allows students to try different approaches to solving problems, think logically, and collaborate. Such an approach contributes not only to academic achievements but also to the development of life skills.

This article examines the essence of PBL and its application in mathematics lessons, and analyzes how it is integrated into the learning process based on real problems. At the same time, it examines in detail how this method increases students' motivation to learn and affects the quality of the teaching process. Thus, the article emphasizes the methodological importance of PBL in teaching mathematics, identifies key directions and recommendations for its widespread application in the educational process in the future, and at the same time presents new perspectives for improving the quality of student learning.

The role of mathematics teachers in the implementation of the PBL method is crucial for the successful implementation of the teaching process. Teachers make the teaching process interactive and purposeful by guiding students appropriately, formulating and developing their solution strategies, and providing effective feedback mechanisms. However, the implementation of the PBL method is accompanied by certain difficulties, especially the limited resources and the time-consuming nature of teacher training. These points are the main aspects that must be paid attention to for the successful implementation of the method.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

When implemented consistently, the PBL method has become an important element of modern educational reforms, not only improving the learning process, but also forming key skills such as critical thinking, problem-solving, and collaboration that will be required in the future. The widespread application of this method in the future will not only improve the quality of mathematics lessons but also increase students' motivation and active participation in learning. In addition, promoting learning through solving real problems in the teaching process will deepen the philosophy of lifelong learning by connecting students more closely with life and will contribute to important innovations in the education system. Thus, the PBL method is considered one of the main directions shaping the future prospects of modern education.

Keywords: Mathematics teaching, Problem-based learning, Critical thinking, Real-world problem solving

ÖĞRETİME YENİLİKÇİ YAKLAŞIM: MATEMATİKTE SORUN TABANLI ÖĞRENME

ÖZET

Problem Tabanlı Öğrenme (PDÖ), 21. yüzyıl eğitim yöntemleri arasında özgün bir yere sahiptir ve matematik derslerinde uygulanması, öğrencilerin eleştirel düşünme, problem çözme ve işbirliği becerilerini geliştirmede etkili bir yaklaşım olarak kabul edilmektedir. Bu yöntem, öğrencilerin teorik bilgilerini gerçek yaşam problemleri üzerinde çalışarak pratiğe dökmelerine olanak tanır ve öğrenmeye olan ilgilerini önemli ölçüde artırır.

PBL yöntemi yalnız bilgi aktarımıyla yetinmeyip öğrenme sürecini aktif, etkileşimli ve öğrenci merkezli bir ortama dönüştürür. Matematik derslerinde PBL uygulaması, öğrencilere problemlerin çözümü sırasında farklı yaklaşımları deneme, mantıklı düşünme ve iş birliği yapma imkanı verir. Bu yaklaşım, yalnız akademik başarılarla değil, aynı zamanda yaşam becerilerinin gelişimine de katkıda bulunur.

Bu makalede PBL'nin doğası ve matematik derslerindeki uygulaması incelenmekte, gerçek problemlere dayalı olarak öğrenme sürecine nasıl entegre edildiği analiz edilmektedir. Aynı zamanda bu yöntemin öğrencilerin öğrenme motivasyonunu nasıl arttırdığı ve öğretim sürecinin kalitesini nasıl etkilediği detaylı olarak incelenmektedir. Bu bağlamda makalede, PBL'nin matematik öğretimindeki metodolojik önemi vurgulanmakta, gelecekte eğitim sürecinde yaygın olarak uygulanmasına yönelik temel yönler ve öneriler belirlenmekte ve aynı zamanda öğrenci öğrenmesinin kalitesinin artırılmasına yönelik yeni bakış açıları sunulmaktadır.

PBL yönteminin uygulanmasında matematik öğretmenlerinin rolü, öğretim sürecinin başarılı bir şekilde yürütülmesi açısından oldukça önemlidir. Öğretmenler, öğrencileri uygun şekilde yönlendirerek, çözüm stratejilerini formüle edip geliştirerek, etkili geri bildirim mekanizmaları sağlayarak öğrenme sürecini etkileşimli ve amaçlı hale getirirler. Ancak PBL yönteminin uygulanması, özellikle sınırlı kaynaklar ve öğretmen eğitiminin zaman alıcı olması gibi bazı zorlukları

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

da beraberinde getirmektedir. Bu noktalar yöntemin başarılı bir şekilde uygulanabilmesi için dikkat edilmesi gereken başlıca hususlardır.

PBL yöntemi tutarlı bir şekilde uygulandığında, öğrenme sürecini iyileştirmenin yanı sıra gelecekte ihtiyaç duyulacak eleştirel düşünme, problem çözme ve işbirliği gibi temel becerilerin oluşmasını sağlayarak modern eğitim reformlarının önemli bir unsuru haline gelmiştir. Bu yöntemin gelecekte yaygın olarak uygulanması, sadece matematik derslerinin kalitesini artırmakla kalmayacak, aynı zamanda öğrencilerin öğrenmeye yönelik motivasyonlarını ve aktif katılımlarını da artıracaktır. Ayrıca, öğretim sürecinde gerçek problemlerin çözümü yoluyla öğrenmenin teşvik edilmesi, öğrencileri hayata daha sıkı bağlayarak yaşam boyu öğrenme felsefesini derinleştirecek ve eğitim sisteminde önemli yeniliklere katkı sağlayacaktır. Bu nedenle PBL yöntemi, çağdaş eğitimin gelecek beklentilerini şekillendiren temel yönelimlerden biri olarak değerlendirilmektedir.

Anahtar Kelimeler: Matematik öğretimi, Problem tabanlı öğrenme, Eleştirel düşünme, Gerçek dünya problem çözme

1. Giriş

Matematik derslerinde Problem Tabanlı Öğrenme (PBL) yöntemi, öğrencilerin öğrenme sürecine aktif olarak katılmalarını sağlayan yenilikçi bir yaklaşımdır. Bu yöntemin özü, matematiksel problemleri kullanarak eleştirel düşünme, problem çözme, bağımsız araştırma ve grup çalışması becerilerini geliştirmektir. Geleneksel öğretim yöntemlerinden farklı olarak PBL öğrencilerin motivasyonunu artırır ve onları pasif dinleyicilerden aktif katılımcılara dönüştürerek öğrenmeyi daha anlamlı hale getirir. Bu yöntemle öğrenciler sadece teorik bilgiyi değil, aynı zamanda bu bilgiyi problem çözerken nasıl uygulayacaklarını da öğreniyorlar.

PBL yönteminin öğretim sürecindeki temel hedeflerinden biri öğrencilerde eleştirel düşünme ve problem çözme becerilerini geliştirmektir. Matematik derslerinde bu, öğrencilerin matematiksel bilgiyi günlük yaşam problemlerine uygulaması anlamına gelir. Örneğin istatistiksel verileri analiz etme, geometrik şekilleri gerçek hayatta kullanma, ekonomi problemlerini çözme gibi etkinlikler öğrencilerin konuya olan ilgisini artırır. Ayrıca PBL yaklaşımı, öğrenme sürecinde işbirliğini ve takım çalışmasını teşvik ederek öğrencilerin sosyal becerilerini de geliştirir.

Bu makalede Problem Tabanlı Öğrenme yönteminin matematik derslerinde uygulamanın temel ilkeleri, uygulama örnekleri ve öğretmenlerin rolü ayrıntılı olarak incelenmektedir. Aynı zamanda yöntemin öğretim sürecine getirdiği avantajlar ve karşılaşılabilecek zorluklar da odak noktasında yer almaktadır. Çalışmanın temel amacı, PBL yönteminin matematik derslerinde kullanılmasının önemini vurgulamak ve bu yöntemin öğrencilerin eleştirel ve analitik düşünme, problem çözme ve işbirliği becerilerini nasıl geliştirdiğini göstermektir.

Bu konu, çağdaş eğitim reformlarının gereklilikleri bağlamında özellikle önem taşımaktadır, çünkü PBL yöntemi ile öğrenciler teorik bilgiyi pratiğe entegre etmeyi ve gerçek problemleri çözerek

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

öğrenme sürecini daha anlamlı kılmayı öğrenmektedirler. Makalede ayrıca PBL yönteminin uygulanmasında karşılaşılan zorluklara ilişkin öneriler sunulmakta ve bu yaklaşımın gelecekte matematik öğretiminin gelişimine nasıl katkıda bulunabileceği tartışılmaktadır. Amaç, PBL'nin matematik öğretimindeki potansiyelini ortaya koymak ve eğitim sisteminde yaygın olarak uygulanması için pratik öneriler sunmaktır.

2. PBL yönteminin matematikte uygulanması

2.1. Matematik öğretiminde Problem Tabanlı Öğrenmenin temel ilkeleri

Problem tabanlı öğrenmenin matematik öğretiminde uygulanmasına ilişkin temel ilkeler şu şekilde formüle edilmiştir:

• Gerçek yaşam sorunlarının sunumu

• Öğrencilerin aktif katılımını sağlayan bir ortam yaratmak

• Öğrenciler arasında işbirliğini ve tartışmayı teşvik etmek

Gerçek yaşam problemlerinin sunumu

Matematik derslerinde Problem Tabanlı Öğrenmenin (PDÖ) temel ilkesi, öğrencileri gerçek yaşam problemleri üzerinde düşünmeye teşvik etmektir. Gerçek yaşam problemleri, öğrencilerin matematiksel kavramları günlük yaşam durumlarına nasıl uygulayabileceklerini gösterir.

PBL'de öğrencilere gerçek dünyadan alınmış açık uçlu problemler sunulur. Bu tür görevler araştırma, tartışma ve analitik düşünme yoluyla çözülür. Öğrencilere verilen ödevler genellikle bağımsız araştırmayı ve grup işbirliğini teşvik eder. Örneğin öğrencilere şu ödev verilir: “Şehrinizde atık geri dönüşümüyle ilgili bir sorun var. Bu sorunu çözmek için bir strateji geliştirin, maliyetleri hesaplayın ve teklifinizin ekonomik ve çevresel faydalarını sunun” (Savery & Duffy, 1995).

Bu görev, öğrencilerin araştırma yapmasını, matematiksel hesaplamalar yapmasını ve tartışmalar yoluyla yaratıcı çözümler önermesini gerektirir.

Öğrencilerin aktif katılımını sağlayan bir ortam yaratmak

PBL ortamında öğretmenin temel rolü rehberlik etmektir. Öğrencilere bağımsız çalışma fırsatı verilir, ancak süreçte yönlerinden sapmamaları için öğretmen tarafından desteklenirler. Bu ortamda öğrenciler bağımsız olarak sorunları araştırır, hipotezler oluşturur ve kendi çözümlerini önerirler. Aktif katılım, araştırma, veri toplama ve sonuçların sunulması gibi faaliyetlerle birlikte gerçekleşir (Barrows & Tamblyn, 1980). Bu yaklaşım, matematik derslerindeki geleneksel "öğretmen konuşur, öğrenciler dinler" modelini değiştirerek daha dinamik bir öğrenme ortamı yaratıyor.

Öğrenciler arasında işbirliğini ve tartışmayı teşvik etmek

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PBL'nin en önemli özelliklerinden biri öğrenciler arasında işbirliğini teşvik etmesidir. Öğrenciler gruplar halinde çalışarak farklı yaklaşımları öğrenir, fikirlerini başkalarıyla paylaşır ve eleştirel tartışmalara katılırlar. Bu işbirliği, matematiğin daha zor problemlerini çözmede kolektif zekanın gücünü ortaya koyuyor. Örneğin, öğrenciler bir şehrin su şebekesinin optimizasyonu konusunda grup halinde çalışabilirler ve herkesin farklı bakış açıları nihai çözüme katkıda bulunabilir (Hmelo-Silver, 2004).

Bu ilkeler, PBL yönteminin matematik derslerinde uygulanmasının önemini vurgulamakta ve öğrencilerin öğrenmeleri üzerindeki olumlu etkilerini ortaya koymaktadır. Bu yaklaşım, yalnızca öğretimin kalitesini artırmakla kalmıyor, aynı zamanda öğrencileri öğrenmenin merkezine yerleştirerek hem akademik hem de sosyal becerileri geliştiriyor.

2.2. Matematik derslerinde Problem Tabanlı Öğrenmeyi uygulama adımları

PBL'nin Matematik derslerinde uygulanması, yöntemin amaca uygun şekilde uygulanmasını sağlayan aşağıdaki temel adımlardan oluşmaktadır:

• Sorun seçimi ve sunumu

• Sorun analizi ve araştırması

• Sorunu çözmek için stratejiler oluşturmak ve uygulamak

• Çözümün sunumu ve sonuçların değerlendirilmesi

Sorun seçimi ve sunumu

PBL yönteminin matematik derslerinde uygulanmasında ilk adım, öğrencilerin yaşamlarıyla ilgili ve gerçek problemlerin seçilmesidir. Örneğin şehir içi trafiğinde en kısa güzergahın bulunması, bir okulun elektrik giderlerinin optimize edilmesi, bir etkinlikte kullanılacak en uygun istatistiksel yöntemin seçilmesi gibi görevler sunulabilir. Bu problemler matematiksel kavramların uygulanmasına temel oluşturur ve öğrencilerin öğrenme motivasyonunu artırır (Barrows & Tamblyn, 1980). Öğretmenler, öğrencilerin sorunun özünü daha iyi anlayabilmeleri için sorunu sunarken belirli bilgiler ve görseller kullanmalıdır.

Sorun analizi ve araştırması

Problem sunulduktan sonra öğrenciler problemin temel unsurlarını analiz eder ve mevcut bilgilerine dayanarak ilk hipotezleri oluştururlar. Öğretmenin buradaki rolü, öğrencilerin dikkatini yönlendirici sorularla problemle ilgili ana noktalara çekmektir. Öğrenciler, grup tartışmaları yoluyla sorunu daha derinlemesine anlamak için araştırma yaparlar. Bu aşamada farklı bilgi kaynaklarını kullanma, bilgi toplama ve bu bilgiyi yapılandırma becerileri geliştirilir (Dolmans et al., 2005).

Sorun çözme stratejilerinin oluşturulması ve uygulanması

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Bu aşamada öğrenciler topladıkları bilgileri gözden geçirerek çeşitli çözümler üretirler. Çözüm stratejileri geliştirilirken öğrencilerin mantıksal akıl yürütmeleri gerekmektedir. Örneğin cebirsel denklemleri çözmek için matematiksel modeller oluşturma veya istatistiksel yöntemler kullanarak belirli sonuçları analiz etme gibi faaliyetler gerçekleştirilir. Öğretmenler öğrencilerin problem çözme stratejileri geliştirmelerini desteklemeli ve her yaklaşımın avantajlarını ve dezavantajlarını değerlendirmelerine yardımcı olmalıdır (Savery & Duffy, 1995).

Çözümün sunumu ve sonuçların değerlendirilmesi

PBL yönteminin son aşaması öğrencilerin geliştirdikleri çözümleri sunmalarıdır. Sunum aşaması öğrencilere sonuçlarını gerekçelendirme ve karşı taraftan gelen soruları cevaplama fırsatı verir. Öğretmenler sonuçları değerlendirirken hem çözüm sürecini hem de çıktıyı göz önünde bulundurmalıdırlar. Öğrenciler ayrıca grup çalışmalarındaki işbirlikçi yetenekleri ve bireysel katkıları açısından da değerlendirilirler (Hmelo-Silver, 2004).

Bu adımlar öğrencilerin hem matematiksel bilgilerini hem de eleştirel düşünme ve işbirliği becerilerini geliştirmelerine yardımcı olur. PBL'nin bu yapısı, matematik derslerinin hem etkileşimli hem de uygulamalı olmasını sağlar.

2.3. PBL yönteminin matematikte uygulanmasına ilişkin örnekler

***Örnek* 1:** Bir şehrin su temin sisteminin planlanması (Denklemler kullanılarak)

Şehrin üç mahallesine su sağlayan üç adet boru hattı bulunmaktadır. Sorunun çözümü için boru hatları boyunca suyun optimum şekilde dağıtılmasına yönelik çözümlerin geliştirilmesi gerekmektedir.

Bu etkinlik kapsamında öğrencilerin şehrin su ihtiyacının karşılanması için farklı kaynaklardan gelen suyun eşit bir şekilde dağıtılmasını sağlamaları gerekiyor. Öğretmen önce şehrin çeşitli mahallelerindeki su ihtiyaçlarını ve çeşitli boruların su akış hızlarını sunar. Öğrenciler, boruların su geçirgenliği ile toplam su talebi arasındaki ilişkiyi yansıtan denklemleri kurarak problemi çözmelidirler. Şehrin üç mahallesine su sağlayan üç adet boru hattı bulunmaktadır. Sorunun çözümü için boru hatları boyunca suyun optimum şekilde dağıtılmasına yönelik çözümlerin geliştirilmesi gerekmektedir.

Örnek 2: Aile bütçesi hazırlama (Faiz hesaplamaları ve cebir)

Öğrencilere aile geliri, giderleri ve tasarruf oranları hakkında bilgi verilir. Aile bütçesi oluşturmaları, harcamaları optimize etmeleri ve gelecekteki hedeflere ulaşmak için bir tasarruf planı geliştirmeleri gerekiyor. Öğrencilere faiz, basit ve bileşik faiz hesaplamaları öğretilmekte, ayrıca cebirsel ifadeleri kullanarak tasarruf stratejileri geliştirilmektedir. Bu etkinlik öğrencilerin finansal okuryazarlığını artırır ve günlük hayatta kullanılabilecek matematiksel bilgi birikimi oluşturur.

***Örnek* 3:** Trafik sorunu analizi (Geometrik şekiller ve mesafe)

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ISBN: 978-9952-610-30-7

Bu etkinlikte öğrencilerden şehrin belirli yollarındaki trafik sıkışıklığını azaltmaya yönelik çözüm önerileri getirmeleri isteniyor. Öğretmen öncelikle yolların uzunlukları, açıları ve alternatif rotalar hakkında bilgi verir. Öğrenciler geometri ve mesafe raporlarını kullanarak en ideal rotayı belirlerler. Öğrenciler bu görev aracılığıyla geometri ve trigonometri bilgilerini uygularlar.

***Örnek* 4:** İklim değişikliği verilerinin analizi (İstatistik)

Öğrencilere iklim değişikliğine ilişkin çeşitli veriler sunulur; örneğin her yılın ortalama sıcaklıkları, karbon emisyon değerleri, buzulların erime hızı. Öğrencilerin bu verilere dayanarak grafikler oluşturmaları, istatistiksel göstergeleri analiz etmeleri ve gelecekteki iklim eğilimlerini tahmin etmeleri gerekiyor. Bu etkinlik verilerin nasıl toplanacağını, analiz edileceğini ve görsel olarak nasıl sunulacağını öğretir.

***Örnek* 5:** Büyük ölçekli bir etkinliğin finansal planlaması (Tahmin ve optimizasyon)

Bu etkinlik sırasında öğrencilerin uluslararası bir konferans için finansal bir plan hazırlamaları gerekmektedir. Öğrenciler verilen bütçeye göre maliyetleri optimize etmeli ve konferans için gerekli kaynakların mevcut olduğundan emin olmalıdır. Etkinlik, matematiksel modeller kurma, optimizasyon ve tahmin yöntemlerini uygulama açısından geniş fırsatlar yaratıyor.

Bu etkinlik örnekleri, PBL yönteminin çeşitli matematik konularına nasıl uygulanabileceğini göstermektedir. Öğrenciler sadece matematiksel bilgilerini geliştirmekle kalmıyor, aynı zamanda bu bilgiyi gerçek hayatta nasıl kullanacaklarını da öğreniyorlar.

2.4. PBL yönteminde matematik öğretmenlerinin rolü

Problem Tabanlı Öğrenme yönteminin etkili bir şekilde uygulanmasında öğretmenin rolü çok önemlidir. PBL yöntemi öğrencilerin bağımsız öğrenme becerilerini geliştirmeyi hedeflediğinden, öğretmenler hem yol gösterici, hem de destekleyici bir rol üstlenmektedir. Öğretmenlerin bu yöntemdeki rolü aşağıda detaylı olarak açıklanmıştır.

1. Öğrencilere yönlendirici sorular sorun

Öğretmenler, öğrencilerin sorunu daha iyi anlamalarına ve çeşitli yönlerini keşfetmelerine yardımcı olmak için yönlendirici sorular sormalıdır. Bu sorular öğrencilerin analitik düşünme becerilerini geliştirir ve problem çözmede yaratıcı yaklaşımları teşvik eder. Yönlendirici sorular aşağıdaki amaçlara hizmet eder:

• Sorunun bağlamı içinde anlaşılmasını sağlayacak ipuçları sağlamak.

• Öğrencilerin ilgi alanlarını genişletmek.

• Farklı çözümlerin teşvik edilmesi.

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Örnek: Bir trafik problemini çözerken, bir öğretmen şuna benzer bir soru sorabilir: "Bir şehirdeki araba sayısı %10 artarsa, trafikte hangi değişiklikler beklenebilir ve bu problemi çözmek için hangi matematiksel modelleri kullanabiliriz?

2. Öğrencileri farklı çözümleri keşfetmeye teşvik etmek

PBL yöntemi çeşitli çözüm yaklaşımlarını teşvik eder. Öğretmenler, öğrencileri belirli bir probleme yönelik birden fazla çözümü düşünmeye ve bu çözümlerin avantajlarını ve sınırlamalarını değerlendirmeye teşvik etmelidir.

• Farklı yaklaşımların karşılaştırılması öğrencilerin eleştirel düşünme ve karar verme becerilerini güçlendirir.

• Alternatif çözümler sunmak öğrenciler arasındaki işbirliğini ve tartışmayı artırır.

Örnek: Bir öğretmen, öğrencilerinden aynı problemi geometrik yaklaşım ve cebirsel yaklaşım kullanarak çözmelerini isteyerek, iki yöntem arasındaki farkları karşılaştırmalarını isteyebilir.

3. Değerlendirme ve geri bildirim mekanizmalarının uygulanması

Öğretmenler, PBL sürecinde öğrencilerin performansını sürekli olarak değerlendirmeli ve onlara geri bildirim sağlamalıdır. Bu sayede hem öğrencilerin güçlü yönlerini ortaya çıkarabilir hem de geliştirilmesi gereken alanları tespit edebiliriz.

• Değerlendirme bireysel ve grup aktivitelerini içerebilir.

• Geri bildirimler öğrencilerin ilerlemelerini açıkça anlayabilmeleri için spesifik ve yapıcı olmalıdır.

Örnek: Bir grup sunumunun ardından öğretmen şu düşünceleri dile getirebilir: "Analiziniz çok güçlüydü, ancak çözümü sunarken daha spesifik örnekler kullanabilirsiniz".

PBL yönteminde matematik öğretmenlerinin bu temel rolleri, öğrencilerin derin anlama ve problem çözme becerilerinin geliştirilmesinde önemli bir rol oynamaktadır. Bu yaklaşımların öğretim sürecinde kullanılması öğrenciler için daha ilgi çekici ve üretken bir öğrenme ortamı yaratır.

3. Matematik derslerinde PBL yönteminin avantajları ve zorlukları

Problem Tabanlı Öğrenme (PDÖ) yöntemi, matematik derslerinde yenilikçi yaklaşımlardan biri olup, öğrencilerin gerçek problemler üzerinde çalışma yeteneklerini geliştirmek ve pratik bilgiyi uygulamaya dökmelerini teşvik etmek için güçlü bir araçtır. Ancak bu yöntemin uygulanmasının hem avantajları hem de zorlukları bulunmaktadır.

Avantajları

- ***Öğrencilerin öğrenmeye olan ilgisini artırmak***

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PBL yöntemi, öğrencilerin gerçek problemler üzerinde çalışmasını sağlayarak motivasyonlarını artırır. Matematik derslerinde soyut kavramların somut konularla ilişkilendirilmesi öğrencilerin ilgisini çeker ve eğitim sürecine daha aktif katılımlarını sağlar.

Örneğin: Öğrenciler bir şehrin su temin sistemi gibi gerçek dünya problemlerini çözdüklerinde, yalnızca matematiksel bilgi değil, aynı zamanda toplumsal sorumluluk duygusu da geliştirirler.

- ***Teorik bilgiyi gerçek problemleri çözerek pratiğe dökmek***

PBL, öğrencilere gerçek hayatta karşılaştıkları sorunları çözmeleri için araçlar sağlar. Bu yaklaşım, onlara bilgilerini uygulamayı ve sorunları bağımsız olarak çözmeyi öğretir. Matematik derslerinde bu yöntem, pratik becerileri ve eleştirel düşünme yeteneğini geliştirir.

Örneğin: Trafik problemlerinin analizinde geometrik hesaplamalar ve noktalar arasındaki mesafelerin hesaplanması gibi yöntemler kullanılır.

- ***İşbirliği ve ekip çalışmasını geliştirin***

PBL yöntemi öğrenciler arasında işbirliği ve tartışma becerilerini artırır. Grup çalışmalarında çeşitli çözümler öneriliyor, bu da hem takım çalışmasını hem de sosyal becerileri geliştiriyor.

Örneğin: İklim değişikliğine ilişkin istatistiksel veriler analiz edilirken grup üyeleri farklı yaklaşımlar sunabilirler.

Zorluklar

- ***Öğretmenler için hazırlık aşaması çok zaman alıcıdır***

PBL yönteminin etkili olabilmesi için öğretmenlerin problemi dikkatli seçmeleri, ders planı hazırlamaları ve değerlendirme kriterlerini belirlemeleri gerekmektedir. Bu süreç zaman ve emek ister.

Örnek: Problemi sunmak için gerekli bilgileri hazırlamak öğretmenler için ek iş yükü yaratabilir.

- ***Bazı sorunları çözmek için kaynak eksikliği***

PBL yöntemi modern teknolojilere ve çeşitli öğretim kaynaklarına ihtiyaç duyar. Bazı okullarda bu kaynakların eksikliği yöntemin uygulanmasını zorlaştırmaktadır.

Örnek: Trafik analizi için gerekli yazılımın bulunmaması sorunların tam olarak çözülmesini sınırlayabilir.

PBL yönteminin matematik derslerinde hem öğrencilerin öğrenme becerilerinin geliştirilmesi hem de uygulamalı bilgi edinmeleri açısından önemli avantajları bulunmaktadır. Ancak uygulanmasında bazı zorluklar yaşanabilir. Öğretmenler ve eğitim kurumları bu zorlukların üstesinden gelmek için kaynakları iyileştirmeye ve ek eğitime odaklanmalıdır.

4. Matematik derslerinde PBL'nin önemi ve beklentileri

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PBL yönteminin genel önemi

Problem Tabanlı Öğrenme yöntemi, öğrencilerin matematik derslerinde eleştirel düşünme, analitik beceriler ve gerçek yaşamda uygulama becerilerinin geliştirilmesinde önemli bir rol oynamaktadır. Geleneksel öğretim yöntemlerinden farklı olarak bu yöntem, öğrencileri öğrenme sürecinin merkezine yerleştirir ve onların aktif katılımını sağlar. Matematik derslerinde PBL, soyut kavramları gerçek dünya problemleriyle ilişkilendirerek öğrencilerin daha derin anlayış ve pratik bilgi edinmelerini sağlar. Bu yaklaşım öğrencilere sadece matematiksel bilgi değil, aynı zamanda sosyal ve işbirlikçi beceriler de kazandırır.

Eğitimde PBL'nin gelecek beklentileri

Eğitimde yeniliklerin artması ve teknolojinin yaygınlaşması sonucunda PBL yöntemi giderek önem kazanmaktadır. Bu yöntemin gelecekte matematik öğretiminde daha yaygın olarak uygulanacağı düşünülmektedir. Özellikle yapay zeka ve eğitim yazılımları gibi teknolojilerin entegre edilmesi PBL yöntemini daha da etkili hale getirecektir. Etkileşimli öğretim platformlarının geliştirilmesiyle birlikte, öğretmenler gerçek sorunları sunma ve çözüm süreçlerini izleme konusunda daha fazla fırsata sahip olacaklar.

Sonuç

PBL yöntemi, öğrencilerin matematik derslerinde öğrenme sürecine olan ilgilerini artırmada ve onları gerçek yaşam problemlerini çözmeye hazırlamada etkili bir yaklaşımdır.

Teknolojinin ve etkileşimli öğretim yöntemlerinin daha geniş bir şekilde uygulanmasıyla bu yöntem, eğitimin geleceğinde önemli bir rol oynayacaktır. Gelecekte daha fazla okul ve eğitim kurumunun bu yöntemden faydalanması bekleniyor.

Tavsiyeler

1. Öğretmenlere yönelik eğitim: Öğretmenlerin PBL yönteminde daha etkili çalışabilmeleri için uygun eğitimlerin düzenlenmesi önemlidir. Bu eğitimler, öğrencilerin sorunları seçme, sunma ve değerlendirme süreçlerindeki becerilerini geliştirmelerine yardımcı olacaktır.

2. Teknolojilerin geliştirilmesi: Öğretim sürecinde simülasyonlar ve dijital müfredat gibi teknolojik kaynaklardan yararlanılmalıdır.

3. Kaynak sağlanması: PBL yönteminin okullarda uygulanabilmesi için gerekli kaynakların sağlanması ve bu kaynakların erişilebilir hale getirilmesi öğrenci öğrenmesinin kalitesini artıracaktır.

4. Bütünleştirici yaklaşım: PBL yönteminin diğer öğretim yöntemleriyle birlikte uygulanması öğretimin kalitesini daha da artıracaktır.

Kaynaklar

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

National Research Council (2000). *How People Learn: Brain, Mind, Experience, and School.* Washington, D.C.: National Academy Press.

Savery, J. R., & Duffy, T. M. (1995). *Problem-based learning: An instructional model and its constructivist framework*. *Educational Technology*, 35(5), 31–38. https://www.jstor.org/stable/44428296

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-Based Learning: An Approach to Medical Education.* Springer Publishing.

Hmelo-Silver, C. E. (2004). *Problem-Based Learning: What and How Do Students Learn? Educational Psychology Review*, 16(3), 235-266.

https://link.springer.com/article/10.1023/B:EDPR.0000034022.16470.f3

Dolmans, D.H. J. M., De Grave, W., Wolfhagen, I. H. A. P., & Van Der Vleuten, C. P. M. (2005). *Problem-based learning: Future challenges for educational practice and research*. *Medical Education*, 39(7), 732-741. https://pubmed.ncbi.nlm.nih.gov/15960794/

CORRECT PLANTING METHOD

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Abstract

In agriculture, the correct planting system is one of the most important conditions for the growth of crops and maximum benefit from the land. If we use the right planting method then we will get high yield .

Indtroduction

First of all, the soil should be prepared for planting, it should be clean and stone-free. Also, the pH level should be suitable for the crop. It should be the right choice of seeds then they must be spaced correctly.

Material and Methods

The most important thing is to use the right materials. This includes: proper water system, pipes, new irrigation method, fertilization method, etc

Conclusion

If all methods and materials are used correctly, then high productivity is achieved.

References

1. “The Vegetable Gardener's Bible” - Edward C. Smith

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

2. "How to Grow More Vegetables" - John Jeavons

3. "The Organic Gardener's Handbook of Natural Insect and Disease Control" - Barbara W. Ellis and Fern Marshall Bradley

4. "The Market Gardener: A Successful Grower's Handbook for Small-Scale Organic Farming" - Jean-Martin Fortier

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ECOTOURISM POTENTIAL OF LAHIJ SETTLEMENT (ISMAYILLI DISTRICT)

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ABSTRACT

Lahij is a settlement included in the administrative territory of Ismayilli district. Lahij is distinguished by its rich ecosystem, ancient history, and interesting tourism opportunities, the settlement is located at 40.6319° N latitude and 48.5000° E longitude. Lahij is mostly mountainous and rocky. Although there are extinct species of plants and animals in its ecosystem, it is an area of rich nature. The wind speed in the area consists of 3.3 km/h, the average annual temperature is about 7°C, the air humidity is 84%, and it is located at an altitude of 1505 m above sea level. Mainly the ancient Tat tribe is living here. There are many long and short mountain rivers and high mountainous lakes around Lahij, which consist of the common aquatic ecosystems. These water resources are important for traditional fish species, waterfalls, and other aquatic wildlife. The mountainous terrain and different climatic conditions affect Lahijh's ecology. In the surrounding areas, trees, grasses and other types of plants are distinguished, therefore, the geographical area of Lahij is characterized by the presence of various vegetation. In the mountain territory of this region, the natural environment is favorable for mountain goats, mountain deer, and other mountain animal species. Official measures should be taken into consideration by local and state organizations and scientific research should be carried out to protect the natural areas around Lahij and ensure the sustainability of ecosystems. Ecotourism can be developed as an interesting area for Lahij, which has a strong potential to protect the quality of the environment and provide livelihoods in the field of tourism.

Keywords: ecotourism, Lahij, ecosystem, climate.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EROSION IN KURMUKCHAY BASIN AND ITS PREVENTIVE METHODS.

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ABSTRACT

My research facility Kurmukchay is located in the north-west of Azerbaijan. The river, which completely surrounds the Gakh region, plays a key role in the water supply of the this area. The water source of the river is formed from the collection of snow and rain water. The river starts from the border of Dagestan and starts from the junction of Kunakhaysu and Hamachay. The length of the Kurmukchay is 55 km, the basin area covered by the river is 562 km^2. Since the terrain relief of the area is mountainous, the process of erosion in the river is carried out in a short time. Erosion in river basin soils is mostly determined by agricultural, felling of trees, mismanagement of cropland or landslides. Erosion is carried out by water or wind from the top layer of soil and moves down from mountain and hilly areas. Erosion is a process that poses a serious threat to river basin soils. Because these soils mainly play an important role in the feeding process of water resources. As a result of the erosion process, it is considered important to take serious complex measures for the protection of soil and water resources by various methods.

Key words: ecology, Kurmukchay, Erosion, river.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A HOLISTIC APPROACH TO HAND TOOL AND MACHINERY DEVELOPMENT: PHYSIOLOGY AND PSYCHOLOGY INTEGRATION

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Abstract

The incorporation of physiological and psycho-physical factors into the design of hand tools and machines is an example of a comprehensive strategy aimed at maximizing performance, safety, and user pleasure. This abstract examines the critical role that human-centered design concepts have in creating equipment and products that meet users' psychological and physiological demands. Tools and machines that minimize physical strain, lower the risk of musculoskeletal problems, and improve general comfort during operation are the result of designing with an awareness of human physiology. This method takes into account elements like weight distribution, grip design, and handle ergonomics, all of which have a big impact on the user's physical health. Incorporating psychological factors also recognizes the significance of user perception, cognitive burden, and mental stress during the design phase. Enhanced user happiness and productivity are positively correlated with tools and machines that are easy to handle, offer unambiguous feedback, and reduce cognitive strain. In addition to being effective and safe, tools and machines that consider the mental and emotional well-being of their users are also produced by the design synergy between physiology and psychology. Holistic approaches address the intricate interactions between psychological and physical aspects, opening the door for equipment and systems that improve human performance and wellbeing in a range of industrial and work settings. This approach emphasizes how important it is to incorporate physiology and psychology into the design of agricultural machinery and hand tools in order to create more efficient and user-friendly solutions.

Keywords: Human-Centered Design, Ergonomics, Hand Tool Development, Machinery Design, Psycho-Physical Integration

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF RATE $NH_4^+/NO_3^-+NH_4^+$TO K^+, IONS UPTAKE ON PEACH TREES (*PRUNUS PERSICA* (L.) BATSCH. CVS. ALBERTA & ZAFERANI)

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Abstract

This experiment was conducted as factorial in a randomized complete block design with 5 nutrient treatments and 10 replications for each cultivar and total number of 100 peach trees that the investigation was at Tehran University about 2 years. In this study the effects of five nutrient solutions with different concentrations of NH_4^+ and $NH_4^+/NO_3^-+NH_4^+$ and equal mineral concentrations of total nitrogen, calcium, phosphorous, magnesium in comparison with the control or treatment one with different concentrations of all nutrients (about half of other treatments) on 4 years old peach trees (*Prunus persica* (L.) Batsch. cvs. Alberta & Zaferani) was studied. The concentrations of NH_4^+ were (0, 0.3, 0.5, 0.7 & 1 meq L^{-1}) and the ratio of concentrations $NH_4^+/NO_3^-+NH_4^+$ were (0, 0.04, 0.07, 0.1 & 0.15) in treatments one to five. The concentration of total nitrogen calcium, phosphorous and magnesium were (6.3, 3.5, 1.5 & 2.1 meq L^{-1}) in treatments two to five and in control they were (2.7, 1.5, 0.75 & 1.2 meq L^{-1}). The result of variance analysis for leaf percent K was affected significantly by nutrient solutions. Also leaf percent NH_4^+ and leaf percent Ca were affected by cultivar. But leaf percent Mg and leaf percent P were not affected by nutrients. Between nutrition elements with each other positive or negative regression relation were observed. Nutrient content in the leaves of Alberta cultivar was higher than Zaferani cultivar. Finally, nutrient solution S3 and S5 was determined to be suitable for peach trees nutrition.

Keywords: Nutrient solution, NH_4^+ , $NH_4^+/NO_3^-+NH_4^+$, Ca, Mg, P, Zaferani, Alberta, Cultivar.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF NUTRIENT SOLUTION ON VEGETATIVE TRAITS , CHLOROPHYLLS AND CAROTENOID OF PEACH TREES

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ABSTRACT

This experiment was conducted as factorial in a randomized complete block design with 5 nutrient treatments and 2 cultivars (Alberta and Saffron) with 2 replications and experimental units of 10 peach trees and total number of 100 pots. Nutrient elements (nitrogen, phosphorus, calcium, magnesium and potassium) had significant effects on the vegetative parts of the peach trees and improved function and growth of peach trees. The results of variance analysis for vegetative characters showed that flower bud density, chlorophylls a and carotenoids were affected by nutrient solutions significantly. But chlorophyll b and total chlorophylls were not affected by nutrients. Finally, solution No. 5 was determined as suitable solution for 2 cultivars peach trees (Alberta and Saffron) nutrition.

Keywords: *Nutrient solution, NH_4^+, $NH_4^+/NO_3^- + NH_4^+$, Alberta, Saffron, Cultivar, Peach.*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STUDY OF CHANGES IN THE FERTILITY PROPERTIES OF GRAY-MEADOW SOILS UNDER THE INFLUENCE OF ANTHROPOGENIC FACTORS

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The article examines the agrophysical properties of gray meadow soils in the Agjabadi region. Research results show that this type of soil has its own natural indicators; the negative impact of any of them leads to the loss of the fertile properties of gray meadow soils, which leads to a decrease in the productivity of cultivated agricultural plants grown on these soils.

Protection of soils from natural and anthropogenic influences and their effective use for agricultural crops are important issues for the sustainable development of the agro-industrial complex. Agriculture is one of the main activities in the densely populated areas that make up the Mil Plain. Improper compliance with agrotechnical and agro-meliorative measures in various areas of agriculture for many years exposed the gray meadow and meadow-gray soils of the Mil Plain to the negative effects of physical and chemical degradation.

Physically and chemically unsuitable soils include acidic, saline, saline, heavy clay, etc. These are special soils. The development of irrigated agriculture on lands leads to the fact that a significant part of them is subject to salinization. This, in turn, leads to a gradual deterioration in soil quality and a decrease in yield. The reclamation measures carried out lead to washing the soil from salts, eliminating acidity, and bringing the mechanical composition into line with the normal development of the plant root system. Acidic soils (pH_{H2O} <7) are made suitable for plants by liming, and alkaline soils (pH_{H2O}) by plastering.

Object and methodology of the study. The lands of the Agjabedi region, located on the Kur-Araz plain and west of the Mil plain, were taken as the object of study. The terrain is predominantly flat, gradually increasing from northeast to southeast. The surface of the territory is composed of continental alluvial and marine deposits of the anthropogenic system. The river network is sparse. The Kur River flows along the northeastern border, and the 111 km long Gargar River flows through its central part. The Upper Karabakh Canal passes through the region. There are salt lakes in this area.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Key words: Granulometric composition, absorbed bases, carbonization, moisture, clayey, loamy.

TOXICITY AND SUB-LETHAL EFFECT OF PYRETHROID İNSECTICIDE TO AN ENDOGEIC EARTHWORM

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ABSTRACT

The work we have undertaken aims to evaluate the effect of the insecticide Décis EC25 (pyrethroid family) on the earthworm Aporrectodea caliginosa. Initially, we focused on the toxicity of Décis EC 25 in adult worms where the evaluation criterion is: mortality. The acute toxicity test was carried out in filter paper for 48 hours, at increasing concentrations between 99.04 and 229.91 µg/cm^2. For better exploitation of the results, six repetitions were run for the control and each concentration. On the other hand, we were interested in a battery of biomarkers such as: glutathione level, Glutathione-S-transferase activity (GST), acetylcholinesterase (AChE) activity and protein level in adult worms treated at sub-lethal concentrations LC5 and LC10. The acute toxicity test enabled us to determine the LC50 = 167.8 µg/cm^2 after 48 hours, which is clearly higher than the recommended concentration for agriculture (RAD). Our results highlight an increase in total protein levels. Also, we noted an induction of the detoxification system (GSH, GST) and an inhibition of AChE activity, by the insecticide decis reflecting neurotoxicity. Our results represent first step in understanding the reaction of the endogeic earthworms to pyrethroid insecticides.

Keywords: Decis EC50, *A.caligionsa*, toxicity, biomarkers, contact test.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

"AN INDISPENSABLE PHARMACOGNOSTIC ACTIVITIES OF A MEDICINAL PLANT *LEEA MACROPHYLLA* ROXB. EX HORNEM. (HASTIKARNAPALASA)"

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Abstract:

Plants have been absolutely necessary as food and good health of living beings since classical time. From human history it is clear to the eye, that plants are of great demanding in traditional along with modern medicines. By nature, plants produce secondary metabolites, also termed as phytochemicals or biologically active compounds, which are embrace in plant physiology, its protection mechanism or just act as waste products for the plants but might be of great importance to human beings.

The aim of this write- up is bird's eye view of the wild edible ethnomedicinal plant *Leea macrophylla* Roxb. ex Hornem., regarding all reported information and research works on this plant.

Leea macrophylla Roxb. ex Hornem. popular as Hastikarnapalasa, is a wild ethnomedicinal herbaceous shrub plant, owns its place to the botanical family Vitaceae. It is blessed with enormous ethnomedicinal importance also known to have several therapeutic properties due to the presence of numerous chemical compounds. This plant is used by mainly tribal people. As well, it is used in hodopathy, ayurveda, allopathic. The leaves of the plant look like an Elephant's ear. Hence, it is traditionally named as 'Hastikarna Palasa' by the local tribal people. It is rich in secondary & primary metabolites. These secondary & primary metabolites were screened through qualitative phytochemical. GC-MS was determined for the same to verify that the plant contains many chemical compounds whose biological activities includes: - Anti-inflammatory, Anti-androgenic, Anti-bacterial, Anti-fungal, Anti-oxidant, Anti-cancer, Anti-diabetic, and so forth. Antibacterial activity was concluded against *Pseudomonas aeruginosa* and *Staphylococcus aureus*.

Multiple studies verified that the plant possesses potential analgesic, neuropharmacological, anti-nociceptive, anti-thrombotic, wound healing, anti-urolithiatic, cardiotonic, hepatoprotective, neuroprotective activities, & many more. The tribal communities used the plant parts as a remedy for a number of ailments as well as nutritional products.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Demanding, Hastikarnapalasa, GC-MS, Phytochemical, Antibacterial.

COMPREHENSIVE ANALYSIS OF GEOTHERMAL ENERGY POTENTIAL AND APPLICABLE GEOTHERMAL SYSTEMS IN AZERBAIJAN: AN IN-DEPTH OVERVIEW

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Abstract

Geothermal energy stands out as an exceptionally sustainable, environmentally benign, and secure energy source when juxtaposed with alternative forms of energy. Over recent decades, the advancement of geothermal energy has experienced notable progress, with numerous studies contributing to the extant body of knowledge. Geothermal energy finds versatile applications, both direct and indirect, offering a broad spectrum of potential uses. This paper endeavors to present a comprehensive overview of the geothermal energy potential and plausible applications within the geographic confines of the Azerbaijan Republic. Drawing on recent research efforts, the analysis underscores Azerbaijan's significant geothermal energy potential, primarily attributed to the presence of thermal waters and springs distributed across diverse regions. Notably, regions such as Istisu, Baghirsag, and Daridagh exhibit substantial geothermal potential, characterized by wells yielding geothermal water with a wide temperature range. Furthermore, researchers have identified noteworthy thermal capacity in the thermal waters and springs of Lankaran, Astara, Guba, Khudat, and Absheron regions. These areas feature thermal water sources with temperatures reaching up to 100°C, rendering them viable for geothermal energy applications. Although the temperatures in these regions may not be sufficiently high for electricity generation, they hold promise for diverse alternative uses. Given Azerbaijan's abundance of petroleum fields, certain geothermal resources intersect with oil fields, such as Absheron, Shikh, and Hovsan. Additionally, the repurposing of abandoned hydrocarbon wells presents an opportunity to convert them into geothermal wells, thereby augmenting the geothermal capacity within the Azerbaijan Republic. This exploration contributes to the burgeoning field of sustainable energy research by elucidating the multifaceted potential of geothermal resources in Azerbaijan and proposing innovative approaches to enhance geothermal capacity.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Azerbaijan, Geothermal energy, geotermal applications, thermal waters

FUZZY MULTI SERVER QUEUING MODEL BY DSW ALGORITHM TECHNIQUE

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Abstract: - This paper provides a Fuzzy Multi Server Queuing Model by DSW Algorithm Technique. We accept the inter-arrival time and service time as triangular and trapezoidal fuzzy numbers, and the arithmetic of interval numbers is enforced. In this proposed model, the idea of the α-cut through DSW calculation is connected to decide the execution proportions. The effectiveness of the proposed model is outlined by fathoming a numerical precedent by thinking about hypothetical information.

Keywords: Queuing Model, Fuzzy Numbers, DSW Algorithm, α-cut, execution proportions.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PERFORMANCE EXPEDIENTS ON A FUZZY NON-PARAMETRIC BATCH ARRIVAL QUEUEING SYSTEM

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Abstract:

Generally a management does not like the arriving customer wait for service in a system. It is not possible for all the times because the situation. In this case parameter estimation is helpful to rectify this difficulty and to analyze the modeling of system performance. Practically the queue parameters are not deterministic. So this paper estimates the queue parameter. Initially we construct the inverse membership function of the k-phase fuzzy queueing system and proposed an algorithm of performing the system. Finally, obtained the level of uncertainty range in the system and analyze the interval optimality level of k-phase fuzzy queueing system. The idea is extended to the work.

Keywords: Fuzzy sets, Mixed integer nonlinear programming, K-phase Erlang distribution, Measures.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PERFORMANCE ANALYSIS ON FUZZY $M^X/M/1$ QUEUEING SYSTEM WITH MULTIPLE WORKING VACATION

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ABSTRACT:

In this paper we analyze the performance measures of an $M^x/M/1$ multiple working vacations queuing model in a fuzzy environment. A mathematical parametric non linear programming method is used to construct the membership function of the system characteristics in which arrival rate, service rate for busy and vacation period, vacation parameter, working vacation rate and group size are fuzzy numbers. The cut and Zadeh's extension principle are used to transform a fuzzy queue into a family of conventional crisp queues. By means of membership function of the system characteristics a set of parametric non linear program is developed to calculate the lower and upper bound of the system characteristics function at . Further, numerical example is also illustrated to check the validity of the

proposed system.

KEYWORDS: $M^x/M/1$ queueing System, Working vacation policy, -cut, Measures.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EXPOSURE TO NATURAL BACKGROUND RADIATION IN NIGERIA'S OILFIELDS: A SYSTEMATIC REVIEW

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Abstract

This systematic review aims to assess the level of exposure to natural background ionizing radiation (NBIR) from oilfields in Nigeria. The review included a total of 13 studies, which were selected based on strict inclusion and exclusion criteria. The studies reported measurements of NBIR levels in oilfields, using different methods such as portable radiation meters, thermo luminescent dosimeters, and gamma spectrometry. The results of the review showed that the levels of NBIR in oilfields in Nigeria are generally higher than the global average. The median annual effective dose due to NBIR in the oilfields ranged from 0.4 to 12.7 mSv, with the highest levels reported in the Niger Delta region. The main sources of NBIR were found to be naturally occurring radioactive materials (NORMs) such as uranium, thorium, and their decay products, which are present in the geology of the region. The review also identified potential health risks associated with exposure to NBIR in oilfields. The most significant risk is the increased incidence of cancer, particularly lung cancer, due to exposure to radon and its decay products. Other potential health risks include genetic mutations, developmental abnormalities, and immune system dysfunction. The findings of this review highlight the need for improved radiation protection measures in oilfields in Nigeria. It is recommended that workers in the oil and gas industry be provided with appropriate radiation protection equipment and training to minimize their exposure to NBIR. Additionally, environmental monitoring of NORMs in oilfields is necessary to identify and mitigate potential risks to the public. Overall, this review provides valuable information for policymakers and stakeholders in the oil and gas industry to make informed decisions about radiation protection and environmental management. Further research is needed to fully understand the health effects associated with such exposure and identify ways to reduce the risks to workers and the general public.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECTIVENESS STUDY OF THE 'MAGNETIC WORKLIGHT' INNOVATION AS A PRACTICAL AID FOR AUTOMOTIVE STUDENTS LAB WORKS

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ABSTRACT

This study aimed to assess the effectiveness of the Magnetic Worklight developed for Automotive Technology Certificate (SAU) students at Pasir Salak Community College. The focus was on addressing challenges faced by students while conducting laboratory work, especially in confined spaces like the engine bay where traditional worklights were insufficient. Hence, a new Magnetic Worklight with strip LED lighting capable of illuminating in multiple directions was introduced. The primary objective of this study was to evaluate the efficacy and impact of the Magnetic Worklight, considering students' interest, perception, and the tool's design. A total of 62 SAU students from different semesters participated in the study, utilizing Google Forms for feedback distribution uses a 5-choice Likert scale questionnaire. Students had a three-week period to use the Magnetic Worklight for various automotive services, ranging from basic maintenance to engine overhaul. Descriptive analysis using Microsoft Office Excel showed that the Magnetic Worklight significantly improved the efficiency of lab work compared to conventional worklights, leading to faster service time. In summary, a significant number of students found that the Magnetic Worklight facilitated quick and comfortable work. with positive feedback on its usage. Moreover, there is potential for widespread application of this innovative product among automotive technology community colleges students throughout Malaysia, with future considerations for broader public use based on study feedback.

Keywords: Magnetic Worklight, Led Strip, Automotive Services

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENHANCING ACADEMIC PERFORMANCE IN AUTOMOTIVE ENGINEERING: A STUDY ON THE IMPACT OF INTERACTIVE LAB SHEETS IN THE SAU20103 COURSE AT PASIR SALAK COMMUNITY COLLEGE

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ABSTRACT

The academic performance of students in the SAU20103: Automatic Transmission System course at Pasir Salak Community College is hindered by difficulties in understanding illustrated lab sheets, specifically related to component placement and independent functionality. This research aims to assess the impact of incorporating Interactive Lab Sheets to address these challenges and improve students' comprehension of practical applications. The objective is to evaluate the effectiveness of these instructional tools in comparison to traditional teaching methods, with a focus on enhancing learning experiences in automotive engineering courses. The research enlisted 26 participants from Semester Two of the Automotive Technology Certificate (SAU) program, all of whom had previously utilized traditional practical sheets lacking interactive elements. Employing a quasi-experimental design, the study spanned eight weeks, with a treatment group (13 students) utilizing Interactive Lab Sheets and a control group (13 students) adhering to conventional teaching methods. In summary, the treatment group exhibited superior performance compared to the control group. In conclusion, the integration of Interactive Lab Sheets significantly improves students' academic achievements, particularly in practical applications. These findings yield valuable insights for educators, advocating for the incorporation of evidence-based strategies to enhance student learning experiences in automotive engineering courses.

Keywords: Interactive Lab sheet, Automotive Transmission, Education

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DIFFUSION CARBIDE COATINGS

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Abstract: Currently, the industry requires structural materials with unique physical and mechanical properties: with high warm and heat corrosion resistance and wear resistance. Pure metals such as chromium, nickel, vanadium, tungsten, and others which have these properties, are rather quite rare and therefore quite expensive, so it is advisable to use their iron-based alloys.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

At the same time, it is possible to replace special steels with less alloyed ones, and even carbon steels, provided that special coatings are applied to them that increase the performance of products under these conditions. This method of hardening gives a longer service life of parts and assemblies of machines and mechanisms than when manufacturing them from bulk alloyed special steels.

Among the many methods of surface hardening, the method of chemical-thermal treatment (CTT) of steels in powder mixtures attracts much attention.

Chemical-thermal treatment is the process of surface saturation of steel with various elements, the process of changing the chemical composition, microstructure and properties of the surface layer of a part. As a result of changes in the chemical composition of the surface layer, its phase composition and microstructure change as well CTT methods make it possible to create diffusion layers of borides, carbides and nitrides on the surface of steel, both individually and in various combinations of iron and many d-elements, and thereby impart high hardness, wear and corrosion resistance to the metal surface.

Powder compositions have been developed for diffusion saturation of the surfaces of steel products with certain transition metals. The CTT process has been carried out in a chamber furnace of the Nabertherm “Folding Tube” type – RS 120/1000/13, and kept at a saturation temperature of 950 – 1100^0C, 4 – 6 hours. Their phase composition has been studied, the thickness of the diffusion layer has been determined.

The structure, phase and chemical composition of the diffusion layers have been studied using X-ray phase analysis and scanning electron microscopy (Riqako Model minifleks 600 Cukα 1.54 Å, Scanning Elchon Microkope (SEM) JSM -6610).

The electrochemical study has been carried out on an IVIUM TECHNOLOGIES potentiostat at a potential sweep rate of $2 \cdot 10^{-4}$ V/min.

Key words: chemical-thermal treatment, powder mixture, diffusion layer, structure, corrosion resistance.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ESTIMATION OF AGRO-ECOTOURISM POTENTIAL IN DASHKASAN DISTRICT, AZERBAIJAN

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ABSTRACT:

The subject of study is the Dashkesan region, located in the western part of the Republic of Azerbaijan. The site is decorated with classical history, high landscape, agricultural fields and pristine natural beauty. For this reason, this area has agroecotourism potential. Everyone especially likes agricultural land, gardens and picturesque nature. Unspoilt nature, interesting peasant life and the civilized heritage of the classic Turkic-Albanian Gipchag make the Dashkasan area an extraordinary area of agroecotourism for travelers and visitors to the city. Dashkesan has a huge number of agricultural lands and gardens, all of which can recommend travelers to experiment with farming and gardening for the sake of relaxation in Dashkesan. These fields guarantee a beautiful surrounding area and ecological purity, pristine nature, which allows for the cultivation of autochthonous crops, and allows clients to adapt to the planting process. The Dashkasan site is known for its mine stock. A hydrophytic basin that includes rivers, lakes, reservoirs and mountains, the cliffs encourage the abilities of natural tourism and nature-based wanderings for all wanderers and tourists. Dashkasan is rich in classical Albanian Hungarian (monasteries and churches) Gipchag Turks, cultural monuments and traditions. In any season, travelers can visit significant places and the festivals that take place here in order to gain additional information about the aboriginal culture.Dashkesan is famous for its natural products, vegetables, fruits and all that fascinating and delicious indigenous cuisine. Guests and travelers have a great chance to get acquainted with indigenous cooking and gardening, including juices, dishes, sorbets (sweet drinks), jams, dried fruits, boiled products. Agroecotourism offers opportunities for nature walks, gardening tours and out-of-town tours in four seasons.

The site has extraordinary hospitality, the travel infrastructure and routes do not currently allow agroecotourism to be maintained in order to guarantee a comfortable and entertaining journey for tourists. That is why the deduction of the route for the sake of travelers after the Dashkasan region is necessary and relevant. In order to discover the agro-ecotourism reserve of Dashkasan for the sake of the powers of the world, first of all it is necessary to prepare the required complex of swamp routes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The rain-fed fields on the mountain slopes are endlessly entertaining and interesting for all visitors, as they are closely matched with natural beauty. The natural and civilized features of this area allow travelers to achieve a more complete connection with the surrounding environment and agricultural life.

Keywords: Agro-ecotourism, Dashkasan district, Azerbaijan, rural tourism, sustainable development

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

REGULATION OF THE EFFECT OF ORGANIC FERTILIZERS ON SOIL FERTILITY INDICATORS

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ABSTRACT

In the republic, 2-3 tons of manure per hectare of arable land, that is, its lack, leads to the violation of the ecology of the land.it was determined from the results of the conducted field research that the annual application of organic fertilizers to the soil not only increased the amount of nutrients in the soil, but also led to an increase in productivity indicators. Fertilizing the soil with properly prepared organic fertilizers not only enriches the soil with nutrients, but also has a positive effect on plant development. For this purpose, the effect of organic fertilizers (manure, compost, biohumus) applied under sugar beet in the gray-meadow soils of Ujar on soil fertility indicators and crop yield was studied. The research work consists of a comparative study of the effect of different organic fertilizers on the dynamics and productivity of soil nutrients under the sugar beet plant in the gray-meadow soils of Ujar in 2018 and 2022.

Keywords: biohumus, sugar beet, productivity, manure.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

UNLOCKING SUSTAINABLE ILLUMINATION: THE COMMERCIAL ADVANTAGES OF SOLAR ROAD LIGHTS OVER TRADITIONAL LIGHTING SOLUTIONS

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ABSTRACT

As we examine the financial benefits of solar road lights over conventional lighting options, discover the revolutionary potential of these products. This article examines the financial and ecological advantages that solar road lighting offer to companies and local governments. Solar road lights not only provide long-term financial benefits but also support sustainability objectives with significant energy cost savings and decreased operating costs, as well as improved visibility and safety. We look at how its allure—government incentives, flexibility to remote locations, and grid independence—contributes to the development of a robust and environmentally responsible lighting system. The article emphasizes how a dedication to innovation and environmental responsibility has a beneficial influence on brand image. Solar road lights are further justified by the addition of smart lighting features and higher property values. Accepting this solar-powered technology is a step in the direction of less carbon emissions and a decreased dependency on fossil fuels. We discover the comprehensive benefits that place solar road lights as a wise option for anyone wishing to light roadways with effectiveness, economy, and environmental consciousness as we investigate the lifespan and warranty advantages.

Keywords: Solar Energy, Solar Road Lights, Sustainable Lighting, Green Infrastructure, Renewable Energy Solutions, Eco-Friendly Innovation

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TREND ANALYSIS OF THUNDERSTORMS DURING PRE-MONSOON (MARCH TO MAY) AND MONSOON (JUNE-SEP) SEASONS IN BANGLADESH

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Abstract

Examining thunderstorm trends in Bangladesh's Monsoon and pre-monsoon seasons is crucial for understanding local weather patterns. Bangladesh's vulnerability to catastrophic weather events makes it an important case study for understanding climate shifts and their repercussions. The investigation of thunderstorm intensities, frequencies, and temporal fluctuations is done in this study using large multi-year data sets. Through the use of advanced statistical methods and meteorological data, the study looks for trends in the frequency of thunderstorms throughout these crucial periods. Infrastructure, agricultural productivity, and social resilience in general are significantly impacted socioeconomically in Bangladesh by the pre-monsoon and monsoon seasons. By conducting a meticulous trend analysis, this research sheds light on potential alterations in thunderstorm patterns, including onset, duration, and severity shifts. Such insights are paramount for disaster management strategies, urban planning, and agricultural practices tailored to withstand and mitigate the impacts of thunderstorms. The study is expected to contribute to existing knowledge on Bangladesh's climate variability. Moreover, they hold the potential to guide policymakers, meteorologists, and relevant stakeholders in devising proactive measures aimed at enhancing resilience and adaptive capacity in the face of changing thunderstorm dynamics. Understanding and anticipating the nuances of thunderstorm trends during these critical seasons is fundamental in fortifying Bangladesh's preparedness and response mechanisms against weather-related adversities.

Keywords- Thunderstorms, Pre-monsoon, Monsoon, Trend analysis, Bangladesh, Climate variability.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BALAKAN LAND RESOURCES AND THEIR EFFICIENT USE

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ABSTRACT

Balakan region is located in the north-west of Azerbaijan, on the southern slopes of the Greater Caucasus, in the Alazan Haftaran valley. Balakan district, distinguished by its wealth of natural resources, economic potential and cultural heritage, borders the Russian Federation (Dagestan Autonomous Republic) to the north, the Republic of Georgia to the west and southwest, and Zagatala district to the east. 709 hectares of the territory of Balakan district, which has an area of 93.4 thousand hectares, is the state reserve fund land, 8.4 thousand hectares are municipal lands, and 25 thousand hectares are private property lands.

Mountain-meadow turf; Mountain-forest brown, typical; Mountain-forest brown, residual carbonate, partly stepped; Meadow-cinnamon carbonate, typical; Meadow-forest, riparian; Flood-plain-alluvial-meadow land types are spread in the area.

Mountain-meadow turf lands were formed under alpine and subalpine meadows at an altitude of 1800-3000 m above sea level. The characteristic feature of these soils is the presence of more than 10% humus in the top layer and more than 50% absorption capacity. The reaction of the soil solution is weakly acidic.

As can be clearly seen from the generalized description of the morphological structure of Mountain-meadow turf soils, the profile of these soils is not very thick and in most cases does not exceed 60-70 cm. Looking at the soil profile, it is possible to clearly distinguish the genetic layers. The presence of a 5-7 cm thick layer of turf "braided" with plant roots in the upper layer is one of the characteristic features of these soils.

Keywords: Balakan region, relief, climate, soil, vegetation

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYSIS OF SOLAR ENERGY AND ITS VARIOUS TECHNIQUES FOR ELECTRICITY GENERATION

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ABSTRACT

This paper presents an in-depth analysis of solar energy and its diverse techniques for electricity generation. As the world grapples with the adverse effects of fossil fuel usage on pollution, health, and the environment, the imminent depletion of these resources underscores the urgency of transitioning to renewable sources.

Solar energy, with its vast potential and eco-friendly attributes, emerges as a key player in this transition. The study explores the solar radiation spectrum, emphasizing that while the solar constant outside the atmosphere is 1367 W/m², the Earth receives an average of 800 W/m².

The paper categorizes solar energy conversion technologies into two main types: solar photovoltaic (PV) and solar thermal systems. Solar PV systems, with an efficiency of up to 30%, directly convert solar radiation into electricity. Conversely, solar thermal systems, particularly Concentrated Solar Power (CSP) technologies, utilize mirrors and lenses to concentrate solar energy. CSP systems, highlighted for their ability to generate electricity even in the absence of sunlight, present characteristics such as high efficiencies and higher capital costs.

The study concludes with a comparative analysis of solar photovoltaic stations and solar thermal power plants, elucidating their respective advantages and disadvantages. It emphasizes the surging interest in supercritical CO2 power cycles, showcasing theoretical conversion efficiencies exceeding 50%.

Keywords: Solar energy, Concentrated Solar Power, supercritical CO_2, photovoltaic, power cycles, sustainable energy

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A COMPREHENSIVE EXPLORATION OF EMULSION STABILIZATION TECHNIQUES

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ABSTRACT

This study investigates various emulsion stabilization techniques crucial for enhancing the stability and performance of emulsions in diverse applications. Emulsions play a crucial role in industries such as food, pharmaceuticals, and cosmetics, where the stability of the dispersed phase is paramount. The research systematically explores conventional and innovative stabilization methods, including the use of surfactants, polymers, as well as solid particles. Through a comprehensive review of literature and experimental analysis, the present study aims to provide insights into the mechanisms underlying emulsion stabilization. Additionally, the research evaluates the impact of different factors, such as emulsion composition, processing conditions, and environmental factors, on the stability of emulsions. The findings of this study contribute valuable insights, guiding researchers and industries toward improved formulations and applications. Overall, this research plays a pivotal role in advancing knowledge about emulsion stabilization techniques, addressing the growing need for robust and effective emulsions in diverse industrial applications.

Keywords : Emulsion, Emulsification, Stabilization, Surfactants, Polymers, Particles.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

OSYNTHESIS AND CHARACTERIZATION OF A TITANIUM-BASED CATALYST FOR THE PRODUCTION OF HYDROGEN BY PHOTOCATALYSIS

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ABSTRACT

Hydrogen is one of the most important clean energy generators with high calorific value and large storage capacity.

The production of hydrogen by photocatalysis is one of the most promising technologies in the field of renewable energy.and the production of energy from the photocatalysis of water means that we can use water as a source of fuel for future energy needs.

Among the various catalytic materials, titanium dioxide is the predominant and the most studied due to its exceptional physical and chemical properties.

In this study, we elaborated titanium dioxide-based photocatalytic systems from $TiCL_4$ as a precursor in an aqueous medium with different concentrations of Ti^{4+} species. The structural and textural properties of the synthesized solids were characterized by XRD, FTIR, Raman, BET, XPS and MEB-EDX. The photocatalytic behavior of different formulations depending on the concentration used has been evaluated in the production of hydrogen.

The results obtained showed that the species concentration of Ti^{4+} has a considerable influence on the structure, the texture and the photocatalytic activity for the production of hydrogen.

We found that the higher the TiO_2 concentration, the lower the hydrogen production efficiency, this can be attributed to the low content of Ti^{4+} species at the photocatalytic surface.

The excellent photoctalytic performances were observed at the concentration of 0.7 mol/L Ti^{4+}.

The recorded results allowed us to establish a good correlation between the structure, the texture and the photocatalytic activity for the production of hydrogen.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Photocatalysis ; titanium dioxide ; renewable energies ; hydrogen.

MOSQUITO REPELLENT SPRAY

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ABSTRACT

Mosquito–transmitted diseases remain the main source of illness and death. To use repellents to protect people from bites of mosquitoes previously has been acknowledged as part of an overall integrated insect-borne disease control program. Most commercial repellents are produced by using chemical components such as N, N- diethyl –meta –toluamide (DEET), allethrin, and dimethyl phthalate. It has been identified that chemical repellents are not safe for public health and should be used carefully because of their harmful impacts on plastic and chemically prepared fabric and toxic reactions like allergy and cardiovascular side effects which have been reported generally after misapplication. In recent years interest in plant-based repellents has been started again, as they contain a ricamountsnt of bioactive phytochemicals that are safe, biodegradable into non-toxic by-products, which could be screened for mosquito–repellent.

Keywords: Mosquito, Plant-based repellent, Nanotechnology, Cancer, Food, Biofuel,

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A STUDY ON IMPACT OF DIGITAL MARKETING ON THE CONSUMER DECISION MAKING FOR INTERIOR DESIGN PRODUCTS

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Abstract: The world today we are living is totally depend on digital media, our lifestyle and deliberations have been affected by Digital Media Platforms. Compared to traditional marketing practices digital marketing has changed the way marketers communicate to consumers. In this scope this study aims to measure the effect of usage of digital media on different stages decision making process for interior design products. Study uses exploratory research methodology and sample from 117 interior design products customers were used for analysis. The data was collected through a structured questionnaire. Factor analysis was carried out and three factors namely Pre-Purchase, Purchase, Post-Purchase were identified and after reliability test all three factors found reliable. Regression analysis was carried out to measure the effect of usage of digital media on different stages decision making process for interior design products and results shows that digital marketing affects more in pre purchase followed by purchase and post purchase. So, we can conclude that digital marketing is more effective in pre-purchase stage followed by purchase and post purchase. So, the interior design organizations need to spend more time in digital media at all stages of decision making to create delight for customers.

Keywords: Digital Marketing, Decision Making, Consumer Behavior, Interior Design

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

KINETIC MODELLING OF POWDER-PACK BORONIZED 4CR5MOSIV1 STEEL BY THE BILAYER MODEL

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Abstract

The objective of this study is to analyze the boronizing kinetics of 4Cr5MoSiV1 steel within the temperature range of 1133-1253 K. The employed kinetic model is based on the conservation principle of mass balance equations at the two phase boundaries, considering the linear distribution of boron across each boride phase. The activation energies of boron in FeB and Fe_2B were evaluated and compared to existing literature. By fitting the calculation results obtained from the bilayer model with Arrhenius relationships, the activation energies in FeB and Fe_2B were determined as 164.92 and 153.39 kJ mol^{-1}, respectively.

Keywords: boronizing, iron borides, diffusion, bilayer model, activation energy.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ROLE OF NGO IN TRANSFER OF FARM TECHNOLOGIES TO EMPOWER THE LIVELIHOOD SECURITY OF SMALL AND MARGINAL FARMING COMMUNITIES

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Abstract

India's gross domestic output is 22 percent derived from agriculture (GDP). The net cultivated area is 142.5 million ha out of a total of 329 million ha. More than 70% of Indians reside in rural areas, and agriculture is the primary source of income for most of them. The largest occupation in the private sector and the one that employs 58% of the workforce in the nation is agriculture. Agricultural advancements are being driven by the use of technology, which has boosted crop yields and has contributed to the farming community's revenue growth. According to estimates, 60% of farmers have no access to sources of knowledge on sophisticated agricultural technologies, which causes a big adoption gap (NSSO, 2005). To make sure that the firm's innovation gets commercialized, technology transfer is crucial. Additionally, it can serve as the foundation for brand-new public-use goods and services. A comprehensive approach and cooperative efforts including numerous departments, agencies, and even NGOs are necessary to accomplish this. Compared to governmental organisations, NGOs, or non-governmental organisations, have greater advantages working in rural areas since they are more adaptable, focused on a particular region, and dedicated to helping the public and community as a whole. An NGO is a non-profit organisation that is run without the involvement of any government and usually has the goal of resolving a social or political issue. Because of their good relationship with farmers, NGOs are able to design technology solutions that draw upon local knowledge systems and reinforce those systems by ensuring that newly developed technologies are included into them. Through this paper, we study about the role of NGO in technology transfer process in agriculture.

Keywords: NGO, Technology transfer, Agriculture.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INVITRO ASSESSMENT OF THE LARVICIDAL ACTIVITY OF VECTOBAC 12AS FORMULATION (*BACILLUS THURINGIENSIS VAR. ISRAELIENSIS)* ON *ANOPHELES MOSQUITO* LARVAE

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Abstract

Bioaccumulation and development of resistance by the vectors to the most commonly used insecticides, in addition to the negative environmental impact, in which the effect of most synthetic insecticide persist in an environment for a longer period of time make them undesirable for vector control. Instead, biological vector control using appropriate biological agent remains the only alternative for effective vector control and management. Therefore this research aimed to evaluate the larvicidal activity of the lower doses of commercially synthetic *Bacillus thuringiensis israelensis* (Vectobac 12AS) against the forth instar larva of Anopheles mosquito. One hundred and fifty blood-fed female anopheles mosquitoes were collected from different resting sites from Abuja Quarters in the month of June 2018 using an aspirator and allowed to breed until the first instar larva appears. The larvae were monitored and fed with 10% yeast until the third instar emerged. 240 healthy third instar larvae were selected and grouped into three treatments containing sixty (60) larvae each and replicated three times. The first, second and the third treatments were respectively treated with 0.84, 0.42 and 0.21ml/l of Vectobac 12AS. Each treatment has a control containing twenty (20) larvae each. Larval mortality was determined using glass rod at an interval of 15minutes for a period of 24hours. ANOVA was used to statistically analysed differences in the larval mortality between the treatment and probit analysis was used to determine the lethal concentration (LC) and the lethal time (LT). Mortality of 1(6.7%) and 3(5.0%) were observed in the first treatment (0.84ml/l) after 15 and 30minute of exposure respectively. The highest mortality of 60(100%) was observed in all the treatments after 24hours of exposure. Statistically, there was no significant difference in the larval mortality with regards to the different concentrations used ($F=0.081$, $P> 0.05$). 2.35 ml/l, 5.54 ml/l and 8.15ml/l was determined to be LC_{50}, LC_{90} and LC_{99} respectively and LT_{50}, LT_{90} and LT_{99} were found to be, 1809.29min and 2451.34min respectively. Conclusively vectobac 12AS has demonstrated a high level of efficacy as it revealed 100% larval mortality even at a lower recommended dose. Further research should be carried

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

out to study the impact of some other biological and environmental factors on the efficacy of vectobac 12AS.

Keywords: Biological control, Vector, Biolarvicide, synthetic insecticide, Dipterans

DETERMINATION OF INCREMENT IN CARBON-DIOXIDE (CO_2) EMISSION PRODUCED FROM AUTOMOBILE ON SELECTED HIGHWAYS IN BAUCHI STATE BY SPEED BUMPS

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ABSTRACT

Transportation is a segment that has a reliance on fossil fuel manufacture and will produce carbon dioxide (CO_2) emissions. Carbon Dioxide (CO_2) is a pollutant produced by vehicles which causes air pollution, but vehicles with fossil fuels are still a need for communal deployment. Traffic-calming devices act as the tools to reduce the rapidity of automobiles. They make a major input to road protection; however, air contamination is more likely to arise due to the fact that motor vehicles use brakes and accelerate more regularly. This study examines the impact of speed bumps brought on by elevated carbon dioxide (CO_2) levels on selected commercial vehicles, including Vectra, Volkswagon, Peugeot, Ford Galaxy, and Toyota Hiace buses, traveling on highways from Bauchi to Jos, Bauchi to Azare, Bauchi to Gombe, and Bauchi to Kano. To estimate the CO_2 emissions of each kind of the specified commercial vehicles, the fuel consumption of the vehicles before and after installation of bumps was gathered and examined using a mathematical model using a macro-scale approach. The result shows that there is an increase of 19.3% of CO_2 emissions on Bauchi to Jos highway, 12.6% CO_2 emissions on Bauchi to Azare, 12.4% of CO_2 emissions on Bauchi to Gombe and 10.7% CO_2 emissions on Bauchi to Kano. The study concludes that transport-related pollution in Bauchi highway is indeed significantly increased with installation of calming traffic device.

Key Words: Fossil fuel, Carbon dioxide (CO_2) emissions, Traffic-calming, Vehicles, Highways.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

WIRELESS COMMUNICATION

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Abstract - In Wired Communication, the medium is a physical path like Co-axial Cables, Twisted Pair Cables and Optical Fiber Links etc. which guides the signal to propagate from one point to other. Such type of medium is called Guided Medium. The term wireless refers to the communication or transmission of information over a distance without requiring wires, cables or any other electrical conductors. Wireless communication is one of the important mediums of transmission of data or information to other devices. There are many devices used for wireless communication like mobiles. Cordless telephones, GPS, Wi-Fi, satellite television and wireless computer parts. Current wireless phones include 3 and 4G networks, Bluetooth and Wi-Fi technologies. This paper is focused on elements of Wireless Communication system, Types of Wireless Communication, Advantage & Disadvantage of it, Smart city, wireless network security

Keywords: wireless communication, Wifi, Bluetooth, NFC, LiFi.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

HYBRID ROUTING PROTOCOL

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Abstract: MANETs consist of a hop-to-hop, self-arrangement and self-configure network in contrast to a mobile network has a central controller. The solutions may not always be sufficient, as ad-hoc networks have their own vulnerabilities that cannot be addressed by these IDS solutions. In the network, some active attacks un-forward capacity nodes pretend to be intermediate nodes of a route to some given targets, drop any packet that subsequently goes through it, is one of the main types of attack. In this paper, they propose black-hole attacks an analysis method to detect malicious nodes in MANETs, the mechanism is cooperative hence the protocol work cooperatively together so that they can analyze, detect malicious nodes in a reliable manner. To verify our developed scheme by running through Network Simulations 2 (NS2) with mobile nodes using hybrid routing protocol namely, Modified - Zone based Hierarchical Link State (M-ZHLS) routing protocol. It is observed that the black hole and malicious node detection rate is very good, reduced average delay and also increased packet delivery ratio compare Zone based Hierarchical Link State (ZHLS) routing protocol when there is a change of mobility speed and varying topology size.

Keywords: MANET, Black hole, M-ZHLP, PDR, Overhead, Throughput.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ACKNOWLEDGEMENTS WITH CRYPTOGRAPHY FOR MANET

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Abstract – Mobile Ad hoc Network (MANET) that allows to the users to access information and services anywhere regardless of their geographic location. MANET is the significant technologies used to more flowing more application conference, meeting, short time connection, natural issues like (flooding, forest fire, agriculture and military) ect., among various un-wired communication technologies where all the mobile nodes are mobile and which can be connected to random dynamically using wireless link in the random manner. But it stream including critical issue and challenges such as security, energy, delay, packet drop quality of service ect., In this research paper proposed Secure Two Acknowledgement method with MARS4 (STACK) that implement for new intrusion detection system for on-demand wireless networks. MARS4 can improve a best performance of trusted quality output to reduce transmission delay, transmission time and also increase network communication throughput help of Network Simulator-2.34 (NS2) to implement it.

Keywords: Ad hoc, Security, Routing, STACK, MAJRS4.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SATELLITE COMMUNICATION LINKS

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ABSTRACT: In all the above applications to observation earth the satellites which placed using the important traditional design called low earth orbit which used to increases the data resolution but above method will take more time to present of duration outcomes because not able to transmit the high resolution data rate to grand station antenna from low earth orbit satellite. Another one is geostationary earth orbit satellite model that one have more visible time than low earth orbit satellite, so inter satellite communication is should be used between necessary between above two methods use to increases higher performance of resolution. In this emerging recent developed design, to compare the result analysis of above two satellite models using three traditional modulation methods like such as quadrature phase shift keying, 8 phase shift keying and 16 SK and 16 quadrature amplitude modulation with different amplifier models like rapp amplifier, saleh and ghorbhani models to measure used via a with eco-signal (doppler effect) air medium. Even though observed the output of quadrature amplitude modulation scheme achieve better error vector magnitude through MATLAB simulator.

Keywords: Long Distance Broadcasting; Modulation Methods; Inter Satellite; Amplifier Models;

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SIMULATION ANALYSIS OF ALGORITHM IN MANETS

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Abstract – MANETs are the significant technologies among various air communication technologies where all the nodes are mobile and can be connected dynamically using wireless link in a random manner. All nodes work router and maintain routes to other nodes in the network. In this recent research work, a new system called, Secure Hybrid Shortest Path (SHSP) Routing compare with optimized link state routing (OLSR) proactive routing protocol is designed for MANETs to reduce end-to-end delay, secure hybrid shortest path routing algorithm besides avoiding delay and packet loss, it increases the node speed also. Network Simulator (NS2) is used to simulate the proposed method and implemented in the test system.

Keywords: MANET, Routing, Security, Malicious Nodes, SHPR, PDR, Delay.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SENSOR NODE LIFETIME USING MULTI-GEOGRAPHICAL ROUTING PROTOCOL

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Abstract: A non fixed temporary network called Wireless Sensor Network (WSN) is an aggregation of sensor nodes which are remotely deployed in large numbers and operate the environmental condition and have limited energy resource. In most of the hierarchical routing protocols, the cluster head (CH) selection is on the basis of random probability equation. There is a scope to reduce the energy dissipation by improving CH selection procedure. The proposed scheme, coined as Multi Geographical Threshold based Routing Protocol, makes use of evolutionary algorithm for improving CH selection in legacy LEACH routing protocol in sensor networks. The concept of relay node is introduced which acts as an intermediary between CH and base station (BS) to ease the communication between the CH and BS. The simulation results obtained supports that our proposed algorithm is efficient in terms of network lifetime.

Keywords: WSN, Cluster, Routing, Hard Threshold, Soft Threshold.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

HYBRID LINK STATE FOR MOBILE AD HOC NETWORKS

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Abstract - We are implementing secure dynamic on-demand routing protocol in order to achieve security goals for following parameters packet delivery ratio, routing overhead and throughput. The proposed model test HHLS-MARS4 hybrid routing protocol and analysis secure method is implemented to avoid any type of attacking model on the network with HHLS-MARS4 routing algorithm besides avoiding delay and packet loss; it increases the node speed also. Network Simulator (NS2) is used to simulate the proposed method and implemented in the test system. The proposed protocol provides secure transmission and further reduces routing overhead, delay and packet loss since HHLS-MARS4 algorithm increases efficiency of network topology.

Keywords: MANET, Security Issues, Routing Protocol, HHLS-MARS4, PDR, RO, NS2.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BUSINESS ORGANIZATION

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Abstract: A Business is an enterprise which distributes or provides services where other members of the community need and are able and willing to pay for it. A Business organisation is one in which people exchange goods and services to satisfy the needs of other people to earn profit. Business firms, State enterprises, public service, organization, and non-profit making charities are the examples of business organisation. Most of the Management theory and practice are common to every kind of business organisation. A Business organisation differs from the non-business organisation or public service organisation that it provides goods and services usually at a profit. Several types of business organisation are existing in order to satisfy the social, economic and human requirements. The most common types of business organisation are as follows:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A STUDY OF DATA SECURITY

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ABSTRACT: To make better data transmission over networks cryptography is used with the internet having reached a level that merges with our lives, growing explosively during the last several decades; data security has become a main concern for anyone connected to the web. Data security ensures that our data is only accessible by the intended receiver and prevents any modification or alteration of data. In order to achieve this level of security, various algorithms and methods have been developed. Cryptography can be defined as techniques that cipher data, depending on specific algorithms that make the data unreadable to the human eye unless decrypted by algorithms that are predefined by the sender.

Keywords: Cryptography, Security, Algorithm, Cipher, Decryption, Data Security.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SCHEDULING ALGORITHM IN INFRASTRUCTURELESS WIRELESS NETWORKS

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ABSTRACT: Wireless sensor networks (WSNs) are increasingly being deployed in security-critical applications. Because of their inherent resource-constrained characteristics, they are prone to various security attacks, and a Grey-hole attack is a type of attack that seriously affects data collection. To conquer that challenge, an active detection-based security and trust routing scheme named Active Trust is proposed for WSNs. The most important innovation of Active Trust is that it avoids black holes through the active creation of a number of detection routes to quickly detect and obtain nodal trust and thus improve the data route security in priority queuing in scheduling algorithm using NS2 Simulator. In this work, perform of priority queuing algorithm is evaluated to attain quality of Service (QoS).

KEYWORDS: Priority queuing, NS2, Wireless Sensor Network, GPS, Black holes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FLYING AD HOC NETWORKS

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Abstract-Recently, FANETs allow multiple UAVs to communicate in 3D space to establish an ad hoc network. FANETs applications, among others, can deliver cost-effective services to help future wildlife achieve their goals. However, adopting FANETs technology in wildlife monitoring is difficult due to its challenges from UAV mobility, data routing, energy, and security considerations. Therefore, this paper aims to look at FANET's possible applications in wildlife monitoring and the implications and issues that come with them.

Keywords: flying ad hoc networks, wildlife monitoring, unmanned aerial vehicle, high mobility, energy consumption.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SECURE APPROACH FOR MOBILE AD HOC NETWORKS

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Abstract – All the mobile nodes are mobile and which can be connected to random dynamically using wireless link in the random manner. It can provide Quality of Service (QoS) requirements in real update transmission for wireless application. But it stream including critical mission application like military use or emergency recovery. In this research paper proposed efficient Acknowledgements based Secure Quality Oriented Distributed, that cam improve a best performance of QoS with reducing delay also increase network communication throughput for Enhanced Adaptive 3 ACK's (S-EA3ACK) using EAACK (DSA) with MAJE4 symmetric cryptography specially designed for MANET through Network Simulator-2.34 (NS2) to implement it.

Keywords: QoS, QOD, EAACK, EA3ACK, S-EA3ACK, Cryptography, MAJE4.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

IMAGE TECHNOLOGY

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ABSTRACT: This invention is an amalgamation of a few distinct strategies each with their own different focal points and inconveniences. Low- Light Imaging, Thermal Imaging and Illumination are the most commonly known techniques. various night vision gadgets (NVDs) that allow images to be produced in levels of light moving towards adding up to darkness, as well as clarifies various applications where innovation in night vision is used to care for of different issues because of low light conditions . Pedestrians and animals have the greatest risk in night time traffic due to darkness, the ability to identify such objects should be the key performance requirement, and the device should remain successful when facing oncoming vehicles 'headlights. The infrared system has been shown to be superior to the near infrared system. Near infrared images have been identified as having substantially higher visual clutter compared to far-reaching infrared images. The visual clutter is shown to correlate with reduced pedestrian detection distance. Far-infrared images are thought to be more peculiar and hence more difficult to view, although the presence of the image is presumably related to the lower visual clutter.

Keywords: Image Intensifier Tubes, Monocular, Night Vision, Thermal Imaging, Wildlife, Spectrum.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SMART FARMING for IoT

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ABSTRACT: IoT refers to a network of things which make a self-configuring network. The development of Intelligent Smart Farming IoT based devices is day by day turning the face of agriculture production by not only enhancing it but also making it cost-effective and reducing wastage. The aim / objective of this paper is to propose a Novel Smart IoT based Agriculture Stick assisting farmers in getting Live Data (Temperature, Soil Moisture) for efficient environment Monitoring which will enable them to do smart farming and increase their overall yield and quality of Products. With IoT productions costs can be reduced to a remarkable level which will in turn increase profitability and sustainability with IoT, efficiency level would be increased in terms of usage of Soil, Water, Fertilizers and Pesticides etc. The Agriculture stick being proposed via this paper is integrated with Arduino Technology, Breadboard mixed with various sensors and live data feed can be obtained online from Thingsspeak.com. The product being proposed is tested on Live Agriculture Fields giving high accuracy over 98% in data Feeds.

Keywords: IoT, Technology, Agriculture, WSN, Cloud Computing.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

WIRELESS MEDIUM TECHNOLOGY

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Abstract - In Wired Communication, the medium is a physical path like Co-axial Cables, Twisted Pair Cables and Optical Fiber Links etc. It encompasses various types of fixed, mobile, and portable Applications, including two-way radios, cellular telephones, personal digital assistants (PDAs) and wireless networking. Other examples of applications of radio wireless technology include GPS units, garage door openers, wireless computer mice, keyboards and headsets, which guides the signal to propagate from one point to other point via channel. Such type of medium is called Guided Medium. The term wireless refers to the communication or transmission of information over a distance without requiring wires, cables or any other electrical conductors. Wireless communication is one of the important mediums of transmission of data or information to other devices. There are many devices used for wireless communication like mobiles. Cordless telephones, GPS, Wi-Fi, satellite television and wireless computer parts. Current wireless phones include 3 and 4G networks, Bluetooth and Wi-Fi technologies. This paper is focused on elements of Wireless Communication system, Types of Wireless Communication, Advantage & Disadvantage of it, Smart city, wireless network security

Keywords: wireless communication, Wifi, Bluetooth, NFC, LiFi.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

NOVEL DISPLAY DESIGN

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Abstract: A number of materials have been developed and improved in order to fulfil the requirements of this application. Electroluminescence is the emission of light from materials in an electric Field, and in the 1960s1 this phenomenon was observed from single crystals of anthracite. Despite The high quantum efficiency obtained with such Organic crystals, no application has emerged owing To the high working voltage required as a result Of the large crystal thickness and poor electrical Contact quality. The materials differ from one another by their structure but also by the mechanism involved in the electroluminescence produced (fluorescence Versus phosphorescence). When properly stacked, these materials result in a device that can achieve the required high efficiency and long lifetime. Such red, green and blue devices can then be combined in Matrices to become the core of a display. Building up these structures onto a display backplane is one of the challenges facing the industry.

Keywords: organic light-emitting diode (OLED); flat-panel display; passive matrix; active matrix; full-colour Device

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANTIOXIDANT ACTIVITY OF SPIRULINA EXTRACT.

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ABSTRACT

The cyanobacterium *Arthrospira platensis* (Spirulina platensis) known as blue-green microalgae, is a natural source of bioactive substances with a variety of important biomedical activities. Since the composition of spirulina varies according to its origin (environmental parameters) and its cultivation conditions, the intensity of the antioxidant activity should also be variable. The aim of our work was to use different in vitro systems that includes DPPH and ABTS radical scavenging assays, to investigate spirulina water extract (SWE) radical scavenging activity (RSA) and the inhibitory concentration IC_{50}. The obtained results showed that SWE had noticeable radical scavenging activity in concentration dependent manner. For a concentraction of 200µg/ml of SWE, the % scavenging activity were 50,60% and 69,00% for DPPH and ABTS assays respectively. There is an indirect relation between RSA and the IC_{50}. In the DPPH assay, IC_{50} was (168µg/ml) as well as for the ABTS assay was (82µg/ml). These results provide a supplementary idea about therapeutic application of Algerian spirulina on large scale basis that it could be explored as powerful alternatives of synthetic antioxidants

Keywords: *Arthrospira* platensis, spirulina, radical scavenging activity, inhibitory concentration.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PRODUCTION PLANNING STRATEGIES AND BIOPROCESS OF LIPASES: A REVIEW

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ABSTRACT

Lipases are enzymes that catalyze the breakdown of lipids into long-chain fatty acids and glycerol in oil-water interface. In addition, they catalyze broad spectrum of bioconversion reactions including esterification, inter-esterification, among others in non-aqueous and micro-aqueous environment. Lipases are universally produced from plants, animals, and microorganisms, however, lipases from microbial origin are mostly preferred owing to their lower production costs, ease of genetic manipulation etc. The secretion of these biocatalysts by microorganisms is influenced by nutritional and physicochemical parameters. Optimization of the bioprocess parameters enhanced lipase production. In addition, microbial lipases have gained renewed efforts for a wide range of applications in food, detergent, and cosmetics industries as well as in environmental bioremediation. This review provides insights into strategies for production of microbial lipases for potential biotechnological applications.

Keywords: Lipases, Microorganisms, Bioprocess parameters, Biotechnological applications

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GREEN SYNTHESIS, CHARACTERIZATION OF IRON-BASED NANO FERTILIZER FOR SUSTAINABLE RELEASE AND EFFICIENT USE OF NUTRIENTS OF IRON NANOPARTICLES USING GREEN TEA EXTRACT.

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ABSTRACT

In recent years, there has been a surge in interest in creating Nanoparticles in a simple and environmentally responsible manner. Physical and chemical methods are commonly utilized for nanoparticle synthesis. However, due to their limitations, the focus of research has recently switched to creating clean and environmentally acceptable synthesis processes. Iron Nanoparticles were synthesized greenly utilizing an environmentally friendly plant extract. *Camellia sinensis* leaf extract converted iron ions into iron nanoparticles at standard temperature. Nanoparticles are emerging as cutting-edge substances with the potential to alter existing agriculture techniques. Many nanoparticle-based formulations have been studied for plant health management and soil enhancement, including nano-sized insecticides, herbicides, fungicides, fertilizers, and sensors. This research aims to create Iron Nanoparticles using *Camellia sinensis* extract in an environmentally friendly and long-term manner as a biofertilizer. Scanning Electron Microscope (SEM) and Fourier Transform Infrared (FTIR) studies analysed the produced Iron Nanoparticles. According to this study, the Iron Nanoparticles may be manufactured utilizing *Camellia sinensis* leaf extract as a reducing agent.

Keywords- Green synthesis, iron nanoparticles, green tea extract, biofertilizer.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

The effects of human food additives on Drosophila melanogaster- A dietary exposure experiment

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Abstract

Many cellular and developmental processes shared by higher eukaryotes, including humans, can be studied using Drosophila melanogaster as a physical model. The human genome is just 60% as redundant as the Drosophila genome, which also contains about 75% of the genes associated with human disease. We investigated the effects of MSG, sodium benzoate, sodium chloride, ascorbic acid and glucose on the life span and morphological changes in Drosophila melanogaster. The results show that Sodium benzoate significantly retarded the development of Drosophila melanogaster larvae, shortened the life span. The continuous exposure to MSG and glucose reduced the life span of the flies and also they became obese. In the future, this type of model research like the Drosophila melanogaster will be helpful to prevent many more diseases rather than suffering. From the above article, we understand that it is not advisable to consume a high amount of food additives during pregnancy to avoid health complications in the unborn child.

Keywords: *Drosophila melanogaster*, Monosodium glutamate, Obesity, Genome, Life span, Sodium Benzoate.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

NATIONAL LEADER HAYDER ALIYEV IS THE FOUNDER OF MODERN AZERBAIJAN EDUCATION

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The Great Leader Heydar Aliyev, speaking about the role of education in the development of society, says:

"*How valuable this education system is can be seen from the fact that Azerbaijan has people with high education, knowledge, qualifications, and high science, and they make up the majority of the society. If they were not there, Azerbaijan's economy could not develop. Without them, we would not be able to manage Azerbaijan as an independent state. They need to be appreciated.*"

Keywords: *Azerbaijan, education, science, society, state*



DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

In history, it is possible to find very few political leaders whose name became a symbol of statehood. The Great Leader Heydar Aliyev, who has rare management and leadership qualities, innate talent, and a high sense of patriotism, is just such a leader. He is a powerful personality who embodies an entire epoch in the most recent history of Azerbaijan, who created the political, economic, legal, socio-cultural foundations and ensured the development of independent Azerbaijan, which has an ancient history. For more than 30 years since the 70s of the last century, the organization and development of science, education, culture and economy in Azerbaijan has been directly related to the name of National Leader Heydar Aliyev. In his large-scale activities, the development of education took an important place as a priority area. The decisions taken by the genius leader, who constantly appreciates the role of education in the development of the society and its importance in the formation of the personality, the conceptual ideas and ideas put forward with foresight, and historical recommendations contribute to the determination of the main directions of educational reforms in our country even today.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BLENDED LEARNING: NAVIGATING CHALLENGES, FUTURE TRAJECTORIES, AND RECOMMENDATIONS

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ABSTRACT

As online learning booms, Blended Learning shines as a star implementation tool. This document dives deep into this rising approach, examining it from various angles: educationally, holistically, practically, and even in the corporate training realm. It explores different strategies, from synchronous and asynchronous instruction to self-paced and live blending, helping you choose the perfect fit. You'll also discover the different dimensions of Blended Learning, from online/offline combos to structured/unstructured learning mixes. While highlighting the benefits, the document acknowledges challenges like technical hurdles and design issues. It then delves into the advantages of Blended Learning and what makes it tick, before wrapping up with recommendations for further exploration in this exciting field.

Keywords: Blended Learning; Holistic perspective; Pragmatic perspective; Synchronous Instructional Method.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE INTEGRATION OF ARTIFICIAL INTELLIGENCE FOR HIGHER EDUCATION ADVANCEMENT IN PAKISTAN

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ABSTRACT

Higher education has always been accompanied by challenges for professors and educators. However, technological advancements have also brought forth various opportunities in the form of educational aids. This study explores the opportunities and challenges of using ChatGPT and virtual assistants in higher education in Pakistan. Among these technologies, artificial intelligence (AI) has emerged as a transformative force, offering both opportunities and challenges. This paper delves into the application of AI-based tools, particularly ChatGPT and virtual assistants, in higher education advancement in Pakistan. It discusses the potential benefits and obstacles associated with their use, while also presenting and analyzing research findings on the utilization of ChatGPT by students in a higher education setting. The study highlights the advantages that ChatGPT and virtual assistants can bring to the learning process, such as personalized assistance and access to information. However, it also acknowledges the challenges, including the need for effective implementation and addressing privacy concerns. By examining the opportunities and challenges associated with these AI-driven tools, this study contributes to a better understanding of their role in enhancing higher education in Pakistan and provides insights for educators and policymakers in leveraging these technologies effectively.

Keywords: Artificial Intelligence; Challenges; Chatbots; Higher Education; Virtual Assistants.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Q232Q, V245V AND L385L POLYMORPHISMS IN THE HUMAN PHENYLALANINE HYDROXYLASE GENE

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Keywords: Polymorphisms, Phenylalanine hydroxylase, Phenylketonurias, Population, Exon

Abstract

Our findings suggest that common genetic variations in *PAH* are associated with verbal memory in healthy adults. Unknown functional polymorphisms in *PAH* or those in other genes nearby might affect memory performance. A haplotype block containing two markers of Q232Q, V245V and L385L polimorphisms was associated with verbal memory index (permutation global p = 0.0091).

We aimed to detect the most frequent PAH gene mutations in Azerbaijan population, firstly forscreening the mutated exons by DHPLC then determining the exact nature of mutations by ARMS technique, which is relatively cheaper and not requesting a large technical capability Preparation of genomic DNA from venous whole blood of subjects was performed according to standard procedures.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STUDY OF ECOSYSTEM DYNAMICS OF TUFAN GOL (LAKE) IN GUSAR, AZERBAIJAN: A COMPREHENSIVE SCIENTIFIC ANALYSIS

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Azerbaijan, Guba, AZ4035, Quba-Xaçmaz chaussée

ABSTRACT

Tufan Gol's situated in Gusar and Gabala districts territory within 41°9′59″N, 47°57′52″E coodinates, on the top of Shahdag mountain rang in the range of Azerbaijan borders at 3277 m altitude above sea level, which possesses the intricate dynamics of alpine ecosystems. The scientific paper endeavors to provide a thorough investigation of the ecological components, interactions, and environmental factors influencing Tufan Gol's ecosystem. By exploring the biodiversity, nutrient cycles, and anthropogenic impacts, this study aims to contribute to the broader understanding of ecosystem functioning in this unique alpine setting. In the investigation geo-geographical parameters have been revealed by applying remote sensing method and using aerospace materials. Biotic and abiotic componenets of the lake have been investigated, the general nature and ecosystem of Tufan Gol was researched in the paper. This comprehensive scientific inquiry focuses on the Tufan Lake (Tufan Gol) ecosystem, aiming to explore its biotic and abiotic components and emphasize their interconnected nature. The study delves into the diverse plant and animal species, particularly alpine flora and fish, shaping the rich biodiversity of the ecosystem. Abiotic factors such as water properties, temperature, pH levels, and habitat structure are scrutinized for their pivotal role in influencing aquatic organisms and overall ecosystem dynamics. However, human activities, notably tourism and infrastructure development, pose significant threats, necessitating urgent implementation of sustainable practices and effective conservation strategies to ensure the continued well-being of the Tufan Lake ecosystem. The comprehensive scientific scrutiny of the unique and vulnerable Tufan Gol ecosystem aims to enhance understanding of its complex interactions, including lake water dynamics, vegetation's role, biological diversity, water quality, and human influence impact, emphasizing the necessity of informed conservation for sustainable coexistence.

Keywords: biotic and abiotic components, picturesque nature, Alpine landscape, fauna and flora.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

TRACES OF ECOLOGICAL TERRORISM: HAZARDOUS IMPACTS IN THE JABRAYIL DISTRICT

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Introduction:

Jabrayil district was the largest economically. Agriculture, cattle breeding and horticulture were developed in our republic. Jabrayil region borders Iran on one side and Khojavand on the other. The total area of the district is 104980 hectares. Before the occupation, 65,400 people lived there. There was one city - Jabrayil (the center itself), one city-type settlement and 74 villages in the region. On August 23, 1993, the occupying Armenian state invaded Jabrayil region.

As a result of the Armenian occupation, the region was damaged in the amount of 13.928 billion US dollars. The population of Jabrayil district mainly lived in rural areas and engaged in agricultural work.

The soils of the Arazboyu plains, spread in the mountainous foothills of the Lesser Caucasus, are dark chestnut soils with high productivity. Depending on the type of climate and climatic conditions prevalent in the territory of the region, there were abundant water resources in the nature of the area. It is known from very ancient times that even from the 1st century of our era, kahriz were widespread in the territory of Azerbaijan. The network of canals was more widely used in Jabrayl. There were 118 kahriz in Jabrayil region, and kahriz were suitable for use both as drinking water and irrigation system. In addition to Kahriz, there were more than 360 springs rich in natural minerals in the region. As a result of the presence of such water potential, people living in the region were able to cultivate both 1-year and perennial agricultural crops. People engaged in agriculture were engaged in acro-farms growing various fruits and vegetables, tobacco, grapes, and cotton in the territory of the region. In the territory of the district, the forest strip was 4039 hectares, the dry and irrigated fields were 58585 hectares, and various garden areas were 1079 hectares. The landscapes and biological diversity of the region were very rich. Before the Armenian occupation, there were 400-500-year-old and even 800-year-old large-diameter plane trees in the region. Mountain-chestnut, chestnut and brown mountain-forest soils are most common in the area. The climate of the area is mild hot semi-desert and dry steppe with dry summer in the southern part, and mild-hot with dry summer in the northern part.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AGROPHYSICAL PROPERTIES OF SOILS OF THE MUGAN PLAIN.

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ABSTRACT

The purpose of the research is to effectively use the soils of the Mugan Plain, determine the current state of the soils, eliminate the degradation occurring in the soils as a result of natural and anthropogenic impacts, restore and improve soil fertility. soils and regulate their agrophysical properties.

The article provides information about some physical and water-physical properties of the soils of the Mugan Plain. Each type of soil has its own physical and water-physical characteristics. The Mugan Plain is part of the Kura-Araz Lowland. In the northwest it is separated from the Mil Plain by the Araz River, and from the Shirvan Plain by the Kura River. In the south and southeast it connects with the Lankaran lowland and the Salyan plain. The southwestern continuation of the Mugan Plain is located on the territory of Southern Azerbaijan. The area is flat and is located on average 16 m below sea level.

The soils of the Mugan Plain consist of various types of gray, gray-brown and saline soils. In addition to these types of soils, grey-meadow, meadow-marsh and sandy soils are also found in different parts of the territory. Gray soils and their individual types are distributed mainly on the Kura-Araz Plain. It is important to study the agrophysical properties of soils to create optimal conditions for water, air, thermal and nutritional regimes important for plant life. Agrophysical indicators of soil fertility include particle size distribution, mineralogical composition, structure, density, porosity, water-physical properties, as well as soil properties that characterize agrotechnological indicators.

The main essence of the work is to develop a system of measures that allows increasing soil fertility through their effective use, optimizing the agrophysical properties of soils. For this purpose, changes in the water-physical properties of soils under different types are being studied. the condition of the soil and agricultural plants was studied in accordance with natural and ecological conditions at various stationary experimental sites. The water absorption capacity of soil is different and varies depending

on the use on the farm. Therefore, these changes must be taken into account when using land efficiently.

Key words: porosity, humus, density, specific gravity, carbonization, particle size distribution.

development of mathematical models for fertilizers in sheki region soils (azerbaijan)

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Abstract. Mathematical modeling of fertilizer processes is described by a difference equation, which can be considered as a discrete analogue of a differential equation. The efficiency of phosphorus addition to soil (γ) is very high for wheat. The efficiency of phosphorus fertilizer (δ) is approximately the same at 20 and 30 kg/ha, while at 40 kg/ha it is approximately 18% higher. Consumption from unrecorded sources for black gram is significantly less (0.2239) than for wheat, which is very high (4.0339). Maximum depletion occurred when black gram crop was treated with approximately 100% P than when treated with 50% P and 75% P. Analysis of the data indicates that the amount of humus formed from root residues in the control variant was 14.94 c/ha in the meter layer, in the second and third variants it was 19.45-21.43 c/ha. The largest amount of humus was formed in the variant Manure 10 t/ha + P_{65} 23.49 c/ha, it follows that the use of manure, increasing the content of roots, contributes to a greater accumulation of humus. Fertilization using mathematical methods is a very important issue for the development of agriculture in Azerbaijan.

Keywords. vegetation, soil fertility, fertilizers, mathematical models, mathematical ecology

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COMPARATIVE ANALYSIS OF AGROPHYSICAL AND OPTICAL PROPERTIES OF SOILS OF THE MUGAN PLAIN

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ABSTRACT

The presented work examines the dependence of the internal properties of soils on the Mugan Plain on spectral reflectance indicators. Currently, using the achievements of science and technology, remote study of soils opens up great opportunities for the effective use of soil resources. As you know, soil is a very complex system, and therefore certain difficulties arise when studying it. Quantitative and qualitative analysis of spectral reflection in laboratory conditions allows us to obtain the necessary information through the use of electronic computing methods to solve the difficulties that arise.

Since the internal properties of soil are complex, the number of factors influencing the formation of its spectral reflectance coefficients is also large. The main ones are soil types, physical and chemical composition, absorption capacity, mineral content, amount of components, heat and water capacity, as well as the pattern of their distribution in the soil. The spectral reflectance curves of each soil type are subject to more intense changes in a certain part of the electromagnetic waves, depending on its properties. This makes it relevant to study the optical properties of soils.

As a result of the studies, it was established that the reflection coefficients and integral reflection coefficients of electromagnetic waves at the depth of the soil profile at wavelengths of 400-750 nm have the form of an increasing function, changing with different patterns depending on its physical and chemical composition.

Depending on the physicochemical composition of the studied soils, differences in the shape of the light reflectance and integral reflectance curves are most clearly observed at electromagnetic wavelengths after 700 nm.

We determined that the part after the 700 nm wavelength provides more information about the compositional properties of soil with different spectral characteristics. The result also shows that, depending on the properties of the soil, the spectral reflectance is directly proportional to dry matter, carbonation and physical clay and inversely proportional to the amount of

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

humus.

Key words: soil sections, integral reflectivity, spectral reflectivity, humus, carbonation.

CHANGES IN MORPHOGENETIC INDICATORS OF SOIL IN THE LANKARAN REGION

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Abstract. The article shows the results of a study of soils around the Khanbulan reservoir and other selected biogeocenoses in order to clarify the influence of anthropogenic factors as a result of growing tourism potential and population growth. Research of the modern vegetation cover of the Lankaran region using innovative methods is a very pressing problem of modern soil science. The results obtained can be used by other scientists as literary material when conducting environmental assessments.

Keywords. anthropogenic factors, climate, morphogenetic characteristics, chemical properties

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ISOTHERM, KINETIC AND THERMODYNAMIC STUDIES OF AZO DYE ADSORPTION BY PHOSPHORIC ACID-ACTIVATED HYDROCHAR

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Abstract :

An azo dye was adsorbed from aqueous meduium using phosphoric acid-activated hydrochar derived from local biomass. For better understanding of the adsorption process and the interaction between dye molecules and activated hydrochar, isothermal, kinetic, and thermodynamic studies have been conducted. The Freundlich model provided the best fit to the isothermal analysis, which suggested that the dye molecules might interact with each other during adsorption. Furthermore, the pseudo-second-order model demonstrated high R^2 values and was able to precisely describe the adsorption kinetics. Additionally, calculating the thermodynamic parameters confirmed that the process was spontaneous, endothermic, and random at the solid/liquid interface.

Keywords : *Phosphoric acid-activated hydrochar, Azo dye, Adsorption, Isotherm, Kinetic, Thermodynamic.*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EVALUATION OF GROWTH INDICES OF *BRACHIARIA RUZIZIENSIS* AS AFFECTED BY POULTRY MANURE APPLICATION AND STAGES OF HARVEST IN THE SUDAN SAVANNAH ZONE OF NIGERIA.

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Target audience: Pastoral farmers, livestock farmers, Researchers and small scale holders

Abstract

This research investigated the short term effect of poultry manure levels and stages of harvest on the agronomic indices of *Brachiaria ruziziensis*. The experiment was conducted at the Teaching and Research Farm of Professor Lawal Abdu Saulawa Livestock Teaching and Research Farm, Department of Animal Science, Federal University Dutsin-Ma. The experiment was laid in a randomized complete block design (RCBD) in a 3 x 3 factorial arrangement. Three (3) levels of Poultry manure application (5, 10 and 15t/ha) and three stages of harvest (6, 8 and 10) weeks after planting. Data on agronomic indices such as plant height, leaf length, leaf width, tiller number, number of leaves, Leaf area index and dry matter yield collected at 6, 8 and 10 weeks after planting were subjected to two-way analysis of variance (ANOVA) using General Linear Model (GLM) procedure of SAS (2005). Significant ($P<0.05$) difference between treatment means were compared using Duncan Multiple Range Test, (Duncan 1995) of SAS package. Result showed that plant height, leaf width, number of leaves, tiller number, Leaf area index and dry matter yield were higher ($P<0.05$) at 10t/ha rate of poultry manure application while the growth indices was higher ($P<0.05$) in forage harvested at 10 WAP. It was concluded that application poultry manure at 10t/ha and harvesting at 10 WAP produced forage with the highest agronomic indices and dry matter yield. It is therefore recommended that farmers apply poultry manure at 10t/ha and harvest at 10 WAP for high DMY to ensure ruminant food security in the area.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

RELATIVE EFFECTS ON ANTHROPOGENIC EFFECTS IN *PYRUS* L. SPECIES UNDER *IN SITU* AND *EX SITU* CONDITIONS IN GREATER CAUCASUS, AZERBAIJAN

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Abstract

Our observations have shown that trees and bushes are cut for fuel and building materials in the areas near the settlements in the northeastern part of the Greater Caucasus, which is the research region. As a result, it causes structural disturbances in plant groups and species composition decreases. Regularly, as this process continues, rare pear species in this plant group tend to decline over time. As a result of the observations, it can be said that in the places where the anthropogenic influences are strong, the forest is replaced by bush type vegetation. In general, our observations have shown that the range of pear species common in the research area is gradually shrinking as a result of the collection of their fruits by people and overgrazing. As we know, in the past, people used the forests without planning and caused their destruction without distinguishing the plant species. In this process, people's lack of information about climate and soil played an important role. Currently, most of the forest areas in our country are used for agriculture. In this regard, the phytocenological structure of wild pear species in these areas is disturbed.

Environmental pollution has a negative effect on the flora, including the growth and development of the plants under *ex situ* conditions .To understand the role of environmental pollutants on vegetation, it is necessary to first know the types of pollution.

Since most of the studied plants are distributed in mountainous regions, we are of the opinion that soil and water pollution in these regions is not at a level that would narrow the areas of those plants. That is, these factors are not among the factors that threaten the generation of rare plants today.

In the research work, the in situ and ex situ areas have been comparatively studied for different years. 5 species belonging to the genus *Pyrus* L. were used as objects. As a result of various environmental monitoring in different years, these were determined that certain differences are observed in the growth and development of plants under different conditions. In both cases, the decrease in the number of species and the status of rarity can be directly attributed to the anthropogenic factor.

Keywords: anthropogenic, *Pyrus* L., *in situ* , *ex situ* , climate, pollution.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE DEVELOPMENT PROSPECTS OF COCOONING AND SERICULTURE IN SHEKI DISTRICT: EMPLOYMENT AND SOCIAL WELFARE IMPLICATIONS.

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Abstract

The study explores the potential for cocooning and sericulture in the Sheki district and its impact on employment and social welfare. At the same time, the aim of the article is to investigate the issues of accelerating the development of Sheki sericulture and cocooning, efficient utilization of the potential opportunities of this field, and increasing public interest in product manufacturing. From this point of view, the development of cocooning and sericulture, which are based on ancient traditions, is of particular importance within the framework of the measures implemented for the development of the non-oil sector in the country.

The article mentions the importance of cocoon production, taking into account the need to develop cocooning, which is the raw material of the sericulture industry, for the development of sericulture, which plays an important role in the production of agricultural products in the new economic conditions. In this regard, the history of the development of sericulture and cocooning in Sheki was briefly reviewed, production indicators were analyzed and future development directions were examined.

Keywords: Sheki district, cocooning, sericulture, employment, social welfare, sustainable development, silk production.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYSIS OF MODERN METHODS OF SPACE MONITORING OF SOIL CONTAMINATED WITH PETROLEUM PRODUCTS

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In recent years, satellite sensors have been increasingly used to detect and monitor oil spills. For this purpose, satellite images are used, that is, visible, near, mid-infrared and microwave radar images. It is necessary to use the latest achievements of science and relevant information support to effectively use hydrocarbon natural resources, to ensure the safety of the activities of oil and oil products storage, transportation and distribution enterprises, as well as to reduce their negative effects on the environment. One of the best ways to solve this problem is the wide spread of modern aerospace methods, technologies and new methods of processing remote sensing, aerospace data and geoinformation technologies. The purpose of this research is to develop data processing methods to detect oil contamination of soils and to propose methods for analyzing environmental changes through remote sensing. In the article, a comparative analysis of the results of calculating vegetation indices (SAVI) based on remote sensing data of different imaging systems is carried out to assess the degree of damage of natural components adversely affected by oil pollution and to determine the suitability of Sentinel satellite space images. The obtained preliminary results were mapped and comparatively analyzed. Based on the comparative analysis, the changes in this area were monitored. New mathematical formulas were developed and applied to the spectrum in question to determine the changes.

Keywords: satallite imagery, spatial data, remote sensing, soil pollution, environmental analysis

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ABŞERONNEFT PGÇD KURULUŞUNDAKI MODERN RADYOEKOLOJIK DURUM

Yagubova Seliga

Azerbaycan Devlet Petrol ve Endüstri Üniversitesi Jeofizik Bölümü Yüksek Lisans Öğrencisi

Özet

Azerbaycan'ın gelişen sanayisinde petrol ve gazın üretimi ve işlenmesi ana ve öncelikli alanlardan biridir. Petrol yataklarının geliştirilmesi ve işletilmesi, petrol ve petrol ürünlerinin işlenmesinin çevreyi kirleten başlıca faktörler olduğu göz önüne alındığında, Azerbaycan'ın ekolojik açıdan en yoğun bölgelerinden birinin Abşeron yarımadası olduğu belirtilebilir.

Abşeron Yarımadası bölgesinin radyoaktif kirlenmesinin karakteristik özelliği, kirlenmenin yalnızca doğal kökenli radyoaktif izotoplarla değil, aynı zamanda insan yapımı süreçlerin bir sonucu olarak da meydana gelmesidir. Petrol sahalarının kirlenmesi, farklı mineralizasyona sahip su çözeltilerinin dağ kayaları ve petrol yatakları ile etkileşimi sonucu ortaya çıkar. Sonuç olarak, uranyum-radyum ve toryum serisinin radyonüklidleri derinliklerden dünya yüzeyine salınır. Petrol sahalarında kirlenme bölgelerinin oluşmasında, üretim sırasında meydana gelen kaya ve suyun petrolle teması büyük rol oynamaktadır.

Abşeron Yarımadası'nda üretimde olan hemen hemen tüm madenlerde zemin yüzeyi, petrol çıkarma ekipmanları, personel binaları vb. radyoaktif kirlenmeye maruz kalır. Radyonüklidlerin tanımlanması, kirliliğin içeriği yüksek konsantrasyona ulaşan uranyum-radyum grubu radyonüklidlerden kaynaklandığını göstermektedir.

Anahtar Kelimeler: *radyoaktif kirlenme, güvenlik, yakıt kalitesi, petrol ve gaz kaynakları, kirletici emisyonlar, çevresel hasar*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MODERN RADIOECOLOGICAL SITUATION AT ABSHERON OGED ENTERPRISE

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Summary

In the developing industry of Azerbaijan, the production and processing of oil and gas is one of the main and priority directions. Taking into account that the development and operation of oil fields, the processing of oil and oil products is the main polluter of the environment, it can be noted that one of the most intensive regions of Azerbaijan from the ecological point of view is the Absheron peninsula.

The characteristic feature of the radioactive contamination of the territory of the Absheron Peninsula is that the contamination occurs not only with radioactive isotopes of natural origin, but also as a result of man-made processes. Pollution of oil fields occurs as a result of the interaction of water solutions with different mineralization with mountain rocks and oil deposits. As a result, radionuclides of the uranium-radium and thorium series are released from the depths to the earth's surface. In the formation of contamination zones in oil fields, the contact of rock and water moving with oil, which occurs during production, plays a major role.

In almost all mines of the Absheron Peninsula, which are in production, the ground surface, oil extraction equipment, staff buildings, etc. exposed to radioactive contamination. The identification of radionuclides shows that the pollution is due to uranium-radium group radionuclides, the content of which reaches a high concentration.

Keywords: *radioactive contamination, safety, fuel quality, oil and gas resources, pollutant emissions, environmental damage*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Yaşıl enerji nədir? Azərbaycanda bu sahədə görülən işlər hansılardır?

Dünya alimlərini, dövlət və hökumət başçılarını son dövrlərdə planetdə baş verən və gələcəkdə də gözlənilən problemlərlə yanaşı, ekoloji məsələlər də narahat edir.

Əksər təhlükələrin, o cümlədən bəşəriyyəti məhv edə biləcək nüvə müharibələrinin, kosmik fəlakətlərin - Yer kürəsinin kometalar, meteoritlərlə toqquşması, Ozon qatının deşilməsi, havada karbon qazının çoxalması hesabına planetin temperaturunun artması ("parnik effekti"), su qıtlığı, ərzaq çatışmazlığı və digər təbiət hadisələrinin qarşısı alınmağa calışılsa da, ekoloji problemlərin dünya miqyasında baş vermə təhlükəsi getdikcə artır. Bütün bunları əvvəlcədən görən Ulu Öndər Heydər Əliyev hələ neçə illər öncə demişdir: "...Təbiətin ölkəmizə bəxş etdiyi zəngin sərvətlərə xüsusi qayğı ilə yanaşmaq, belə misilsiz xəzinələri bəşəriyyətin gələcəyi naminə qorumaq üzərimizə düşən başlıca vəzifələrdəndir..."

Bir siqaret kötüyü 500 kubmetr suyu, bir kiçik batareya 20 kvadratmetr torpağı zəhərləyir. Əgər polietilen torbalardan istifadənin qarşısı alınmazsa, dünyanı antropogen - özümüzün yaratdığı təbii fəlakət gözləyir. Polimer tullantılar yanmır, çürümür, torpağa qarışmır, ətrafı zəhərləyir və s. Deməli, ətraf mühit, ekologiya antropogen olaraq əhali tərəfindən pozulur.

Bu gün insanlara hava və su qədər əhəmiyyətli olan elektrik enerjisi də lazımdır. Əhalinin sayının artması, yaşayış səviyyəsinin yüksəlməsi, enerji istifadəçilərinin çoxalması, sənayenin və kənd təsərrüfatının sürətli inkişafı məişətdə istifadə edilən yanacağa tələbatı artırır. Təbii enerji ehtiyatlarının azalması, onların əldə olunması prosesində ətraf mühitə dəyən zərər və s. kimi amillər alternativ enerji mənbələrinin axtarılması zərurətini meydana çıxarmışdır.

Respublikamızın təbii-coğrafi mövqeyi, relyefi, iqlim şəraiti, günəş, torpaq, külək, su, biokütlə təbii enerjiyaratma potensialı baxımından zəngindir və bu, ölkəmizdə ekoloji cəhətdən təmiz alternativ və bərpaolunan enerji mənbələrindən düzgün və səmərəli istifadə edilməsinə geniş imkanlar yaradır.

Alternativ energetikanın Azərbaycanda inkişaf perspektivlərini yüksək qiymətləndirən Ümummilli Lider Heydər Əliyev 1993-cü ildə deyirdi ki, Azərbaycanda günəş, külək və su energetikasının ehtiyatları böyükdür, amma bunların əsl inkişafı 30-40 ildən sonra baş verəcək və həmin dövrdən sonra alternativ energetika respublikanın yanacaq-enerji balansında mühüm rol oynayacaq. Azərbaycan Respublikasının bu istiqamətdə inkişaf edən ekoloji siyasəti, sonra da ekoloji konsepsiyasının yaranması, yeni ekoloji təfəkkürün formalaşması və onun həyata tətbiqi Ulu Öndərin rəhbərliyi dövründə həyata keçirilib və bu gün də dövlət başçısı İlham Əliyevin yürütdüyü siyasətin mühüm tərkib hissəsi kimi uğurla davam etdirilməkdədir.

Prezidentin 2004-cü il 21 oktyabr tarixli sərəncamı ilə "Azərbaycan Respublikasında alternativ və bərpa olunan enerji mənbələrindən istifadə olunması üzrə Dövlət Proqramı" təsdiq edilmişdir. 2009-cu

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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il 16 iyul tarixli fərmanla Azərbaycan Respublikası Sənaye və Energetika Nazirliyinin Alternativ və Bərpa Olunan Enerji Mənbələri üzrə Dövlət Agentliyi yaradılmışdır. Bu sahədə dövlət siyasətini uğurla həyata keçirmək üçün Prezident tərəfindən 1 iyun 2012-ci il tarixli fərman imzalanmışdır. Həmin fərmanla Alternativ və Bərpa Olunan Enerji Mənbələri (ABOEM) üzrə Dövlət Şirkəti yaradılmışdır. 29 dekabr 2011-ci il tarixli sərəncamla isə Alternativ və Bərpa Olunan Enerji Mənbələri üzrə Dövlət Şirkətinə "2012-2020-ci illəri əhatə edən ABOEM-dən istifadənin inkişafı üçün Dövlət Strategiyasının layihəsi"nin hazırlanması tapşırılmışdır.

Azərbaycanda ildə 270 küləkli və 300 günəşli günün olmasını nəzərə alsaq, demək olar bu regionda Günəş və külək energetikasının inkişafı daha perspektivlidir. Alternativ və bərpaolunan enerji mənbələrindən biri hesab olunan külək enerjisi - küləyi meydana gətirən hava axınının sahib olduğu hərəkət (kinetik) enerjisidir. Bu enerjinin bir hissəsi faydalı olan mexaniki və ya elektrik enerjisinə çevrilə bilər. 60 faizi dağlıq ərazilərdən ibarət olan Azərbaycan üçün külək enerjisi digər alternativ enerji mənbələri olan günəş, hidroenergetika, geotermal və biokütlə enerjisindən özünün maya dəyərinə, ekoloji təmizliyinə və tükənməzliyinə görə ən sərfəlisidir. Azərbaycanda əsasən Bakı, Sumqayıt, Abşeron, Binə ərazilərində külək enerjisindən istifadə etmək daha məqsədəuyğun sayılır. Ölkəmizdə fəaliyyət göstərən Hökməli KES (8 MVt), Yeni Yaşma KES (50 MVt), Şurabad KES (1,7 MVt) və Qobustan KES (2,7 MVt) hesabına enerji istehsalı 80 milyon kilovat-saata çatdırılıb ki, bu da ildə 13-14 milyon kubmetr qaza qənaət etməyə bərabərdir.

Ölkəmizin ərazisində günəşli günlərin sayının çox olması günəş-istilik enerjisindən istifadə üçün əlverişli imkanlar yaradır. Yerdən 150 milyon km məsafədə yerləşən Günəşin Yer səthinə düşən enerjisinin miqdarı dünyada olan bütün neft, təbii qaz, daş kömür və digər yanacaq ehtiyatlarından qat-qat çoxdur. Bu gün Günəş enerjisinin 0,0125 faizini səmərəli istifadə etməklə dünyaya lazım olan enerjinin bütün ehtiyaclarını tam ödəmək mümkündür.

Günəş enerjisinin istifadəsinin üstünlüyü bir də ondadır ki, günəş qurğuları işləyən zaman "parnik effekti" yaranmır, havanın çirklənməsi baş vermir, istilik aşağı atmosfer qatlarına yayılmır. Hazırda dünyanın 70-ə yaxın ölkəsində Günəş Elektrik Stansiyaları (GES) fəaliyyət göstərir və yaxın gələcəkdə onların istehsal gücünün artırılması üçün daha perspektiv layihələr hazırlanır. Bu gün Günəşdən ABŞ-da 600 MVt, Fransada - 100 MVt, İsraildə - 100 MVt, Türkiyədə - 50 MVt və s. elektrik enerjisi alınır.

Azərbaycanda 20 MVt gücünə malik Naxçıvan GES və 1,2 MVt gücünə malik Suraxanı GES fəaliyyət göstərir. Nazirlər Kabinetinin 2020-ci il üzrə hesabatında qeyd edildiyi kimi, Ali Baş Komandanın rəhbərliyi ilə işğaldan azad edilmiş 6 rayonda günəş və külək elektrik stansiyalarının tikintisi üçün potensialı müvafiq olaraq 7214 MVt və 2120 MVt qiymətləndirilən ərazilər müəyyən olunub. Səmərəliliyi nəzərə alınaraq ölkəmizdə GES-lərin sayının artırılması istiqamətində sistemli tədbirlər davam etdirilir.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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Elektrik enerjisi dünyada ilk dəfə XIX əsrin sonunda istehsal olunmağa başlanmışdır. Azərbaycanda isə elektrik enerjisinin istifadə olunması neftin çıxarılması ilə bağlı olmuşdu. 1898-ci ildə Bakıda çıxan neft dünyada istehsal olunan neftin yarısından çoxunu təşkil edirdi. Neft mədənlərini elektriklə təmin etmək üçün 1897-ci ildə Nobel qardaşları tərəfindən ilk dəfə olaraq 550 kVt-lıq elektrik stansiyaları quraşdırılmışdır. Neft sənayesinin intensiv inkişafi elektrik enerjisinin istehsalını zəruri edirdi. Buna görə də Xəzər dənizinin ətrafında Bakının neft çıxarılan ərazilərində kiçik elektrik stansiyalarının tikilməsi davam etdirilirdi. Artıq 1940-cı ildə Azərbaycanda energetika sisteminin gücü 1920-ci il sistemindən 5 dəfə çox idi. Həmin vaxt elektrik stansiyalarının tikintisi ilə yanaşı, elektrik şəbəkələri də sistematik şəkildə inkişaf etmiş və ölkənin davamlı enerji sistemi yaradılmışdı. Azərbaycanda alternativ enerji mənbələrinin daha geniş istifadəsi məhz Mingəçevir Su Elektrik Stansiyasının (SES) tikintisi ilə başlamışdır. İnşası Kür çayı üzərində nəzərdə tutulan bu elektrik stansiyaları silsiləsinin aşağı pilləsi olan Mingəçevir SES 1954-cü ildə istifadəyə verilmişdir. Üç il sonra isə həmin su qovşağı qurğuları kompleksinə daxil olan Varvara SES istismara buraxılmışdır. 1970-ci ildə Araz, 1976-cı ildə Tərtər, 1982-ci ildə isə Şəmkir SES tikilərək istifadəyə verilmişdir.

Dünyada hasil edilən elektrik enerjisinin 75 faizi İstilik Elektrik stansiyalarının (İES), 16 faizi isə Atom Elektrik stansiyalarının (AES) payına düşür. Azərbaycanda isə istehsal olunan elektrik enerjisinin 90 faizini İES təmin edir. Respublikamızın hazırda elektrik tələbatını əsasən 13 İES və 6 SES ödəyir.

Bütövlükdə dünya üzrə nüvə təhlükəsizliyi problemilə bağlı koordinator qismində BMT tərkibində fəaliyyət göstərən MAQATE-nin 2005-ci ildə hazırladığı hesabata görə dünyanın 31 ölkəsində hazırda 440 Atom Elektrik Stansiyası (AES) var. 2030-cu ilədək dünyada AES-lərin sayının 60 faiz artaraq 700-ə çatacağı bildirilir.

Elektrik enerjisi istehsalında İES-lərin böyük yer tutması dünyanın ayrı-ayrı yerlərində yanacağın çox olması, onun asanlıqla İES-lərə nəql edilməsi, İES-lərin tələbatçılara yaxın yerdə tikilməsi, onların tələbatçıları həm istilik, həm də elektrik enerjisi ilə təmin etməsi, İES-lərdə böyük güclü turbinlərin qoyulması ilə əlaqədardır. Amma onların ekologiyaya vurduğu zərərlər bu gün insanları düşündürməyə sövq edir. Buna görə də Prezident İlham Əliyev yenə də bütün sahələrdə olduğu kimi, enerji sahəsində də dünyanın "nəbzini" tutaraq 2019-cu ilin 5 dekabrında "Bərpa olunan enerji mənbələrindən istifadə sahəsində pilot layihələrin həyata keçirilməsi tədbirləri haqqında" sərəncam imzalamışdır.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

QARABAĞDA EKOSİD

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Keçmişdə ətraf mühitə dərin ziyan vurulsa da, baş verənlərə görə heç kim günahlandırılmadı. Bununla belə, dövlətləri və şirkətləri xüsusilə son 40 ildə təbiətə qarşı cinayətlərə görə bağışlamaq artıq mümkün deyil. İstər fərdlərin, istərsə də kapitalın xeyrinə və ya "ictimai" naminə dövlət tərəfindən təbii həyata qaytarıla bilməyən ziyan bəşəriyyətə qarşı cinayət kimi qiymətləndirilməlidir. Beynəlxalq cinayətlər sırasına daxil olan "soyqırım" cinayəti bəşəriyyətə qarşı cinayət kimi işləndiyi üçün "ekosit" cinayəti həm beynəlxalq cinayət hüququna, həm də ölkələrin konstitusiyasına daxil edilməlidir.

Ekosid anlayışı müəyyən bir bölgənin ekosistemində yaradılmış, bölgə əhalisinin dinc həyatına təhlükə yaradan təbiətin məhv edilməsidir. Yəni ekoloji terrordur.

İlk öncə ekoloji terrorun nə olduğunu qeyd etsək, ölkə tərəfindən və ya şəxs tərəfindən digər ölkənin flora və faunasına zərər yetirmək, təbii sərvətlərini məhv etməklə bilərəkdən vurulan ziyandır. Ətraf mühitə və inkişafa dair Rio-de-Caneyro bəyannaməsinə görə, *müharibələr davamlı inkişaf prosesinə dağıdıcı təsir göstərməməlidir*. Bu səbəbdən dövlətlər silahlı konfliktlər zamanı ətraf mühiti mühafizə edən beynəlxalq hüquqa hörmət etməlidirlər. Lakin, ermənilər nəinki bu prinsipləri gözləmir, həmçinin həmin prinsipləri kobud surətdə pozaraq işğal etdikləri ərazilərdə təbiəti viran qoydular.

Azərbaycan Respublikası beynəlxalq terrorizmə qarşı mübarizədə fəal iştirak edən dövlətlər sırasındadır. Ölkəmizdə istər daxili, istərsə də xarici terrorizmə qarşı güclü mübarizə siyasəti yürüdülür.

Hər hansı bir dövlətdə ekoloji tarazlığın pozulmasına yönəldilən terror aktları ekosidin tərkib hissəsi olub, ekoloji problemlərin yaradılması məqsədini güdür. Ekoloji terrorizmin qarşısının alınmasında əsas məqsəd əhalinin ekoloji təhlükəsizliyinin təmin edilməsi, ətraf mühitin qorunması və canlıların tələfatına yol verməməkdir. Hər hansı bir ölkə və yaxud şəxslər tərəfindən bilərəkdən digər ölkənin təbiətinə, flora və faunasına zərər yetirməklə, təbii sərvətlərini məhv etməklə vurulan ziyan ekoloji terror hesab edilir.

1988-ci ildən başlayaraq ermənilərin və onlara havadarlıq edən qüvvələr tərəfindən Azərbaycana qarşı başlanan müharibə, torpaqlarımızın 30 ilə yaxın işğal altında qalması ilə nəticələnən, şəhər və kəndlərin dağıdılmasına, dinc əhalinin genosidinə və eyni zamanda, bitki və heyvanlar aləminin məhv edilməsinə səbəb olub. Hərbi münaqişə və müharibə yalnız Azərbaycan Respublikasının ərazisində

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

aparıldığından atmosfer, su mənbələri və torpaqlarımız bioloji, kimyəvi və fiziki çirklənməyə məruz qalıb.

Azərbaycanın təbii sərvətlərini bacardıqca tükəndirməyi qarşılarına ən ali məqsəd kimi qoyan ermənilər işğaldan azad olunmuş ərazilərimizdə nadir fauna və floraya malik meşə sərvətləri, çox qiymətli su mənbələrini, Azərbaycanın təbii sərvətlərini bacardıqca tükəndirməyi qarşılarına ən ali məqsəd kimi qoymuşdular. Ermənilər işğal etdiyi ərazilərdə bu qiymətli sərvətləri amansızcasına dağıdıb, Ermənistana daşınıb, daşınması mümkün olmayanları isə yandırmaqla ekologiyaya ciddi ziyan vurublar. Ermənilərin meşələrdə hər il mütəmadi olaraq törətdiyi yanğınlar min hektarlarla əraziləri əhatə etməklə, eyni zamanda, digər ərazilərə də yayılaraq ətraf mühitə və canlı təbiətə çox ciddi ziyan vurduğunu mətbutdan izləmək olurdu.

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DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MONITORING EDDY CURRENT DENSITY FLUCTUATION AND POWER MANAGEMENT IN DOPED AL2O3 NANOWIRE

Gizachew Diga

Abstract

Al_2O_3 nanowire presents fascinating electrical properties which span from insulating (dielectric) to superconducting. It also exhibits resistive effects associated with room temperature magnetism caused by doping effects resulting in defects and quantum confinement. Dissipative effects associated with magneto resistance are responsible for electric current fluctuations. A model is designed to describe the Phenomenon of eddy electric current and eddy current density fluctuation. Accordingly the Greens –Kubo theorem is incorporated to explain the not only electric current density but also the relation between electric conductivity, magnetic field, and frequency of oscillations. This model is preferred since it is sufficient to describe defects states, magnetic or spin state, and electronic band structure with electronic states. The current density is therefore, proportional to power dissipation. Besides, the current density fluctuation is expected to be proportional to the penetration depth. We will explore the effect of coating nanowire for reducing eddy current lose. Due to its transparent and thermal stability, it is used for variety of applications.

KEY WORDS: eddy current density fluctuation, dielectric, defects, nanowire, spin state, quantum confinement

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

REVAMPING NIGERIAN CERAMIC ARTISTRY THROUGH MODERNIZED COMMERCE

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Abstract

Ceramics, also known as *Keramos* typified "burnt vessel" hitherto doubles as product of commerce with apparent exchanges from nations to nation. Rome, Greece, Egypt, Babylon and Nigeria are some of the nations and civilizations where such exchanges occurred, either as royal gifts or as custom items. The remains of these civilizations, in recent times come handy in terms of teaching and practice in the arts, science and engineering. The aforementioned is not without its limitations as far as commerce is concern, more importantly with the new commercialized frontiers in modern times. This study consequently, attempt threading within the threshold of applied arts, advocating inculcation of commerce ideas into ceramics training, practice and business in Nigeria. Prominent among such ideas, are strategic technological and innovational adaptation such as 3D printing technology, e-commerce and internet of things (social media). Leveraging on these digital channels will not only widens the horizons of ceramic training and practice (interns) and business (startups), it will also facilitate direct connections with a global audience, clients and aficionados alike. Conclusively, adaptations of modernized commerce will bring to fore sustainable ceramic industry in Nigeria, opening a new frontier for revamping the sector by fostering collective vision in ceramic art.

Keywords: Nigeria, Intern, Commerce, Ceramics, Art, Technology

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYZING THREAT INTELLIGENCE FRAMEWORK FOR ENHANCE CYBER SECURITY IN NETWORK ENVIRONMENT

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Abstract

In today's interconnected digital landscape, the proliferation of cyber threats poses significant challenges to maintaining robust security in network environments. This abstract delves into the analysis of threat intelligence frameworks aimed at bolstering cyber defense mechanisms. By scrutinizing various methodologies and approaches within threat intelligence, this study aims to provide insights into enhancing cyber security posture effectively. The research assesses the efficacy of threat intelligence frameworks in identifying, analyzing, and mitigating cyber threats within network environments. Through a comprehensive review of existing literature and case studies, key components and best practices are identified to construct an optimal threat intelligence framework. Emphasis is placed on the integration of advanced technologies such as machine learning, artificial intelligence, and big data analytics to augment threat detection and response capabilities. Furthermore, the abstract explores the significance of collaboration and information sharing among stakeholders within the cyber security ecosystem to combat evolving threats effectively. By synthesizing findings from academic research and industry reports, this analysis aims to offer valuable recommendations for organizations seeking to fortify their cyber defenses through the strategic implementation of threat intelligence frameworks. Ultimately, this abstract serves as a foundation for further research and practical implementations aimed at bolstering cyber resilience in network environments amidst an increasingly sophisticated threat landscape.

Keyword: Cyber security, Threat intelligence, Network environments, Framework analysis, Enhancements

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PAULOWNIA *(PAULÓWNIA)*: POSSIBILITIES OF APPLICATION IN SOLVING ENVIRONMENTAL PROBLEMS

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ABSTRACT

At the moment, environmental protection issues are highly relevant for many countries. Intensive development, industrial activity, and high vehicle density contribute to the accumulation of various pollutants in the biosphere and atmosphere. Soil, the most crucial component of the ecosystem, accumulates chemical pollutants. Among the numerous pollutants, heavy metals occupy a special place; they bind with mineral and organic compounds, increasing the overall level of soil toxicity. Additionally, the release of large amounts of harmful compounds, including carbon dioxide, into the atmosphere is a global problem, leading to climate change. Increasing the area of green spaces, especially fast-growing ones resistant to high levels of anthropogenic load, is one way to address air and soil pollution in urban areas. Paulownia, a fast-growing and waste-free tree, is one such plant. All of its organs (trunk, roots, leaves, seeds, flowers, bark) can be utilized for various purposes. Therefore, this tree is highly valued from both an economic and environmental perspective. This article discusses the utilization of paulownia for landscaping, with particular attention to its environmental benefits for both the environment and humans, its potential for soil bioremediation, and its ability to absorb carbon dioxide.

Keywords: Paulownia, landscaping, soil bioremediation, carbon dioxide absorption, environmental benefits.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ECOLOGICAL CHARACTERISTICS OF CHERRY VARIETIES

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ABSTRACT

Fruit growing is one of the most important developed fields of agriculture in Azerbaijan. The soil and climate conditions of the Guba-Khachmaz economic region are very favorable for the development of fruit growing. Cherry *(Prunus avium L.)* is a pome fruit plant belonging to the plant kingdom *(Plantae)*, angiosperm department *(Magnoliophyta)*, dicotyledons *(Magnoliopsida)* class, Rosales order *(Rosales)*, rose family *(Rosaceae)*, plum *(Prunus)* genus. Cherry varieties are an important fruit crop cultivated all over the world. These cultivars have unique ecological characteristics that adapt to different environments. In the article, the ecological characteristics of the cherry plant: climate and growth tolerance, soil requirements, pollination requirements, sunlight, water requirements, disease and pest resistance, etc. shown. The object of the research is cherry varieties grown in the Guba-Khachmaz economic region in Azerbaijan. The purpose of the work is to create and select varieties that meet the requirements of intensive horticulture, are adapted to soil and climate conditions, are productive, and meet the requirements of the market economy.

As a result of the work, we can state that the cherry plant is always organically related to the external conditions surrounding it. The attitude of plants to external factors is not the same, it varies depending on the age of the plant, time of year, and phenological phases.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CHARACTERIZING THE BEHAVIOR OF ONE-PARAMETER-AT-A-TIME APPROACH IN COMBINATORIAL T-WAY TESTING FOR EFFICIENT TEST SUITE GENERATION

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ABSTRACT

Software quality and accuracy can be improved through testing various aspects of the configurations. Combinatorial interaction testing emerges as an effective method among different testing approaches that uses one-parameter-at-a-time or one-test-at-a-time approach for generating test cases. However, a significant challenge in strategies like t-way testing is the combinatorial explosion problem, where the number of software inputs increases exponentially with the number of test cases. To address this issue, numerous strategies have been suggested to manage and alleviate the problem. Consequently, it is often infeasible for an efficient strategy to consistently generate optimal tests that ensure the minimum number of test cases covering each t-way interaction. As a result, this paper presents a new strategy for generating test suites using a combinatorial t-way testing technique, known as the improved one-parameter-at-a-time approach testing strategy (iOP_TS). The iOP_TS strategy acts as the means through which we conduct our research into the application of harmony search algorithm in generating optimal and efficient combinatorial t-way test suites. Characterizing the behavior of a t-way testing strategy involves assessing its effectiveness in achieving its objectives, such as reducing the number of test cases while maximizing coverage. Thus, we characterized the behavior of both iOP_TS and other strategies adopting the one-parameter-at-a-time approach in terms of expansion in test suite size and time required for test generation. Both strategies were subjected to several experiments using well-known benchmarking configurations. Moreover, in order to assess their performance, both strategies underwent statistical analysis. Encouragingly, both approaches yielded promising results, indicating the effectiveness of employing a one-parameter-at-a-time approach for generating t-way test suites; however, iOP_TS yielded more satisfactory and competitive results.

Keywords: One-parameter-at-a-time approach, combinatorial t-way testing strategy, test case, test suite, characterization, harmony search algorithm.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STUDY OF BIOREGIONAL CHARACTERISTICS OF LOCAL HAZELNUT CULTIVARS

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ABSTRACT

Hazelnut growing is one of the most priority areas of agriculture in the world, improved with new technologies. Sheki-Zagatala and Guba-Khachmaz economic regions have favorable agro-climatic conditions for hazelnut cultivation. The hazelnut plant is a fruit plant belonging to the genus Corylus of the Betulaceae family of the Fegales order. Most of the cultivated hazel species were created as a result of the selection of Corylus maxima and Corylus avellana. Hazelnuts are the most widely grown fruit crops in Azerbaijan after almonds and walnuts. Azerbaijan ranks 4th in the world in terms of hazelnut export. In the article, bioregional characteristics of local hazelnut varieties: biotic and abiotic factors affecting plant development, resistance to pests and disease-causing pathogens common in the region, etc. shown. The gene pool of both local and introduced and selected varieties of hazelnuts was collected at the Zagatala DM of the Scientific Research Institute of Fruit and Tea Cultivation in the village of Parzivan in the Zagatala district of the Sheki Zagatala economic geographic region of Azerbaijan. 15 varieties obtained through selection, as well as 14 introduced varieties imported from other countries are stored here. The Ata-baba variety, which is widely spread in Azerbaijan due to its use since ancient times, ranks first in terms of kernel yield, oiliness and storage conditions, is also grown in this support area. The object of the study: Hazelnut varieties grown in Sheki-Zagatala economic geographical region. The purpose of the work is the selection of varieties that fully reflect the requirements of super-intensive horticulture, are adapted to environmental conditions, are productive and meet the standards of the foreign market.

Key words: DM, abiotic, introduction, Ata-baba.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE TECHNOLOGY OF GROWING VEGETATIVE APPLE TREES WITH WOODED FENCES

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ABSTRACT

At the Fruit and Tea Cultivation Scientific Research Institute, located 10 km east of the Guba district center, research work is being conducted on the technology of propagating vegetative apple seedlings with woody stems. The m-9 (dwarf), 62-396 (dwarf), MM-106 (medium), and 54-118 (tall) apple cultivars were taken as the research object. To root the cuttings, 0.2% indolyl butyric acid and sawdust were used. Research work is carried out in greenhouse conditions. The cuttings were leveled with a sharp knife, then the cuttings were left for 15-20 minutes in 0.2% indolylic butyric acid. The experiment was carried out in greenhouse mode. Before the appearance of callus, the cuttings were kept at a temperature of 20-25 Celsius and 45-70% humidity. Calluses appeared on the cuttings within 15-20 days after moving the greenhouse. The purpose of the study is that in the nursery, the remaining waste after grafting turned into rooted plants.

Key words: M-9, 62-396, MM-106, 62-396, MM-106

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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ON THE ACTIVITY OF STUDENTS IN MATHEMATICS LESSONS THE EFFECT OF PYGMALION EFFECT

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ABSTRACT

The application of mathematical sciences has a great role in the development of society. Mathematical education is a necessary and important part of general education. Therefore, strengthening the mathematical preparation of students is considered the most important task facing secondary schools.

Mathematics is taught in a wide range of programs at every level of education in secondary schools. However, it is not perceived in the same way by all students. While some students find mathematics easy to understand, others find it difficult. There are several reasons for this: poor assimilation of mathematical concepts from elementary grades, genetic influences, the student's lack of independent work, the complexity of concepts from grade to grade, age level, environment, etc.

We must remember that it is impossible to succeed in life without understanding mathematics. Therefore, it is necessary to look for the cause of difficulties and try to eliminate them. The purpose of this study is to study the effect of the Pygmalion effect on the performance of students in mathematics classes in secondary schools.

Using the Pygmalion effect directs students with a poor understanding of mathematics to positive thinking and creates interest in learning mathematics. Many empirical studies also support the predictions of the Pygmalion effect, but it has been found that its effect sizes can vary from low to moderate.

As a result of the research, we concluded that applying the Pygmalion effect in teaching mathematics is one of the best ways to achieve success. The research is expected to be useful for mathematics teachers and parents and contribute to the relevant literature.

Keywords: Mathematics, student, Pygmalion effect, positive thinking

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENHANCING PORTFOLIO OPTIMIZATION THROUGH BAYESIAN OPTIMIZATION AND PARTICLE SWARM OPTIMIZATION FOR PARAMETER TUNING

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ABSTRACT

In modern financial markets, effective portfolio optimization remains a critical challenge for investors seeking to maximize returns while managing risk. This study proposes a novel approach to enhance portfolio optimization by integrating Bayesian Optimization (BO) and Particle Swarm Optimization (PSO) for parameter tuning.

BO offers a probabilistic framework for incorporating prior knowledge and updating beliefs based on observed data, providing a robust foundation for decision-making in uncertain financial environments. By utilizing Bayesian inference, investors can better model the complex relationships between asset returns, correlations, and other relevant factors, thus improving the accuracy of portfolio optimization.

Additionally, Particle Swarm Optimization (PSO) presents a powerful metaheuristic algorithm to solve non-linear optimization problem. PSO iteratively optimizes a problem by simulating the behavior of particles moving through a multidimensional search space to find optimal solutions. When applied to portfolio optimization, PSO enables efficient exploration of the vast solution space, facilitating the discovery of optimal asset allocations that maximize returns and minimize risk.

This research contributes to advancing portfolio optimization methodologies by introducing a comprehensive framework that incorporates both BO and PSO for parameter tuning, thereby enhancing decision-making in investment environments.

Keywords: BO, PSO, portfolio optimization, parameters, tuning.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ENHANCING 5G SYSTEM EFFICIENCY THROUGH IMPROVED HANDOVER DELAYS WITH INTELLIGENT CONTEXT HANDOVER SERVICES

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Abstract

In the fast-paced realm of 5G systems, seamless connectivity, and minimal handover delays, coupled with efficient mobility management, are paramount for delivering an optimal user experience. This paper proposes a novel approach to enhance 5G system efficiency by addressing the challenge of handover delays through the implementation of Intelligent Context Handover (ICH) services. Traditional handover mechanisms in 5G networks often suffer from latency issues and inefficient resource utilization, leading to degraded performance and user dissatisfaction. By leveraging intelligent context-aware techniques, such as predictive analytics and dynamic decision-making algorithms, our proposed ICH services aim to mitigate handover delays and optimize resource allocation in real-time while ensuring effective mobility management. Through extensive simulations and performance evaluations, we demonstrate the effectiveness of our approach in reducing handover delays, improving network efficiency, and enhancing overall user satisfaction in 5G systems. This research contributes to advancing the state-of-the-art in 5G networking by offering a practical solution to one of its critical challenges, thus paving the way for more reliable and efficient next-generation communication networks. Enhancing 5G system efficiency through improved handover delays with intelligent context handover services has the potential to significantly improve the performance and user experience of mobile networks. It can lead to more reliable connections, better service quality, and open possibilities for new applications that rely on consistent and robust mobile connectivity. However, the realization of these results depends on the effective implementation of these services and the surrounding network infrastructure.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Handover, Latency, 5G, ICH, UE, Mobility, EE and MIPV6

ELIMINATE OF ACTIVE ATTACK FOR MANET USING HYBRID ROUTING PROTOCOL

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Abstract: Mobile Ad-hoc Networks (MANETs) are a type of Wireless ad-hoc network that usually has a routable networking environment on top of an end-to-end Link Layer (LL) ad-hoc network. MANETs consist of a hop-to-hop, self-arrangement and self-configure network in contrast to a mobile network has a central controller. The solutions may not always be sufficient, as ad-hoc networks have their own vulnerabilities that cannot be addressed by these IDS solutions. In the network, some active attacks un-forward capacity nodes pretend to be intermediate nodes of a route to some given targets, drop any packet that subsequently goes through it, is one of the main types of attack. In this paper, they propose black-hole attacks an analysis method to detect malicious nodes in MANETs, the mechanism is cooperative hence the protocol work cooperatively together so that they can analyze, detect malicious nodes in a reliable manner. To verify our developed scheme by running through Network Simulations 2 (NS2) with mobile nodes using hybrid routing protocol namely, Modified - Zone based Hierarchical Link State (M-ZHLS) routing protocol. It is observed that the black hole and malicious node detection rate is very good, reduced average delay and also increased packet delivery ratio compare Zone based Hierarchical Link State (ZHLS) routing protocol when there is a change of mobility speed and varying topology size.

Keywords: MANET, Black hole, M-ZHLP, PDR, Overhead, Throughput.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MANET ATTACKS USING FUZZY APPROACH

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Abstract-Military application required secure way of data transmission and protect data from the third party, due to dynamic topology the nodes are change to various security attacks like data modification, reduced by limited battery power, computational power and bandwidth. Mobile Ad hoc Networks (MANETs) is a kind of ad-hoc network with mobile nodes is particularly vulnerable to security attacks due to its characteristics Black-hole attack is one of the possible attacks in MANET. In this research work, they propose secured network scheme that fuzzy logic scheme is used to detect black-hole attack based on certificate authority and trust node to improve the performance of network also result analysis different reactive routing protocols. Fuzzy logic is used to detect misbehaving node by giving certificate to only trusted node. The proposed technique is more secure and reliable to increase the network lifetime, packet delivery ratio, throughput and routing overhead with fixed topology size by continuously monitoring the individual nodes in the network. Network Simulator 2 (NS2) is used to employ and investigation our proposed system.

Keywords - MANET, fuzzy logic, Protocols, network lifetime, delivery ratio, throughput, traffic.

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ISBN: 978-9952-610-30-7

MULTIPATH ROUTING PROTOCOL FOR MANET

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ABSTRACT: We present a a class of Minimum Cost Blocking (MCB) problems Wireless Sensor Network with multipath routing protocols. To conquer that challenge, an active detection-based security and trust routing scheme named Multipath routing protocol is proposed for WSNs. We establish the provable superiority of multipath routing protocols over the Conventional protocol against blocking, node isolation and network partitioning type attacks. In our attack model, an adversary is considered successful if anyone is able to capture or isolate a subset of nodes such that no more than a certain amount of traffic from source node reaches the gateway. In this work, the performance of multipath routing protocol to support application constraints such as reliability, load-balancing, energy-conservation and Quality-of-Service (QoS).

KEYWORDS: Multipath routing, reliability, load balancing, CMR, Bandwidth, security, Wireless Sensor network, Minimum Cost Blocking.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CYBER SECURITY CHALLENGES IN HIGHER EDUCATION INSTITUTIONS

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ABSTRACT

Higher education institutions are constantly faced with challenges in the field of cyber security within an environment where information technology is highly developed. These challenges become even more apparent due to the way university and academic environment interacts with, which includes academic and administrative staff, and students as well. In this respect, in a university environment it is noticed a very large number of users who generally access services, such as e-mail accesses information and communication systems related to the registration of subjects, timetables, information on grades and/or evaluations, or other services offered on the website etc. This high number of users performs a continuous exchange of data with the university all the time. University in itself is obliged to protect these data volume from unauthorized access, as they mainly include personal information of students, scientific research, financial data, projects, etc.

In this optic, our study aims to identify and analyze the main cyber security challenges faced by higher education institutions by focusing on a security analysis of the website, as the first element we face when looking for a university. In this study, we will also take note of the possible types of attacks that can affect these services. Through a deep analysis of the problems that will appear during the vulnerable scanning of these systems, the paper will also explore the best strategies and practices for improving the cyber security of these institutions. An important factor to consider is the importance of training and awareness of staff and students, as well as the possibility of implementing advanced security policies and technologies.

Keywords: Cyber Security, Vulnerability, Information Systems.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BILINGUALISM IN THE PERSPECTIVES OF TEACHERS

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Abstract

This phenomenological study explored the essential knowledge on bilingualism through teachers' perspectives. Seven teachers in a certain public high school were interviewed then transcription, translation, intensive review of related literature, and thematic analysis were used to gather and analyze data. Persons involved in the language events were teachers, a principal, students, teachers' family members, and a market vendor. Pairs of languages found were English and Local Dialect (Davao Bisaya), English and Filipino (Tagalog), and Filipino and Local Dialect (Davao Bisaya) with various dominant language found. Language events used to determine bilingualism were meetings, casual conversation, class discussion, dinner, and product buying. Reasons of pairing a language used are "being used to", type of people, and language events. The concept of bilingualism is a very important phenomenon to be understood.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
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LAVENDER LANGUAGE: EXPLORING THE COLORS OF GAY LINGO IN THE ACADEME

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Abstract

The purpose of this phenomenological study was to explore the perception of teachers on gay lingo and to analyze the features of this language as used by Grade 10 teachers in Sto.Tomas National High School in the following language events: before class hours, recess, lunch break, and after class hours. In-depth interview and conversation recording are two of the primary means of gathering data which were then analyzed through triangulation. The results show that even non-gay teachers were adapting the language due to their daily exposure to the terms used by their gay co-teachers. Frequency of exposure triggers their interest and even let them adapt the language. The sense of acceptance is manifested through their adaption of the lingo and uses them in conversing with each other. Teachers perceived the language as a by-product of creativity and intelligence and social understanding. Terms were then analyzed through its morphological formation and several techniques were found. Linguistic features were also explored and the main themes emerged are derivation, avoidance of taboo words, pronunciation, and use of feminine pronouns. This study reveals that gay lingo is in a faster state of evolution.

Keywords: Gay Lingo, Phenomenology, Academe

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ISBN: 978-9952-610-30-7

ACTION RESEARCH COMPETENCE AND TEACHING PERFORMANCE

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Abstract

This research utilizing quantitative non-experimental descriptive correlational design tested the significant influence of action research competence to teaching performance of 144 secondary school teachers of Sto.Tomas National High School of Davao del Norte Division for the S.Y. 2016-2017. Purposive sampling enumerating all the teachers was done considering only the secondary data from the IPCRF (Individual Performance Commitment Review Form) rating. Statistical tools used to describe the mean of both the variables were weighted mean while regression analysis was used to test the significant influence of action research competence to teaching performance. Results showed that action research competence was unsatisfactory *(mean = 1.54; S.D. = 1.12)* while teaching performance was very satisfactory *(mean = 4.05; S.D. = 0.56)*. It was found out that there is a very low relationship *(r-value = 0.03)* and was also found out that action research competence does not significantly influence *(p-value > 0.05)* teaching performance. However, the value of action research is hereby recommended to still look at into by teachers despite the results of this research.

Keywords: *action research, teaching performance, IPCRF,*

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Keywords*: action research, teaching performance, IPCRF,*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CYBERBULLYING AND SELF-ESTEEM OF GRADE 11 STUDENTS

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ABSTRACT. This study was conducted to determine the level of cyber bullying and self-esteem and as well as the significant relationship between cyber bullying and self-esteem of Grade 12 students. A quantitative non-experimental correlational design was employed in the study considering weighted mean and Pearson-r as statistical tools. As a result, the level of both cyber bullying and self-esteem of the Grade 12 students are at moderate level. Further, the negative relationship between the two variables implies that as cyber bullying increases, self-esteem of the students decreases. The findings of the study are good springboard to address the cyber bullying issues in the classroom and in schools and enhance the self-esteem of students.

Keywords: cyber bullying, self-esteem, Grade 12

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SOCIAL INTELLIGENCE AND MATH ANXIETY OF GRADE 10 STUDENTS

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Abstract

This study determined the significant relationship between social intelligence and mathematics anxiety among high school students in a certain public high school of Davao del Norte. Participants were 64 Grade 10 students purposively chosen considering the complete enumeration. Quantitative non-experimental descriptive correlation was the design utilized in this study. Survey questionnaires were used in the collection of data. Mean, Pearson-r, and regression analysis were used to present the data in a meaningful way. It was found out that there is a moderate level of social intelligence and mathematics anxiety. Only empathy is significantly related to the three domains of math anxiety while manipulation and social irritability are not. Moreover, there is no domain in social intelligence that significantly predicted mathematics anxiety of students. It is recommended that social intelligence of high school students must be enhanced to very high level, while mathematics anxiety is recommended to be eliminated or at least reduced to very low level. Further studies are recommended to be conducted to explore other factors influencing mathematics anxiety.

Keywords: social intelligence, Math anxiety, Grade 10

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MORPHO-ANATOMICAL FEATURES OF *MALUS NIEDZWETKYANA* DIECK. SPECIES INTRODUCED IN ABSHERON

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ABSTRACT

In the article for the first time has been studied morphological and anatomical characteristics of *Malus niedzwetkyana* Dieck. species. This species was introduced in Absheron from Central Asia. The studies have shown that the donor tissue on the root is well developed. The root stalks are developing rapidly and get a lot. Xylem and new layers of phloem have a lot of live elements which cause the mass transportation of organic and non-organic substances. The thickened wall of water pipes gives strength to the leaves. The endocarp in fruits develops maximum and consists of sclereid. There are three of four seed lobes. It is connected with an early fragmentation of the ovary. Some bodies of the plant are enriched with the red dour anthocyanin. So, it gives a plant a special beauty. It also facilitates the absorption of water and mineral substances and creates conditions for the cultivation of decorative gardening in Absheron's dry subtropical climate. This species can be used as a first material in the works of selection and hybridization for getting new variates too.

Keywords: Apple, organs, vegetative, generative

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE INFLUENCE OF SOCIAL MEDIA EXPOSURE TO FAMILY RELATIONSHIP OF SPA STUDENTS

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Utilizing the proposition of Alolyan (2015) that with the approach of current modern phones and social media, it is conceivable to be physically present at a family or get-together yet losing of time for genuine social exercises, this study was conducted to determine the significant relationship between the social media exposure and family relationship among SPA students of Sto.Tomas National High School. A quantitative non-experimental descriptive-correlational design was employed in the study utilizing a stratified random sampling technique among 176 out of 335 students. Frequency was used to determine the social media exposure and family relationship while Chi-square Analysis was used to test the significant association between the two variables. As a result, 71 students were exposed in social media for an hour every day, 41 students were exposed in social media for two hours every day, 56 students were exposed in social media for three hours every day, and only eight students were exposed to social media for more than four hours every day. While only one student has very poor family relationship, 13 students have poor family relationship, 94 students have good family relationship, 66 students have very good family relationship, and two students have excellent family relationship. It was also found out that there is a significant association between social media exposure and family relationship. Thus, SPA students' exposure to social media is recommended to be in minimal level to enhance the good family relationship.

Keywords: social media exposure, family relationship, SPA students

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE INFLUENCE OF COMPUTER LITERACY TO PERCEIVED ACADEMIC PERFORMANCE OF GRADE 11 STUDENTS

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Abstract

This study was conducted to determine the significant relationship between computer literacy and perceived academic performance of Grade 11 students of a certain public secondary school. A quantitative non-experimental correlational descriptive method was employed in the study. As a result, the computer literacy of the Grade 11 students is excellent. Meanwhile, the perceived academic performance was gleamed to be a high level. The findings also revealed that there is a significant relationship between computer literacy and perceived academic performance. Based on the results, the researchers concluded that there is excellent manifestation in computer literacy and perceived academic performance.

Keywords: Computer Literacy, Perceived Academic performance, Grade 11

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE USE OF L+S IN IMPROVING THE PERFORMANCE OF SHS STUDENTS IN STATISTICS AND PROBABILITY

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Abstract

This research entitled “The Use of Lecture Plus Strategy in Improving the Performance of Students in Statistics and Probability” discussed the integration of activating prior knowledge through the use of video clip presentation as the PLUS, an acronym which means Precision in process, Learn to identify and analyze information, Understand concepts, and Solve basic to complex problems. The study used experimental design particularly the two groups, random selection, Pretest and Posttest. There were two groups being studied with a total of 62 respondents. The study aimed to determine the pretest and the posttest mean scores of experimental and control groups, the significant difference between the pre-test and the post-test mean scores of experimental and control groups, and the significant difference between the mean gain scores of experimental and control group. The mean pretest and posttest scores of both groups were taken and tested whether there is significant difference at 0.05 level of significance. There is no significant difference in the pretest mean scores between two groups and it implies that two groups were academically equal at the start of the study. At the end of the treatment, it was found out that there is a significant difference in the posttest mean score of the two groups. The experimental group who undergone the Lecture PLUS strategy performed better compare to the control group. It was also noted that the mean gain score is significant.

***Keywords**:* Traditional Lecture, Lecture PLUS, students’ performance

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PREFERENCES AND BEHAVIOR IN BUYING SMARTPHONES AMONG PUBLIC SCHOOL TEACHERS

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Abstract

This study was conducted to determine the relationship between preferences and behaviour in buying phones among public-school teachers in a certain municipality. A quantitative non-experimental correlational design was a employed in the study considering the population of the school with weighted mean and Pearson-r as statistical tools used in the analysis of data. It was found out that preference in buying smartphones among public-school teachers is high. Also, their behaviour in buying smartphones is also high. It is also found out that there is a significant relationship between their preferences and behaviours in buying smart phones and that preferences significantly influence their behaviour.

Keywords: Preferences, Behaviours, Smartphones

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GOOSE GRASS *(ELEUCINE INDICA)* AND HEAVENLY ELIXIR *(TINOSPORA RUMPHII)* EXTRACTS AS BOTANICAL PESTICIDE FOR HOUSEFLY *(MUSCA DOMESTICA)*

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Abstract

Our food is one of the main targets likely to become contaminated because of the germs spreads by the houseflies *(Musca Domestica)* and Goose grass *(Eleucine indica)* and makabuhay *(Tinospora rumphii)* are both abundant in our surrounding, these were enlightens the minds of the researchers to made a botanical pesticide for flies. The main purpose of this study was to determine the significant difference of the effectiveness of goose grass and heavenly elixir extracts compare to the commercial pesticide when analyzed by the number of flies killed and its time duration. There were two processes involved in the study extracting the juices of the plants and experimenting. The study has six set-ups with 2 replications and each replication has 5 houseflies and there are two trials each set-up. The first set-up was sprayed with goose grass extract, the second was with heavenly elixir extracts, the third set-up was sprayed with mixed goose grass and heavenly elixir extracts, the fourth was with commercial and the fifth was with mixed weeds while the sixth set-up was only the controlled set-up. The collected data showed that the goose grass and heavenly elixir extracts was not effective as botanical pesticide for flies compared to commercial pesticide computed using the spss application.

Keywords: *Musca Domestica, Eleucine indica, Tinospora rumphii*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PREDICTING WATER CONSUMPTION: A REGRESSION ANALYSIS ON NUMBER OF HOUSEHOLD CONSUMERS

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Abstract

This study is a quantitative non-experimental descriptive correlational which determined the significant influence of the registered household members and the volume of water consumption from year 2005 until 2016. The researchers collected the data from the Rural Water Supply and Sanitation Agency (RUWASSA) main office of the municipality of Sto.Tomas, Davao del Norte, hence, secondary data was used. As a result, registered household members significantly influence the volume of water consumption as the year is constantly increasing. It was found out that from year 2005-2016, the registered household members is constantly increasing so as the distribution of water consumption leading to the unequal distribution of water in the different households in barangay Tibal-og, Sto.Tomas, Davao del Norte, resulted to the water shortage.

Keywords: *consumption, RUWASSA, household members*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE EFFECTIVENESS OF CAVENDISH BANANA (*MUSA ACUMINATA*) AND EGGSHELLS AS FOLIAR FERTILIZER

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Abstract

The purpose of this science investigatory project was to determine the effectiveness of researcher-made (*Musa acuminata* fruits and eggshells) foliar fertilizer in enhancing the growth of eggplant (*Solanum melongena*) since Cavendish bananas rejected for exportation were abundant and eggshells were considered waste products in bakeries in the locality of Sto.Tomas. The study took place in Sto.Tomas National High School involving two main processes which were the fertilizer making and experimenting. Banana fruits and eggshells underwent processes with vinegar and sugar to come up with a researcher-made foliar fertilizer. Sets of product were then sent to laboratory for testing for chemical content and properties. However, the laboratory results are still not available. Further, a quasi-experimental approach was done in order to evaluate the effectiveness of foliar fertilizer in enhancing the growth of the eggplants. Three plots were prepared and each plot has 15 eggplants. Plot 1 received no fertilizer, plot 2 received researcher-made fertilizer, and plot 3 received commercial fertilizer. Results revealed that researcher-made fertilizer significantly enhances the growth and number of leaves of eggplants. However, commercial fertilizer is more effective than researcher-made fertilizer. Further, it was also found out that researcher-made foliar fertilizer can be a good agent for the growth and number of leaves of eggplants. Researcher-made foliar fertilizer is also environment-friendly and cheaper.

Keywords: *Musa acuminate, eggshell, Cavendish, Solanum, melongena*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BICYCLE AS CELLPHONE CHARGER

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Abstract

The purpose of this science investigatory project was to utilize the mechanical energy of a bicycle into a useful electrical energy as cellular phone charger. The study took place in Sto. Tomas National High School involving the process of inventing a simple machine with several electronic materials in order to come up with a charging machine while running a bicycle.The Pilot study was used for potential instrument development of alternative charger for moving objects so that mechanical energy can be useful. Ohm's law was considered in the research and results showed that the in the invented charger attached to bicycle, it is better to use capacitor and regulator (IC 7805) than without the presence of the two. In the comparison between the direct current and bicycling, Oppo cellular phone fully charged in direct current at 2 hours and 50 minutes while in the bicycle-attached charger, it only took 3 hours and 30 minutes. However, there were several limitations that were not considered in the study such as careful control of time and other factors affecting the experiment. With this, it is hereby recommended that further experiments looking for the factors affecting the study shall be considered.

Keywords: *regulator, capacitor, Ohm's Law, Oppo, pilot study*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COCONUT (*COCOS NUCIFERA)* SAP AND CALAMANSI (*CITROFORTUNELLA X MICROCARPA)* EXTRACT AS AN ALTERNATIVE CONTACT WEED KILLER

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Abstract

The purpose of this science investigatory project was to determine the effectiveness of coconut (*Cocos nucifera)* sap and kalamansi (*Citrofortunella x microcarpa)* extract as an alternative contact weed killer. The study took place in Sto.Tomas National High School involving two main processes which were the weed killer making and experimenting. Sets of product were then sent to laboratory for testing for chemical content and properties. However, the laboratory results are still not available. Further, a quasi-experimental approach was done in order to to determine the effectiveness of coconut (*Cocos nucifera)* sap and kalamansi (*Citrofortunella x microcarpa)* extract. Five sets were prepared and each has grass for experimenting. Plot 1 was applied with no weed killer, plot 2 r was applied with commercial weed killer, plot 3 was applied with only coconut sap, plot 4 was applied with calamansi extract, while plot 5 was applied with.coconut sap and calamansi extract. Results revealed that coconut sap and calamansi extract was more effective weed killer than only the calamansi and only coconut sap. However, the commercialized weed killer is better than the rest.

Keywords: *Citrofortunella x microcarpa, Cocos nucifera, sap, extract*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE POTENTIAL OF CAVENDISH *(MUSA ACUMINATA)* BANANA STALKS FOR PAPER MAKING

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Abstract

The purpose of this science investigatory project was to explore the potential of Cavendish banana (*Musa acuminata*) stalks for paper making. The study took place in Sto. Tomas National High School involving the two main processes which were the papermaking and acceptability testing from first to second grading period. Banana stalks underwent pulping and papermaking processes to come up with a researcher-made paper. The Pilot study was used for potential instrument development of the banana stalks that used pure water and banana stalks only and a solution of water with sodium hydroxide (NaOH) and banana stalks. Sets of product were sent to DOST-FPRDI for testing. A descriptive comparative survey was also done in order to evaluate the perceived acceptability of researcher-made paper in terms of texture, durability, and strength as perceived by 30 students, 30 teachers, and 30 office workers. Weighted mean was used to determine the level of acceptability while t-test was used to determine the significant difference on the acceptability between researcher-made and commercial paper. Results show that there is a low acceptability of the researcher-made paper in terms of texture, average acceptability in terms of durability, and high acceptability in terms of strength. While there is no significant difference between the researcher-made and the commercial paper. This study implied that waste materials like stalks can be useful in some ways around since making a paper out from it would only take minimal cost. Further, nore innovations on improving the quality of products made is suggested to be given emphasis on the next round of research conduct.

Keywords: *Cavendish (Musa acuminata), NaOH, stalks*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STUDY OF THE HOPF BIFURTACION IN THE LORENZ SYSTEM

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ABSTRACT

In this paper, we conduct a comprehensive examination of the Hopf bifurcations within the three-parameter Lorenz system. Our investigation reveals the presence of a Hopf bifurcation, with a particular focus on the subcritical case leading to an unstable limit cycle. Through our analysis of the Hopf bifurcation, we demonstrate that the emerging unstable limit cycle closely aligns with a bifurcation point. Utilizing the tools of local bifurcation theory, notably the center manifold and the normal form theorem, we establish that the unstable limit cycle near the bifurcation point arises from the Lorenz system. Our study includes the identification of fixed points, determination of the Jacobian matrix, and computation of eigenvalues for stability analysis. Furthermore, we enhance the understanding of chaotic systems through the visualization of pictures and diagrams generated with the aid of MAPLE.

Keywords: Hopf bifurcation, Lorenz system, limit cycles, nonlinear dynamics, bifurcation analysis.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

STUDY OF BIOREGIONAL CHARACTERISTICS OF LOCAL NUT CULTIVARS

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ABSTRACT

Hazelnut growing is one of the most priority areas of agriculture in the world, improved with new technologies. Sheki-Zagatala and Guba-Khachmaz economic regions have favorable agro-climatic conditions for hazelnut cultivation. The hazelnut plant is a fruit plant belonging to the genus Corylus of the Betulaceae family of the Fegales order. Most of the cultivated hazel species were created as a result of the selection of Corylus maxima and Corylus avellana. Hazelnuts are the most widely grown fruit crops in Azerbaijan after almonds and walnuts. Azerbaijan ranks 4th in the world in terms of hazelnut export. In the article, bioregional characteristics of local hazelnut varieties: biotic and abiotic factors affecting plant development, resistance to pests and disease-causing pathogens common in the region, etc. shown. The gene pool of both local and introduced and selected varieties of hazelnuts was collected at the Zagatala DM of the Scientific Research Institute of Fruit and Tea Cultivation in the village of Parzivan in the Zagatala district of the Sheki Zagatala economic geographic region of Azerbaijan. 15 varieties obtained through selection, as well as 14 introduced varieties imported from other countries are stored here. The Ata-baba variety, which is widely spread in Azerbaijan due to its use since ancient times, ranks first in terms of kernel yield, oiliness, and storage conditions, and is also grown in this support area. The object of the study: Hazelnut varieties grown in Sheki-Zagatala economic geographical region. The purpose of the work is the select of varieties that fully reflect the requirements of super-intensive horticulture, are adapted to environmental conditions, are productive, and meet the standards of the foreign market.

Keywords: DM, abiotic, introduction, Ata-baba.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

"BIBLIOMETRIC ANALYSIS OF STREAMING SERVICES' IMPACT ON THE CINEMATOGRAPHIC INDUSTRY"

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ABSTRACT

This bibliometric analysis and thematic exploration span twenty years of scholarly dialogue on streaming services and series, revealing the contours of an evolving digital entertainment landscape. An examination of the data from 2003 to 2023 shows a healthy compound annual growth rate of 12.74%, indicating sustained scholarly interest and an expanding research domain.

The corpus comprises research from 80 distinct sources, indicating a field that is both broad and inclusive, with a multitude of academic journals contributing to the discourse. The diversity of authorship, with 279 researchers, and affiliations, spanning 149 institutions, portrays a decentralized and vibrant scholarly community. These contributors hail from 32 different regions, illustrating the global impact and interest streaming services have garnered.

A thematic analysis utilizing Callon's density and centrality quadrants on a set of 371 unique keywords highlights 'streaming services' as a high-density and central node in the research network. It is surrounded by emerging yet influential themes like 'Netflix', 'binge-watching', and 'quality of experience', pointing to new directions and frontiers in the field. These terms encapsulate the consumer experience and technical challenges, shaping the industry's future.

The international and interdisciplinary nature of the contributions is a testament to the complexity and multifaceted aspects of streaming services. As we look beyond the dataset, the trend towards personalized, on-demand content, and the technological advancements in delivery and quality assurance promise to keep this field at the forefront of digital innovation and consumer habits research.

Keywords:

Streaming Services;

Series Consumption;

Bibliometric Analysis;

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Thematic Exploration;

Digital Entertainment.

"CYBERSECURITY STATE OF THE ART: A BIBLIOMETRIC ANALYSIS FROM 2021 TO 2024"

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ABSTRACT

The domain of cybersecurity is in a state of continuous evolution, with burgeoning technologies like machine learning (ML) and artificial intelligence (AI) becoming central to its advancement. This bibliometric study analyzes the trends, directions, and focal points of cybersecurity research over a four-year period, drawing on a corpus of 477 documents from a diverse array of 173 academic sources. The surge in the volume of literature highlights the escalating complexity and the multifaceted nature of cybersecurity challenges. Key findings from the most globally cited documents reveal a pronounced emphasis on the integration of ML and AI techniques in the development of sophisticated cybersecurity mechanisms. These technologies are not only redefining the protective measures against cyber threats but are also enhancing the resilience of blockchain systems and revolutionizing risk management strategies.

ML and AI's role extends beyond mere threat detection, delving into predictive analytics for preemptive action against potential breaches. Blockchain technology, frequently discussed in tandem with cybersecurity, shows a trend towards fortifying digital transactions and creating immutable records, proving critical in the fight against cybercrime. The frequent citation of terms like 'machine learning', 'artificial intelligence', 'risk management', 'blockchain', and 'cybercrime' across the dataset underscores their significance in current research narratives.

The thematic analysis also sheds light on the growing importance of cross-disciplinary approaches, as evidenced by the intersection of cybersecurity with domains such as logistics and technology forecasting. This cross-pollination is anticipated to drive innovation and foster robust cybersecurity frameworks. The implications of these findings are profound for both academic research and practical applications, suggesting that future cybersecurity solutions will increasingly rely on the confluence of AI-driven analytics and blockchain technology to address the sophisticated and evolving threat landscape.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Bibliometrics; Cybersecurity; Risk Management; Blockchain; Cybercrime

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ASSESSMENT OF THE TOURISM AND RECREATION POTENTIAL OF GAKH DISTRICT AND ITS DEVELOPMENT PROSPECTS

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Abstract

The socio-economic development program of the regions in the Republic of Azerbaijan prioritizes the rapid growth of the tourism industry, particularly in Gakh district. Situated advantageously with diverse landscapes, abundant fauna and flora, mineral springs, historical and cultural monuments, and a modern infrastructure, Gakh holds significant untapped potential for tourism. Despite its natural beauty, the district faces challenges in fully realizing its tourism prospects. This research conducts a comprehensive analysis of Gakh's geographical, historical, and cultural features to identify key factors that contribute to its appeal as a tourist destination.

The purpose of this study is to assess the tourism and recreation potential of Gakh district and explore its development prospects. The research delves into the existing tourism infrastructure, highlights key attractions, and proposes sustainable development strategies to unlock the district's full potential as a tourist destination. Through this work, the aim is to provide valuable insights for policymakers and stakeholders to foster the sustainable growth of tourism in Gakh district, contributing to the overall socio-economic development of the region.

Keywords: Socio-economic development, tourism industry, Gakh district, geographical features, cultural attractions, sustainable development, tourism infrastructure, recreational potential, development prospects.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PUBLIC LEADERSHIP BEHAVIOR AND COMPETENCE OF STUDENT LEADERS

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Abstract

This research utilizing quantitative non-experimental descriptive correlational design tested the significant influence of public leadership behavior to competence of student leaders in secondary schools in a certain municipality of Davao del Norte Division. Purposive-quota sampling enumerating all officers of the student council except for the president were chosen as respondents and the president as the subject of the study. Statistical tools used to describe both the variables were weighted mean while Pearson-r was used to test the significant influence of public leadership behavior on competence of student leaders. Results showed that both public leadership behavior and leadership competence were very high. It was found out that there is a significant relationship between the two variables.

Keywords: *leadership behavior, leadership competence, student leaders*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF RATE $NH_4^+/NO_3^-+NH_4^+$TO K^+, IONS UPTAKE ON PEACH TREES (*PRUNUS PERSICA* (L.) BATSCH. CVS. ALBERTA & ZAFERANI)

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Abstract

This experiment was conducted as factorial in a randomized complete block design with 5 nutrient treatments and 10 replications for each cultivar and total number of 100 peach trees that the investigation was at Tehran University about 2 years. In this study the effects of five nutrient solutions with different concentrations of $NH_4^+$and $NH_4^+/NO_3^-+NH_4^+$ and equal mineral concentrations of total nitrogen, calcium, phosphorous, magnesium in comparison with the control or treatment one with different concentrations of all nutrients (about half of other treatments) on 4 years old peach trees (*Prunus persica* (L.) Batsch. cvs. Alberta & Zaferani) was studied. The concentrations of NH_4^+ were (0, 0.3, 0.5, 0.7 & 1 meq L^{-1}) and the ratio of concentrations $NH_4^+/NO_3^-+NH_4^+$ were (0, 0.04, 0.07, 0.1 & 0.15) in treatments one to five. The concentration of total nitrogen calcium, phosphorous and magnesium were (6.3, 3.5, 1.5 & 2.1 meq L^{-1}) in treatments two to five and in control they were (2.7, 1.5, 0.75 & 1.2 meq L^{-1}). The result of variance analysis for leaf percent K was affected significantly by nutrient solutions. Also leaf percent $NH_4^+$and leaf percent Ca were affected by cultivar. But leaf percent Mg and leaf percent P were not affected by nutrients. Between nutrition elements with each other

positive or negative regression relation were observed. Nutrient content in the leaves of Alberta cultivar was higher than Zaferani cultivar. Finally, nutrient solution S3 and S5 was determined to be suitable for peach trees nutrition.

Keywords: Nutrient solution, NH_4^+, $NH_4^+/NO_3^-+NH_4^+$, Ca, Mg, P, Zaferani, Alberta, Cultivar.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF NUTRIENT SOLUTION ON VEGETATIVE TRAITS , CHLOROPHYLLS AND CAROTENOID OF PEACH TREES

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ABSTRACT

This experiment was conducted as factorial in a randomized complete block design with 5 nutrient treatments and 2 cultivars (Alberta and Saffron) with 2 replications and experimental units of 10 peach trees and total number of 100 pots. Nutrient elements (nitrogen, phosphorus, calcium, magnesium and potassium) had significant effects on the vegetative parts of the peach trees and improved function and growth of peach trees. The results of variance analysis for vegetative characters showed that flower bud density, chlorophylls a and carotenoids were affected by nutrient solutions significantly. But chlorophyll b and total chlorophylls were not affected by nutrients. Finally, solution No. 5 was determined as suitable solution for 2 cultivars peach trees (Alberta and Saffron) nutrition.

Keywords: *Nutrient solution, NH_4^+, NH_4^+/NO_3^- + NH_4^+, Alberta, Saffron, Cultivar, Peach*.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF ERBIUM DOPING ON THE STRUCTURAL AND OPTICAL PROPERTIES OF ZINC SULFIDE PREPARED BY HYDROTHERMAL METHOD

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Abstract

Recently, semiconducting nanoparticles were received huge interestfor their potential application in the field of sensors, emitters and catalysts due to their optical, electric and structural properties. Among these semiconductor nanoparticles. In the field of optical and microelectronic industries ZnS has become an outstanding candidate, due to its high refractive index, high effective dielectric constant and wide wavelength pass band .ZnS is a wide band gap semiconductor of about 3.6eV, which makes it as a promising transparent material in the visible region. They are widely used for optoelectronic applications such as filters, photoelectric cells, and LED's. Many deposition techniques have been used to prepare ZnS Nps, such as chemical vapour deposition, electron beam deposition, sputtering, chemical bath deposition, and hydrothermal methods. Zinc sulfide is a binary compound II-VI with a wide gap and therefore transparent with a high refractive index and good transmittance in the visible range. In this work, we prepared pure ZnS and doped with Erbium using different concentration of Er (2and 4%) by hydrothermal method. The results of structural, optical, vibrational and morphological characterization of Er-doped ZnS NPs was compared with those of Pur ZnS NPs.to Characterize crystal structure and morphology samples an X-Ray diffraction with Cu Kα radiation (1.54056 Å) in the range of 20-90°, . Optical properties of undoped and doped ZnS is investigated by using UV-Visible spectrophotometer at the wavelength range between(200 and 800 nm) .

Keywords: DRX; ZnS; optical; IFTR, Erbium

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SHORTEST JOB FIRST SCHEDULING ALGORITHM FOR TEMPORARY WIRELESS COMMUNICATION

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Abstract-Some of recent researchers interested in the field of sensor network based wireless field (WSN) because of very difficult to communication via air medium due to lack of problems in using same carrier channel in all communication and easy to attack for security issues like malicious attacks or misbehavior attacks, Grey hole attacks, block hole attacks, etc... In truest based path not easy to fine this drawbacks overcome we proposed and implement one type of scheduling algorithm called shortest first job with help of infrastructure less network. This leading algorithm is overcome above issue of security issue in the wireless sensor networks problems, because of finding best cost and distance unbreakable path between sender to receiver simulated using NS2.

Keywords: SJF algorithm, emptive algorithm, turnaround time, average waiting time, NS2 Simulator, Wireless Sensor Network, GPS, Black holes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PRIORITY QUEUING FOR TEMPORARY WIRELESS COMMUNICATION

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ABSTRACT: Air medium based dipole networks increased in security-critical applications, because of their inherent resource-constrained characteristics, they are prone to various security attacks, and a Grey-hole attack is a type of attack that seriously affects data collection. To conquer that challenge, an active detection-based security and trust routing scheme named Active Trust is proposed for WSNs. Route security in priority queuing in scheduling algorithm using NS2 Simulator. In this work, perform of priority queuing algorithm is evaluated to attain quality of Service (QoS).

KEYWORDS: Priority queuing, NS2, Wireless Sensor Network, GPS, Black holes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BLACK HOLE ATTACK FOR MANET USING HYBRID ROUTING PROTOCOL

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Abstract: MANETs consist of a hop-to-hop, self-arrangement and self-configure network in contrast to a mobile network has a central controller. The solutions may not always be sufficient, as ad-hoc networks have their own vulnerabilities that cannot be addressed by these IDS solutions. In the network, some active attacks un-forward capacity nodes pretend to be intermediate nodes of a route to some given targets, drop any packet that subsequently goes through it, is one of the main types of attack. In this paper, they propose black-hole attacks an analysis method to detect malicious nodes in MANETs, the mechanism is cooperative hence the protocol work cooperatively together so that they can analyze, detect malicious nodes in a reliable manner. To verify our developed scheme by running through Network Simulations 2 (NS2) with mobile nodes using hybrid routing protocol namely, Modified - Zone based Hierarchical Link State (M-ZHLS) routing protocol. It is observed that the black hole and malicious node detection rate is very good, reduced average delay and also increased packet delivery ratio compare Zone based Hierarchical Link State (ZHLS) routing protocol when there is a change of mobility speed and varying topology size.

Keywords: MANET, Black hole, M-ZHLP, PDR, Overhead, Throughput.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A REVIEW OF SATELLITE INTERNET & STAR LINK FOR LOW EARTH ORBIT

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Abstract - Internet services are now part of humanity's basic infrastructure and an important means of delivering awide variety of public services to the world's people. Currently, about 4 billion people, more than half the world's population, do not have access to reliable Internet networks. And that is because the tradition always to deliver the Internet fibre-optic cables or wireless networks cannot take it everywhere on Earth. In many remote areas or places with difficult terrain, it is not feasible or viable to set up cables or mobile towers.

Keywords: Satellite, Internet, Uplink, Downlink, Issue.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MINI PROJECTOR COUPLED CAMERA FOR SIXTH SENSE TECHNOLOGY

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ABSTRACT: Sixth Sense Technology integrates digital information into the physical world and its objects, making the entire world your computer. It can turn any surface into a touch-screen for computing, controlled by simple hand gestures. It is not a technology which is aimed at changing human habits but causing computers and other machines to adapt to human needs. It also supports multi user and multi touch provisions. Sixth Sense device is a mini-projector coupled with a camera and a cell phone-which acts as the computer and your connection to the Cloud, all the information stored on the web. The current prototype costs around $350. The Sixth Sense prototype is used to implement several applications that have shown the usefulness, viability and flexibility of the system.

Keywords: Sixth Sense, Gesture, Portable, Cost.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SECURE WIRELESS MOBILE AD HOC NETWORKS USING REACTIVE DYNAMIC ROUTING

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Abstract: The frequent discoveries result in a lot of network congestion. To avoid this multipath routing protocols are planned to seek out multiple routes to destination and put on to alternate secondary path just in case of route broken and its offer higher routing performance and security. In this developed research paper attempt to compare the performance of two reactive routing protocols for MANETs that is Secure Dynamic Source Routing (SDSR) and Dynamic Source Routing (DSR), on-demand gateway discovery protocol where a mobile device of MANET gets connected to gateway. SDSR using the Intrusion Detection system (IDS) and trust based routing, the performance results are analysed by varying simulation time. Furthermore, all the above mentioned protocols are compared based on several important performance metrics which are packet delivery ratio, end-to-end delay and average energy.

Key words: MANET, IDS, DSR, SDSR, PDR, Delay, Energy.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECTIVE COMMUNICATION VARYING PARAMETERS FOR MOBILE AD HOC NETWORKS

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Abstract - Continuous transmission of small packet is called beacon packet, that advertises the presence of a base station and the mobile units sense the beacons and attempt to establish a wireless connections. Basing their forwarding decisions only on the local topology, geographic routing protocols have drawn a lot of attentions in recent years. MANET nodes square measure distinguished by their restricted resources like multi-path communication, end-to-end delay, routing conjunction, remaining energy, bandwidth and storage. MANET routing is serious issue as a result of topology. In this emerging research article developed with my pervious published paper and proposed multipath work with three different topology size, three different set of nodes, three different set of malicious nodes with various parameters such as packet delivery ratio, throughput, routing overhead, packet loss, delay and remaining energy via Network Simulator 2 (NS2).

Keywords: MANET, Attack, Energy, Routing Protocols, Network Simulator.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A STUDY OF FUZZY LOGIC CONTROLLER

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Abstract: Recently, there have emerged many fuzzy logic software and hardware products. In this work focus to give a comparative review of these resources and techniques and introduce the reader to the state of knowledge in fuzzy controller design research and education. Subjects such as fuzzy set theory, fuzzy logic, fuzzy ruled based expert systems, intelligent control, and fuzzy control will be studied. A number of case studies and applications of fuzzy controls, and some fuzzy logic hardware and software tools are pointed out.

Keywords: Fuzzy logic controller, Mobile Ad hoc network, Routing algorithm, Quality of Service, AODV, NS2.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PERFORMANCE COMPARISON OF FUZZY LOGIC CONTROLLER – A STUDY

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Abstract: Fuzzy controllers over the classical ones have been demonstrated by recent results in diverse application domains as well as the surge of commercial products to worldwide consumer market. Fortunately, this area finally found its long-expected place in academia and industry, after its first introduction about thirty years ago. Recently, there have emerged many fuzzy logic software and hardware products. In this work focus to give a comparative review of these resources and techniques and introduce the reader to the state of knowledge in fuzzy controller design research and education. Subjects such as fuzzy set theory, fuzzy logic, fuzzy ruled based expert systems, intelligent control, and fuzzy control will be studied. A number of case studies and applications of fuzzy controls, and some fuzzy logic hardware and software tools are pointed out.

Keywords: Fuzzy logic controller, MANET, Routing algorithm, QoS, NS2.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A REVIEW OF SHORTEST PATH NETWORK

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Abstract: Performance of the network can be enhanced through shortest path routing but it also depends upon the functionality of the routing protocol and the parameters that are selected for the shortest path routing. The primary goal of such an ad-hoc network routing protocol is correct and efficient route establishment between a pair of nodes so that messages may be delivered in a timely manner. Route construction should be done with a minimum of cost, overhead and bandwidth consumption. Some of researchers explored the concept of shortest path routing over ad hoc network. Each one uses his own parameters with different topology.

Keywords: Ad-hoc network, Routing Algorithms, Bellman Ford, Dijkstra, MANET Routing Protocol problems, Shortest Path.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ASSESSING WIND POTENTIAL AS A PANACEA FOR SUSTAINABLE RURAL AND URBAN POWER USAGE.

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Abstract

Rural and urban electricity supply in Nigeria has been a major crisis. Not only the supply is inadequate, but the urban to rural electricity connectivity ratio is very wide where about 76% of rural communities in Nigeria are not connected to the National grid as at 2020. This research presents an evaluation of wind power potential in Kebbi State, Northwestern Nigeria based on the Weibull model using 10 years monthly wind speed recorded data spanning from 2011 to 2020 at 10 m height obtained from Nigeria Meteorological Agency (NiMet Abuja). Its mean annual wind speed is 12m/s. The monthly variation recorded for the speed is maximum 16.75m/s in September whiles the minimum 10.07m/s in January. It is observed that the study area and environs falls into class 7, which is considered suitable for wind power generation with annual mean power density ranges from 152.8w/m to 297.8w/m. This result indicates that, it is ideal for grid connection and application. The study area lies in the northwestern part of Nigeria, with latitude 12.4318^0N, and longitude 4.1956^0E with an elevation of 235 m above sea level.

Keyword: Assessment, Greenhouse Gases, Power, Sustainable, & Wind speed.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ANALYSIS OF KNEE ANGLES IN INSTEP AND OUTSIDE KICKING TECHNIQUES IN FOOTBALL

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ABSTRACT

This study investigates knee flexion angles during two key football kicking techniques: the instep kick and the outside kick. Eleven football players from the Central University of Rajasthan, aged 21 to 23, were analyzed. Video recordings were made using smartphone cameras, and the Coach's Eye app facilitated precise angle assessment. The results indicate a significant difference in knee flexion angles between these techniques, with the instep kick displaying higher angles. This information has practical implications for optimizing kicking techniques, though larger sample sizes and consideration of other factors are recommended for future research. Additionally, excessive knee flexion in kicking may compromise stability and increase injury risk, emphasizing the importance of technique precision.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

THE IMPACT OF SURYA NAMASKAR EXERCISE ON AGILITY PERFORMANCE AMONG RESIDENTIAL JUNIOR FOOTBALL PLAYERS

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ABSTRACT

This study aimed to examine the effect of Surya Namaskar exercise on the agility performance of junior football players in the Sportto Football Academy in Wayanad, Kerala. A total of 20 players between the ages of 14 and 17 were chosen to participate in the study. The researchers focused on two main factors: the Surya Namaskar training (which was the independent variable) and agility (which was the dependent variable). Data was collected through tests conducted before and after a 6-week period of Surya Namaskar training. The participants underwent both the initial test and the final test.

The researchers used descriptive analysis and paired t-tests to compare the average agility scores before and after the training. They set a significance level of 0.05 to determine if any differences observed were statistically significant. The results of the statistical analysis showed that the calculated t-value (6.339) exceeded the tabulated t-value (2.024), and the P-value (0.000) was less than 0.05. This indicates that there is a significant difference between the scores obtained in the pre-test and post-test agility evaluations. In simpler terms, the study's findings clearly show a noticeable improvement in agility after the participants underwent the Surya Namaskar training.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COMPARATIVE ANALYSIS OF SPORTS COMPETITION ANXIETY: A STUDY OF UNIVERSITY-LEVEL FOOTBALL PLAYERS AT TWO DIFFERENT UNIVERSITIES IN INDIA

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Post graduation Student, Central University Of Rajasthan

ABSTRACT

This study examined and compared the levels of sports competition anxiety among male football players at two prestigious universities, the National Sports University Manipur and the Central University of Rajasthan. A sample of 40 participants, with 20 players from each university, was selected for the study. The researchers utilized Martin's (1990) Sports Competition Anxiety Test as a reliable measure to assess the anxiety levels experienced by the players. The collected data were analyzed using an independent t-test, facilitating a comprehensive evaluation and comparison of sports competition anxiety between university-level football players at the two institutions.

The results of the data analysis revealed that the calculated t-value of 1.984 was lower than the tabulated t-value of 2.00, and the corresponding p-value exceeded the significance level of 0.05. These findings lead to the conclusion that there is no significant difference in sports competition anxiety between the football players from both universities. Notably, comparable skill levels, competitive environments, training methods, expectations, and team dynamics likely contribute to the observed similarity in sports competition anxiety levels among university-level football players at the National Sports University Manipur and the Central University of Rajasthan.

Key words : anxiety, competition, football, player

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CRYSTALLINE CERIUM PHOSPHATE-GLASSY ZIRCONIUM TITANIUM TELLURATES COMPOSITES SELF-DOPED AND SELF-SUPPORT POLYMERIZATION OF BENZIMIDAZOLE-CO-ANILINE, BENZIMIDAZOLE-CO-PYRROLE

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ABSTRACT

Glassy zirconium titanium tellurates and crystalline cerium phosphate, $Zr_{0.9}Ti_{0.1}O(HTeO_4)_2.4.21H_2O$, $Zr_{0.8}Ti_{0.2}O(HTeO_4)_2.4.51H_2O$, (g-$Zr_xTi_{(1-x)}Te$) ,$Ce(HPO_4)_2$. $1.33H_2O$(CeP), respectively (x=0.9,0.8), were prepared and characterized by chemical, XRD. SEM and FT-IR spectroscopy. Solid-solid mixing of glassy zirconium titanium tellurates and crystalline cerium phosphate, in 33:67 wt./ wt% mixing ratios, respectively, lead to formation of novel [g-$Zr_xTi_{(1-x)}Te$]$_{0.34}$ $[CeP]_{0.66}$ composite. [g-$Zr_xTi_{(1-x)}Te$]$_{0.34}$ $[CeP]_{0.66}$ / polybenzimidazole-co-polyaniline, polybenzimidazole-co-polypyrrole composites were prepared and characterized by elemental (C,H,N) analysis, FT-IR, SEM and UV-Vis. spectroscopy. The formation of the conducting copolymers were promoted by the reduction of Ce(iv) ions present in the inorganic matrix [g-$Zr_xTi_{(1-x)}Te$]$_{0.34}$[CeP]$_{0.66}$. A possible explanation is part of CeP was attacked by the comonomers and converted to cerium orthophosphate ($Ce^{III}PO_4$). From elemental (C, H, N) analysis the amounts of organic materials % in wt. present in resultant [g-$Zr_{0.9}Ti_{0.1}Te$]$_{0.34}$[CeP]$_{0.66}$ / polybenzimidazole-co-polyaniline composite, found to be (PBI = 5.55, PAni = 6.84 % in wt.) , while for [g-$Zr_{0.8}Ti_{0.2}Te$]$_{0.34}$[CeP]$_{0.66}$ / polybenzimidazole-co-polyaniline composite were (PBI =4.89, PAni = 6;04 % in wt.). The amounts of organic materials % in wt. present in resultant [g-$Zr_{0.9}Ti_{0.1}Te$]$_{0.34}$[CeP]$_{0.66}$ / polybenzimidazole-co-polypyrrole composite, found to be (PBI = 6.71, PPy = 4.33 % in wt). while for [g-$Zr_{0.8}Ti_{0.2}Te$]$_{0.34}$[CeP]$_{0.66}$ / polybenzimidazole-co-polypyrrole composite were (PBI = 6.45, PPy = 4.26. % in wt), Electrical conductance of the resultant copolymer found to be in the range of semiconductors.

Keywords: crystalline cerium phosphate, glassy zirconium titanium tellurates, composites, self-support polymerization, benzimidazole-co-aniline and benzimidazole-co-pyrrole.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

UNVEILING THE IMPACT OF ELECTION RESULTS ON SOCIAL MEDIA DISCOURSE: TRENDS, SENTIMENTS, AND SOCIOPOLITICAL DYNAMICS

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Abstract

Ideologies, trends, and socio politics all play a complex role in shaping election results on the internet. Social media has a significant historical impact on elections and society by igniting discussions. This study looks closely at election outcomes to show the various ways they shape and influence conversations on social media. This methodology ensures a comprehensive and sound research plan by utilizing both qualitative and quantitative methodologies. generate a lot of content from social media sites related to the election by using data mining algorithms. This work uses natural language processing (NLP) algorithms to examine sentiment, trends, and patterns in election-related social media material in order to understand the dynamics of information transmission. Qualitative study investigates online discourse, revealing recurrent themes and complex concepts inside discussion boards. The results show how flexible the conversation around elections on social media is. They show how public opinion may change after elections, either from happiness to unhappiness or the other way around.

Research points to an increase in online narratives that both challenge and exaggerate socioeconomic gaps. These narratives give insight on sociopolitical processes that are impacted by the results of the midterm elections, either intensifying or reinforcing preexisting tendencies. Deciphering how social media, public opinion, and ideological arguments influence contemporary political discourse and human relationships is crucial to understanding.

Keywords: *Online Conversations Election, Results, Social Media Discourse, Sociopolitical Dynamic, Sentiment Interactions,*

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

"PHARMACOGNOSTIC ACTIVITIES OF A WILD EDIBLE MEDICINAL PLANT *LEEA MACROPHYLLA* ROXB. EX HORNEM."

Riya

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Abstract:

Plants have been absolutely necessary as food and good health of living beings since classical time. From human history it is clear to the eye, that plants are of great demanding in traditional along with modern medicines. By nature, plants produce secondary metabolites, also termed as phytochemicals or biologically active compounds, which are embrace in plant physiology, its protection mechanism or just act as waste products for the plants but might be of great importance to human beings.

The aim of this write- up is bird's eye view of the wild edible ethnomedicinal plant *Leea macrophylla* Roxb. ex Hornem., regarding all reported information and research works on this plant.

Leea macrophylla Roxb. ex Hornem. popular as Hastikarnapalasa, is a wild ethnomedicinal herbaceous shrub plant, owns its place to the botanical family Vitaceae. It is blessed with enormous ethnomedicinal importance also known to have several therapeutic properties due to the presence of numerous chemical compounds. This plant is used by mainly tribal people. As well, it is used in hodopathy, ayurveda, allopathic. The leaves of the plant look like an Elephant's ear. Hence, it is traditionally named as 'Hastikarna Palasa' by the local tribal people. It is rich in secondary & primary metabolites. These secondary & primary metabolites were screened through qualitative phytochemical. GC-MS was determined for the same to verify that the plant contains many chemical compounds whose biological activities includes: - Anti-inflammatory, Anti-androgenic, Anti-bacterial, Anti-fungal, Anti-oxidant, Anti-cancer, Anti-diabetic, and so forth. Antibacterial activity was concluded against *Pseudomonas aeruginosa* and *Staphylococcus aureus*.

Multiple studies verified that the plant possesses potential analgesic, neuropharmacological, anti-nociceptive, anti-thrombotic, wound healing, anti-urolithiatic, cardiotonic, hepatoprotective, neuroprotective activities, & many more. The tribal communities used the plant parts as a remedy for a number of ailments as well as nutritional products.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Keywords: Demanding, Hastikarnapalasa, GC-MS, Phytochemical, Antibacterial.

EFFICIENCY OF WHEAT STRAW BIOCHAR IN COMBINATION WITH COMPOST AND BIOGAS SLURRY FOR ENHANCING NUTRITIONAL STATUS AND PRODUCTIVITY OF SOIL AND PLANT

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Abstract

In the present study, we investigated the impact of different combinations of wheat straw biochar, compost and biogas slurry on maize growth, physiology, and nutritional status in less productive soils. The experiment was performed as a completely randomized block design in a greenhouse pot experiment. The compost and biogas slurry were applied with and without biochar. The results revealed that a combination of biochar, compost, and biogas slurry enhanced the cation exchange capacity (31%), carbon (83%), phosphorus (67%) and potassium (81%) contents in the soil. Likewise, a significant increase in soil microbial biomass carbon (15%) and nitrogen (37%) was noticed with the combined use of all organic amendments. Moreover, the combined application of biochar, compost and biogas slurry enhanced soil urease and β-glucosidase activity up to 96% and 67% over control respectively. In addition, plant height, chlorophyll content, water use efficiency and 1000-grain weight were also enhanced up to 54%, 90%, 53% and 21% respectively, with the combined use of all amendments. Here, biochar addition helped to reduce the nutrient losses of compost and biogas slurry as well. It is concluded that biochar application in combination with compost and biogas slurry could be a more sustainable, environment-friendly and cost-effective approach, particularly for less fertile soils.

Keywords: wheat straw biochar; **biogas slurry**; **compost**; **soil health**; **maize**

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BIOCHAR IMPROVES PHOSPHORUS USE EFFICIENCY OF ORGANIC-INORGANIC FERTILIZERS, MAIZE-WHEAT PRODUCTIVITY AND SOIL QUALITY IN A LOW FERTILITY ALKALINE SOIL

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Abstract:

Low and declining soil organic matter contents pose a significant threat to soil fertility, crop productivity and economic returns in arid and semi-arid agroecosystems. Holistic approaches are required to build and sustain soil organic matter in such soils to enhance nutrient use efficiencies and meet food security. Biochar is emerging as an attractive option for multiple benefits to soil-plant systems and carbon sequestration, especially in low fertility soils. We conducted a two-year maize-wheat rotation field experiments during 2015 and 2016 to test the effects of biochar on crop productivity, soil properties and phosphorous use efficiency (PUE) when applied with organic P sources as either farmyard manure (FYM) or poultry manure (PM) and diammonium phosphate (DAP) chemical fertilizer. Biochar was applied at two rates (0 and 10 t ha−1) whereas percentage of organic-inorganic P sources were 0, 25, 50 and 100% respectively. Biochar and manures were incorporated only once at the start of the field experiments whereas chemical fertilizers were applied during each crop cycle. Analysis of the two-year data revealed that biochar and P sources significantly and positively changed crop and soil quality attributes. Application of biochar significantly increased biological and grain yields of maize and wheat, soil organic carbon (SOC), and available nitrogen (N) and P contents without any negative effects on soil pH and electrical conductivity (EC). Addition of 50% P each from organic (FYM or PM) and chemical fertilizer increased biological and grain yields of maize, however, wheat biological and grain yields were higher with 100% PM or FYM in the presence of biochar. SOC and P contents were the highest when biochar was integrated with 100% P from FYM under maize crop. Biochar enhanced PUE from organic P sources more than the chemical fertilizer for both crops. Grain and biological yields of both crops correlated positively with SOC, soil N and soil P contents. We also found strong correlations between SOC, PUE and harvest index (HI) suggesting the benefits of increasing SOC contents under biochar-related integrated nutrient management practices. Overall results from these field experiments indicate potential of biochar to

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

enhance plant nutrition, crop productivity and soil quality in nutrient poor alkaline calcareous soil under maize-wheat cropping system. Long-term farmers' participatory field experiments, however, are required to extrapolate the potential of biochar integrations into current cereal-based cropping systems of Pakistan.

Keywords: Biochar, P sources, Maize, Wheat, Phosphorus use efficiency

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EXAMINING THE IMPACT OF INTERSPACING *MEGATHYRUS MAXIMUS* WITH LEGUMES ON AGRONOMIC PARAMETERS AND NUTRIENT CONTENTS

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Abstract

This study examins 50 and 75 cm spacing interval of *Megathyrsus maximus* interplanted with Legumes and its effect on agronomic parameters and nutrient contents.

The study is a16 weeks finding, carried out at the Teaching and Research Farm, Ladoke Akintola University of Technology, Ogbomoso, Nigeria. Its intent is to determine biomass yield (BMY), dry matter yield (DMY) and Crude protein content (CP) of *Megathyrsus maximus* (Mm) interplant with *Tephrosia bracteolata* (Tb) T_1 and *Crotalaria ochroleuca* (Co) T_2 at 50 cm and 75 cm spacing. Results shows that, 12 weeks old T_1 had 72. 85 kg/ha BMY, 44. 65 kg/ha DMY at 50 cm and 70.84 kg/ha BMY, 42. 80 kg/ha DMY at 75 cm, while T_2 had 53. 78 kg/ha BMY, 35. 52 kg/ha DMY at 50 cm and 36. 43 kg/ha BMY, 30. 71 kg/ha DMY at 75 cm. In the same vain 16 weeks T_1 records 263. 33 kg/ha BMY, 67. 42 kg/ha DMY at 50 cm and 226. 05 kg/ha BMY, 78. 09 kg/ha DMY at 75 cm. 12 weeks T_1 CP records 8. 44 % CP at 50 cm and 6. 72 % CP at 75 cm. CP for T_2 records 10. 20 % at 50 cm and 6. 14 % at 75 cm 12 while 16 weeks T_1 records 21. 84 % CP at 50 cm and 20. 87 % CP at 75 cm. T_2 has 20. 09 % CP at 50 cm, 20. 09 at 75cm spacing. Base on the results, the study recommended interplant of *Megathyrsus* with *Tephrosia* at 16 weeks on 50 cm spacing for good and maximal forage production.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

MYCORRHIZAE-RHIZOBACTERIAL INTERACTION TO ENHANCE THE GROWTH, DEVELOPMENT, NUTRIENT CONTENT, AND PHYSIOLOGICAL ATTRIBUTES OF OKRA IN COMPOST AMENDED SOIL

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Abstract

Soil fertility, soil quality, and crop yield decline due to the misuse of chemical fertilizers. Eco-friendly strategies based on biological or organic procedures can mitigate the harmful effects of agrochemicals on the environment. A more effective option for boosting plant development and production is the use of Arbuscular mycorrhizae fungi (AMF) and plant growth-promoting bacteria (PGPR). Therefore, a completely randomized design (CRD) pot experiment was carried out to assess the efficacy of AMF, PGPR, and their interaction in enhancing okra's growth, physiology, nutrient absorption, and yield, with and without the addition of compost. While both AMF and PGPR improved the traits that were tested, the results showed that combined inoculation of the two was far more effective than either inoculation alone or the control treatment at increasing fresh and dry weight, plant length, fruit yield per plant, chlorophyll A and B, and carotenoids. The combined application of AMF and PGPR significantly enhanced the plant height (48.4%), the number of okra fruits (87.4%), fresh weight (60.7%), dry weight (83.2%), and P (63.2%) without compost but the maximum increase in N (55.5%) and K (64%) concentrations, stomatal conductance (22.1%), transpiration rate (2.7 times), photosynthetic (1.4 times), water use efficiency (1.1 times) was found under combined inoculation of AMF and PGPR in compost amended soil. Pearson correlation showed that the plant height, number of okra fruits, and fresh and dry weight were significantly associated with chlorophyll a, chlorophyll b, carotenoid, water use efficiency, and P concentration. The PLS-SEM showed that the 88% shift in nutrient concentration and 98.5% variation (indirectly) in growth and yield can be elucidated by the addition of microbes under compost amendment. The PCA results concluded that the studied attributes were improved under the integrated application of AMF and PGPR, especially in compost-amended soil.

Keywords: soil fertility, soil quality, phosphorous, physiology

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PROXIMATE COMPOSITION OF *BRACHIARIA RUZIZIENSIS* AS AFFECTED BY COW DUNG AND CUTTING STAGES IN THE SUDAN SAVANNAH ZONE OF NIGERIA.

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Abstract

The study was carried out to investigate the proximate composition of *Brachiaria ruziziensis* as affected by cow dung application and cutting stages. The research was conducted in Nigeria's Sudan Savannah zone and the experiment was designed as a randomized complete block design with three replications in a 3 x 3 factorial arrangement with 3 levels of cow dung (5, 10 and 15t/ha) application as the main plot factor and three cutting stages (6, 8 and 10 weeks after planting) The results showed that cow dung rates and cutting stages significantly affected the proximate composition of *Brachiaria ruziziensis*. The crude protein of the grass increased as the rate of manure application increased and decreased with advancing cutting stages. The crude fiber content decreased with increasing cow dung rates and advancing cutting stages. The ash content increased with increasing cow dung rates and advancing cutting stages. The study concluded that cow dung application and cutting stages can be used to manipulate the proximate composition of *Brachiaria ruziziensis*, which can be beneficial for livestock production in the Sudan Savannah zone of Nigeria.

Key words: cow dung, proximate, cutting stage, *Brachiaria*, forage.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A COMPREHENSIVE STUDY ON THE KNOWLEDGE LEVEL OF FARM YOUTH REGARDING THE CROP INSURANCE SCHEME IN THANJAVUR DISTRICT

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Abstract

Agriculture is the backbone of India's economy, providing livelihoods to a significant portion of the population. However, the agricultural sector is susceptible to various risks such as natural calamities, pests, and diseases, which can adversely impact crop yields and farmers' incomes. To address these challenges and safeguard the interests of farmers, the Indian government has implemented the Pradhan Mantri Fasal Bima Yojana (PMFBY), a comprehensive crop insurance scheme. The PMFBY, launched with the objective of providing financial security to farmers, operates with several key features. One of its pivotal aspects is the premium subsidy, wherein farmers contribute a nominal premium and the remaining amount is subsidized by both the central and state governments. This ensures that the insurance coverage is affordable for farmers across the country. The scheme covers a wide array of crops, including food crops, oilseeds, commercial crops, and horticultural crops.

In the event of crop loss, farmers are entitled to receive the sum insured, and claims are settled based on actual yield data collected through crop cutting experiments. To expedite the process and ensure transparency, the scheme integrates technology, utilizing remote sensing technology, smartphones, and satellite imagery for a quicker assessment of crop losses. Hence, the present research study was taken up in Thanjavur district of Tamil Nadu, India. The sample size of 120 farm youths was selected by using snowball sampling technique. The results showed that the overall mean knowledge percentage on crop insurance was 47.04. Majority of the respondents (79.17 %) had knowledge on crop insurance scheme followed by purpose of crop insurance scheme (60.00 %), risks covered under the crop insurance scheme (54.17 %) and eligible criteria for crop insurance scheme (47.50 %). Majority of the farmers had knowledge on crop insurance scheme because the State Department of Agriculture created awareness about the crop insurance scheme.

Keywords: Crop Insurance Scheme, Agriculture, Knowledge Level & Farm Youth

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SELF-ADAPTIVE PHOTONIC THERMAL MANAGEMENT BASED ON A FLEXIBLE METASURFACE

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Abstract: As a new technology that uses thermal radiation to transmit the heat of objects to the universe through the transparent window of the atmosphere, radiative cooling has the advantages of zero energy consumption and zero pollution. However, most of the reported radiative cooling materials cannot sense the change of the ambient temperature and make corresponding thermal regulation behaviors independently. To address this issue, we propose a novel design based on flexible metasurface to realize the passive self-adaptive radiative cooling. By depositing flexible thermal expansion material in the sandwich structure, the metasurface can switch between 'ON' and 'OFF' states of radiative cooling function with the change of ambient temperature, and effectively control the absorption and reflection of electromagnetic waves in the atmospheric window, realizing flexible transformation of radiation cooling and insulation. Meanwhile, the cooler can achieve extremely low absorptivity across the entire solar spectrum for daytime cooling. This study is expected to provide practical solutions for the development of modern energy-efficient buildings.

Keywords: Self-adaptive Radiative cooling Photonic thermal management Flexible Metasurface

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DETERMINING THE VARIABILITY IN GROUNDWATER QUALITY AROUND THE NUBUAMIS HAZARDOUS WASTE DUMPSITE, WINDHOEK.

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Abstract

Water quality is a worldwide problem that affects human lives fundamentally. Water scarcity is intensified as a result of quality deterioration. Due to factors such as population increase, economic development, and waste disposal. Waste disposal and management remains' one of the major challenges in developing countries such as Namibia. Waste if not properly disposed of could lead to contamination of surface and groundwater in its immediate. The study determined if there is variability in groundwater quality around the Nubuamis hazardous decommissioned waste dumpsite, Windhoek. The main objective of the study was to assess if the decommissioned Nubuamis dumpsite has an impact on the variability of groundwater quality over the years (2012-2022). This study used the time series model to determine if there is a variation in groundwater quality around the Nubuamis hazardous waste dumpsite, in Windhoek. 21 parameters of water quality were studied such as pH, Temperature, TDS, Turbidity, $CaCO_3$, total alkalinity, Cl^-, SO_4^{2-}, F^-, Br, K, Mg^{2+}, Ca^{2+}, Na^+, Fe, EC, Mn, dissolved organic carbon, chemical oxygen demand, NH_3 and UV 254. The results revealed that the physico-chemical parameters of groundwater varied over time and were within the limits set by WHO and Namibian water quality which would pose no significant threat to domestic use. However, there seems to be a little contamination in the area as typified by the presence of Fe, TDS, EC, turbidity, total hardness, and Na^+ in high concentration. Groundwater has to be treated before being used for domestic purposes.

Key words: water quality, boreholes, Nubuamis dumpsite.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AN INTELLIGENT HEALTHCARE SYSTEM USING IOT IN WIRELESS SENSOR

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Abstract- The Internet of Things (IoT) uses wireless networks without infrastructure to install a huge number of wireless sensors that track system, physical, and environmental factors. There are a variety of WSN uses, and some well-known application factors include energy consumption and lifespan duration for routing purposes. The sensors have detecting, processing, and communication capabilities. In this paper, an intelligent healthcare system is proposed which consists of nano sensors that collect real-time health status and transfer it to the doctor's server. Time consumption and various attacks are major concerns, and some existing techniques contain stumbling blocks. Therefore, in this research, a genetic-based encryption method is advocated to protect data transmitted over a wireless channel using sensors to avoid an uncomfortable data transmission environment. An authentication procedure is also proposed for legitimate users to access the data channel. Results show that the proposed algorithm is lightweight and energy efficient, and time consumption is 90% lower with a higher security ratio.

Keywords: genetic-based encryption; nano sensors; authentication; transmission ; environment; Time consumption .

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COUPLING ADSORPTION-PHOTOCATALYTIC DEGRADATION OF SAFRANINE O DYE BY TERNARY NANOCOMPOSITE SUPPORTED ON NATURAL CLAY

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ABSTRACT

An attempt to degrade the organic dyes led to the development of n-p heterojunction photocatalysts based on TiO_2 supported on a local clay by-product in the context of the waste valorization, collected from Tinebdar-Bejaia for the photodegradation of basic red 2 (Safranine) dye into a non-harmful by-product. The heterosystems were easily prepared by the eco-friendly method using TiO_2 and two metal oxides with different oxidation states (+II) and (+III) as precursors, supported on a zeolite (Zn) by-product with different ratio: M(30%)/Zn(70%) and M(50%)/Zn(50%). Used for the first time in the photocatalytic water treatment sector.

The results show a high degree of crystallinity and an orderly distribution of the grains in the solid. The support on a zeolite increases the specific surface area, which improves the contact surface between the pollutant and the composite. The determination of the optical gap shows strong absorption of light in the visible range, allowing less energetic light-absorption and a lower rate of electron-hole recombination. The influence of the most critical parameters of the process, such as the material/clay ratio, the light nature (solar/ artificial light), and the effect of the presence of an oxidizing agent (PDS), were studied. The n-p catalysts provide excellent results in photocatalysis, with a removal efficiency of 80% under visible-light. The presence of PDS (25 ppm) improves the degradation yields up to 93.2%. As a result, the composite developed in this investigation can inhibit the ($\bar{e}$, h+) recombination. The synergy between both phenomena (adsorption - photocatalysis) enhances its catalytic activity.

Keywords: Clay, photocatalysis, sunlight, heterojunction, PDS .

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SFLT-1/PLGF AS A BIOMARKER OF PREECLAMPSIA (PE)

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ABSTRACT

Preeclampsia is a hypertensive disorder of pregnancy characterised by a triad of hypertension, proteinuria and edema occurring after 20 weeks of gestation in previously normotensive women. It affects 2-7% of all pregnancies leading to ~70,000 direct maternal deaths and ~500,000 perinatal deaths annually. Although the exact cause of preeclampsia is unknown, aberrant remodeling of the maternal spiral arteries is assumed to be the source of placental malperfusion. The anti-angiogenic factor, soluble fms-like tyrosine kinase 1 (sFlt-1) and the pro- angiogenic factor, placental growth factor (PlGF), can be measured in plasma and serum and are usually reported as a ratio, which specifically relates to the onset and severity of preeclampsia. Currently, there is no clear consensus on the practical use of angiogenic biomarkers in the detection and management of preeclampsia in routine clinical practice.

Key words: fms-like tyrosine kinase 1, placental growth factor, Preeclampsia

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

A THERAPEUTIC JOURNEY OF FURAN DERIVATIVES AS A VERSATILE SCAFFOLD

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Furan derivatives have emerged as a versatile and intriguing class of compounds with unique chemical properties that make them promising candidates for various applications in medicinal chemistry, materials science, and organic synthesis. This abstract provides a concise overview of the multifaceted nature of furan derivatives, focusing on their enigmatic and pulsatile characteristics. The enigmatic nature of furan derivatives stems from their diverse chemical reactivity, allowing for the synthesis of a wide range of functionalized structures. The ability of furan rings to undergo various transformations, such as cycloaddition reactions and functional group manipulations, has led to the development of diverse molecular architectures with applications in drug discovery and the design of advanced materials. Furthermore, the pulsatile behavior of furan derivatives refers to their dynamic and responsive properties, making them suitable for stimuli-responsive drug delivery systems and smart materials. Furan-based systems can exhibit controlled release profiles in response to specific environmental triggers, including changes in pH, temperature, or light. This pulsatile behavior is pivotal in the development of targeted and personalized therapeutic interventions.

This abstract highlights recent advances in the synthesis and applications of furan derivatives, showcasing their enigmatic and pulsatile attributes. The exploration of furan scaffolds in medicinal chemistry, coupled with their dynamic responsiveness, opens new avenues for the design and development of innovative materials and therapeutics with enhanced precision and efficacy. As researchers continue to unravel the mysteries of furan derivatives, their role as an enigmatic and pulsatile scaffold is poised to contribute significantly to the advancement of diverse scientific disciplines.

Keywords: Furan, drug discovery, cycloaddition reaction, therapeutic interventions.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EVALUATION OF SUSTAINABLE COMPOSITES OF SUGARCANE BAGASSE WITH MIXED ALGAE-SOY PROTEIN BINDERS

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Abstract

The development of new sustainably-sourced adhesives is essential in order to displace conventional particleboard adhesives which are petroleum-based. These conventional adhesives also formaldehyde and other toxic, volatile compounds. As a proposed sustainable composite material, particleboards prepared from bagasse, spirulina algae, soybean, and sodium hydroxide were fabricated. Statistical significance of the modulus of elasticity, modulus of rupture, yield stress, flow behavior index, lap shear strength, and internal bond strength on the algae content and denaturation time was determined. The algae content has a significant impact on the lap shear strength, yield stress, flow behavior index, internal bond strength, and modulus of rupture but the same was not applicable for the secant and tangent modulus of elasticity. The denaturation time has a significant impact on the flow behavior index but the same was not applicable for the yield stress, internal bond strength, and lap shear test. We meet the minimum requirement set by ANSI/A208.1-1999 for general-use particleboards for the modulus of elasticity and modulus of rupture but the same was not applicable for the internal bond strength.

Institution: University of Louisiana at Lafayette

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

QARABAĞIN FLORA VƏ FAUNASI

Kerimov Camal

1.Azerbaycan Müasir İnnovasiyalar Lisesi
2-Bioloji öyretmeni

Bitki örtüyü

Zəngin bitki örtüyünə malik olan ərazidə 2 000-dən çox bitki növünə rast gəlinir.

Dəniz səviyyəsindən 2000-2300 m-dən yüksəklikdə subalp və alp çəmənlikləri mövcuddur. Landşaft müxtəlifliyi baxımından əlverişli olan bu ərazilərdə 460 növdən çox yabanı ağac və kol bitkiləri bitir, onlardan 70-i endemik növ olub, dünyanın heç bir yerində təbii halda bitmir Bundan əlavə, son 30 ildə Azərbaycan Respublikasının "Qırmızı kitabı"na salınan ayıfındığı növündən ibarət meşələri və relikt bitki sayılan, Laçın Dövlət Təbiət Yasaqlığı ərazisində yayılan qırmızı palıd ağacları kütləvi surətdə qırılaraq mebel istehsalı üçün istifadə olunur və xaricə satılır. Meşələrdə ağac və kol bitkiləri ilə yanaşı, bənövşə, lalə, qızılgül, zanbaq, qərənfil, böyürtkən və s. cinslərə daxil olan birillik, ikiillik, çoxillik və soğanaqlı növlər təbii halda bitirdi. Xüsusəndə Ağdərə, Əsgəran, Xocavənd rayonları palıd, vələs, fıstıq və ağcaqayın meşələri ilə zəngin idi. Yüksək dağlıq hissələrdə şərq palıdına (Quercus majranthera), trautveter ağcaqayınına (Acer trautvetteri), tozağacının 4 növünə (Betula sp. Div), Şərq fıstığına (Fagus orientalis) rast gəlinirdi. Bu tip meşələrdə qeyd edilən bitkilik tipləri ilə yanaşı, bəzi yerlərdə su-bataqlıq bitkiliyinə də təsadüf edilirdi. Otlaq, meşə və kol massivləri arasında isə yerli əhali əsasən taxıl, bostan və texniki bitkilər becərirdilər.

Qarabağın faunası

Zəngin fauna müxtəlifliyinə malik bu ərazilərdə Azərbaycan Respublikasının "Qırmızı kitabı"na daxil edilən məməlilərin 4, quşların 8, balıqların 1, amfibiya və reptililərin 3, həşəratların 8, bitkilərin isə 27 növü yayılıb. Onlardan bəziləri Beynəlxalq Qırmızı Siyahıya daxildir. Qarabağ ərazilərində Avropadan Afrikaya, Asiyaya və əks istiqamətdə quşların vacib transqafqaz miqrasiya yollarından birini təşkil edir. Baş vermiş proseslə əlaqədar olaraq, torpağın üst münbit qatının sıradan çıxmasından əlavə burada məskunlaşan heyvanların yanması, quş yumurtalarının, balalarının tələfatına və həmin növlərin yaşayış yeri ilə əlaqəsinin birdəfəlik itirilməsinə, sayının kəskin azalmasına səbəb olur. Qarabağın 70 faizi sürünən heyvanların növ müxtəlifliyinin geniş yayıldığı ərazilərdir. Zoosenozların qida zəncirində əhəmiyyətli mövqe tutan amfibilər və reptililər ekosistemin fauna biomüxtəlifliyinin stabilliyində mühüm rol oynayırlar.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Qarabağ ərazilərində zəhərli ilan növü olan Levantin gürzəsi də geniş yayılıb. Burada floranın zənginliyi heyvandarlığın inkişafına da səbəb olmuşdur. Qış dövründə (altı ay ərzində) yüz minlərlə heyvan Kiçik Qafqazın aran rayonlarında otarılar, yayda isə heyvanlar 3-4 ay müddətində yay otlaqlarına köçürülərdilər. Belə bir sistem heyvanları bütün mövsümlərdə (qışda - səhra, yarımsəhra, bozqır, yayda - çəmən) yemlə təmin etməyə imkan verirdi. Göründüyü kimi vaxtı ilə Qarabağın florası və onun bitkiçiliyinin biomüxtəlifliyi dünyada analoqu olmayan rəngarəng şaquli zonallığı ilə fərqlənirdi. Qarabağ, həmçinin Azərbaycan Respublikasının "Qırmızı Kitabı"na daxil edilən safsar, çay samuru, qonur ayı, zolaqlı kaftar, qamışlıq pişiyi, çöl pişiyi, vaşaq, Qafqaz bəbiri, nəcib maral, cüyür, Bezoar keçisi kimi nəsli tükənmək təhlükəsində olan orta və iri ölçülü nadir məməlilər də az deyil.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

GREEN LOGISTICS PRACTICES: INTEGRATING RENEWABLE ENERGY AND SUSTAINABLE TRANSPORTATION ACROSS SUPPLY CHAINS

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Abstract

The adoption of green logistics techniques has the potential to completely transform supply chain management in a world where environmental sustainability is a must. To encourage a peaceful coexistence between trade and the ecosystem, this study focuses on the dynamic synergy between renewable energy sources and sustainable transportation methods within supply chains. The study looks into the various facets of "Green Logistics Practices: Integrating Renewable Energy and Sustainable Transportation in Supply Chains." Examining the viability, advantages, and difficulties of integrating renewable energy options and environmentally friendly transportation modes in supply chain operations is the main goal of this research. We can use electric or hybrid vehicles, bicycles, or even sustainable transportation options like trains and ships for longer distances. Hydro treated Vegetable Oil (HVO) is also good option for green logistics. This integration aims to improve the ecological integrity of logistics networks while simultaneously fostering cost savings and operational efficiencies by lowering the carbon footprint and eliminating reliance on non-renewable resources. This study analyzes the current frameworks, technologies, and best practices related to green logistics through a thorough examination of the literature. The study evaluates the concrete effects of adopting renewable energy on transportation networks, including emissions reduction, energy savings, and resilience against fluctuating fuel prices. It does this by using real-world case studies and quantitative analysis. The results of this study are of utmost significance for both academia and business. The study provides information to supply chain professionals, legislators, and environmental advocates looking to implement eco-friendly logistics solutions by revealing the possible alignment between sustainable practices and economic growth. "Green Logistics Practices: Integrating Renewable Energy and Sustainable Transportation in Supply Chains" represents a trailblazing avenue for fusing environmental stewardship and operational excellence. Additionally, this research emphasizes the need for collaboration and innovation in the face of logistical challenges, propelling discussions on novel methodologies and cross-sector partnerships. This research creates a greater knowledge of the

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

potential for sustainable logistics to transform the future of supply chain management by diving into the complex web of logistics networks and environmental dynamics.

LEVERAGING BALAKAN'S BIODIVERSITY FOR SUSTAINABLE TOURISM OPPORTUNITIES

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ABSTRACT

Balakan, located in northwest Azerbaijan, possesses diverse natural assets including forests, rivers, lakes, mineral spas, and mountains that provide favorable conditions for developing ecotourism. This paper examines Balakan's ecotourism potential to identify strategies for expanding sustainable tourism centered on appreciation of the region's ecological riches. The current limited tourism offerings, community context, protected areas, and natural attractions are analyzed to determine opportunities for strategic growth of specialized ecotourism activities. Findings suggest that regulated development of low-impact activities such as hiking, camping, boating, village tours, agritourism and more, combined with infrastructure upgrades and capacity building, can enable Balakan to leverage its biodiversity for economic gains while also supporting conservation goals. Collaborative tourism planning with local residents is recommended to ensure community-oriented development priorities. Realizing the area's potential sustainably requires controlled visitor numbers in vulnerable natural areas, training programs to build tourism sector jobs for locals, partnerships with travel firms for marketing, and impact monitoring to identify regulatory needs. Balakan contains diverse topography, endemic wildlife, preserves like the Ismailli Nature Reserve, and tourist sites like the Istisu mineral spas and Lake Zagatala. These natural riches offer abundant possibilities for activities like birdwatching, guided expeditions, wellness tourism, community-based agritourism, and more. With strategic planning focused on sustainability, Balakan can develop as a leading ecotourism destination that provides income for residents while protecting the environment. Further research should analyze optimal tourism capacities to prevent overcrowding. In conclusion, Balakan possesses tremendous natural assets that form a strong foundation for ecotourism growth if leveraged responsibly. Prudent planning and development can enable Balakan to showcase its ecological riches while bringing economic benefits to local communities.

Keywords: Azerbaijan tourism, Balakan, Ecotourism

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ECOTOURISM POTENTIAL OF ZAQATALA'S NATURAL LANDSCAPES

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ABSTRACT

Zaqatala, located in northwest Azerbaijan, possesses diverse natural assets including mountains, forests, lakes, rivers, endemic wildlife, and the Zaqatala Nature Reserve. These features provide favorable conditions to develop ecotourism centered on appreciation of the region's ecological riches. This paper examines Zaqatala's prospects for growing as an ecotourism destination, analyzing the current limited tourism offerings, community context, protected areas, and natural attractions to identify sustainable growth strategies. Findings suggest regulated expansion of low-impact activities such as hiking, camping, birdwatching, boating, and community-based tourism can enable Zaqatala to leverage its natural splendor for economic gains while pursuing conservation goals. Strategic infrastructure upgrades, capacity building, marketing, and resident engagement in planning are recommended to support ecologically and socially responsible ecotourism. Zaqatala contains scenic landscapes spanning the Greater Caucasus Mountains, with rich biodiversity and tourist sites like Lake Zagatala. These assets provide a foundation for specialized activities like wildlife viewing, trekking expeditions, forest therapy retreats, agritourism programs, and more. Sustainable development requires participatory planning with locals to determine ecotourism goals, visitor education, controlled access to fragile areas, partnerships with travel firms, and impact monitoring. With careful management, Zaqatala can grow successful community-oriented ecotourism that showcases its natural beauty while supporting environmental protection and bringing new vitality to local economies. Further research should analyze carrying capacities to identify optimal sustainable tourism levels. In conclusion, Zaqatala possesses tremendous natural capital that can be leveraged through strategic ecotourism development focused on conservation. Embracing sustainability principles will allow Zaqatala to benefit economically and environmentally by harnessing its magnificent nature responsibly.

Keywords: Azerbaijan tourism, Ecotourism, Zaqatala

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ECOTOURISM POTENTIAL OF SHUSHA'S NATURAL LANDSCAPES

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Abstract

Shusha, a city in Azerbaijan's Karabakh region, contains diverse natural landscapes. This paper assesses Shusha's prospects for growing ecotourism focused on its ecological and cultural assets.

Introduction

Ecotourism involves responsible travel focused on exploring nature that sustains both ecosystems and local people (Honey 2008). As Azerbaijan grows its tourism industry, the city of Shusha provides favorable conditions for ecotourism growth based on its natural beauty.

Shusha's Natural Features

Shusha is situated on the Karabakh Plateau, surrounded by dense forests, mountain rivers, and the iconic waterfalls of Lachin Valley (Abbasov et al. 2021). Shusha's unique is natural attributies and strong foundation.

Tourism Overview

Tourism in Shusha is currently limited, having faced past constraints of restricted access and lack of infrastructure investment. Basic accommodations include a few hotels and guest houses (Mammadzade 2022).

Ecotourism Opportunities

Shusha offers prime conditions for activities like:

Guided hiking, mountain biking, and horseback riding through forests

Agritourism with community homestays, and village tours

Strategic Recommendations

To develop ecotourism sustainably, Shusha should:

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

Engage in participatory tourism planning with residents to identify development priorities and manage growth

Partner with tour operators to market specialized ecotours and enforce sustainability standards

Conclusion

Shusha possesses tremendous natural assets combined with cultural heritage to establish itself as a leading ecotourism destination in Azerbaijan.

References

Abbasov, T. et al. (2021). Fauna of the Karabakh floristic region of Azerbaijan. Eurasian Journal of Biosciences, 15(2), 2837-2845.

Honey, M. (2008). Ecotourism and Sustainable Development: Who Owns Paradise? Island Press.

Mammadzade, L. (2022). Evaluation of ecotourism resources in Shusha city. International Journal of Innovations in Engineering Research and Technology, 9(6), 101-108.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

EFFECT OF FILLER LOADING ON SOME PHYSICAL AND MECHANICAL PROPERTIES OF YAM PEEL POWDER WITH UNSATURATED POLYESTER RESIN COMPISITE

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Abstract

This study investigates the effect of filler loading on the physical and mechanical properties of Yam peel powder (YPP) reinforced Unsaturated Polyester resin composites. Samples with different weight percentage of YPP 10, 20,30,40, and 50%) respectively were prepared and their mechanical properties such as tensile strength, impact test and water absorption test were measured according to ASTM standards. The results indicate that, the mechanical properties of YPP reinforced decreases significantly, the decrease in Young modulus observed from the samples is due to disruption of three-dimensional structure of polymer composites thereby making the polymer to be highly regid, which means the composite polymer cannot be recommended for as a reinforcement composite rather can be used as a filler. The filler loading plays a significant role in determining the physical properties and mechanical properties of Yam peel powder / Unsaturated Polyester resin composites.

Keywords: Unsaturated Polyester, Yam Peel Powder, Filler Loading, Mechanical Properties, & Composite

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

REMOVAL OF EMERGING CONTAMINANTS BY ADVANCED OXIDATION COUPLED DENITRIFICATION FROM WASTEWATER

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ABSTRACT

The effective management of pharmaceutical wastewater is of paramount importance to mitigate its adverse impacts on both human health and the environment. This study delves into the advanced degradation and removal of two prevalent antibiotics, Ampicillin and Ciprofloxacin, from pharmaceutical wastewater. Employing a combination of ozonation and hydrogen peroxide (H_2O_2) treatments, the research explores the influence of various retention times (HRTs) i.e. (10, 30, 60, 80,120 min) in continuous mode on the efficacy of antibiotic removal. The results demonstrate that a retention time of 80 minutes yields exceptional removal efficiency of antibiotics. Subsequent denitrification of the 60-minute treated sample showcases the potent synergy between treatment processes. Utilizing High-Performance Ion Chromatography (HPIC) analysis, the study proceeds with the denitrification process which reveals complete toxicity elimination. This underscores the pivotal role of ozonation coupled with hydrogen peroxide treatment, followed by denitrification, in achieving comprehensive antibiotic degradation and detoxification. The findings accentuate the significance of innovative treatment techniques in addressing the escalating concern of pharmaceutical wastewater. By effectively diminishing antibiotics and diminishing toxicity, the proposed approach contributes not only to environmental preservation but also to safeguarding human and animal well-being. Overall, this research sheds light on wastewater treatment strategies, underscoring the necessity of integrating diverse treatment modalities to ensure holistic pollutant degradation and removal.

Keywords: antibiotics; advanced oxidation; denitrification; **master culture reactor**

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

FOR CLASSES VI-VII ON THE CONTENT LINE "ANIMALS AND ENVIRONMENT" OPPORTUNITIES FOR IMPARTING ENVIRONMENTAL KNOWLEDGE

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Abstrakt

According to estimates, the number of people on Earth has more than doubled in the last 40 years and has exceeded 7 billion. Such a rapid increase of the population increases the demand for industrial and agricultural products, requires the expansion of the industry and the creation of new jobs. This eventually intensified the destructive effect on the environment and led to the disturbance of the ecological balance. Currently, as a result of people's blind and rapid use of nature, many natural resources are depleted, most of them are about to be depleted, the environment is excessively polluted, some living things are extinct or about to be extinct, all this shows that the destructive effect of humans on the environment is increasing. For this purpose, it is very important to provide a wide range of environmental knowledge in grades VI-VII.

Key words: Canlı, ətraf mühit, ekoloji bilik, sinif, məzmun xətti.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

“Canlılar və ətraf mühit” məzmun xətti üzrə VI-VII siniflər üzrə ekoloji biliklərin verilməsinin imkanları

Xülasə

Hesablamalara görə, son 40 ildə Yer kürəsində sayı 2 dəfədən çox artaraq 7 milyardı keçmişdir. Əhalinin belə sürətlə çoxalması sənaye və kənd təsərrüfatı məhsulllarına tələbatı artırır, sənayenin genişləndirilməsini, yeni iş yerlərinin yaradılmasını tələb edir. Bu isə sonda mühitə dağıdıcı təsiri gücləndirərək, ekoloji tarazlığın pozulmasına gətirib çıxarmışdır. Hazırda insanların təbiətdən kor-koranə və sürətlə istifadə etməsi nəticəsində bir çox təbii ehtiyatların tükənməsi, əksəriyyətinin isə tükənmək üzrə olması, ətraf mühitin həddindən artıq çirkləndirilməsi, bəzi canlıların nəslinin kəsilməsi, yaxud kəsilmək üzrə olması, bütün bunlar insanların ətraf mühitə dağıdıcı təsirinin çoxaldığını göstərir. Bu məqsədlə VI-VII siniflərdə ekoloji biliklərin geniş verilməsi çox əhəmiyyətlidir.

Açar sözlər: Living, environment, environmental knowledge, classroom, content line.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

AN EXPLAINABLE A.I FOR INTEGRATION OF KNOWLEDGE MANAGEMENT SYSTEMS AND INDUSTRIAL REVOLUTION 4.0. (IR4.0) TECHNOLOGIES

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Abstract

Technology, automation, and data-driven decision-making have significantly advanced with the onset of the Industrial Revolution 4.0. The efficient integration of knowledge management systems (KMS) becomes essential as firms work to use these technologies to improve their business values. In order to facilitate the seamless integration of KMS with technologies from the Industrial Revolution 4.0, this project seeks to present an explainable artificial intelligence (XAI) framework. This framework will support increased business values by enhancing knowledge usage and decision-making processes. The suggested framework takes a comprehensive approach to combining the advantages of KMS and technologies from the Industrial Revolution 4.0, including the Internet of Things (IoT), big data analytics, artificial intelligence, and machine learning. The framework uses XAI methodologies to improve decision-making processes' transparency, interpretability, and trustworthiness. This facilitates the efficient use of knowledge and value generation inside businesses. A thorough assessment of the literature on XAI, knowledge management, and Industrial Revolution 4.0 technologies will be part of the research process. The suggested XAI framework will be developed based on the observed gaps and difficulties. The framework will be put through a proof-of-concept implementation using data from firms that have used KMS and Industrial Revolution 4.0 technologies in real-world case studies. In order to measure the framework's success in boosting business values and decision-making processes, qualitative and quantitative analyses will be used.

Keywords: Explainable Artificial Intelligence, knowledge management systems, Industrial Revolution 4.0, Internet of Things, decision-making, business values.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

BEST PRACTICES FOR REDUCING AFLATOXIN CONTAMINATION IN PEANUT PROCESSING

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Abstract :

Aflatoxins are toxic secondary metabolites produced by fungi in the genus Aspergillus, including A. flavus, A. parasiticus, and A. nomius. These fungi grow naturally on food products, and the aflatoxins they produce cause a variety of toxic effects in vertebrates, including humans. Aflatoxin contamination of peanuts and peanut-based products is a significant concern because it is associated with carcinogenicity and toxicity.

In-site investigations have shown that the lack of good agricultural, hygiene, and manufacturing practices is mainly responsible for high levels of aflatoxins. The study aimed to investigate the effectiveness of good agricultural, hygiene, and manufacturing practices in minimizing aflatoxin contamination of peanuts and peanut-based products. The study found that the implementation of these practices can significantly reduce aflatoxin contamination throughout the peanut processing chain. The following are some of the effective approaches for minimizing aflatoxin contamination: Managing official controls of good hygiene practices and prevention of aflatoxin contamination, awareness creation and education on good agricultural practices to reduce aflatoxin contamination, improvements in the peanut production chain, including the adoption of Good Agricultural Practices (GAPs) and proper drying and shelling methods, sampling and testing peanuts and peanut-based products for aflatoxin, moisture, grade, and microbiological testing to prevent contamination, compliance with global aflatoxin legislation and regulations for peanuts and peanut products, use of resistant peanut varieties, timely irrigation and fertilization practices, monitoring and controlling pests and diseases, proper cleaning and sanitation practices.

By implementing these best practices, peanut processors can minimize the risk of aflatoxin contamination and ensure the safety and quality of their products.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PRETREATEMENT OF MELANOIDINS USING ADVANCED TECHNIQUES TO ENHANCE DECOLORIZATION AND ANAEROBIC DIGESTION

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ABSTRACT

The distillery waste water contain dark brown colored recalcitrant compounds collectively termed as melanoidins. Untreated distillery effluent or spent wash are well known to cause pollution in the natural streams by increase in organic load, depletion of oxygen content, discoloration and destruction of aquatic life. This study was conducted to degrade the synthetic melanoidins to enhance color removal and anaerobic digestion. Three pretreatments were done, ozone, ozone+H_2O_2 and sonication. As these recalcitrant compounds are difficult to be degraded anaerobically, so advanced pretreatments were involved to make easily degradable. Ozonation experiment were carried out in the lab. Ozonator was feeded with oxygen from the oxygen cylinder, ozonator was turned on and it started to produce ozone at a fixed rate of 3g/h which was supplied to 100 ml melanoidins solution from one point and the residual ozone was guided towards KI solution where it was destroyed. The samples were taken at 5, 10 and 15 minutes for the analysis of COD color. Ozone+H_2O_2 was also done with the same way just 1 ml H_2O_2 was added. In sonication, sonicator worked at a frequency of 40 Hz. It was observed that ozone removed a maximum of 20% color and COD removal of 27% at 15 minutes. Ozone+H_2O_2 were able to remove 28% color and 30% COD at 10 minutes. While in sonication, 54% COD and 11% color were removed at 120 and 60 minutes. Treated samples digested anaerobically digestion and it was found that a maximum of 325 ml CH_4 was produced from ozone+H_2O_2 treated sample. It is concluded from the work that ozone+H_2O_2 is the best advanced technique in degrading melanoidins.

Keywords: Anaerobic digestion. Ozonation. Ozone+H_2O_2. Sonication. Melanoidins. Decolorization.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

CHITIN AND CHITOSAN PRODUCTION FROM LOCAL SQUID PEN

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ABSTRACT

Moroccan industrial fish processing waste significantly contributes to pollution. Nevertheless, it holds a substantial content of chitin—a well-known versatile biopolymer. This study explores an efficient extraction method for obtaining chitin and chitosan from local squid waste, employing various characterization techniques to evaluate their structural and physicochemical properties. Chitin was extracted from squid pens through a two-step process involving the removal of minerals and proteins, while chitosan was derived via chitin deacetylation. X-ray Diffraction unveiled the crystalline natures of chitin and chitosan, complemented by Scanning Electron Microscopy that illustrated their distinct morphological features. Potentiometric Titration quantified chitin's conversion into chitosan. Hygroscopy and water absorption studies provided insights into their water interaction behavior, vital for potential applications in biomedicine and packaging. This research underscores squid pens potential as a valuable source of chitin and chitosan, while offering a comprehensive characterization, thereby contributing to waste reduction and sustainable resource utilization in Morocco.

Keywords: Waste management, Chitin, Chitosan, Sustainable materials.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

ASSESSMENT ON THE IMPLEMENTATION OF SECTION 59 OF THE ELECTRIC POWER INDUSTRY REFORM ACT OF 2001 TOWARDS POLICY ENHANCEMENT

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ABSTRACT

Electrification has been one of the Philippine Government's major priorities since electricity access is a main component to attain economic development and improve living standards. Having electricity provides lighting for educational activities, access to life information, and entertainment, especially in the countryside and remote areas. Electricity also provides opportunities for income-generating activities which can lead to commercial development and social growth. Hence, the government made significant investments on several electrification reforms and programs to achieve its long-term developmental goals. To attain wide-scale electricity access, rural electrification is pursued by the government, especially in remote rural areas which have contributed to the high poverty incidence in the country. Further, the geographic characteristics of the country have been a challenge to bring electricity to the remote rural areas requiring greater initiatives from the government. Through Republic Act No. 9136, or the Electric Power Industry Reform Act of 2001 (EPIRA), public-private partnership is promoted to encourage private sector investment in rural electrification and is further supplemented under EPIRA's Section 59 allowing electric services by alternative service providers, or Qualified Third Parties (QTPs), in remote and unviable areas, a key component for electricity access and economic growth. However, since the issuance of the necessary policies, the QTP Program has achieved little progress and minor contributions to the country's electrification efforts which aim to achieve 100% household level electrification. This study is an assessment on the implementation of Section 59 of the EPIRA towards policy enhancement to increase private sector investment in providing electric services to more households in the remote and unviable areas. Further, this study aims to contribute to the field of public administration and to the research agenda of the Polytechnic University of the Philippines (PUP) aimed at social development for inclusive national growth.

Keywords: Rural electrification, private sector investment, economic development, poverty, geographic challenge, public administration, research

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

DETERMINATION OF COLIFORM BACTERIA IN MEAT PRODUCTS MARKETED IN KOSOVO

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ABSTRACT

Due to their high nutritional value, meat products can be prone to deterioration as a result of microbial growth ranging from spoilage to pathogenic microorganisms. Coliform bacteria present a suitable indicator of meat bacterial contamination such as fecal bacteria. The present study aimed to investigate the microbiological stability of meat products marketed in Kosovo through monitoring coliform bacteria. For this, 40 meat samples from five different cities of Kosovo have been analyzed for total coliform bacteria. According to our results, 82.5 % of the analyzed meat samples resulted to be contaminated by coliform bacteria, from which 2 samples were non-countable. The mean coliform colonies from all the analyzed meat samples were approximately 8.5×10^3 CFU/g. The most contaminated meat products with coliforms resulted to be meatballs and beefburger. Meanwhile less contaminated meat products with coliforms were minced meat and sausages. Around 20 % of all analyzed samples had higher than 4 log CFU/g total coliform bacteria which present a risk for the microbiological safety of meat products. Therefore, it is recommended that the National Authority of Food Safety in Kosovo must conduct continuous microbiological assessments and take strict monitoring on hygienic practices of production processes of meat products.

Keywords: coliform, meatballs, fecal bacteria, beefburger.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COMBINED EFFECT OF SOUS VIDE AND FROZEN STORAGE ON TEXTURE ATTRIBUTES OF CHICKEN BREAST

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ABSTRACT

Minimal processing technologies such as sous vide treatment have been shown to be very effective in improving the quality properties of meat such as water holding capacity and texture. Depending on the sous vide parameters, these products must be maintained at strictly controlled refrigerated temperatures or at frozen storage. The present study is focused on examining the combined effect of one step or two step sous vide and frozen storage on texture attributes of chicken breast. According to our study, frozen storage at -20 °C had significantly decreased the shear force values on all the studied sous vide chicken breast ($P < 0.05$). Botinestean et. al. (2016) reported a positive effect of freezing on lowering the shear force values of sous vide cooked beef steaks. Two-step sous vide cooked chicken breast remained tender than one-step sous vide ones having significantly lower shear force values even after 21 days of frozen storage at -20 °C ($P < 0.05$). Hardness, gumminess and chewiness values of sous vide cooked chicken breast were significantly reduced after frozen storage at -20 °C ($P < 0.05$). Similarly, previous studies have reported that freezing technology can improve the texture attributes of sous vide cooked meat mainly shear force, hardness and chewiness (Botinestean et. al. 2016; Ji et. al. 2019). In conclusion, frozen sous vide treated chicken breast had improved texture attributes which may have a positive effect on increasing meat consumption among elderly consumers.

Keywords: frozen storage, texture, chewiness, sous vide, chicken breast.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

NATURAL BIOACTIVE COMPOUNDS FROM WILD EDIBLE PLANT *LEEA MACROPHYLLA* ROXB. EX HORNEM.

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Abstract:

Plants, which have one or more of its parts having substances that can be used for treatment of diseases are known as medicinal plants. The medicines which are derived from plants are widely famous because of their safety, easy availability and low cost. The term "Medicinal plant" includes various types of plants used in herbalism. Herbalism is a traditional medicine which is based on the use of plants and plant extracts, it is also known as botanical medicine, medical herbalism, herbal medicine, herbology and herblore. It is the use of plants for medicinal purpose, and the study of such uses. Plants have evolved the ability to synthesize chemical compounds that help them defend against attack from a wide variety of predators, such as insects, fungi and herbivorous mammals. Plants are a very important source of nutrients and a very important part in the human diet. Medicinal plants which have been aided as nature's gift to make disease free healthy strong life. Many herbal therapies separately or in grouping have been suggested in countless medicinal treatises plants in widespread in developing countries. The healing powers of traditional herbal medicines have been realized since antiquities.

(GC-MS) Gas Chromatography - Mass Spectrometry is a hyphenated analytical technique that combines the separation properties of gas – liquid chromatography with the detection feature of mass spectrometry to identify different substances within a test sample.

Attempt has been made to gather the information about *Leea macrophylla* Roxb. ex Hornem. of family Vitaceae. This plant is known to have several therapeutic properties. These are due to the presence of numerous chemical compounds. The pharmacological activity of a plant can be predicted by the identification of the phytochemicals. The study was conducted to identify the bioactive components & phytochemical constituents of *Leea macrophylla* tuberous root, stem, & leaf extracts using (GC-MS). Phytochemicals are beneficial to boost up immunomodulatory responses and also provide immunity against many diseases. *Leea macrophylla* is ample in secondary & primary metabolites. It has many

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therapeutic properties like - antidiabetic, gastroprotective, neuroprotective, anti-urolithiasis effect, hepatoprotective, anti-thrombotic, cytotoxic, antimicrobial, cardiotonic, anticancer, antioxidant, anti-inflammatory, antinociceptive, wound healing properties. Now a days medicinal herbs are important sources for pharmaceutical manufacturing.

Keywords: Therapeutic properties, GC-MS, Herbalism, Medicinal plant.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SECURE ROUTING FOR MOBILE AD HOC NETWORKS USING CRYPTOGRAPHY

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Abstract: Network Security & Cryptography is a concept to protect network and data transmission over wireless network. Network security involves the authorization of access to data in a network, which is controlled by the network administrator. Users choose or are assigned an ID and password or other authenticating information that allows them access to information and programs within their authority. Network security covers a variety of computer networks, both public and private, that are used in everyday jobs conducting transactions and communications among businesses, government agencies and individuals. Networks can be private, such as within a company, and others which might be open to public access. Network security is involved in organizations, enterprises, and other types of institutions. In this paper we also studied cryptography along with its principles. Cryptographic systems with ciphers are described.

Keywords: Network Security, Authentication; Cryptography; Encryption; Decryption;

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

INFRASTRUCTURE LESS SUPPORT BASED SECURE REACTIVE ROUTING PROTOCOL FOR MANETS

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Abstract: MANET topology changes frequently that leads to link failure and lack of infrastructure support and resource constraint is the key issue that causes dishonest and non co-operative nodes. As the nodes square measure mobile thus topology changes oft that ends up in link failure and lack of infrastructure support and resource constraint is that the key issue that causes dishonest and non co-operative nodes. There square measure finding a route to destination, new route discovery is initiated. The frequent discoveries result in a lot of network congestion. To avoid this multipath routing protocols are planned to seek out multiple routes to destination and put on to alternate secondary path just in case of route broken and its offer higher routing performance and security. In this developed research paper attempt to compare simulation performance of two on demand protocols Secure Dynamic Source Routing (SDSR) and traditional Dynamic Source Routing (DSR) with different topology and malicious nodes, on-demand gateway discovery protocol where a mobile device of MANET gets connected to gateway. SDSR using the Intrusion Detection system (IDS) and trust based routing, the performance results are analysed by varying simulation time. Furthermore, all the above mentioned protocols are compared based on several important performance metrics which are packet delivery ratio, end-to-end delay and remaining energy through NS2.

Key words: MANET, SDSR, PDR, Delay, Energy.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SERVICE ORIENTATED DISTRIBUTED IN QUALITY OF SERVICE FOR MOBILE AD HOC NETWORKS

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Abstract – Mobile Ad hoc Network is the significant technologies among various un-wired communication technologies where all the mobile nodes are mobile and which can be connected to random dynamically using wireless link in the random manner. It can provide Quality of Service (QoS) requirements in real update transmission for wireless application. But it stream including critical mission application like military use or emergency recovery. In this research paper proposed efficient Secure Quality Oriented Distributed (S-QOD) Secure Enhanced Adaptive 3 Acknowledgements (S-EA3ACK). Implement a new intrusion detection system for on-demand wireless networks. SQOD can improve a best performance of output quality (QoS) to reduce transmission delay, transmission time and also increase network communication throughput for Enhanced Adaptive 3 ACK's (S-EA3ACK) using EAACK (DSA) with MAJE4 symmetric cryptography specially designed for MANET through Network Simulator-2.34 (NS2) to implement it.

Keywords: QoS, QOD, EAACK, EA3ACK, S-EA3ACK, Cryptography, MAJE4.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COMPARISON OF DSDV AND OLSR WITH ATTACKS USING DCFM IN MANET

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ABSTRACT- All nodes work as routers on take path in discovery and maintenance of routes to other nodes in the network to know there advantages are more, still drawbacks are security, energy and transmission. There are different protocols for handling the routing in the mobile environment. Because of highly dynamic in nature, performance of routing protocols is an important issue. This project will focus on two well known protocols: Destination Sequenced Distance Vector (DSDV) and Optimized Link State Routing (OLSR) Protocols. In this project One major attack is DDOS attack against the Optimized Link State Routing protocol (OLSR) known as the node isolation attack, the simulation result presents the best routing protocol which gives the highest performance when the routing protocols are implemented using NS2.34. The simulation compares the two ad hoc routing protocols named destination-sequenced distance vector and optimized link state routing protocols. Our project presents simulation based comparison and performance analysis on different parameters like; Average end-to-end delay, Throughput and Normalized routing overhead.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

COMPARISON VARIOUS MODULATION METHODS USING INTER SATELLITE COMMUNICATION

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ABSTRACT: In main role to provide and use various space and other public applications such as communication, navigation, earth observation, weather reading checking and monitoring, environment monitoring etc. In all the above applications to observation earth the satellites which placed using the important traditional design called low earth orbit which used to increases the data resolution but above method will take more time to present of duration outcomes because not able to transmit the high resolution data rate to grand station antenna from low earth orbit satellite. Another one is geostationary earth orbit satellite model that one have more visible time than low earth orbit satellite, so inter satellite communication is should be used between necessary between above two methods use to increases higher performance of resolution. In this emerging recent developed design, to compare the result analysis of above two satellite models using three traditional modulation methods like such as quadrature phase shift keying, 8 phase shift keying and 16 SK and 16 quadrature amplitude modulation with different amplifier models like rapp amplifier, saleh and ghorbhani models to measure used via a with eco-signal (doppler effect) air medium.

Keywords: Long Distance Broadcasting; Modulation Methods; Inter Satellite; Amplifier Models;

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

SECURE ON-DEMAND DYNAMIC ROUTING PROTOCOL IN MOBILE AD HOC NETWORKS

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Abstract: As the nodes are mobile so topology changes frequently that leads to link failure and lack of infrastructure support and resource constraint is the key issue that causes dishonest and non co-operative nodes. As the nodes square measure mobile thus topology changes oft that ends up in link failure and lack of infrastructure support and resource constraint is that the key issue that causes dishonest and non co-operative nodes. There square measure finding a route to destination, new route discovery is initiated. The frequent discoveries result in a lot of network congestion. To avoid this multipath routing protocols are planned to seek out multiple routes to destination and put on to alternate secondary path just in case of route broken and its offer higher routing performance and security. In this developed research paper attempt to compare the performance of two reactive routing protocols for MANETs that is Secure Dynamic Source Routing (SDSR) and Dynamic Source Routing (DSR), on-demand gateway discovery protocol where a mobile device of MANET gets connected to gateway. SDSR using the Intrusion Detection system (IDS) and trust based routing, the performance results are analysed by varying simulation time. Furthermore, all the above mentioned protocols are compared based on several important performance metrics which are packet delivery ratio, end-to-end delay and average energy.

Key words: MANET, IDS, DSR, SDSR, PDR, Delay, Energy.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7

PRIORITY QUEUING IN SCHEDULING ALGORITHM IN INFRASTRUCTURELESS WIRELESS NETWORK

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ABSTRACT: Wireless sensor networks (WSNs) are increasingly being deployed in security-critical applications. Because of their inherent resource-constrained characteristics, they are prone to various security attacks, and a Grey-hole attack is a type of attack that seriously affects data collection. To conquer that challenge, an active detection-based security and trust routing scheme named Active Trust is proposed for WSNs. The most important innovation of Active Trust is that it avoids black holes through the active creation of a number of detection routes to quickly detect and obtain nodal trust and thus improve the data route security in priority queuing in scheduling algorithm using NS2 Simulator. In this work, perform of priority queuing algorithm is evaluated to attain quality of Service (QoS).

KEYWORDS: Priority queuing, NS2, Wireless Sensor Network, GPS, Black holes.

DOI: https://doi.org/10.30546/19023.978-9952-610-30-7.2025.5095
ISBN: 978-9952-610-30-7