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**Research Article**

# Barriers to the digital transformation process in the Turkish construction industry

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## ABSTRACT

Technological developments continue to accelerate from the past to the present. The increase in the pace of development has caused a decrease in the cost of technology. With the decreasing costs, technology has begun to take place in every aspect of our lives. An effort has emerged to incorporate these developments in business life. Although other industries' close relationship with digital developments come to the fore, unfortunately, it is not possible to see this situation in the construction industry. On the other hand, taken into account of competitive market conditions and inefficiency problems that the sector faces, there is a need for the construction industry to adopt digital technologies. For the adoption process to digitalization to proceed quickly and accurately, the barriers to digitalization need to be identified. Just as the construction industry lags other sectors in digital transformation processes, the Turkish construction industry also lags other countries in digital transformation processes. This study aims to pave the way for the creation of successful and easy-to-implement digital transformation strategies by identifying the barriers to digitalization in the Turkish construction industry. The research methodology of this study involved conducting a comprehensive literature review of articles published in the last 10 years. As a result of this research, 14 potential factors that could hinder the digital transformation process in the construction industry were identified from 38 sources and frequency analysis of these factors was carried out. Then, to determine the suitability of determined factors for the Turkish construction industry, a pilot study was conducted with 6 experts who have expertise in digital transformation and building information modeling applications. The findings emphasize the importance of these barriers to the digital transformation process in the Turkish construction industry. As a result, this study sheds light on the need to identify the factors that hinder digital transformation in the Turkish construction industry. The results of the study can guide studies aiming to examine the relationship between barriers to digital transformation in the Turkish construction industry or future studies aiming to develop digital transformation strategies in the Turkish construction industry.

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## INTRODUCTION

Patel and McCarthy first mentioned digital transformation in 2000. The most accepted definition of digital transformation in the literature is "digital transformation can be understood as the changes caused or affected by digital technology in all areas of human life." [1]. Digital transformation does not just mean keeping up with technology; customer satisfaction will also increase while adapting to technology. The main purpose of the transformation is to create digital business models that focus on organizational processes that will increase the agility, revenue, and cost of the business [2]. Digital transformation will help organizations become more efficient and productive and keep up with competitive market conditions (Fig. 1).

The construction industry is showing a new trend toward digital information exchange from the traditional written information exchange method that other sectors such as aviation and banking adopted and benefited from long ago. While this process was going on, it was observed that the construction and real estate sector was one of the lagging sectors in terms of digital maturity [4]. Therefore, the construction industry needs to change the way it works to compete in the digital age. Professionals in the construction industry, which has become a digital organization, will need to completely restructure the industry and processes in terms of customer engagement. In addition, it will be necessary to define and scope the digital strategy, which determines the structure of the transformation and the goals to be achieved, and to determine the progress processes, because the real strength of the digital strategy lies in its scope and goals [5].

The main purpose of this study is to determine the barriers to the digital transformation process in the Turkish construction industry. The results presented in line with the information obtained from the literature review, frequency analysis, and pilot study surveys are intended to help develop effective digital strategies.

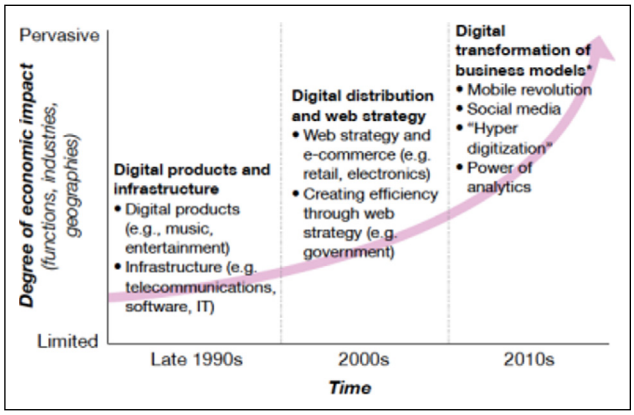


**Figure 1**. Evolution of digital transformation [3].

## THE CONCEPT OF DIGITAL TRANSFORMATION IN THE CONSTRUCTION INDUSTRY

The concept of Industry 4.0 is a strategic plan that aims to bring information communication technologies and industries together on a common ground and work together. It aims to incorporate technologies such as the Internet of Things (IoT), sensors, and cloud computing into industrial processes. Construction can already be said to be Industry 4.0 as it shares many similarities:

Building products are always adapted to the investor's requirements, standards, contracts, locations, and the like. In this direction, smart buildings and smart cities continue to develop in line with the needs of customers. From a business perspective, project work in construction has a dynamic nature. Construction 4.0 affects the improvement of construction costs and schedules. In addition, Construction 4.0 stands out as the biggest impact factor on business processes and security. From a technological perspective, the construction industry had digital twins even before these terms emerged, even if they were not called digital twins. Building Information Modeling (BIM), Asset Information Models, and Geographic Information Systems (GIS) are digital copies of their physical counterparts. The reason why the engineering and architecture industry is so remarkable is that digitalization will create many profit opportunities that will reduce costs throughout the entire life cycle [6].

### Construction 4.0

While innovative concepts covering technological developments are included even in traditional heavy industry, the construction sector stands out as one of the sectors with the lowest R&D intensity, although it is one of the most important industrial sectors. Construction 4.0 is a combination of various sensors, cameras, builders, and users; it is about exploiting the potential created by digitizing in digital form the data it reveals about buildings, objects, and the already-built environment [6].

The naming of Industry 4.0 specifically for the construction industry is referred to as Construction 4.0 by the European Construction Industry Federation. Digitalization of the construction industry has many aspects of advanced processes and technologies such as Industrial production (prefabrication, automation, 3D printing, Robots, and Digital construction sites [6].

Analyses regarding the factors affecting the demand direction in the market and production environment show that organizing customers' demands for unique designs and inert products according to projects has become the most appropriate choice. Structuring by projects means that time, cost, and scope will be central to the management system. However, traditional demands from customers for a low-price-based procurement policy force actors to create a project network with the lowest bidders.

This can be seen as an important reason for the short-term market-based relationships that characterize the sector. It is worth noting that the engineering and architecture industry is approaching Industry 4.0 from a different direction than others. Construction 4.0 does not describe the mass production of consumer-specific products, but industrialization, an organization for mass production that seeks opportunities for repetition and continuity of production. Construction has always been involved in the production of unique, one-of-a-kind products and has never had examples of true mass production within the scope of construction processes. The engineering industry's approach to producing goods can be viewed as craft production on a large scale; The product is traditionally a skyscraper, bridge, or residential type. Therefore, the main goal of the industry is the industrialization of the production of unique products, which is quite different from other industries, which is the privatization of production [7].

In the construction industry, the project has an interdisciplinary, fragmented, and temporary structure. Organizations are characterized by process disruptions and unique projects. This fragmentation makes it very difficult to meet the requirements of the construction project in terms of cost, time, and productivity. Interdependencies between finance, institutions, authorities, architects, engineers, and other different stakeholders increase complexity, making it necessary for construction projects to improve integration, collaboration, communication, and coordination. The most important elements of stakeholder interaction are information management and communication processes, which are considered essential components of human collaboration. Documents serve as an important carrier of information. In today's business world, files created and stored with computers that require ICT are considered documents. The mentioned aspects of construction projects are very dependent on reliable and up-to-date information. For this reason, it is an undeniable fact that ICT-based business systems, communication tools, and shared storage servers are needed [8].

It can be said that the lack of innovation in construction project management practices leads to a loss of productivity. Digitalization is a hot topic in the construction industry today, supported by a multitude of advanced ICT tools. Web-based project platforms, digital meetings, and BIM have been around for some time, although they often do not reach their full potential. For most professionals in the construction industry, ICT provides essential needs in daily work. Proper digitalization of construction and project management applications can help reverse the decline in productivity [8]. Therefore, in order to increase the digital maturity of companies, the digital competencies of company employees need to be developed and strengthened across the cross-section of information technologies and business. Since it is a business initiative enabled by information technology, it is beneficial to assign accountable job roles to ICT personnel. It is important to develop and build an organizational culture conducive to successful digital transformation. The appropriate institutional environment needs to be strengthened and its development accelerated [6].

**Digital Applications in the Construction Industry**

Some digital applications commonly used in the construction industry can be listed as follows:

- **Building Information Modeling (BIM):** The software used by construction stakeholders for all construction stages is different from each other. This has made integrating design, schedule, and cost in real-time unattainable. In addition to the 3D parameters of standard spatial design, Building Information Modeling also allows entering time data into models and cost data into objects. Provides faster reaction and greater accuracy. It allows construction users to analyze the variable schedule and project cost and determine results. Building Information Modeling offers an alternative that incorporates virtual reality and augmented reality to make both design and construction processes more sustainable and more efficient [2].
- **Prefabrication:** Due to its off-site capabilities, prefabricated construction can be integrated with the construction site and transformed into a production system. This integration will increase efficiency and safety also reduce waste [2].
- **Unmanned Aerial Vehicle (UAV):** Unmanned aerial vehicles, known as UAVs, are pilotless, remotely guided vehicles equipped with cameras and sensors. These vehicles, which are used in areas such as the defense industry, have been commercialized and produced in different sizes, capacities, and features. They may have scanners, cameras, and radio frequency recognition readers. While conducting surveillance, they can detect environmental problems, see the danger, and report it. With their maneuverability and speed advantage, they can be used for purposes such as work monitoring, inspection, reducing work accidents, accessing remote points, dominating large areas, field control, and spatial analysis [9].
- **Laser scanning technology:** Laser scanning technologies enable realistic three-dimensional surveys of buildings or lands to be taken. Thanks to the use of laser scanning technologies in the construction industry, works such as renovation of buildings and repairs are accelerated, and measurement-based errors are eliminated. There are different types of laser scanners such as airborne laser scanners, mobile laser scanners, and terrestrial laser scanners. Reconstruction and 3D models of buildings/cities/streets can be produced with aerial laser scanners. During this process, auxiliary

elements such as image techniques and map data are also used.

- **3D Printing:** 3D printing is the process of obtaining a concrete object from virtual data in computer systems. To obtain a concrete object through printing, 3D printers are needed as well as data with which the printer can visualize the 3D object. The time and cost of construction can be significantly reduced by using a 3D printer. Additionally, the printer can produce a variety of building materials, from concrete to mortar.
- **Robots:** Large machines such as cranes and bulldozers are frequently encountered in the construction field. Construction industry, demolition, leveling, digging, etc. It requires more robots that can perform operations more effectively and with less human energy. Making these machines autonomous can yield great results for projects in many ways. It enables safer sites by controlling progress and ensuring workers are not harmed. It also increases the efficiency of the work. In terms of safety, robots can perform more risky and challenging jobs on the construction site [2].

## METHODOLOGY

The research methodology of this study involved 1) conducting a comprehensive literature review for determining the barriers to the digital transformation process in the construction industry and 2) conducting pilot study with experts who have expertise in digital transformation and building information modeling applications in order to validate the suitability of determined factors for Turkish construction industry. Details for each stage can be found below.

### Literature Review for Identifying Barriers to the Digital Transformation Process in the Construction Industry

To determine the factors that hinder digital transformation in the construction industry, publications were searched in Scopus and Google Scholar databases using the keywords "digital adaptation, digital technology, digital transformation, construction industry, barriers". From the results, those that were not related to the construction industry were eliminated, and then 38 sources with publication dates between 2013 and 2023 were identified. Thanks to this approach, relevant and up-to-date sources related to the subject were provided to guide the study. The factors that hinder digital transformation in the construction industry in these determined sources and the frequency analysis results of these factors are presented in Table 1.

In the study, the high cost of the digital transformation process stands out as the most prominent barrier, being mentioned in 28 out of 38 sources. This barrier is followed by the barrier of the team working in the construction industry not accepting the digital transformation process, with a frequency of mention in 26 out of 38 sources, and by the factor of lack of competent technical personnel and the lack of existing legislation and standards for digital transformation, with a frequency of mention in 23 out of 38 sources. The barriers with the least frequency of mention are the government's lack of support for digital transformation, which is mentioned in 7 out of 38 sources, hardware, and software errors in technological structures, and lack of competition and motivation for digital transformation in the construction industry.

### Pilot Study

The factors shown in Table 1 include the barriers to digital transformation processes in different countries. However, since each country must be evaluated within its conditions, the determined factors should be validated in terms of their suitability for the Turkish construction industry. For achieving this, a pilot study was carried out with a total number of six participant who have expertise in digital transformation and building information modeling applications. The demographic structure of the participants is presented in Table 2.

While five of the six experts who participated in the survey are civil engineers, one of them is an architect. In addition, five of these six participants are academicians and one of them works as a project manager. The participant with the least professional experience has been working in his current position for four years, while the participant with the longest professional experience has ten years of experience. The average age of the people participating in the survey stands out as 32 years, and the average professional experience is 6.58 years.

In the pilot study, participants evaluated the suitability of determined barriers to the digital transformation process for the Turkish construction industry and expressed their opinions on why they did not find them suitable. In line with the evaluations and comments from experts, the barriers to the digital transformation process in the Turkish construction industry were identified.

## RESULTS

As a result of the literature study, the participants expressed their opinions about the suitability of the barriers to digital transformation in the construction industry for the Turkish construction industry. Participant No. 1 stated that the barrier "Lack of competition and motivation for digital transformation in the Construction Industry" and the barrier "Lack of models that can exemplify digital transformation" overlap with each other. He also said that the barrier "The government's lack of support for digital transformation" was not appropriate but did not express any opinion and stated that other barriers were appropri-

**Table 1.** Barriers to the Digital Transformation Process in the Construction Industry

| | Barriers | Explanation | Reference | Frequency |
|---|---|---|---|---|
| 1 | Lack of information about digital transformation in the construction industry | The construction industry, with its traditional structure, has been left out of technological developments and has not been able to follow the digital developments in different sectors. Industry stakeholders do not have sufficient information about the benefits and innovations that new technologies can bring to the construction industry. | [11-24] | 14/38 |
| 2 | The team working in the construction industry does not accept the digital transformation process | Adapting to the use of digital developments and taking part in new training processes requires extra work and effort for team members. In addition, the belief that the human factor in business processes will decrease with the use of new technologies causes employees to be reluctant about digitalization. | [6, 10, 13-19, 23-39] | 26/38 |
| 3 | Lack of competent technical personnel | The construction industry is highly competitive. To increase company success, it becomes necessary to transition to innovative technologies. The sooner adaptation to this transition process is achieved, the easier it will be to keep up with the competition. To increase the adaptation and skills of employees, the adaptation skills of employees should be kept at the highest level by providing qualified trainers and appropriate motivation management. However, the number of competent technical personnel who will provide the necessary training to employees is limited. | [1, 3, 6, 10-18, 20, 22-25, 28, 30, 32, 34, 40-42] | 23/38 |
| 4 | Lack of effective leadership in the digital transformation of companies | Digital transformation processes of companies require high financial investment, a new organizational structure, and training processes. Therefore, transformation processes must be carefully planned and carried out down to the smallest detail. It is very difficult to find a manager who is qualified to lead this process. | [13, 17-19, 22-24, 36, 38] | 9/38 |
| 5 | The high cost of the digital transformation process | The high budget to be allocated to the training of employees in the digital transformation process and the uncertainty about the estimation of financial returns in response to high investments such as technological infrastructure costs cause companies to refrain from transforming their organizations. | [1, 6, 10, 11-19, 21, 22, 24-29, 30-35, 37, 41] | 28/38 |
| 6 | Length of personnel training processes | For a digital structure to operate smoothly, employees within the organization must receive qualified training. Since digital structures are not easy to understand, the training to be provided will require a certain process. The fact that this process is not short causes a distant attitude toward transformation in the construction industry, which is already racing against time. | [11-13, 15, 17, 19, 24, 35, 40, 41, 43] | 11/38 |

**Table 1.** CONT.

| | Barriers | Explanation | Reference | Frequency |
|---|---|---|---|---|
| 7 | Government's lack of support for digital transformation | The inadequacy of policies to encourage companies by the state constitutes a barrier to accelerating the transformation process. | [17, 18, 20, 22, 38, 39, 41] | 7/38 |
| 8 | Lack of current legislation and standards for digital transformation | Particularly in developing countries, governments' positive approach to innovative technologies is rarely encountered. This distant attitude towards new technologies also delays the change process of legal regulations. For digital transformation to occur, compliance with legal processes is required. In particular, rules regarding privacy and confidentiality pose a barrier to transformation. | [6, 10, 11-14, 17, 18, 20-25, 27-31, 34, 35, 37, 44] | 23/38 |
| 9 | Data security concern | The inclusion of new technologies in organizations also brings cybersecurity concerns. Especially in a sector such as the construction sector, which is constantly progressing actively and constantly producing data; Storing all this accumulated data and the concern that anyone can access the stored data constitute a barrier to technological transformation. | [6, 10-12, 14, 16, 17, 20, 21, 23, 24, 27-29, 31, 32, 36, 39, 41] | 19/38 |
| 10 | Uncertainties arising from the complete restructuring of the company structure | To get full efficiency from the implementation of digital transformation, all levels of the organization must be involved in the change. Any error occurring at any lower level during the transformation process will affect the entire structure. It is very difficult to predict the loss of time and money that possible disruptions will bring. | [1, 6, 10, 13-17, 19-21, 23, 29, 34, 42, 43] | 16/38 |
| 11 | Interoperability and coordination concern | Digital structures are systems that directly interact with all employees. Therefore, it is more important than ever that all participants are aware that they are part of a whole. Incompatibilities between participants will completely affect the functioning of the digital system. | [1, 14, 17, 22, 23, 26, 28, 33, 35, 36, 40, 43] | 12/38 |
| 12 | Lack of models that can provide examples of digital transformation | The number of companies going through digital transformation processes in the construction industry is quite low. Therefore, it is not clear how to complete the digital transformation phases most efficiently. The lack of a model that sets an example for the sector causes companies to take a distant attitude toward digital transformation. | [6, 10, 15, 17, 19, 20, 23, 24, 27, 29, 31, 34, 38, 40, 42] | 15/38 |
| 13 | Hardware and software errors in technological structures | Hardware and software errors that occur in digital technologies are not the type of errors that can be easily intervened. The problem should be resolved by experts on the subject. The time it will take for the solution process and the fact that things will not proceed manually throughout the process make companies think about the approach to digital transformation. | [13, 16, 24, 27, 32, 34, 43] | 7/38 |
| 14 | Lack of competition and motivation for digital transformation in the construction industry | There is a need for organizations that have completed their digital transformation in the construction industry and will set an example for other companies that benefit from the benefits of the transformation. However, since the number of companies involved in the digital transformation process is low, there is a lack of competition and motivation within the sector. | [14, 17, 19, 21, 36-38] | 7/38 |

**Table 2.** Demographics of participants

| | Job | Age | Position | Professional Experience |
|---|---|---|---|---|
| Participant 1 | Civil Engineer | 33 | Academician | 10 Years |
| Participant 2 | Architect | 29 | Academician | 5 Years |
| Participant 3 | Civil Engineer | 32 | Academician | 10 Years |
| Participant 3 | Civil Engineer | 28 | Academician | 5,5 Years |
| Participant 4 | Civil Engineer | 28 | Academician | 5 Years |
| Participant 5 | Civil Engineer | 42 | Project Manager | 4 Years |

ate. Participant No. 5 stated that the barrier of "Lack of effective leadership in the digital transformation of companies" is that although managers have shortcomings, they can take an active role in the processes due to the benefits they can bring and stated that this barrier is not suitable for the Turkish Construction industry. He stated that the barrier of "length of personnel training processes" is not appropriate because it is a factor affecting the motivation of the personnel to receive training. He also stated that the barrier of "Lack of models that can exemplify digital transformation" is not suitable, stating that there are exemplary models that can be taken from developed countries and that the other barriers are suitable for the Turkish Construction industry. Participant No. 6 stated that the barriers of the "High cost of the digital transformation process", "Lack of support from the government for digital transformation", "Lack of current legislation and standards for digital transformation", "Data security concern" and "Lack of a model to exemplify digital transformation" are suitable for the Turkish Construction industry. He expressed his opinion that it was not. However, he did not share any opinion as to why he found it inappropriate. Participants No. 2, 3, and 4 stated that all the determined barriers are suitable for the Turkish Construction industry. The answers given by the participants are presented in Table 3.

The participants' opinions, it was observed that two out of six participants stated that the barrier of lack of a model that could exemplify digital transformation was not appropriate. In addition, considering the opinion of another participant that this barrier is similar to the barrier of lack of competition and motivation for digital transformation in the construction industry, the barriers of "lack of competition and motivation for digital transformation in the construction sector" and "lack of models that can exemplify digital transformation" were combined into a single barrier. It was concluded that it should be evaluated.

The opinion stated that the barrier of "lack of effective leadership in the digital transformation of companies" is that even though managers have shortcomings, they can take an active role in the processes due to the benefits they can bring, the comment was made considering that the desire of the managers to take an active role in the process does not compensate for their shortcomings in leading the process was not found valid, and considering the decision of the majority, the barrier Turkish construction industry It has been accepted as valid for.

The comment that the "length of personnel training processes" barrier is a factor affecting the motivation of the personnel to receive training was not found to be meaningful, considering that the same barrier would also affect the ideas of the management staff in the transformation processes, and considering the decision of the majority, this barrier was accepted as valid for the Turkish construction industry.

The comment stating that the barrier of "lack of models that can exemplify digital transformation" is that there are exemplary models that can be taken from developed countries shows that the participant thinks that there is a lack of models in the Turkish construction industry. The comment received is a solution proposal to this barrier, therefore, considering the decision of the majority, this barrier has been accepted as valid for the Turkish construction industry.

Since there were no comments regarding other barriers, they were accepted to be valid in the Turkish construction industry, considering the decision of the majority. The results identifying the barriers to the digital transformation process in the Turkish construction industry are presented in Table 4.

## CONCLUSION

This study aims to identify barriers to the digital transformation process in the Turkish construction industry and to support initiatives aimed at developing digital transformation strategies. For this purpose, a literature review was conducted to determine the barriers to the digital transformation process in the construction industry, and fourteen barriers were identified. Barriers selected from international studies were presented to experts in the field in Turkey along with their frequency analysis, and a survey was conducted to evaluate the validity of the barriers for the Turkish construction industry. As a result of the study,

**Table 3.** Participants' responses regarding the suitability of Barriers for the Turkish construction industry

| | Barriers | Participant 1 | Participant 2 | Participant 3 | Participant 4 | Participant 5 | Participant 6 |
|---|---|---|---|---|---|---|---|
| 1 | Lack of information about digital transformation in the construction industry | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 2 | The team working in the construction industry does not accept the digital transformation process | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 3 | Lack of competent technical personnel | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 4 | Lack of effective leadership in the digital transformation of companies | ✓ | ✓ | ✓ | ✓ | × | ✓ |
| 5 | The high cost of the digital transformation process | ✓ | ✓ | ✓ | ✓ | ✓ | × |
| 6 | Length of personnel training processes | ✓ | ✓ | ✓ | ✓ | × | ✓ |
| 7 | Government's lack of support for digital transformation | × | ✓ | ✓ | ✓ | ✓ | × |
| 8 | Lack of current legislation and standards for digital transformation | ✓ | ✓ | ✓ | ✓ | ✓ | × |
| 9 | Data security concern | ✓ | ✓ | ✓ | ✓ | ✓ | × |
| 10 | Uncertainties arising from the complete restructuring of the company structure | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 11 | Interoperability and coordination concern | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 12 | Lack of models that can provide examples of digital transformation | ✓ | ✓ | ✓ | ✓ | × | × |
| 13 | Hardware and software errors in technological structures | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 14 | Lack of competition and motivation for digital transformation in the construction industry | × | ✓ | ✓ | ✓ | ✓ | ✓ |

**Table 4.** Barriers to the Digital Transformation Process in the Turkish Construction Industry

| | Barriers | Explanation |
|---|---|---|
| 1 | Lack of information about digital transformation in the construction industry | Industry stakeholders do not have sufficient information about the benefits and innovations that new technologies can bring to the construction industry. |
| 2 | The team working in the construction industry does not accept digitalization | Employees are reluctant to digitalize due to the belief that the human factor in business processes will decrease with the use of new technologies. |
| 3 | Lack of competent technical personnel | The limited number of technical personnel competent to provide the necessary training to sector employees. |
| 4 | Lack of effective leadership in the digital transformation of companies | The difficulty of finding a manager who will carefully plan and carry out the transformation processes down to the smallest detail and lead this process. |
| 5 | The high cost of the digital transformation process | During the digital transformation process, high investments such as the high budget to be allocated to employee training and the cost of technological infrastructure cause companies to refrain from transforming their organizations. |
| 6 | Length of personnel training processes | The training process to be given to personnel for the use of digital technologies is long. |
| 7 | Government's lack of support for digital transformation | Insufficiency of policies to encourage companies by the state. |
| 8 | Lack of current legislation and standards for digital transformation | As a result of the government's lack of a positive approach to innovative technologies in developing countries, their distant attitude towards new technologies delays legal regulations. |
| 9 | Data security concern | Concern that anyone can access stored data. |
| 10 | Uncertainties arising from the complete restructuring of the company structure | To achieve full efficiency in the implementation of technological transformation, all levels of the organization must be involved in the change and the uncertainties that come with it. |
| 11 | Interoperability and coordination concern | Since digital structures are directly active interactive systems with all employees, incompatibilities between participants completely affect the functioning of the digital system |
| 12 | Lack of models that can provide examples of digital transformation | The number of companies going through digital transformation processes in the construction industry is very low and therefore there is a lack of a model that can set an example for the sector |
| 13 | Hardware and software errors in technological structures | An error that occurs in digital systems can only be corrected with the intervention of experts in the field and work cannot proceed manually in this process. |

it was concluded that the barrier of "lack of competition and motivation for digital transformation in the construction industry" and the barrier of "lack of a model that can exemplify digital transformation" should be combined and evaluated as a single barrier. Thus, the number of barriers, which was initially determined as fourteen, decreased to thirteen.

This study only aims to identify the barriers to the digital transformation process in the Turkish construction industry. Based on the study results, the relationship between barriers can be examined and prioritized in order of importance. In addition, the relationship between barriers and their order of importance may vary among companies, so the relationship between barriers can also be evaluated on a company scale basis. Survey results can still help determine priority steps by shedding light on future studies on developing digital transformation strategies.

## AUTHORSHIP CONTRIBUTIONS

Authors equally contributed to this work

## DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

## CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

## ETHICS

There are no ethical issues with the publication of this manuscript.

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