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A physical activity focused typology to guide urban neighbourhood evaluation and re-design: Evidence from Ankara, Türkiye

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Abstract

Physical inactivity is a major risk for non-communicable diseases (NCDs) and is a growing public health epidemic of the 21st century. Limited walkability, a lack of green spaces in dense neighbourhoods, and excessive reliance on motorised transportation support sedentary lifestyles. Urban planning and design decisions shape these built environments by encouraging or restricting physical activity (PA). This study uses applied geographical analysis, including spatial network analytics, principal component analysis (PCA), indexing, and clustering, performed with the *k*-means elbow method to define neighbourhood typologies for planning healthy cities that support PA. We aggregate individual-level data to inform policies that target neighbourhoods for walkability and other healthy city interventions. We demonstrate this in the context of Türkiye's capital city, Ankara, which is subject to car-driven urban sprawl with low-density peripheral development. Our findings show that the features that support PA are associated with housing density, accessibility (betweenness), centrality, and local health infrastructure. These are most commonly found in inner-city mature neighbourhoods in Ankara, which aligns with Ankara's earlier master plans. The study, stemming from time geography of health, presents a typological guide using an applied geographical method and highlights that designing connected, walkable, and mixed-use developments can reduce physical inactivity and create healthier cities around the world.

KEYWORDS
applied geography, built environment, healthy neighbourhood planning, physical activity, walkability

1 | INTRODUCTION

The United Nations Sustainable Development Goals (SDGs), SDG 3: Good Health and Well-being, and SDG 11: Sustainable Cities and Communities, are pivotal objectives that cities have to adopt to enhance health and well-being (Nawaro et al., 2024; Ramirez-Rubio et al., 2019; World Health Organisation [WHO], 2023). Walkable, accessible, mixed-use neighbourhoods supported by strong urban services have become essential for supporting physically active lifestyles (Cerin et al., 2018; Haskell et al., 2009). Rapid population growth, extensive rural-to-urban migration, and accelerated urbanisation—particularly in cities of developing countries—have often resulted in uncontrolled urban sprawl, where the built environment fails to meet the growing demand for healthy living.

Studies have shown that the built environment characteristics of a neighbourhood significantly affects its inhabitants' lifestyle and preferences, and that effective urban policies and development strategies, controlled by city plans, can be used to manage these characteristics (Bennett et al., 2024; Corburn, 2015; Sarkar & Webster, 2017). Neighbourhoods are multidimensional and complex, and shaped by different planning periods. Some are healthier, safer, and well-connected; in

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contrast, others are physically disadvantaged and unattractive with inferior conditions. The latter is common in rapidly sprawling cities in developing countries, where substandard built environments, shaped by insufficient or poorly implemented planning and design strategies, significantly reduce the quality of life (Giles-Corti et al., 2022). The physical characteristics of neighbourhoods—such as residential density, land use diversity, accessibility, centrality, health infrastructure, and green space availability—strongly influence physical activity (PA) levels in cities (Ho et al., 2023; Lai et al., 2023; Sarkar et al., 2014). Diverse land use, in particular, promotes social cohesion and active lifestyles by creating walkable environments that encourage PA (Sonta & Jiang, 2023). The characteristics of neighbourhoods have become increasingly important, particularly because of more time spent in immediate living environments after the COVID-19 epidemic. As a result, conditions have been set to plan and design neighbourhoods via city plans, design, and development strategies (Mouratidis & Yiannakou, 2022).

In this context, city planning and design strategies can help shape place-based determinants of health, including the distribution of demographic, socio-economic, and environmental elements, referred to as social determinants of health (Irwin & Scali, 2010). For example, a master plan that frames public health as a core social policy can guide the transformation of neighbourhoods through appropriate density, mixed land use, accessible green spaces, and integrated, walkable urban patterns that promote active mobility. These plans also support compact and balanced growth in urban fringes, with high connectivity and centrality that further encourages PA. Transit-oriented development, new urbanism, and the 15-min city exemplify policy approaches that promote proximity and functional integration. These health-oriented planning strategies are crucial in addressing risk factors such as physical inactivity that increase non-communicable diseases (NCDs) (Jebb & Moore, 1999). This emphasis is timely, as NCDs account for 74% of global deaths (WHO, 2023), 90% of deaths in Europe (European Environment Agency [EEA], 2020), and 70–80% of European health-care costs (European Commission [EC], 2020).

By integrating applied geographical analysis with public health objectives, health-oriented neighbourhood planning can be grounded in empirical evidence that identifies how the built environment influences health outcomes. Spatial analysis tools such as GIS, spatial statistics, and network analysis allow planners to evaluate accessibility, walkability, and land-use patterns at the neighbourhood scale—factors that are closely linked to PA, and thus NCDs. Such an interdisciplinary approach helps inform urban policy and allows the design of interventions aimed at creating more active and resilient urban environments. By leveraging the analytical strengths of geography, health-focused planning can better address the socio-spatial determinants of health and contribute to the development of healthier neighbourhoods. Globally, research that considers spatial characteristics—such as distance and location—as key determinants of individual health outcomes has gained prominence (Oostenbach et al., 2023). Despite limitations in data availability, small-area studies at the neighbourhood level remain crucial, as they provide localised insights and support more targeted and effective geographical analyses (Rothenberg et al., 2015). This is particularly important within the framework of time-geography, where local spatial features fundamentally shape individual spatial behaviour (Schwanen & Wang, 2014).

Our study adopts geographical techniques, including network analytics, to identify and map non-contiguous clusters of neighbourhoods with characteristics linked to PA, specified by literature-driven dimensions, principal component analysis (PCA), indexing, and *k*-means clustering. Urban evaluation and re-design necessitates selecting a geographical unit for spatial reference, often requiring approximations and statistical justifications. We utilise an applied geographical approach that converts knowledge from the recent wave of health and place studies (Liu et al., 2023; Sarkar et al., 2013) conducted at the individual level using network geography (Gastner & Newman, 2006; Boeing, 2021) into aggregate indicators suitable for urban policy, design, and planning interventions (Moon & Kearns, 2019). Many individual-level health and place studies successfully isolate associational or causal relationships between particular health conditions and specific built environment features. These findings are not always useful for applied geographical policy analysis, and, ironically, the results need re-aggregation to become useful in this

Key Insights

The study presents a neighbourhood-level geographical method, including spatial network analytics, which is aligned with the time geography of health. This study demonstrates that re-aggregating individual-level data is useful for urban planning, policymaking, and design guidelines. Findings show that optimised housing density, accessibility, and centrality support physical activity by promoting connected, walkable, mixed-use neighbourhood typologies. In Ankara, the capital of Türkiye, earlier city planning strategies that shaped mature inner-city neighbourhoods have been more conducive to supporting physical activity than the low-density, car-oriented peripheral developments resulting from urban sprawl.

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way. With a unique perspective, our study adopts neighbourhoods as a geographical reference. It defines neighbourhoods based on characteristics influencing residents' PA levels while mapping them by combinations of factors associated with PA, thus offering a focused framework for analysis and policymaking. We develop this method and demonstrate it in the context of Türkiye's capital city, Ankara, which has been subject to car-driven urban sprawl and low-density peripheral neighbourhood development. This trend has shifted the city's centres of gravity (Ozuduru et al., 2021), and new policy frameworks are thus required to target neighbourhoods for walkability and other healthy city interventions.

By visualising Ankara's plan periods and analysing neighbourhood production strategies, this study identifies policy pathways to support healthy neighbourhood planning, bridging built environment epidemiology with healthy city planning perspectives. Our method groups neighbourhoods based on their similarities, enabling the development of generalisable policy frameworks tailored to each cluster. Our findings show that built environment characteristics, particularly housing density, accessibility, and centrality, significantly support a neighbourhood's PA qualifications. These attributes are the products of different plan periods, providing a scheme for urban public policies that support healthy cities. Traditional planning principles that create vibrant urban spaces where people can live, work, and play alongside a mixed-use character and accessible local health infrastructure remain essential for promoting active, mobile lifestyles and deserve renewed focus from decision-makers. In contrast, mono-use residential developments, such as the sprawling peripheries of Ankara developed in later plan periods, foster car-dependent environments that encourage inactivity and sedentary habits.

This paper consists of six sections. Following the introduction, Section 2 reviews the literature on the constructs of healthy neighbourhood planning influencing PA levels. Section 3 discusses the case study, including the major city planning strategies in Ankara, the capital of Türkiye. The methodology is detailed in Section 4, outlining the applied geographical analysis principles employed in the study. The findings, accompanied by statistical analyses, are presented in Section 5, and the paper concludes in Section 6 with a summary of the key insights and implications.

2 | KEY DIMENSIONS OF HEALTHY NEIGHBOURHOOD PLANNING

The socio-spatial interaction of people with their neighbourhoods is a product of their lifestyles and the built environment's physical characteristics; therefore, it deserves a more focussed planning and design evaluation (Safizadeh et al., 2024). Built environment characteristics can both mitigate people's tendencies to be sedentary and sustain active living. Studies covering healthy cities (Li et al., 2020; Sarkar et al., 2014) are grouped at various geographical scales, including metropolitan, neighbourhood, and individual levels, using key metrics such as walkability indices, access to amenities, transportation modes, and environmental indicators. As highlighted by Corvalan et al. (2000), while a wide range of factors influence health, the environment stands out as a modifiable, effect-based indicator. Unlike genetic or biological predispositions, environmental conditions can be deliberately shaped to promote and support healthy living. In a recent study, 11 dimensions appear to support healthy cities: (i) housing and land use diversity (mixed-use), (ii) accessibility, (iii) access by public transportation, (iv) design of movement networks, (v) attractiveness of active transportation modes, (vi) density, (vii) distribution of labour force, (viii) management of demand for urban services, (ix) destination proximity, (x) disaster mitigation, and (xi) distributed interventions and resources (Giles-Corti et al., 2022). Therefore, evaluating and re-designing neighbourhoods through these dimensions can guide neighbourhood planning for healthy living.

A more systematic approach has been specified at the city level via health project networks. For example, the WHO European Healthy Cities Network collected 32 indicators at the city level for a structured and systematic monitoring and analysis of the trends (Webster & Sanderson, 2013). The Healthy Cities Project in China developed a comprehensive framework of 76 health indicators, spanning three levels of analysis from broad to specific, to assess city-level environments, societies, services, populations, health literacy, and behaviours, emphasising PA (Li et al., 2020). In another study (Bafarasat et al., 2023), 131 prespecified healthy city indicators were decreased to 99 after expert interviews and a literature review. Except for a few studies at the city level (Hooper & Edwards, 2024; Hsu et al., 2024), smaller geographical units, such as small and midsized cities, municipalities, and neighbourhoods, have remained unexplored (Luo et al., 2022). Adopting healthy city indicators to develop a city profile and a health plan should set a framework for urban planning and design strategies. Such studies help translate research on health and place into an applied geographical framework, where the use of small-scale units of analysis—such as neighbourhoods—yields localised insights that can inform planning processes and guide decision-makers in developing context-sensitive interventions.

There is a growing number and range of indicators for health; for that reason, many studies have adopted a geographical scale to align with local urban contexts, resources, and socio-cultural dynamics (Pineo

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et al., 2018). In one of the earliest studies of its kind, Takano and Nakamura (2001) selected 71 indicators and reduced them to nine major determinants using PCA. These determinants covered health-care resources, socio-economic characteristics, and physical attributes of the built environment in cities with populations over 100,000. They identified constructs of urban living environments at a geographically aggregated level, using various neighbourhood-scale indices—such as health indices and health determinant indices—related to environmental quality, access to green spaces, housing conditions, urban clutter, health-care access, and socio-economic status. The EURO-HEALTHY project (Costa et al., 2019) developed a population health index using 26 health indicators at two geographical scales, namely small area and municipality level, from nine metropolitan areas in Europe to identify health determinants and outcomes and capture a range of local factors addressing wider dimensions of health. Luo et al. (2022) linked urban design and public health in small and midsized cities and developed, through questionnaires and interviews, six primary dimensions and 37 variables including urban form and transportation; health-friendly service; environmental quality and governance; community and facility; green and open space; and ecological construction and biodiversity. A recent study defined 28 health indicators and selected 11 for health-care system analysis across Italian municipalities (Nawaro et al., 2024).

PA has been set at the core of smaller-unit geographical analysis because of its significant relationship to lifestyle habits (Gray et al., 2018). In transportation and built environment research, the level of PA is directly related to land use diversity, density of road network intersections, presence of urban green areas, distance to public transportation stops, and the number of destinations within walking distance (Ewing & Cervero, 2010; Zhang et al., 2022). In addition, green space size and its accessibility, the presence of green areas, opportunities, and land use variability in a neighbourhood, as well as the extent of urban sprawl, are specified as other influential factors on PA levels (Carmona, 2019). Investments in mono-use residential developments for new suburban neighbourhoods drive urban sprawl and promote increased reliance on motorised transportation (Sonta & Jiang, 2023). A well-designed built environment should attract people to live, work, and play, while encouraging them to do so on foot or by bike—thereby reducing sedentary behaviour and, where possible, promoting physical activity. (WHO, 2018). Adequate housing is more than just shelter; it is a dynamic blend of physical structure, surrounding urban services, and facilities that shape the quality of life through social, economic, and psychological dimensions (Pacione, 2003).

One of the key indicators of PA levels is mixed-use neighbourhoods covering residential, commercial, education, and health facilities within walking distance (Giles-Corti et al., 2015; Rodrigue et al., 2024; Sonta & Jiang, 2023). Mixed-use neighbourhoods often attract people for different purposes (for example, residents, workers, or visitors); they have high vitality, helping to build social capital, a sense of community, and increased public safety; and are positively associated with walking, neighbourhood satisfaction, and PA (Jia, 2021; Sarkar et al., 2013). A mixed-use neighbourhood covers open and green spaces; the existence of these areas is important for PA and, thus, health (Liu et al., 2023; Yang & Jiang, 2023). For this reason, besides mixed land use, the availability of and proximity to green spaces are also important to increase PA levels. Green spaces can ameliorate the detrimental effects of air pollution and positively influence health. They strengthen social life by mediating social interaction and contribute to social harmony and liveable communities (Hooper & Edwards, 2024). By providing tranquil natural environments for residents and adding recreational and aesthetic values, they also offer opportunities for walking and cycling (Sarkar et al., 2014).

Mixed-use neighbourhoods increase accessibility, facilitate pedestrian circulation, and increase PA levels (Cerin et al., 2018). City morphology, street network patterns, and connection types provide important information about the accessibility levels in cities (Handy et al., 2002; Jia, 2021; Ozuduru et al., 2021). Quantitative methods like space syntax (Hillier, 1999; Hillier & Hanson, 1984), urban network analysis (Sevtsuk & Mekonnen, 2012), and spatial design network analysis (sDNA) (Chiaradia et al., 2013; Cooper et al., 2019) offer a foundation for understanding how street network design and accessibility shape social behaviour and urban development—highlighting the street network as the DNA of the urban environment. For example, it is expected that a denser street network, which allows for frequent use while moving from an origin to a destination in the city, would have higher depth and betweenness values (Chiaradia et al., 2013; Cooper et al., 2019; Zhou et al., 2022). High betweenness values can be affiliated with denser urban activities, and on these axes, accessibility is particularly important for commercial facilities (Ozuduru et al., 2021). Topographic variation can deter walkability (Rahman, 2022). Long commutes increase stress, but research shows that easy access to shops and restaurants within walking distance in mixed-use areas can provide several health benefits (Barton et al., 2015). Living environments with high walkability and accessibility can reduce the rate of dementia, and for healthy ageing, public housing neighbourhoods should include spaces that are more accessible and community facilities along walking paths for PAs and daily needs (Ho et al., 2023). In addition, a study using indices generated by

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assessing street networks shows that neighbourhood accessibility can motivate residents to engage in outdoor PA (Safizadeh et al., 2024).

Although many indices have been developed using qualitative or quantitative methods to assess PA and walkability at the street level (De Leeuw & Simos, 2017; Rahman, 2022; Zhang et al., 2021), an applied geographical analysis is required to take a broader and comprehensive view and identify differences and similarities across neighbourhoods. Such an analysis can provide evidence for urban plans and agencies because it provides a mesoscale evaluation of healthy neighbourhoods.

Developing plans to promote PA through active transportation and living while reducing sedentary behaviour in healthy urban environments is possible. Proximity-based contemporary urban planning and design paradigms, such as New Urbanism (Cysek-Pawlak & Pabich, 2021), the 15-Minute City (Teixeira et al., 2024), Transit-Oriented Development (TOD) (Cervero & Kockelman, 1997), and Net Zero Cities (Nieuwenhuijsen, 2021), emphasise reduced reliance on motorised transportation, enhancing walkability, fostering social interaction in public spaces, and expanding access to green infrastructure. At the local level, policymakers can shape city ecosystems and public health by prioritising health-focused development strategies in urban planning, such as establishing local attractions, open green spaces, and outdoor recreational facilities, and enforcing environmental monitoring to support PA.

The locations, accessibility, and adequacy of health infrastructure (hospitals, family health centres, availability of relevant services, and health personnel) are important for improved health. Hospitals and health centres, frequently used by medical staff and patients, should be located at the most accessible sites because easy access can save lives, particularly in emergencies (Corburn, 2015). Moreover, frequent access to these locations by different modes of transportation also increases their accessibility. A study found that ensuring health-care facilities are well-located and accessible to low-income groups is especially important in cities of developing countries (Basu et al., 2018). Peri-urban areas often lack public health infrastructure, while inner-city areas rely on comprehensive transport networks for better access. Therefore, spatial accessibility is a key concern for health services.

Housing units depend on their surroundings and the neighbourhood characteristics in which they are located. Physical factors, such as building block size, density, height, and facade features, affect urban health (Sarkar et al., 2013). Disease risks are higher in overcrowded living environments, where green areas accessible to everyone are limited in number and size. Density is a significant factor for PA support in neighbourhoods. In addition to overcrowded living environments, overly isolated areas are also unfavourable for PA. A city's living environments require a certain density of buildings, housing, and population for both physical and mental health; therefore, it is important to design the city's density along with other features of neighbourhoods. A positive relationship between obesity and residential density (Sarkar & Webster, 2017) and elevated risks of dementia and Alzheimer's disease (Ho et al., 2023; Lai et al., 2023) has been identified.

PA is a healthy lifestyle behaviour in preventing both physical and mental diseases, including reducing the risk factors for NCDs, such as obesity and type II diabetes. One of WHO's main strategy recommendations for "Healthy Cities" is to create a physical and social environment that supports PA (WHO, 2018). Neighbourhoods that support PA will improve healthy living and should be accessible to all segments of society, particularly women, children, those in the 65+ age group, and those in special needs groups who are considered disadvantaged. In settlements where all segments of society have access to high-quality neighbourhoods and where individual and social interests are kept at the same level, the sense of belonging to the living environment will increase, and the quality of life will be high.

In our analysis, we specify the neighbourhood-built environment characteristics that support PA, along with the indicators stemming from the literature review. Built environment characteristics, such as land use diversity, green space access, walkability, and spatial accessibility, are consistently shown to influence PA and overall health outcomes at various spatial scales. These features shape daily behaviours and offer opportunities to promote active living, particularly when planned with health-oriented indicators and metrics. There is a growing emphasis on neighbourhood-level analysis in geographical and urban planning studies, as localised assessments provide actionable insights for designing healthier cities.

3 | CASE STUDY DESCRIPTION

Ankara was selected as a case study because of its unique characteristics as a young capital founded in the 1920s. It has since evolved into a model city in Türkiye through distinct planning phases. The city has nine central and 16 peripheral districts; among the central districts, we selected 378 neighbourhoods as the study area. These neighbourhoods were selected because they exhibit urban characteristics and accommodate a critical neighbourhood density. The study area population was 4,988,358 as of 2020, accounting for 88.1% of the total population in Ankara. Table 1 illustrates the descriptive statistics of population distribution by districts (Turkish Statistical Institute [TSTAT], 2020).

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TABLE 1 Descriptive statistical analysis of population distribution by districts in the study area.

District	Number of neighbourhoods	Total	Percentage (%)	Minimum	Maximum	Average	Standard deviation
Altindag	21	393,871	8	1796	81,657	18,755.76	18,422.93
Cankaya	115	919,361	18	11	38,647	7994.44	6571.85
Etimesgut	30	595,892	12	4028	43,763	19,863.07	10,549.48
Golbasi	14	122,441	2	573	25,076	8745.79	8542.09
Kecioren	47	938,042	19	2570	51,263	19,958.34	11,999.67
Mamak	55	640,732	13	206	37,595	11,649.67	8922.73
Pursaklar	11	149,201	3	206	37,298	13,563.73	12,330.62
Sincan	30	536,442	11	79	44,760	17,881.4	11,370.94
Yenimahalle	55	692,376	14	150	56,464	12,588.65	10,384.06
TOTAL	378	4,988,358	100	11	81,657	13,196.71	11,074.37

Source: TSTAT, Population Statistics, 2020.

Our selected neighbourhoods were formed as a result of city planning in Ankara, which can be classified under four major plan periods: (1) the Jansen Plan (1932), (2) the Yucel–Uybadin Plan (1957), (3) the 1990 Master Plan, and (4) the 2023 Master Plan.

A range of planning decisions have shaped Ankara's macro form since its establishment as the capital city of Türkiye in the 1920s. Since then, the city has evolved into a medium-low-density urban area characterised by plans that increasingly reinforce car-dependent, sprawling suburban forms. Peripheral expansion has become the norm, and neighbourhoods have transformed into mono-use areas dominated by private vehicle-oriented long streets and block lengths, lacking interconnection across parks and greenways, and sustainable public or non-motorised transportation options that are essential for healthy cities.

In the initial city plan proposed by Jansen, the city had a CBD supported by a residential area (the Newtown–Yenisehir) and a subcentre, Kizilay, an extension of the CBD. Many production facilities, commercial services, and administrative units in this "new" capital were interdependent and strategically positioned along the linear axis connecting the old town centre to the subcentre (GMA, 1987). The Jansen Plan emphasised public health as a key social policy, integrating it into the city's physical layout; featured an open-system design with empty spaces, valleys, ridges, and dedicated recreational and sports areas; and the housing layout followed a low-density, low-rise pattern, with low apartments located within walking distance of natural peripheries (Caliskan, 2009).

In the 1950s, this linearity transformed into a radial form. Extensions along the major axes streaming from the CBD were developed with mixed land use, covering producer and commercial services and several government offices. The CBD was populated by upper-class households while growing into its south with other prestigious uses, such as foreign embassies, universities, prominent banks, and their headquarters (GMA, 1987). The neighbourhoods developed during this period were mainly inner-city neighbourhoods with a highly accessible street network and mixed land use. These included various urban facilities (health centres, education facilities, and fire stations), small to medium-sized green spaces, and residences with specific heights (Caliskan, 2009).

The Yucel Uybadin Plan (1957) changed the macro-form with new developments on the city's north–south axis and a District Height Regulation (GMA, 2006). In this period, the city underwent an urban transformation, and the inner-city neighbourhoods became denser with the destruction of the existing urban fabric and the construction of doubled and tripled building heights. Along with densification, existing roads were widened and new arteries were constructed, enabling expansion at the urban fringe through annexation-led growth. This approach, often described as resembling an oil drop, reflects uncoordinated outward development radiating from the city centre. The CBD and inner-city neighbourhoods correspond to the Jansen and Yucel–Uybadin Plan periods that suggested mixed land use and annexed development strategies, with narrow and short streets incompatible with the automobile age.

Peripheral expansion and strategies facilitating car-dependent suburban expansion began with the development strategies of the 1990 Master Plan. The development axis was in two opposing directions, growing toward the city's periphery, particularly the west and southwest. Ankara was mono-centric but transformed with "controlled decentralisation policies" into a polycentric city, with new sub-centres on these two corridors (Babalik-Sutcliffe, 2013). High-density, high-rise, isolated, single-use zoned suburbs featuring privately owned green spaces, mass housing developments, master-planned communities, new industrial zones, and shopping centres were systematically planned and developed. While the density was sufficient to support public transportation, and the plan sought to preserve urban-nature relationships and

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facilitate access to rural areas, additional extensions occurred along the urban fringe (GMA, 2006). The urban fabric was characterised by high-density patterns in the inner-city, with high-density and high-rise developments dominating the broader urban landscape.

The final Plan of Ankara, the 2023 Master Plan (GMA, 2006) created new commercial cores built on the development corridors, supporting further peripheral expansion. The urban fringe accommodated campus-like structures for employment centres and residential and commercial uses. The number of shopping centres increased significantly during this period. Instead of investing in public spaces, the city expanded with privatised spaces, such as gated communities, shopping centres, and office spaces. In addition, the squatter areas have transformed into large-scale residential complexes, health facilities, and private school campuses, creating a scale shift where daily activities require a motorised vehicle. Therefore, such developments induced the use of cars and decreased non-motorised transportation modes (Babalik-Sutcliffe, 2013). The polycentric city presented significant growth and change, creating a decentralised structure where single land uses are specified and inaccessible. Overall, through each planning period, the spatial coverage of the plans has expanded significantly.

4 | DATA DESCRIPTION AND METHOD

Through iterative trials and PCA, we specified housing density and accessibility (betweenness measured by TPBtA1000 and TPBtA5000), centrality (determined by the land use mix number of chain markets [per 1000 people], number of food and beverage places [per 1000 people], number of pharmacies [per 1000 people], and average land price), health infrastructure (number of Family Health Centres [FHCs] [per 1000 people], number of FHC doctors [per 1000 people]), accessibility (closeness measured by MAD1000 and MAD5000), average building height and volume, green area per capita (km^2/person), and green area ratio (green area/total area) for neighbourhoods in Ankara.

The street network accessibility was assessed using the topological characteristics, closeness, and betweenness indices, measured as network statistics using sDNA+ (Cooper et al., 2019) and at two spatial scales (1000 m as walking distance, 5000 m as driving distance radii), complying with the findings of the Ankara Transportation Plan, completed in 2015.[1] (UAP, 2014). The measures for each spatial scale were taken as surrogates for accessibility for different modes. In this analysis, angular distance is used to measure the network friction. The degree of accessibility shows the overall hierarchy and use of the street network in a city's hierarchy.

The closeness index, Mean Angular Distance (MAD), is the inverse of closeness and measures the directness of navigating to all other possible destinations in the specified radius from each link, and its computation accounts for the weight of the network links based on geometric distance. Closeness classifies links based on their proximity to other links. If the index is large, the network can be classified as more inaccessible (less direct). The betweenness-angular (TPBtA) index classifies streets based on the number of shortest paths (most direct) between origin–destination pairs of all other links passing through a link. This number reveals the degree and intensity of pedestrian/traffic flow/congestion potential on a link. It measures the frequency with which each link falls on the shortest angular path between each pair of links within the network in the specified radius (Cooper et al., 2019; Cooper & Chiaradia, 2015). PCA helped to regroup these characteristics of the built environment. Table 2 illustrates the descriptive statistics of the selected variables.

Large quantities of data are available for urban planning and public health research, and data analysis has been complex and at various scales. PCA is a simple and effective statistical technique that reduces the dimensions of datasets while retaining as much of the variance as possible (Jolliffe & Cadima, 2016). It transforms a set of correlated variables into a smaller set of uncorrelated variables as principal components (PCs). PCA is also a preprocessing step for clustering and classification, as it reduces the complexity of the data and highlights its most significant features (Wold et al., 1987). For example, in a geographical analysis of health care across Italian municipalities to assess compliance with SDG3, municipalities were clustered, using PCA and other tools, to examine the significance of regional and provincial differences (Nawaro et al., 2024). Similarly, using PCA, Takano and Nakamura (2001) decreased 71 health indicators into nine determinants of health for their analysis.

In our analysis, we created a large database of built environment characteristics and analysed them in relation to the findings in the literature. We selected data where we identified a direct relationship between these variables and the level of PA in the neighbourhoods. The existence of collinearity required dimension reduction for a focused assessment of the characteristics. Therefore, we ran PCA and classified these variables into six PCs with varying loadings. PCA, as a dimension reduction method, allows the dependent/independent or hidden structures among the built environment characteristics of the neighbourhoods explained by a large number of variables that are correlated to be represented by a small number of variables that are not correlated. For example, centrality characteristics show a geographical distribution and variability in parallel with the concentration of commercial uses; therefore, these variables are evaluated as dependent.

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TABLE 2 Descriptive statistics of the selected variables.

	Minimum	Maximum	Average	Standard deviation
Housing density (housing unit/neighbourhood area [km^2])	8.043	25,725.428	6452.959	4872.242
Floor area ratio (FAR*) (total floor area/neighbourhood area [km^2])	0.002	0.438	0.193	0.121
TPBtA1000	1.224	15.417	6.192	1.862
TPBtA5000	2.113	60.055	8.533	5.416
Number of pharmacies per 1000 people	0	28.037	.539	1.956
Number of eating and drinking places per 1000 people	0	1018.692	10.678	74.073
Average land price	1.110	4368.331	572.875	510.480
Number of chain markets per 1000 people	0	90.909	0.944	5.103
Number of physicians per 1000 people	0	12.132	0.316	0.889
Number of primary healthcare centres per 1000 people	0	3.466	0.091	0.234
MAD1000	192.593	663.021	347.905	71.948
MAD5000	532.780	1353.460	862.687	173.712
Volume (FAR*average height [in meters])	0	11,689.198	2650.257	1896.408
Average height (in meters)	0	24.371	9.833	4.427
Green area per person (m^2/person)	0	7,557,053.167	108,604.761	564,757.255
Green area ratio (m^2/neighbourhood Area (m^2)*1000	0	16.522	0.275	1.313

TABLE 3 KMO measure and Bartlett's test of sphericity.

KMO measure of sampling adequacy	**0.57**	
Bartlett's test of sphericity	Chi-square value	3952.65
	Degrees of freedom	120
	p-value	<0.001

The sphericity test tests the significance of the correlation between variables (Bartlett, 1950). The suitability of the data for PCA was assessed using the Kaiser–Meyer–Olkin (KMO) criterion (Table 3). This criterion is required to be at least 0.50 (Field, 2009; Kaiser, 1974). The KMO criterion was found to be 57.0%, and this rate was found to be sufficient for the PCA.

PCA is a form of analysis in its own right, but it is also used as a data preparation technique for other analyses. The *k*-means algorithm is a straightforward clustering algorithm broadly applicable to many fields. The primary goal of data mining is to extract meaningful and tangible information from collected data; clustering helps group unlabelled data for research purposes (Ikotun et al., 2023). A clustering algorithm groups unlabelled data so that the objects with similar attributes are grouped in one class. In other words, data clustering helps ensure higher intra-cluster similarity and lower inter-cluster similarity (Ezugwu et al., 2021).

PCA generates the components used for the cluster analysis. The method partitions given datasets into *k* clusters in which each observation has the minimum squared error in the data set to the nearest mean of a cluster, serving as a prototype of the cluster; the data point is assigned to the cluster centre nearest to it (Ikotun et al., 2023; Jain, 2010). In addition, the number of clusters was specified using the Elbow method based on a plot of the sum of squares concerning *k* (Anselin, 2023). The PCA helped specify a neighbourhood index (NBE index) with variables influencing PA, and cluster analysis helped regroup Ankara's neighbourhoods and match plans.

Utilising the *k*-means and the Elbow techniques, we identified seven distinct clusters across neighbourhoods in Ankara. Each cluster exhibits unique characteristics and reflects a specific urban planning development period in the city's history. This clustering approach focuses on the shared characteristics of the built environments rather than built environment epidemiology, where individual behavioural patterns are of concern. When the final clusters are matched with the various planning periods of Ankara, using thematic maps, the shared features of the built environments associated with those periods' planning practices become apparent. These features illustrate the significance of different planning policies and practices.

5 | FINDINGS

PCA was used to create a composite indicator (index) that explains the variability in the data, obtained by linearly combining six variables. This analysis reduced the variables to six basic components (Table 4).

The contribution of each variable's loadings over 30.0% on the PCs shows that the contributions in the First Principal Component (PC1) are "TPBtA1000" with

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TABLE 4 Loadings of variables on six principal components.

Variables	PC1	PC2	PC3	PC4	PC6	PC5
Housing density	0.841					
Floor area ratio (FAR[a])	0.840					
TPBtA1000	0.773					
TPBtA5000	0.716					
Number of pharmacies per 1000 people		0.929				
Number of eating and drinking places per 1000 people		0.914				
Land price		0.607				
Number of chain markets per 1000 people		0.599				
Number of physicians per 1000 people			0.980			
Number of primary health-care centres per 1000 people			0.974			
MAD1000				0.890		
MAD5000				0.881		
Volume					0.910	
Average height					0.880	
Active green areas per person						0.763
Active green area ratio						0.851

[a]Ratio of the total floor area of the buildings in the neighbourhood to the total area of the neighbourhood.

TABLE 5 Variance explanation rates of principal components.

	PC1	PC2	PC3	PC4	PC6	PC5
Eigenvalues	2.737	2.518	2.000	1.938	1.913	1.406
The ratio of explanation of total variance	0.171	0.157	0.125	0.121	0.120	0.088
Ratio of explanation of cumulative total variance	0.171	0.328	0.453	0.575	0.694	0.782

77.3%, "TPBtA5000" with 71.6%, "Housing Density" with 84.1%, and "FAR" with 84.0%; in the Second Principal Component (PC2) are "Number of chain markets per 1000 people" with 59.9%, "Number of eating and drinking places per 1000 people" with 91.4%, "Number of pharmacies per 1000 people" with 92.9%, and "Average Market Price" with 60.7%". In general, PC1 covers housing density and accessibility (betweenness), PC2 covers centrality, PC3 health (infrastructure), PC4 accessibility (closeness), PC6 built environment morphology, and PC5 green area indicators. The total variation these six PCs explain is 78.2% (Table 5).

Various indexing and weighting methods are used in urban health studies (Davidescu, 2017; OECD, 2008). The Neighbourhood Built Environment (NBE) index was obtained by weighting each component's contribution according to its share in the total explained variability (Equation 1). With these indexing coefficients, the influential PCs and their share within the index can be specified for Ankara neighbourhoods. For example, because variables within the scope of PC1 have a more weighted share in the NBE index, they will be relatively more influential in scaling. Among the neighbourhood parameters affecting PA, PC1 has greater importance. The remaining PCs are listed and mapped with respect to the ratio of explanation of total variance.

$$NBE\ Index = \frac{0.17}{0.78}PC1 + \frac{0.16}{0.78}PC2 + \frac{0.13}{0.78}PC3 + \frac{0.12}{0.78}PC4 + \frac{0.12}{0.78}PC6 + \frac{0.08}{0.78}PC5 \quad (1)$$

When the geographical distributions of the PCs are examined, the characteristics of the neighbourhoods can be distinguished (Figures 1a–f). The distribution of PC1 shows that the inner-city neighbourhoods, developed by the Yucel–Uybadin Plan on the north and south of the central areas, are dense and have high betweenness (TPBtA). The CBD and the peripheral neighbourhoods developed by the 1990 Master Plan and 2023 Master Plan have lower PC1 values; however, they are relatively less dense and accessible. PC2, representing centrality, however, has a higher share in the central neighbourhoods (e.g. Kizilay, Mesrutiyet), southern (e.g. Oran, Universiteler) neighbourhoods, and in subcentres on the north (e.g. Ivedik, Ostim, Ragip Tuzun). In particular, PC2 has lower values for the neighbourhoods developed by the 2023 Master Plan. The geographical distribution of PC3, pointing to the health infrastructure, generally shows no

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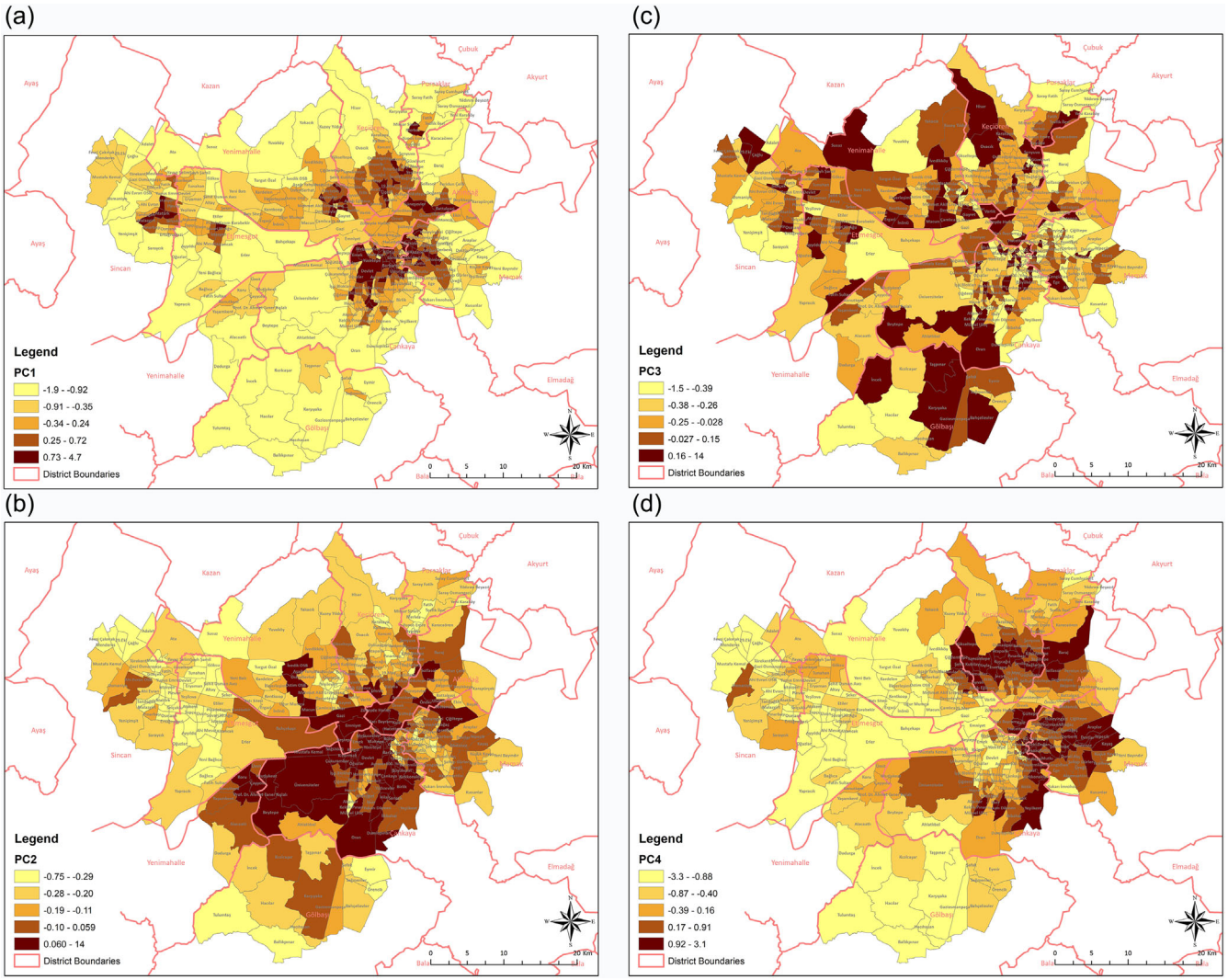


FIGURE 1 Geographical distribution of principal components by neighbourhoods: (a) PC1, (b) PC2, (c) PC3, (d) PC4, (e) PC6, and (f) PC5.

pattern. When weighted by population, it can be observed that larger neighbourhoods with a smaller population, particularly in the North and South, and smaller neighbourhoods with dense populations, particularly in the mature inner city, have higher shares of health infrastructure indicators.

PC4 represents the mean angularity of the street network (MAD1000, MAD5000) by walking and driving distances. The geographical distribution shows that Ankara's eastern and northern parts have higher angularity, pointing to irregular street patterns. These neighbourhoods have been transformed from squatter formations and have a steeper geography, which shows itself in the street pattern's angularity. For that reason, these neighbourhoods have higher closeness and are less accessible. The Yucel–Uybadin and 1990 Master Plans developed a significant share of these neighbourhoods. PC6 shows the urban morphology, including the height and volume of the buildings in the city. The newly developed neighbourhoods in the 2023 Master Plan period in Ankara have high buildings with large floor areas. For this reason, the morphology indicators are higher and show clustering in the city's northern, southern, and western parts.

The geographical distribution of PC5 indicates that public green areas weighted by population are higher in the city's southern and inner-city neighbourhoods. These parts of the city have large-scale urban public parks, including university campuses, such as Dikmen Park and ODTU Forest. These areas were developed during the 1990 Master Plan period. However, in the 2023 Master Plan, the greenest areas are situated within private sector housing development, namely the construction of residences, gated communities, and condominiums. For that reason, the peripheral neighbourhoods have lower values of PC5.

The clustering algorithm suggests that the most distinctive grouping was obtained with seven clusters. Neighbourhoods in the clusters were classified by their common characteristics regarding the indicators that

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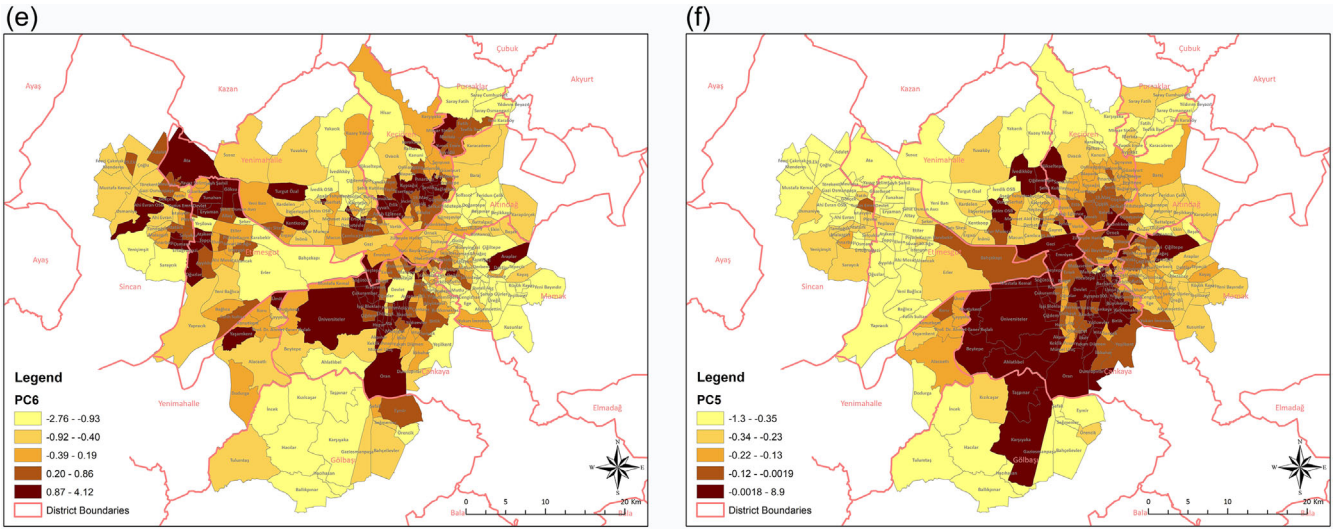


FIGURE 1 (Continued)

TABLE 6 PC means majority neighbourhood plan periods, number, and share of neighbourhoods by clusters.

Clusters	PC means[a] PC1	PC2	PC3	PC4	PC6	PC5	Majority neighbourhood plan period[a]	Number and share (%) of neighbourhoods
2	−1.20	−0.24	−0.24	−0.84	−0.96	−0.33	2023 master plan (urban periphery neighbourhoods)	41 (10.8%)
4	−0.61	−0.18	−0.02	−0.48	−0.38	−0.25	2023 master plan and 1990 plan (newly developed neighbourhoods)	66 (17.5%)
1	−0.15	−0.13	−0.09	−0.04	−0.01	−0.12	1990 plan (newly developed neighbourhoods on the east–west axis)	87 (23.0%)
5	0.41	−0.04	−0.12	0.38	0.21	0.03	Yucel–Uybadin plan (older neighbourhoods on the north–south axis)	106 (28.0%)
6	0.87	−0.01	0.14	0.44	0.61	0.15	Yucel–Uybadin plan and Jansen plan (inner-city neighbourhoods)	66 (17.5%)
3	0.23	2.47	0.88	−0.21	0.32	3.00	Jansen plan (inner-city neighbourhoods on the north–south axis)	10 (2.6%)
7	−0.13	6.99	6.66	1.45	0.05	−1.14	Jansen plan (inner-city neighbourhoods)	2 (0.5%)
Total	−0.08	1.27	1.03	0.10	−0.02	0.19		378 (100.0%)

[a]PC1: Housing Density, TPBtA1000, TPBtA5000, Floor Area Ratio (FAR); PC2: Number of chain markets per 1000 people, Number of eating and drinking places per 1000 people, Number of pharmacies per 1000 people, Land Price; PC3: Number of physicians per 1000 people, Number of primary health-care centres per 1000 people; PC4: MAD1000, MAD5000; PC6: Mean Height, Volume; PC5: Green Area per Person, Green Area Ratio.

support PA. Table 6 presents cluster descriptions of the indicators, the total number, and the share of neighbourhoods. The NBE index of all neighbourhoods is calculated, and the final evaluation shows that when the neighbourhoods are ranked by their NBE index, the ranking is 7, 3, 6, 5, 1, 4, 2 (7 with the highest NBE index, 2 with the lowest NBE index).

Benchmarking the NBE index, the PCA results show variability by component values concerning each cluster. The neighbourhoods in clusters 7 and 3 have the highest NBE indices, which means that in relation to housing/building density and accessibility, centrality, health infrastructure, the angularity of the street network, mean height and volume, and public green space ratio, these neighbourhoods are more likely support PA and healthy living. In particular, centrality and health infrastructure (PC2 and PC3) are more crucial for a higher NBE index, and they create deviation, although

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the share of PC1 is higher in the index computation. These neighbourhoods have higher centrality, covering many chain stores, eating and drinking places, and pharmacies normalised by the number of people living there, which is also reflected in land prices (Table 7). Mixed-land use and proximity to local health services can support PA as people generally walk to these facilities.

Table 7 presents the clusters and their corresponding built environment characteristics, ranking them by PCs from highest to lowest across six scales. Further, by looking at the specifications of the neighbourhoods in cluster 3, the level of public green space in a neighbourhood proves to be important for a higher NBE index. The availability of green space has been referred to as a prevention tool against risk factors for NCDs (Sarkar et al., 2014; Zhang et al., 2021). Our findings support this argument, particularly with the specifications of the neighbourhood characteristics in clusters 7 and 3. Accessibility, density, and urban morphology, including volume and height, affect the NBE index. The neighbourhoods in cluster 6 have such characteristics with a higher NBE index. These are dense inner-city neighbourhoods developed under the Jansen and Yucel–Uybadin Plans, characterised by their emphasis on proximity and mixed land use. They are highly accessible and have major shopping streets in a dense urban pattern. Therefore, the annexed development in cities may cause people to get out more, walk, and be more physically active.

Nevertheless, neighbourhoods in the cluster 2 have low levels of density and accessibility (Figure 2a). These neighbourhoods are not central, have lower height and volume, and have less access to health services; they are located on the urban periphery and were developed by the 2023 Master Plan of Ankara. In these neighbourhoods, the NBE index is low, and specifications indicate that they do not particularly support PA. Neighbourhoods in clusters 1 and 4 are similar to the qualifications of neighbourhoods in cluster 2 with some variations, such as relatively higher density, accessibility, and centrality. Cluster 5 of neighbourhoods represents the average of the indices and the PCs; this cluster also has the highest share, showing

TABLE 7 Clusters and respective built environment characteristics.

Clusters	Density and accessibility	Centrality	Health infrastructure	Street angularity	Volume and height	Public green areas
2	Lowest	Lowest	Lowest	Lowest	Lowest	Low
4	Low	Low	Medium	Low	Low	Medium–low
1	Medium–low	Medium–low	Medium–low	Medium	Medium–low	Medium–low
5	Medium–high	Medium	Low	Medium–high	Medium–high	Medium–high
6	Highest	Medium–high	Medium–high	High	Highest	High
3	High	High	High	Medium–low	High	Highest
7	Medium	Highest	Highest	Highest	Medium	Lowest

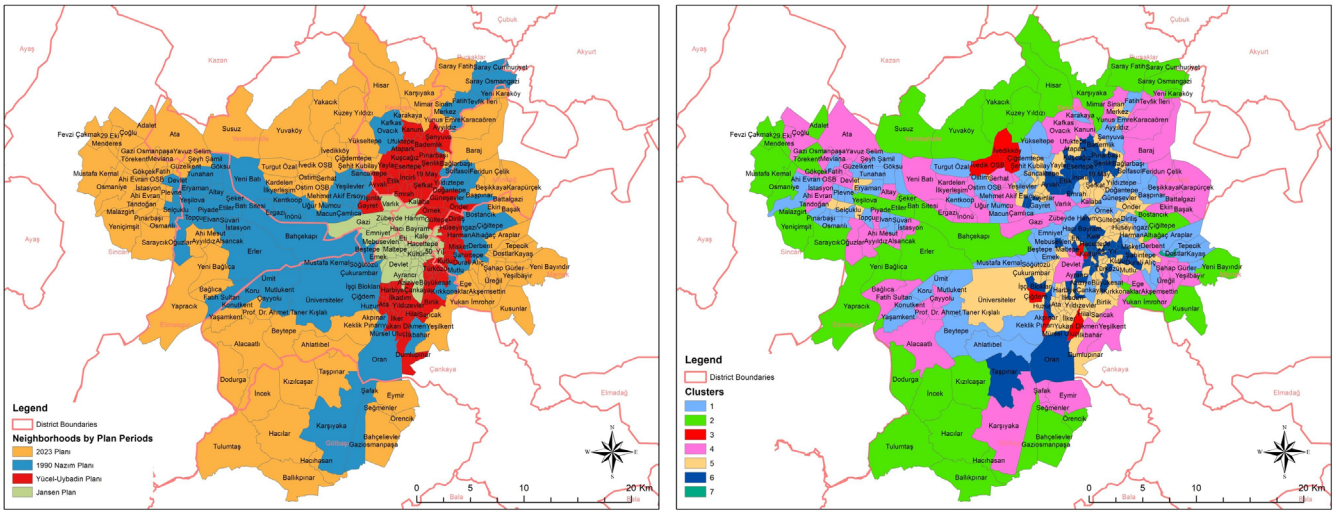


FIGURE 2 Neighbourhoods by (a) plan periods and (b) geographical distribution of clusters in the study area (produced and approximated by the authors).

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that 28% of Ankara's neighbourhoods have moderate density, accessibility, health infrastructure, centrality, height, volume, and public green space.

The neighbourhoods in clusters 7 and 3, mostly (50%) in the inner-city neighbourhoods, were developed in the Jansen Plan boundary on the north–south axis (Figure 2b). Cluster 6 neighbourhoods are also mostly located in the inner-city neighbourhoods but were instead generally developed (45%) by the Yücel–Uybadin Plan. Cluster 5 neighbourhoods can also be classified as older neighbourhoods on the north–south axis, mostly (55%) produced through the Yücel–Uybadin Plan. Cluster 1 neighbourhoods are mostly (46%) located in the development extension of the inner-city neighbourhoods surrounding them, and a few (32%) are located on the development corridors.

Cluster 4 neighbourhoods are located on the urban periphery and are located in newly developed neighbourhoods by the 2023 Master Plan (53%) and the 1990 Master Plan (38%). These are the neighbourhoods on the development axis of Ankara. Cluster 2 neighbourhoods were generally (73%) developed through the 2023 Master Plan. The neighbourhoods with average values (cluster 5) have the highest share (28%) among all study area neighbourhoods. Overall, neighbourhoods with lower NBE index (2, 4, 1) have a higher share than neighbourhoods with higher NBE index (7, 3, 6), with 51.3% and 20.6%, respectively. Table 8 summarises the cluster distribution by plan periods.

To justify our findings statistically and to understand how the midpoints of the clusters by indices are affiliated with the plans, we analysed the plan periods and clusters by using the chi-square (Pearson Chi-Square) test to explore whether there is a relationship between the two categorical variables. The test shows how well-observed data aligns with expected patterns and whether there are differences or relationships. In the chi-square test result, the relationship between clusters and plan periods is found to be significant (low p-value), and the amount of correlation is calculated. The null hypothesis that there is no relationship/association between the clusters and the plan periods was rejected (p-value $= 0.000 < \alpha = 0.05$) (Table 9). When this relationship amount was examined, Somer's d statistic was obtained as -0.563 (Table 9). There is a decrease in the NBE index from the old plan periods to the newer plan periods.

These results show that mature neighbourhoods, developed in earlier city plans with annexed development, mixed-land use, and health services with high levels of public green space, can increase the NBE index, supporting PA. However, neighbourhoods developed by recent city plans, with decentralised development and suburban uses that generated isolate land use, coinciding with most neighbourhoods, have lower NBE indexes, supporting physical inactivity and sedentary lifestyles. This can be affiliated with suburban developments that prioritise motorised travel and isolated single-use neighbourhoods.

6 | CONCLUSION

Citizens' lives, health, and well-being are at the core of what defines a healthy city (WHO, 2023). In terms of built environment features that support physical activity, healthy living, and sustainable urban development, it is essential to adhere to principles of optimal density, urban design, and land use diversity

TABLE 8 Clusters by plan periods.

Clusters[a]								
Plan periods	**Share (%)**	**2**	**4**	**1**	**5**	**6**	**3 and 7[b]**	**Total**
Jansen Plan	4		5	5	15	25	6	56
1970 Yucel–Uybadin Plan	8		1	14	58	30	1	104
1990 Master Plan	29	11	25	40	27	9	1	113
2023 Master Plan	59	30	35	28	6	2	4	105
Total	100	41	66	87	106	66	10	378

[a]Clusters are arranged in ascending order based on their mean NBE index values.
[b]Clusters 3 and 7 were merged because of the similarity in their NBE index values.

TABLE 9 Chi-Square test and Somers' d statistics.

	Value	***df***	**Asymptotic significance (two-sided)**
Pearson chi-square test	213.435	15	0.000
	Value	**Asymptotic standardised error**	**Approximate significance**
Somers' d	−0.563	0.035	0.000

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(Cervero & Kockelman, 1997). However, the considerable geographical variation among neighbourhoods within cities calls for a more nuanced evaluation. This variation underscores the need for a re-design framework that can guide evidence-based decision-making for policymakers. In line with the geographical literature (Pacione, 2003; Schwanen & Wang, 2014), healthy cities are composed of neighbourhoods with distinctive characteristics in terms of density, accessibility, centrality, health infrastructure, public green space, and morphology, and these are recognised as neighbourhood parameters (see for instance, Henry et al., 2023).

Local factors, and the facilities within the immediate vicinity of an individual's residence, are crucial in time geography (Schwanen & Wang, 2014) and contribute to healthy neighbourhood planning. For example, increasing the diversity of land uses, along with well-established urban health facilities (Family Health Centres) and public green spaces, and strategically locating these health facilities at accessible locations can increase the walkability rate in a neighbourhood. Such environments will also create a higher quality of life, one of the most fundamental principles of SDG 3 and 11 (Ramirez-Rubio et al., 2019; UN, 2015; WHO, 2023). Transitioning towards healthy neighbourhood planning requires a multifaceted approach, for which tailored planning and design strategies must be adopted to overcome challenges associated with its existing urban form and development history.

Drawing on evidence from the case of Ankara and its neighbourhoods, our study utilises an applied geographical method that enables identification of the features that hinder PA and targets them for intervention. These were initially defined as 3D's (Ewing & Cervero, 2010) but later developed into 11D's of planning and design (Giles-Corti et al., 2022). Our findings indicate that factors such as centrality, health infrastructure, and access to public green spaces diverge from existing city plans, highlighting the need for urban policies and strategies more closely aligned with the principles of Health in All Policies (Greer et al., 2022). Ankara is a capital city with a fast-paced urban sprawl, as its periphery has expanded significantly via suburbanisation and mass housing projects. Our study provides evidence that dense, mature neighbourhoods in the city, particularly those developed in earlier planning periods, are more conducive to PA.

Redeveloping existing neighbourhoods, particularly on the low-density periphery, to incorporate mixed land use within walking and cycling proximity to parks and transforming underutilised spaces into functional parks, streets, and community hubs would benefit healthy living in Ankara. It is clear that developing higher-density and mixed-use transit nodes can support active travel and decrease reliance on private vehicles (Cervero & Kockelman, 1997). High-density, mixed-use locations had relatively shorter block lengths, safe pedestrian crossings, and bike lanes which enhances connectivity and walkability in line with the current trends (Cysek-Pawlak & Pabich, 2021; Teixeira et al., 2024). However, the interconnected green infrastructure envisioned in the Jansen Plan for Ankara has been fragmented over time, resulting in disconnected parks and greenways and contributing to inequities in the availability of and access to green spaces. Both the 2023 and 1990 Master Plans led to significant peripheral growth and development, meaning that the enforcement of PA supporting features needs specific planning and control. The NBE index shows that these neighbourhoods need time for such features to emerge.

More specific policy suggestions include integrating transit planning with peripheral developments to make active transportation integral to commuting. Expanded transit networks with high-quality public transit connections should link the periphery with the city centre and encourage transit access as a prerequisite for approving peripheral developments. Enforcement of selective growth controls, such as urban growth boundaries, phased development policies that promote the sequential approval of development projects after urban services are in place, and the infill and densification of underutilised or vacant urban areas before peripheral development could also enhance health-promoting neighbourhoods. Policymakers should develop policy incentives for concentrated growth alongside active design guidelines and health-promoting features such as public parks, bike paths, and safe pedestrian environments. Nevertheless, these suggestions could only be realised with multi-stakeholder collaboration, thus requiring coordination among transit authorities, planners, private developers, and public health agencies.

Our geographical analysis offers a comprehensive evaluation of similarities across neighbourhoods that are the products of different planning periods. It facilitates a holistic understanding of urban patterns and relations, concluding that high centrality with mixed land use, health infrastructure, and green space availability have been the urban features significantly supporting PA. Zoning regulations and urban policies should be adjusted to incentivise higher density and mixed-use, along with optimised availability of green space. Developers and policymakers should prioritise walkable design, active-use facilities, and the effective use of urban areas, including retrofitting neighbourhoods and guiding peripheral development, to reduce NCD risk factors. This would enable medium-to-low-density cities to expand sustainably, promoting health and PA instead of car-dependent sprawl.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Research data are not shared.

ETHICS STATEMENT

Ethical approval was not required for this study as it is based on the analysis of secondary data without any involvement of human subjects.

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ENDNOTE

[1] The Plan (UAP, 2014) suggests that inhabitants of Ankara walk an average distance of 1200 m and drive an average distance of 4700 m. Therefore, 1000 m for walking and 5000 m for driving distance proved useful for the analysis and used as proxied walking and driving distances.

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