Impacts of Remote Working on Productivity of Civil Engineers during the COVID-19 Pandemic

Ayşegül TEPE[1]
Bengi AYKAÇ[2]
Murat AYHAN[3]

Introduction

The first cases of COVID-19 disease, caused by the novel coronavirus, were reported in December 2019 in Wuhan, China. Due to the spreading speed and severity of the disease, the World Health Organization (WHO) declared that COVID-19 is qualified as a pandemic (WHO, 2020). Unfortunately, this highly contagious disease has spread to more than 200 countries and has caused more than 600 million confirmed cases, with more than 6.5 million deaths worldwide as of 21 November 2022 (WHO, 2022). Besides the adverse effects of the pandemic on the public health, commercial establishments, including the construction industry, were also affected severely (Ogunnusi et al., 2020: 120). Due to the contagious nature of the disease, social distancing was needed to slow the spread of COVID-19 and therefore all business activities were initially suspended or limited, except in essential sectors such as the medical and supply sectors (Gamil and Alhagar, 2020: 122-123). For this reason, commercial organizations have resorted to alternative forms of work and many companies had to switch to remote work, which can also be called Work-From-Home (WFH). Several on-site activities in the construction industry were stopped or postponed and employees were encouraged to work remotely to fulfill their ongoing tasks (Esa et al., 2020: 977). Besides on-site activities that cannot be performed remotely (i.e., concrete casting), there is no other option but to switch to remote work in order to carry out activities such as design and management in the construction industry.

Aim of the Study

Considering that remote working has a significant impact on employee performance due to various factors (Mardianah and Hidayat, 2020: 1043-1044), investigating the productivity during remote working period has become an issue that needs to be taken into consideration. In the construction industry, which makes a significant contribution to the country's economy and Gross Domestic Product, the effects of the COVID-19 on productivity should be examined in order to prevent performance loss and to continue business activities as before. In this study, it is thought that working remotely or WFH will have direct effects on the productivity of civil engineers. The study has two major objectives. First, it is aimed to provide empirical evidence showing whether there is an increase or a decrease in the productivity of civil engineers during the remote working period using the data collected from the construction industry. Secondly, is it aimed to identify the

[1] Student, Gazi University, Civil Engineering Department, Orcıd: 0000-0002-5220-0309
[2] Assoc. Prof., Gazi University, Civil Engineering Department, Orcıd: 0000-0002-6285-5667
[3] Asst. Prof., Gazi University, Civil Engineering Department, Orcıd: 0000-0002-2011-4190

factors affecting the engineering productivity in the construction industry during the remote working period and to reveal improvement opportunities for the sector.

Research Background

The impact of remote working on employee productivity has been discussed in the literature for more than a decade (Mustajab et al., 2020: 14). Recent studies on this subject have revealed two opposing findings. It was stated that the COVID-19 pandemic caused disruptions in the performance of employees in various activities (Mardianah and Hidayat, 2020: 1043-1044). In a study that examines the effects of the COVID-19 on companies from the Ghana construction industry, Agyekum et al. (2021: 231) stated that there were delays in project deliveries due to COVID-19. Kutluay Tutar et al. (2021: 705-706) stated that the works in the construction industry were disrupted during the COVID-19 period. In another study, the results of a questionnaire conducted with 71 civil engineers, the positive and negative experiences of the participants in the process of WFH were revealed (Ogunnusi et al., 2020: 126-127). It is also claimed that the virtual working environment provided during the pandemic period can be considered as a new normal. Shibani et al. (2020: 57), investigated the effects of the pandemic on the construction industry in the United Kingdom and observed an increment in the office productivity during the remote working period. There are other researchers claiming that remote work can increase employee productivity (Akça and Tepe Küçükoğlu, 2020: 79-80; Angelici and Profeta, 2020: 23-24; Galanti et al., 2021: 430-431).

Previous Studies on Productivity in the Construction Industry

Productivity includes all factors that can affect the progress, development, and production outputs of construction processes (King et al., 2021: 5). Considering the competitive nature of the construction industry, it is clear that achieving higher productivity is critically important and performance improvements are a constant requirement for construction companies to remain competitive and profitable (Zhang etal., 2018: 1). In a broad perspective, productivity is the ratio of output produced to all or some of the input resources expended in the production process, or vice versa (Hughes and Thorpe, 2014: 211; Poirier et al., 2015: 75; Ayele and Fayek, 2019: 195-198). In the literature, the productivity measurement levels in the construction industry are classified as (1) Activity level (i.e., the productivity of steel elements' assembly activity), (2) Project level (i.e., the productivity of the construction of a new building), and (3) Industry level (i.e., the productivity of a country's construction industry as a whole). Regardless of the measurement level, the productivity of the construction industry can be divided into three: (1) Single factor productivity, (2) Partial factor productivity, and (3) Multi-factor productivity. If productivity corresponds to the ratio of output to a single particular input (i.e., labor force only), then this measurement is considered as a single factor productivity measure. On the other hand, the ratio of output to all relevant inputs is considered as a multi-factor productivity measure (Huang et al., 2009: 2139). Partial factor productivity is the ratio of output to some of the expended inputs spent (i.e., labor and capital resources). The tendency in the literature is to focus on single-factor productivity measures and on the labor productivity in particular (Ellis Jr and Lee, 2006: 317; Poirier et al., 2015: 74-84; Vereen et al., 2016: 2). Labor productivity; corresponds to the ratio of output to the working hours required to install a unit of that output (as cited in Hughes and Thorpe, 2014: 211). Labor productivity is an adequate way of monitoring the performance of an activity; however, activity-based labor productivity may not represent the true state of productivity at project or industry levels (Bernstein, 2003: 47-50). In other words, the overall performance to produce an output can be affected by various factors that need to be considered and it may not reveal the whole picture based solely on the performance of certain activities (AlChaer and Issa,

2020: 1). Therefore, in the case of performance monitoring on labor productivity, measurements at the project level are more appropriate than measurements at the activity level.

Based on the findings of the literature review, a single factor productivity approach over labor productivity is adopted in this study. Labor productivity will be measured at the project level.

Previous Studies on Engineering Productivity in the Construction Industry

Engineering productivity is the ratio of output to input; however, output has intangible aspects, unlike tangible products in the construction process (Sacks and Barak, 2008: 440). Rather than dealing with intangible inputs and outputs, previous studies have used simplified approaches for quantifications and measurements. In one of the earliest studies on design and engineering productivity by Thomas et al., (1999: 1), the amount of design sheets produced was used as the output and the hours required to create these sheets were used as the amount of input, and the productivity was measured in hours per design sheet. Song and AbouRizk (2005: 362) mentioned that working hours are the primary inputs in design work, since working hours are measurable, easily traceable, and most engineering companies keep records of working hours.

$$Engineering\ Productivity = \left(\frac{Output}{Input}\right) = \left(\frac{Construction\ Quantity}{\sum Direct\ Engineering\ Work\ Hours}\right) \quad (1)$$

In this study, engineering productivity will be compared using a project-level measurement approach, considering that the selected cases should have similar project scopes. In the study, (1) the engineering productivity before remote working will be compared with the engineering productivity during the remote working period, and (2) the productivity of similar projects undertaken by the same team before and during the pandemic will be compared, instead of comparing the project-level productivity values of different projects between companies or industries. The study's dataset will compare similar with similar, which removes output heterogeneity. Therefore, the sample cases in the dataset were selected based on similar project scope constraints.

Methodology

In the study, the Impacts of WFH/Remote Working Process on Civil Engineering Productivity during the COVID-19 Pandemic Period are quantitatively determined and evaluated. The basis of the study is primarily the determination of the factors affecting the productivity of an employee. A questionnaire was designed to categorize the factors affecting employee productivity for data collection and statistical analysis. Productivity was measured by conducting a questionnaire with the construction industry employees who produced similar works before and during the COVID-19 Pandemic in Ankara and comparing the works produced by the individuals in unit time. The questionnaire was sent to the participants online and then confirmed by phone. 102 people were reached, but 12 people were not included in the study because they filled the questionnaire incompletely. The study was completed with a total of 90 participants. In the first part of the questionnaire, there are questions to collect demographic information. In other sections, questions are categorized related to sub-factors which are affecting productivity.

Research Findings

While evaluating the data obtained in the study, SPSS (Statistical Package for Social Sciences for Windows) 22.0 program was used for the statistical analysis. Shapiro Wilk-W test and Kolmogorov Smirnov test were used to show the normality distribution of the data. In addition,

skewness and kurtosis values were used to understand the shape of the distribution. Descriptive statistics were expressed as mean and standard deviation for continuous variables and were given as frequency and percentage for categorical data. Chi-square test was used for comparisons of categorical data. In the comparison of quantitative data, Independent Samples T-Test and One-Way Analysis of Variance (ANOVA) test were used for variables that met the assumption of normal distribution. When significance was detected in the ANOVA test, the significance was evaluated with Tukey measure as a post-hoc test. Statistical significance was accepted as $p<0.05$. For those who did not meet the normal distribution assumption, the Mann-Whitney U test, which is the non-parametric equivalent of the Independent Samples T-Test, and the Kruskal-Wallis H test, which is the non-parametric equivalent of the One-Way ANOVA, were used.

The questionnaire was based on a 5-point Likert-scale. The Cronbach Alpha (α) coefficient was used in the reliability and internal consistency analysis of the factors. Cronbach Alpha (α) coefficient, which takes a value in the range of 0 to 1, provides acceptable reliability for any value greater than 0,7 (Kılıç, 2016: 47). The Cronbach Alpha (α) values calculated for all the sub-factors were either very close to the threshold of 0,7 or higher. This indicates that the sub-factors are adequately reliable.

Table 1 shows the percentages and frequency distributions of the socio-demographic variables from the first part of the questionnaire .

Table 1 - Distribution of Participants' Socio-Demographic Characteristics

Variables and Corresponding Categories		n (%)
Gender	Male	47 (%52,22)
	Female	43 (%47,78)
Marital Status	Single	55 (%61,11)
	Married	35 (%38,89)
Position	Project Engineer	41 (%45,56)
	Center Office Engineer	13 (%14,44)
	Architect	17 (%18,89)
	Project Director	6 (%6,67)
	Draftsman	9 (%10,00)
	Other	4 (%4,44)
Professional Experience	0-2 Years	21 (%23,33)
	2-4 Years	20 (%22,22)
	5-9 Years	26 (%28,89)
	10 Years and Over	23 (%25,56)
Designated-Separate Room as a Workstation	No	14 (%15,56)
	Yes	76 (%84,44)
Support of Government	No	28 (%31,11)
	Yes	28 (%31,11)
	No idea	34 (%37,78)
Changes in Work Duration	Decreased	22 (%24,44)
	Not Changed	35 (%38,89)
	Increased	33 (%36,67)
Use of Building Information Modeling Tools	No	41 (%45,56)
	Yes	49 (%54,44)

The mean and standard deviation values for the continuous variables and factor scores are given in Table 2.

Table 2 - Mean, Standard Deviation, and Median Scores of Sub-Factors

	Mean & Standard Deviation	Median (minimum-maximum)
Employee	2,911±0,934	2,93 (1-4,43)
Manager	2,929±0,767	3 (1,33-5)
Equipment	3,27±1,32	3 (1-5)
Financial	2,86±1,27	3 (1-5)
Project	2,64±1,25	2,5 (1-5)
Environment	3,14±0,95	3,2 (1,2-5)
Productivity Change Percentage	0,626±6,018	0 (-13,01-16)

The distribution of the responses of participants for each variable is given in Table 3.

Table 3 - The Distribution of the Responses

Sub-Factor	Question	Strongly Disagree	Disagree	Neither agree nor disagree	Agree	Strongly Agree
		n (%)	n (%)	n (%)	n (%)	n (%)
Employee	Job Discipline	23 (%25,56)	14 (%15,56)	21 (%23,33)	19 (%21,11)	13 (%14,44)
	Changes in the Methods of Communication	20 (%22,22)	21 (%23,33)	19 (%21,11)	16 (%17,78)	14 (%15,56)
	Remote Control of CAD Files	22 (%24,44)	13 (%14,44)	20 (%22,22)	11 (%12,22)	24 (%26,67)
	Same Workplace and Living Space	17 (%19,1)	25 (%28,09)	10 (%11,24)	22 (%24,72)	15 (%16,85)
	External Stimuli in the House	16 (%17,78)	23 (%25,56)	12 (%13,33)	22 (%24,44)	17 (%18,89)
	The Disappearance of Control Pressure	30 (%33,33)	12 (%13,33)	11 (%12,22)	11 (%12,22)	26 (%28,89)
	Changes in Work Duration	23 (%25,56)	17 (%18,89)	15 (%16,67)	19 (%21,11)	16 (%17,78)
Manager	Not Familiar with the WFH Process	13 (%14,44)	20 (%22,22)	21 (%23,33)	11 (%12,22)	25 (%27,78)
	Motivation Enhancing Flexibility	14 (%15,56)	11 (%12,22)	34 (%37,78)	21 (%23,33)	10 (%11,11)
	Online Meeting Productivity	4 (%6,56)	8 (%13,11)	10 (%16,39)	29 (%47,54)	10 (%16,39)
	Status of Hiring a New Person	35 (%42,17)	16 (%19,28)	22 (%26,51)	4 (%4,82)	6 (%7,23)
Equipment	Lack of Infrastructure and Materials	15 (%16,67)	21 (%23,33)	10 (%11,11)	13 (%14,44)	31 (%34,44)
	Need for Technical Support	5 (%8,06)	18 (%29,03)	13 (%20,97)	13 (%20,97)	13 (%20,97)
Financial	Payment Problems	5 (%10,2)	9 (%18,37)	13 (%26,53)	5 (%10,2)	17 (%34,69)
	No Overtime Pay	25 (%40,98)	13 (%21,31)	6 (%9,84)	7 (%11,48)	10 (%16,39)
	Not Receiving the Expected Raises	12 (%23,53)	8 (%15,69)	10 (%19,61)	7 (%13,73)	14 (%27,45)
Project	Repetition of Work	23 (%26,14)	12 (%13,64)	20 (%22,73)	14 (%15,91)	19 (%21,59)
	Unforeseen Changes in the Project	33 (%36,67)	20 (%22,22)	17 (%18,89)	11 (%12,22)	9 (%10)
Environment	Decreased Health Concern	2 (%2,22)	17 (%18,89)	10 (%11,11)	22 (%24,44)	39 (%43,33)
	Lack of Coordination	13 (%14,44)	19 (%21,11)	14 (%15,56)	28 (%31,11)	16 (%17,78)
	Home Office Performance Drop	20 (%22,22)	17 (%18,89)	9 (%10)	32 (%35,56)	12 (%13,33)
	Work-Life Balance	17 (%18,89)	22 (%24,44)	12 (%13,33)	28 (%31,11)	11 (%12,22)
	Chores	27 (%30)	14 (%15,56)	16 (%17,78)	21 (%23,33)	12 (%13,33)

Hypotheses of the Research

The hypothesis of the study is listed below. The statistical analysis with respect to these hypotheses can be seen in Table 4.

H_1: Socio-demographic characteristics have a direct effect on productivity sub-factors.

H_{1_1}: Gender has a direct effect on the environment-related sub-factors related to productivity.

H_{1_2}: Presence of a designated-separate room as a workstation directly affects the changes in the productivity.

H_{1_3}: Changes in the work duration has a direct effect on the changes in the productivity.

Table 4: Statistical evaluation of H_{1_1}, H_{1_2} and H_{1_3}hypotheses

		Mean & Standard Deviation	Median (minimum-maximum)	t\F	p
Gender	Male	3,40±0,90	3,60 (1,40-5,00)	t=**2,796**	**0,006**
	Female	2,86±0,93	2,80 (1,20-4,20)		
Designated-Separate Room as a Workstation	No	-2,49±5,46	-1,45 (-13,01-9,00)	**t=-2,150**	**0,034**
	Yes	1,19±5,97	0,00 (-11,56-16,00)		
Changes in Work Duration	Decreased	4,73±5,05	4,78 (-3,67-16,00)	**F=23,193**	**<0,001** p^{ac}**<0,001** p^{bc}**<0,001**
	Not Changed	2,30±4,76	0,00 (-6,44-12,05)		
	Increased	-3,89±4,92	-3,50 (-13,01-7,40)		

A statistically significant difference was identified between male (3.40±0.90) and female (2.86±0.93) participants related to the environmental sub-factor scores with respect to gender (t=2.796; p=0.006). In terms of environment-related variables, the productivity of males was affected more severely than the productivity of females.

A statistically significant difference was identified between those who have a designated-separate room as a workstation at home (1.199±5.971) and those who do not (-2,489±5.464) with respect to the change percentage in the productivity **(t=-2,150; p=0,034)**. The productivity of those who do not have a designated-separate room as a workstation in their home is lower than those who have.

A statistically significant difference was identified between the change percentage in the productivity and the change in work duration **(F=23,193; p<0,001)**. Tukey's test was performed as a post-hoc analysis to determine which groups originated the difference. There is a difference between those whose working hours have decreased (4.733±5.046) and those whose working hours have increased (-3.892±4.922). There is also a difference between those whose working hours did not change (2.304±4.758) and those whose working hours increased (-3.892±4.922) **(p^{ac}<0,001; p^{bc}<0,001)**. The productivity of those whose working hours increased was lower than the productivity of those whose working hours decreased or did not change.

In the light of these explanations, hypothesis H_{1_1}, H_{1_2} and H_{1_3} were accepted.

Discussion of Findings

This study aims to determine how the transition to remote working, which is a new way of doing business, has affected employees' productivity in the construction industry during the COVID-19 pandemic. In addition, it is aimed to determine the factors affecting engineering productivity during the remote working period and to make improvement suggestions for the industry. Limitations of the study include the dataset being collected from a specific region only and the questionnaire being applied to people who produced similar projects before and during the COVID-19 pandemic. In other words, the dataset was collected from participants that produced similar projects before and during the pandemic period in Ankara.

Impact of Gender on Productivity

Transitions to remote work with the COVID-19 pandemic reduced health concerns as well as limiting people's social interactions. This exposed people at high levels of loneliness. In

particular, remote workers may suffer more from the process of staying at home because they do not have the opportunity to socialize with their colleagues. This situation reflects negatively on their work performance (Larson et al., 2020: 3; Toscano and Zappalà, 2020: 14; Wang et al., 2021:27). While people, who work in a regular office environment but had to switch to remote working due to the pandemic, may have a negative impact on their desire to work and their productivity may decrease. In addition, the same working and living space makes it difficult to determine the boundaries and balance between home responsibilities and work duties (Awada et al., 2021:1173). Work-related stress, role ambiguity arising from responsibilities between home and work, family-work conflict, disagreements with other people living at home are reflected in the performance of employees and affect their work productivity and work commitment (Galanti et al., 2021:427; Tong et al., 2021: 1). In a study that acknowledges work-family conflicts as gender-related, it is stated that such conflict attributes to women due to women being primary responsible of housework and childcare. The same study argued that men are affected by family-work conflict as much as women in the transition to WFH with the COVID-19 pandemic (Galanti et al., 2021: 427). Today, although men contribute more to housework, the traditional gender roles of society, which places childcare and housework responsibilities on women (Cerrato and Cifre, 2018: 9; Baert et al., 2020: 9). Therefore, WFH facilitates the balance of women's responsibilities between family-work-home and meeting the demands of other household members at home (Awada et al., 2021: 1183; Farooq and Sultana, 2021: 309). In another study, it was stated that while WFH, women were able to balance their work-home-child care responsibilities better than when they worked at the office and this was contributing to their productivity (Colley and Williamson, 2020: 23). It has been observed that women are more willing to work remotely than men and have higher productivity during the remote working period (Awada et al., 2021: 1185; Pérez et al., 2002: 273).

Impact of Having a Designated-Separate Room as a Workstation on Productivity

WFH during the COVID-19 pandemic has also highlighted the need for physical space in home-office environments. The point to be noted is that not all individuals working from home have a designated area for work. In this case, it may be necessary to use other areas in the house, such as the dining table or areas such as the kitchen counter and the coffee table. The lack of a special work area can affect the person both physically and mentally and reduce her/his performance at work (Xiao et al., 2021: 182-189). Working in a designated room for work ensures that the employee is isolated from distractions and gets the work done without interruption. Employees need to leave the living space and distractions to focus on their own work (Mello, 2007: 258). Huls et al., (2022: 84) found that participants, who have a designated-separate room at home and work there all day, had a higher productivity than those without a designated-separate room at home, or only use a designated-separate room for part of the day.

Impact of Changes in Work Duration on Productivity

Labor productivity depends on long working hours (Maqsoom et al, 2018: 16). Continuing overtime period throughout the project causes a decrease in labor productivity (Acıkara, 2016: 43). Employees who work overtime feel stress and fatigue that do not only decrease their productivities but also it causes them to make mistakes and get sick (Pencavel, 2015: 2073). Considering a certain hourly working time per week, overtime hours longer than 3 or 4 weeks cause fatigue and lead to productivity losses (Thomas and Raynar, 1997: 184-187). Moreover, the long working hours and the fact that individuals have to work outside of working hours negatively affect the work-life balance (Suvacı and Şimşek, 2021: 186). Work-life balance is the balancing of expectations at the work and private life of employees (Bekmezci et al., 2021: 3-4). Failure to establish a work-life balance causes an elevated level of stress in employees and accordingly negatively affects

motivation, performance, and productivity (Yılmaz and Sağlam, 2021: 522). Some of the employees believe that working fewer hours will reduce distraction and increase productivity as it will establish a better work-life balance (Colley and Williamson, 2020: 10).

Conclusion

In the fight against the COVID-19 pandemic, it has become a significant issue to continue the normal flow of life and work without interruption. Therefore, examining the changes in the productivity of employees during the transition to remote work has become a necessity for both managers and employees. This study aims to reveal how remote work, which is a new way of doing business after the COVID-19 pandemic, affects the productivity of employees in the construction industry. At the same time, it is aimed to determine the factors affecting productivity and to make suggestions for the improvements. Limitations of the study include the dataset being collected from a specific region only and the questionnaire being applied to people who produced similar projects before and during the COVID-19 pandemic.

If the productivity of the employees is increased and they are required to work with maximum efficiency, the first thing to do is to determine the factors affecting employee productivity. Therefore, within the scope of this study, the factors affecting the productivity of an employee, mostly a construction industry employee, were examined. With the results obtained from the literature review, the factors affecting the engineering productivity were categorized and a questionnaire was designed. The results of the questionnaire were analyzed statistically, and the acceptance-rejection status of the hypotheses was determined.

It was concluded that gender has a direct effect on the environment-related sub-factors of productivity. In other words, it was concluded that women are more productive than men during the remote working period. This shows that the remote working provides an advantage for women to establish a more comfortable home-work-life balance. In this regard, although the fact that men stay at home more and become more involved in the routines at home during the pandemic, this interrupts them although it is not an insurmountable situation.

Another hypothesis is that having a designated-separate room at home affects productivity. Having a designated-separate room as a workstation increases productivity. However, a designated-separate room as a workstation may not be in everyone's home. In this case, great sacrifice falls on the employee and the household members who lives with them. Employees, who do not have a designated-separate room, can use any room in the house as a workstation. Appropriate work duties may be assigned to employees, who do not have a designated-separate room, by managers. For example, they may attend only mandatory meetings and not included in every meeting.

The last hypothesis is the changes in working duration having an effect on productivity. It has been concluded that employees whose working durations decrease or do not change are more productive than those that increase. Working overtime does not always mean the work is perfect. After a while, working overtime gets tiring and wears out the employee. It also makes them more prone to mistakes. Although remote working provides flexibility, managers observing a decrease in the performance of their employees should intervene in this situation and certain time schedule for work should be arranged similar to the normal office environment.

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