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RESEARCH ARTICLE

Barriers to the Adoption of Digitalization in the Construction Industry: Perspectives of Owners, Consultants, and Contractors

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Abstract

Construction organizations are moving toward adopting digitalization in response to Industry 4.0. However, the slow adoption of digitalization has been observed. This study aimed to assess the level of digitalization adoption and evaluate the barriers to adopting digitalization in the Jordanian construction industry by all project parties in the public and private sectors. Data was collected from 438 replies from construction practitioners through a structured questionnaire. The study targets were achieved by analysing data using SPSS software through the following statistical tests: Normality test, Mann-Whitney U, Kruskal-Wallis H, and Exploratory Factor Analysis (EFA). Most respondents used software at the design stage, and less than half did not use any software during the finishing stage. Regarding the barriers, twenty barriers to adopting digitalization were identified and grouped into five factors according to their importance: barriers related to the nature and system of the construction company, barriers related to the project parties, financial barriers, barriers related to system characteristics, and barriers related to construction project characteristics. Decision-makers should take the necessary measures to overcome such barriers depending on their importance. Previous studies have focused on the contractor's adoption of digitalization while neglecting other parties. This contributed to the full adoption of digitalization from the contractor side, with a

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noticeable delay from other project parties. This study focused on revealing the most critical barriers to adopting digitalization in the Jordanian construction industry from all project parties' perspectives based on their ranks. Furthermore, the study recommends effective strategies to overcome barriers as an update of past research.

Keywords

Industry 4.0; Construction 4.0; Digitalization; Barriers; Adoption; Jordan

Introduction

The construction sector is an influential support in the Jordanian economy (Khlaifat, et al., 2019). Its participation rate in the Gross Domestic Product (GDP) has increased to 7%, at the end of January 2022 according to the Hashemite Kingdom of Jordan department of statistics DOS in 2022. However, the Jordanian economy has faced many challenges lately, especially during COVID-19: similar, to the global economy. The biggest challenge is attempting to revive the economy (Al-Lozi and Hamed, 2021).

Considering the recent global experience and the need to improve the management of construction projects, it is necessary to search for successful solutions. One of the proposed solutions is the shift toward digitalization (Weisner, Cawley and Sindlinger, 2017), which represents a response to the Fourth Industrial Revolution (Alaloul, et al., 2020). Understanding the importance of digital transformation, the Jordanian government has made strategies to establish the idea of such transformation in most sectors since 2016. The strategies aimed to reach full adoption by 2025 (Adaileh and Alshawawreh, 2021).

Attempts to adopt digitalization have faced many international barriers that prevent its implementation. It should be noticed here that most studies (Nitithamyong and Skibniewski, 2006; Dossick and Sakagami, 2008; Lu, et al., 2014; Sweis, 2015) have focused on the contractor's adoption while neglecting other project parties (Jahanger, et al., 2021a; 2021b). Based on that, research must be continued to reveal the critical barriers from all project parties' perspectives, especially in countries such as Jordan, which has a recent experience in digitalization.

This encourages the research goals of this paper, which are to assess the level of digitalization adoption and identify barriers that prevent the adoption of digitalization in the Jordanian construction industry by the construction project's major players. This paper defines barriers as any restriction, challenge, or limitation that could affect digitalization adoption in construction. The paper focuses on the four phases of the project to reach full digitalization adoption in construction. Based on a sequence of statistical analyses performed on a structured questionnaire, data were collected from the practitioners of Jordanian construction companies. A general agreement was noticed about the importance of digitalization barriers between the project parties, with slight differences. Accordingly, the most significant barriers were identified and ranked. These results can guide the Jordanian construction industry's attempt to implement digitalization.

This paper consists of six sections: the first section clarifies the research background, objectives, and significance; the second section reviews digitalization literature; the third section shows the systematic methodology used; the fourth section presents and analyzes research results, the fifth section discusses research results, and the last section ends the paper with a set of conclusions and recommendations.

Literature Review

BACKGROUND AND OVERVIEW OF THE CONSTRUCTION INDUSTRY

Centuries ago, construction was seen as a craft, but it became a systematic sector with a set of rules in the 1900s (Chinowsky and Diekmann, 2004). In the early fifties of the last century, project management

emerged as an administrative position (Alshawi and Ingirige, 2003). However, several challenges hinder the development of the construction sector (Schöberl, et al., 2020). Traditional management practices in construction projects face challenges such as the efficiency of the construction work, time and cost, and coordination between parties (Amusan, et al., 2018). The Jordanian construction industry has been exposed to many impediments due to the Covid-19 lockdown. Social distancing and public safety obligations affected construction (Bsisu, 2020)

The world has recently reached the Fourth Industrial Revolution, which is based on three basic concepts: activating automation, adopting digitalization, and using Information and Communication Technology (ICT) (Alaloul, et al., 2020). Many sectors adopted the main principles of the Fourth Industrial Revolution, where digitalization is one of its most important concepts (Sriram and Vinodh, 2021). The Fourth Industrial Revolution is called Industry 4.0 (Wang, et al., 2021), and the adoption of Industry 4.0 technologies in the construction sector is called Construction 4.0 (Kozlovska, Klosova and Strukova, 2021; Osunsanmi, et al., 2020; Perrier, et al., 2020).

Digitalization in construction is defined as improving various phases of the construction project by utilizing digital tools and techniques (Aghimien, Aigbavboa and Oke, 2019). Such techniques can be adopted in any part of the delivery or management process. The required software for this digital transformation is divided into: (1) electronic document management systems (EDMSs) such as Doc Express and 2) construction management software (CMS), such as Primavera P6 (Shah, et al., 2017). Unfortunately, the construction sector suffers from a noticeable delay in the adopting digitalization compared to other sectors (Aghimien, et al., 2021). The Jordanian construction sector also experiences such delays in implementing digitalization (Alabbadi, 2022; Alweshah, 2022). However, it is necessary to identify such obstacles that limit digitalization implementation (Jahanger, et al., 2021b).

TECHNOLOGY ADOPTION IN THE CONSTRUCTION INDUSTRY AS PART OF THE SHIFT TOWARD DIGITALIZATION

The research process to determine the benefits, challenges, and barriers of various technological methods have begun in the past 20 years, leading to the digitalization trend lately. Studies' different experiences are discussed chronologically.

Much research appeared in Australia regarding ICT implementation in construction. Peansupap and Walker (2005) clarified that using ICT has improved communication between project parties and has contributed to enhancing the effectiveness of many construction processes.

Generally, there is a lack of research related to technology adoption in the construction industry of Middle Eastern countries. Ahmad and Zink (1998) studied Information Technology (IT) adoption in the public sector in Jordan. Results were promising as they indicated that most companies use computers in their work. It should also be noted that the research on the use of IT in the Saudi construction sector began early. Shash and Al-Amir (2006) indicated a need for the Saudi construction sector to adopt IT in response to population growth.

Rezgui and Zarli (2006) identified a set of limitations that prevent the effective implementation of ICT. Most of the identified limitations arose from insufficient technological support. While Nitithamyong and Skibniewski (2006) identified a set of factors that could influence the success of Web-based Project Management System (WPMS) implementation, such as workforce, and project features.

Dossick and Sakagami (2008) showed that the complexity of the construction project and project type are the main obstacles that prevent the use of WPMS in construction. Chen and Kamara (2008) focused on mobile computing in construction project management, where mobile computer type and storage were considered as the potential factors that affected mobile computing adoption. Therefore, Lam, Wang and Tse (2009) focused on the barriers that prevent the practical application of ICT in construction project

management in Hong Kong. IT technical support and the absorptive capability of the system in transferring information were the most significant barriers.

Wong and Lam (2010) studied the difficulties that prevent the successful implementation of ICT in construction projects. The results showed that end-users accepted the use of ICT. However, their institutions did not provide sufficient support for this issue.

In response and as a development of previous research, Chen and Kamara (2011) provided a framework for effectively implementing mobile computing in construction projects through technical and application models. However, there is a need to develop research in this field and evaluate the validity of previous studies.

Doloi (2014) focused on highlighting the need to rationalize the Web-Based Project Management (WBPM) implementation in construction projects based on two main factors: information streamlining and project complexity. Thus, Lu, et al. (2014) covered all aspects of ICT adoption in construction projects. The importance of ICT adoption lies in enhancing work efficiency and improving communication. Martínez-Rojas, Marin and Vila (2015) indicated that enabling ICT from project data will positively impact controlling and managing project costs.

Hasan, et al. (2019) explained that the tendency of the construction sector to adopt ICT in managing construction projects must be justified. Improving work planning and decreasing time waste are the main results of adopting ICT.

Highlighting the Middle East once again, Alsahli (2011) studied factors that may affect the use of IT in construction. The most important factors can be categorized as follows: the readiness of the organization, available resources, financial readiness, and institutional laws. As for Jordan, Sweis (2015) studied the reasons behind delays in adopting IT in Jordanian construction. Frequent changes at relatively late stages in the design and continuous attempts to reduce the schedule were considered the main factors that limit and influence IT adoption.

As previously mentioned, digitalization is one of the essential concepts of Construction 4.0. Several studies revealed the hurdles to adopting construction 4.0 principles.

Osunsanmi, et al. (2020) considered the costs of implementing Construction 4.0 and the nature of the construction industry as the most critical hurdles. Zabidin, Belayutham and Ibrahim (2021) clarified the impact of the financial and knowledge constraints in adopting Construction 4.0. Demirkesen and Tezel (2022) indicated that the financial costs, poor understanding of technology features, and construction project characteristics are the main difficulties in implementing Construction 4.0.

Digitalization involves using software in construction work, document management, monitoring construction activities (ASCE Grand Challenge, 2017; Abu-Khader, 2023). Jahanger, et al. (2021a) identified the positive results of owner adoption of Digital Construction-phase Information Management DCIM: improving transparency and credibility of project data and managing documents efficiently. However, it is necessary to identify the factors that limit the successful implementation of DCIM. Considering this, Jahanger, et al. (2021b) identified a series of factors that hinder the implementation of DCIM. Adequate support from institutions, the system's adequacy to business needs, the degree of the project's complexity, and financial requirements were the main factors behind DCIM delay implementation.

Schöberl, et al. (2020) clarified three main aims to achieve digitalization in the construction industry as follows: connecting and automating construction equipment with auxiliary systems, digitalizing the infrastructure and any process associated with it, and digitalizing all construction processes with a tracking system. Therefore, Bajpai and Misra (2021) studied digitalization obstacles in Indian construction. The study resulted in 14 obstacles related to training, management skills, and legislation.

There is no doubt about digitalization's importance in construction. Sanchez-Riofrio, et al. (2020) studied the impact of marketing digitalization on improving the performance of companies. The study showed that many institutions failed to benefit from market digitalization which was negatively reflected in their performance. By contrast, Aghimien, et al. (2021) evaluated the risks of digitalizing the construction sector. The study showed the following five fundamental factors related to digitalization: financial and human factors, safety and legal factors, technological factor, operation factors, and socioeconomic factors.

In particular, the Middle East and Jordan, many studies have focused on the positive impact and challenges of adopting Construction 4.0. Improving performance, controlling the schedule, and improving labour efficiency were the most important benefits of adopting Construction 4.0. Costs and workforce were the most formidable challenges (Alabbadi, 2022; Alweshah, 2022). Both studies paved the way for the current study, which is concerned with an essential concept of Construction 4.0 digitalization.

BARRIERS OF ADOPTING DIGITALIZATION IN THE CONSTRUCTION INDUSTRY

The main objective of the previous section is to review the past literature on digitalization barriers in construction to fill the gaps and complete the research. Table 1.a, and 1.b shows the most critical extracted barriers preventing the adoption of digitalization in construction, their reference citation, and their frequency percentages. Digitalization barriers are presented in descending order according to their frequency. The inefficiency of training systems associated with the use of digitalization software barrier got the highest percentage in frequency.

Table1.a. Barriers with their reference citation

Reference	Country	Barriers																		
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
Demirkesen and Tezel (2022)	USA			X	X												X				
Zabidin, Belayuthin and Ibrahim (2021)	Malaysia	X			X																
Bajpai and Misra (2021)	India	X	X		X	X		X	X		X					X					
Jahanger, et al. (2021b)	USA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X
Osunsanmi, et al. (2020)	South Africa			X	X																
Sweis (2015)	Jordan			X																	
Doloi (2014)	Australia			X																	
Alsahali (2011)	Saudi Arabia		X		X	X					X						X				
Chen and Kamara (2011)	UK												X							X	
Wong and Lam (2010)	Hong Kong	X	X	X			X	X		X		X									

Table 1.a. continued

Reference	Country	Barriers																		
		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15	B16	B17	B18	B19	B20
Lam, Wong and Tse [2009]	Hong Kong	X	X			X	X	X		X		X		X							
Dossick and Sakagami [2008]	USA Japan	X											X								
Rezgui and Zarli [2006]	Europe	X	X			X			X					X	X	X					
Nitithamyong and Skibniewski [2006]	USA	X	X	X	X		X	X				X	X		X			X			
Peansupap and Walker [2005]	Australia	X				X	X		X	X	X						X		X		
Percentage %		60	47	47	47	40	33	33	27	27	27	27	27	20	20	20	20	13	13	13	6

Table 1.b. Digitalization Barriers

B	Barrier
1	The inefficiency of training systems associated with the use of digitalization software
2	Inadequateness of the purchased software to meet the expected business needs
3	Characteristics of the project in terms of its complexity, location, costs, and implementation period
4	Lack of financial resources
5	Legal issues
6	Insufficient support from service providers
7	Internet speed and wireless access
8	Ineffective return on investment
9	The lack of an effective IT department to implement, follow up and develop digitalization
10	Organizational environment and culture
11	Quality of outcomes
12	Insufficient support from top management
13	Incompatibility of new software with existing tools and systems
14	The type of project contract concluded between the parties
15	Dual system
16	Technology features
17	Lack of proficiency in the use of computers by different project members

Table 1.b. continued

B	Barrier
18	The dissatisfaction of digitalization software users
19	Old computing devices
20	Refusal the project funder to adopt digitalization

GAPS AND LIMITATIONS IN PREVIOUS STUDIES

Over the past 20 years, many studies have focused on the adoption of modern technologies in construction; examples of such technologies include IT, ICT, WPMS, mobile computing, and the internet. These studies mentioned the positive results of adopting such techniques and the challenges and difficulties that could be faced.

A group of gaps was identified in previous studies as follows:

- Most of these studies were limited to a specific player in the construction project; contractor in specific, ignoring the role of both the consultant and the owner in construction (Nitithamyong and Skibniewski, 2006; Dossick and Sakagami, 2008; Lu, et al., 2014; Sweis, 2015)
- A limited number of studies on digitalization barriers in the construction industry have been conducted in the Middle East, Africa, and some parts of Asia. Reviewing digitalization studies in the construction sector, the following are summarized:
  a. As for Bajpai and Misra (2021) study in India, its limitations were represented by the number of respondents and its need for statistical analysis.
  b. Jahanger, et al. (2021a, b) studies were limited to the public owner.
  c. Schöberl (2020) pointed to the lack of digitalization studies in Germany, with recommendations to intensify the research. Without revealing the critical barriers of digitalization.
  d. Aghimien, et al. (2021) and Sanchez-Riofrio, et al. (2020) have taken new research directions that focus on the need to rationalize digitalization adoption according to the circumstances and the results obtained from following it.

Therefore, the construction sector is witnessing a noticeable delay in keeping pace with modern technology (Aghimien, et al., 2021). Based on the above and the need for such studies in the Middle East, there is an urgent need to conduct a comprehensive study focused on digitalization barriers to construction and including all project parties (Contractor, Owner, and Consultant) at all stages of construction work.

This study contributed to expanding the knowledge of existing literature on digitalizing construction globally. For Jordan in particular, it provides a precise understanding of the digitalization implementation situation and offers an effective strategy to overcome digitalization barriers.

Research Methodology

RESEARCH APPROACH AND STRATEGY

This study aimed to assess the level of digitalization adoption and evaluate the barriers to the adoption of digitalization in the Jordanian construction industry by all project parties in the public and private sectors. Accordingly, a structured questionnaire was used as a quantitative approach to achieve the desired goals.

The research methodology consisted of three main stages: data collection, data analysis, with results and discussion in sections 4 and 5.

DATA COLLECTION

Questionnaire Design and Piloting

Questionnaires are commonly used because they offer efficient, easy, fast, and inexpensive methods of collecting data. A precise procedure was adopted, where the research process started by examining papers with keywords similar to Industry 4.0, Building 4.0, Digitalization, and Barriers. The highly ranked journals according to the Scientific Journal Ranking (SJR) containing the desired papers were reviewed to check the purpose compatibility with the research in construction. Furthermore, the publisher's reputation was confirmed with a turn to prestigious publishing houses such as Emerald and ASCE. Then, extracting hundreds of barriers and challenges from the selected papers; most cited in previous studies, filtering barriers by removing repetitive or one-meaning barriers to reach a hundred, and finally grouping by categorizing the barriers into main twenty barriers.

The study questionnaire included three sections. Section one specified the demographic data of the respondents. It contained seven items: gender, age, years of experience, work field, work sector, educational degree, and the number of employees in the company; demographic data were used to assess the extent of agreement and disagreement among the population about digitalization barriers in construction.

Section two assessed the extent to which the Jordanian construction industry has adopted digitalization in the various stages of the project. In this section, the choices were limited to yes or no. Section three identified the most critical barriers preventing the adoption of digitalization in the construction industry. This was achieved by asking questions about the respondents' opinions on the importance of these barriers. The questions represented digitalization barriers shown in Table 1. For each question, the respondent was asked to rate the importance of each barrier on a 5-point Likert scale, from 1 (not important) to 5 (extremely important). The reason behind choosing a 5-point Likert scale in section three was its wide use in the quantitative approach, and the literature already established its efficiency (Jahanger, et al., 2021a, b). The survey was designed on Google Forms and distributed via e-mail and LinkedIn.

The pilot study was conducted on a small sample subjected to the application of the questionnaire in advance. This helped discover any confusion or errors and modify them (Connelly, 2008). The pilot study involved a group of Jordanian construction experts holding master's degrees in engineering management.

Study Population

The Jordanian public and private construction sectors; consisting of the three major players (Contractor, Consultant, and Owner), were selected as the target population using systematic sampling.

The number of civil engineers in Jordan is 56,609 (Jordan Engineers Association, 2022), which constitutes the population. It should be noted here that the civil engineer occupies several roles as an owner, consultant, or contractor in the public and private construction sectors. Accordingly, systematic sampling was adopted to distribute surveys to all target groups without being biased toward a certain group. The convenience sample can be calculated according to Israel (1992) as follows:

$$n_0 = \frac{z^2 pq}{e^2} \quad (1)$$

where:

n_0: the needed sample size.

Z^2: the required value to reach the level of confidence; at 95%, Z will be 1.96.

P: the assumed percentage of a specific attribute in the population, p is equal to 0.5.

q: 1-p.

e: chosen level of precision; the margin of error, e equals 0.05.

After substituting the variables into the equation,

$n_0 = \frac{1.96^2 * 0.5 * 0.5}{0.05^2} = 384$ required samples; 438 valid answers were obtained.

The data was collected through the respondents' replies. The questionnaire was distributed to the target population. Electronic copies were sent via e-mail, LinkedIn, and social media to a group of civil engineers working in Jordan. Furthermore, hard copies were distributed to practitioners involved in construction projects. The questionnaire was distributed randomly to all Jordanian construction industry stakeholders according to different factors, ensuring that the questionnaire covered all study groups, which confirms the representation of the population accurately.

DATA ANALYSIS

Content, Face, and Construct Validity

The content validity of this study was validated by reviewing previous literature to identify the most critical barriers that prevent the adoption of digitalization in the construction industry. Face validity was verified by presenting the questionnaire to a group of experts for assessment regarding translation correctness and clarity.

Factor analysis is one of the most common techniques used to check construct validity in studies (Goodwin, 1999). Exploratory factor analysis summarizes the data by specifying the factors in terms of type and number based on the collected data (Jamil, et al., 2014). The Kaiser–Meyer–Olkin (KMO) test explains the proportion of variance in variables caused by the underlying factors. Accordingly, values close to 1.0 confirm the adequacy of the data for factor analysis. Bartlett's test of sphericity is used to measure the correlation between variables. Both tests were checked before conducting EFA (Field, 2013).

Reliability

One of the most popular approaches to check the internal consistency of the results is Cronbach's alpha coefficients. A value of Cronbach's alpha of 0.6 or higher indicates that the questionnaire has a high degree of internal consistency, that is, reliability (Huck, 2007). Cronbach's alpha was 0.88, which indicated a high degree of consistency.

Analysis Methods

Data were analysed using SPSS software version 23.0. Data normality was verified using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Data are not normally distributed; P-value equals 0.00, which is less than α, and α equals 0.05 at the 95% confidence level.

Mann–Whitney Test was used to check if there is a significant difference between the binary groups and Kruskal–Wallis Test was used to compare three groups or more. Since these tests are nonparametric, they make fewer assumptions about the data than their parametric equivalent tests. They are powerful non-parametric tests and are an alternative to the t-test when the data is non-normal.

The Relative Importance Index was used to rank digitalization barriers in the questionnaire using the following equation:

$$RII = \frac{\sum w}{AN} \times 100\% \quad (2)$$

Where:

RII: the relative importance index

N: the total number of respondents

W: the weight given to each barrier by the respondent.

A: the highest weight, depending on the questionnaire and using the 5-point Likert scale, A=5.

RII identified the most important barrier based on participants' replies; it is a suitable tool to prioritise barriers when using Likert scales. It is easy technique to rank and compare the barriers and it can be used with non-parametric data. However, using RII may exploit skewed data; in other words, the ranking is influenced by the extreme values. Despite all, RII remains an appropriate technique of analysis when using surveys for collecting data (Tholibon, et al., 2021).

RESULTS

RESPONDENTS' DEMOGRAPHIC INFORMATION

Demographic data divided respondents into categories according to gender, age, years of experience, work field, work sector, educational degree, and the number of employees in the company. This division contributed to realizing the extent of agreement and disagreement between the groups regarding the study's main objectives. Among the respondents, 60.73% were male, 66.9% were between the ages of 20 and 30 years, 53.88% had less than 5 years of experience,39.95% were consultants, 82.19% belonged to the private

Table 2. Demographic profile of the respondents

Item	Respondents (Percentage %)				
Gender	Male		Female		
	60.73		39.27		
Work Sector	Public		Private		
	17.81		82.19		
Age-Years	20-30	31-40	41-50	> 50	
	66.90	24.20	5.25	3.65	
Work Field	Owner	Contractor	Consultant	Others	
	14.38	34.25	39.95	11.42	
Educational level -Degree	Diploma	Bachelor's	Master's	Doctoral	
	0.46	79.91	18.49	1.14	
Company Size-Number of Employees	<5	5-25	26-50	<50	
	17.80	29.68	12.56	39.96	
Experience-Years	Less than 5	5-10	11-15	16-20	> 20
	53.88	26.94	10.50	3.20	5.48

sector, 72.46% had a bachelor's degree, and 39.96% worked in companies with more than 50 employees. Table 2 shows the demographic profile of the respondents.

EXTENT TO WHICH DIGITALIZATION IS USED IN THE JORDANIAN CONSTRUCTION INDUSTRY

A group of questions was asked about using any software in the four phases of the project to measure the extent of using digitalization in the Jordanian construction industry. 79.68% of the respondents confirmed that they had used software in the design phase. Table 3 shows the extent to which digitalization software is used in the Jordanian construction industry.

Table 3. Extent to which digitalization is used in the Jordanian construction industry

Yes/No	Percentage %			
	Planning	Design	Construction	Finishing
Yes	73.06	79.68	72.15	54.34
No	26.94	20.32	27.85	45.66

BARRIERS TO ADOPTING DIGITALIZATION IN THE CONSTRUCTION INDUSTRY

A set of questions was asked about the importance of some barriers in hindering the adoption of digitalization in the Jordanian construction industry using a 5-point Likert scale.

To rank the barriers, the RII method was used. Insufficient support from top management for the adoption and use of digitalization software had the highest RII. Table 4 displays the digitalization barriers in construction and the RII value for each barrier.

Table 4. Ranking of barriers to adopting digitalization

Barriers	RII	Rank
Insufficient support from top management for the adoption and use of digitalization software	0.8110	1
Lack of financial resources to purchase, update, and develop software and train manpower	0.7910	2
Organizational environment and culture in terms of adopting new systems	0.7850	3
Characteristics of the project in terms of its complexity, location, costs, and implementation period	0.7610	4
The lack of an effective IT department to implement, follow up, and develop digitalization	0.7590	5
The inefficiency of training systems associated with the use of digitalization software	0.7550	6
Barriers associated with technology features	0.7520	7
Lack of proficiency in the use of computers by different project members	0.7490	8
Dual system	0.7440	9
Insufficient support from service providers	0.7430	10

Table 4. continued

Barriers	RII	Rank
Old computing devices available in the organization to adopt and use digitalization programs	0.7390	11
Barriers related to internet speed and wireless access	0.7280	12
Incompatibility of new software with existing tools and systems	0.7190	13
Barriers related to the type of project contract concluded between the parties	0.7130	14
Refusal of the project funder to adopt digitalization techniques in construction projects	0.7100	15
Inadequateness of the purchased software to meet the expected business needs	0.7050	16
Fear of legal issues related to digitalizing the construction work and its documentation	0.6980	17
Ineffective return on investment	0.6780	18
Low quality of outcomes obtained from adopting digitalization software	0.6740	19
The dissatisfaction of digitalization software users	0.6580	20

BARRIERS AMONG COUNTRIES

This study showed that insufficient support from top management barrier had the highest RII, followed by the financial barrier. In the United State of America (USA), most studies highlighted the role of the financial and project characteristics barriers in hindering the adoption of digitalization and its related technologies, while in the United Kingdom (UK), studies referred to the role of digitalization outputs in the extent of their adoption. In Australia, India, and Hong Kong, several studies showed that the suitability of training systems has been the main driver for the adoption of digitalization and its related technologies.

DIFFERENCES BETWEEN RESPONDENTS ON DIGITALIZATION BARRIERS IN THE CONSTRUCTION

Data normality was verified using the Kolmogorov–Smirnov, and Shapiro–Wilk tests in the SPSS software to measure the differences between respondents on digitalization barriers in construction. Data are not normally distributed; P-value equals 0.0000, less than α, and α equals 0.0500 at the 95% confidence level. The Mann–Whitney, and Kruskal–Wallis tests were conducted on data to check if there was a significant difference between the groups; the classified groups according to the study variables: gender, age, years of experience, work field, work sector, educational degree, and the number of employees in the company. Significant differences between respondents according to gender, age, experience, work sector, and the number of employees in the company in which the respondents worked were found.

FACTOR ANALYSIS OF BARRIERS TO ADOPTING DIGITALIZATION IN THE CONSTRUCTION INDUSTRY

The EFA was used to group the twenty barriers into a representative factor. The use of oblique rotation initially showed no correlation between variables; accordingly, orthogonal rotation was used. KMO value is 0.895, higher than 0.8, which indicates a very approving value for EFA in terms of the sample size (Field, 2013). Bartlett's test of sphericity shows that the chi-square value was 2661.5200 at 190 df, and the *P*-value

was 0.0000 at a 95% confidence level, which indicates a correlation between variables with a significant difference from the identity matrix. The value of the correlation matrix determinate $|R|$ was 0.0020, higher than 0.00001, representing the acceptance criteria for the multicollinearity check. In addition, it has been confirmed that there is no high correlation between variables, that is, a correlation coefficient higher than 0.8000. Eigenvalues were determined during the application of EFA to determine the number of extracted factors. Therefore, all barriers with eigenvalues greater than one were retained.

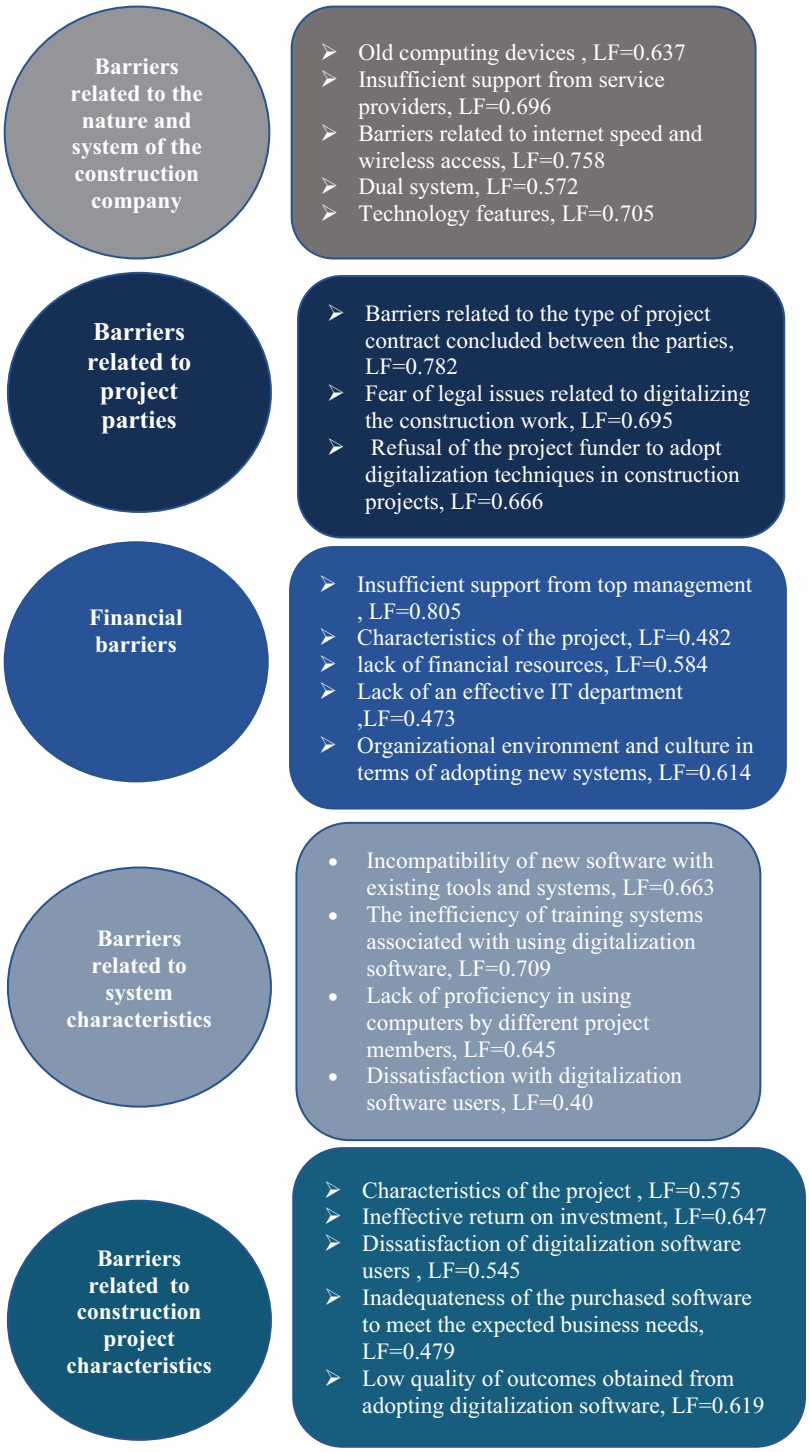

Figure 1. Loading factor (LF) for each barrier.

Barriers were divided into five main factors according to the barriers' loading factor, as shown below in Figure 1, where barriers with a loading factor of less than 0.4 were removed. In general, factor loadings of 0.3 or lower are considered poor and factor loadings greater than 0.4 are considered stable (Samuels, 2017).

The reliability of the measuring tools was verified using Cronbach's alpha test. All Cronbach's alpha values were higher than 0.6, indicating a high degree of internal consistency, that is, reliability (Huck, 2007). Table 5 displays Cronbach's alpha values for each factor.

Table 5. Cronbach's alpha value for each factor

Factor	Cronbach's alpha
1	0.7720
2	07090
3	0.7060
4	0.7090
5	0.7080

Cronbach's alpha values for each factor were calculated if a particular barrier was omitted. A decrease in Cronbach's alpha value was observed. Therefore, all barriers are retained according to their distribution on the factors and their role and weight in the overall reliability (Bonett and Wright, 2015). SPSS software arranged the factors according to the highest explained variance, which represents a descending order of the factors from the highest to the lowest importance as follows: barriers related to the nature and system of the construction company, barriers related to the project parties, financial barriers, barriers related to system characteristics, and barriers related to construction project characteristics.

Discussion

EXTENT TO WHICH DIGITALIZATION IS USED IN THE JORDANIAN CONSTRUCTION INDUSTRY

Results showed that the majority, 79.68%, have used software at the design stage. However, less than half, 45.66%, did not use any software during the finishing stage. These results are expected, most Jordanian construction companies tend to rely entirely on software at the design stage when issuing drawings, which is a prerequisite to obtaining approval from the Jordan Engineers Association. However, the finishing phase depends on the supervising engineers who do not use the software. Accordingly, laws that enforce using the software at all stages must be legislated.

BARRIERS TO ADOPTING DIGITALIZATION IN THE JORDANIAN CONSTRUCTION INDUSTRY

Table 4 shows the importance of twenty barriers that hinder the adoption of digitalization in the Jordanian construction industry. These barriers should be considered during digitalization adoption based on their significance ranks. Figure 1 summarizes these twenty barriers into five factors according to their importance. The Jordanian construction industry should pay attention to each factor and sub-barriers it contains from the construction company and the project parties' perspectives to reach full adoption in construction.

CLASSIFICATION OF DIGITALIZATION BARRIERS IN THE JORDANIAN CONSTRUCTION INDUSTRY

Twenty barriers were ranked according to their RII values. Insufficient support from top management for the adoption and use of digitalization software ranked first in limiting digitalization adoption. This is primarily due to the role of top management in deciding the use of modern technologies in institutions. Accordingly, administrative policies must be taken to encourage and support digitalization implementation in construction.

Jahanger, et al. (2021b) considered the factors based on the organization as the most crucial factors that should focus on adopting and implementing digitalization in construction. Bajpai and Misra (2021) considered that the absence of management commitment toward adoption and implementation had the highest impact on the rest of the barriers and adoption of digitalization in construction. This was confirmed by the results of this study on the top management support barrier. Wong and Lam (2010) ranked hindrances based on their means. They found that the lack of self-discipline had the highest value, with a mean of 3.31 out of five. This confirms the role of upper management in providing adequate support and legislating the regulations and laws which enforce self-discipline.

AGREEMENT AND DIFFERENCES BETWEEN RESPONDENTS' OPINIONS REGARDING THE IMPORTANCE OF DIGITALIZATION BARRIERS IN THE JORDANIAN CONSTRUCTION INDUSTRY

Respondents' opinions were studied through a set of variables to determine the agreement and differences regarding the importance of digitalization barriers in the Jordanian construction industry. Significant differences were found between respondents according to gender, age, experience, work sector, and the number of employees in the respondent's company. The existence of differences between groups regarding digitalization barriers results from the extent to which the different groups are exposed to challenges in their attempts to adopt and implement digitalization. The age and experience factors play a major role in digitalization implementation; the more practical experience and age, the greater the practice and implementation of digitalization, which increases the observed barriers. This step contributed to selecting the appropriate strategies to overcome digitalization barriers for each category according to the identified influencing factors. Bajpai and Misra (2021) explained the role of the age factor as a significant influence on various digitalization barriers. This is consistent with the study results; the age factor must be addressed when structuring digitalization adoption strategies.

Conclusions and Recommendations

CONCLUSIONS

The main goals of the study were achieved:

- Firstly, assessing the extent to which digitalization was used in the Jordanian construction industry by distributing the questionnaire to practitioners in Jordanian construction. The results show that most companies tend to rely entirely on software. The majority of respondents confirmed the use of software in the design phase rather than in the finishing phase. This is due to institutional legislation. Approximately one-third of the respondents did not use any software during some phases of construction work. This indicates promising signs for expanding its use in the coming years and raising the usage percentage at all stages of construction projects by implementing an integrated framework for the adoption of digitalization techniques in the sector.

- Secondly, barriers to the adoption of digitalization in the construction industry were identified in terms of their importance to the respondents; through the third section of the questionnaire.

The results showed that the importance of barriers ranged from important to extremely important in hindering digitalization adoption. This confirms the need to be aware of these barriers to overcome them and achieve effective implementation of digitalization.

There were significant differences between respondents according to gender, age, experience, work sector, and the number of employees in the company in which the respondents work because of time and location factors; such influencing factors should be taken into consideration when adopting digitalization.

The twenty barriers were grouped into five main factors according to their importance: barriers related to the nature and system of the construction company, barriers related to the project parties, financial barriers, barriers related to system characteristics, and barriers related to construction project characteristics.

The geographical area and the extent to which it adopts digitalization play a major role in identifying digitalization barriers. Most studies around the world are similar to Jordan in terms of financial barriers.

RECOMMENDATIONS

It is crucial to adopt an integrated framework between all project parties to digitalize the construction industry. This can be done by imposing laws from the concerned authorities, such as the Jordan Engineers Association by linking the required permits for building to the extent of adopting digitalization techniques during all stages of the project by all project parties. Furthermore, addressing the barriers related to the nature and system of the construction company and their sub-barriers is of significant importance because of their essential role in impeding the adoption of digitalization in the Jordanian construction industry. Finally, it is necessary to develop educational programs in Jordanian universities construction and offer appropriate training opportunities on digitalizing construction. Subsequently, plan a case study to assess the actual implementation and adoption of digitalization.

LIMITATIONS AND FURTHER RESEARCH

This study focused on adopting digitalization in all construction project phases, and further studies should be conducted on specific phases. In addition, this study was limited by using questionnaires for data collection; further studies can be performed using interviews or case studies; conducting interviews with specialists in adopting digitalization techniques will expose more hidden barriers and the case study will realistically reveals the incentives and barriers of adopting of digitalization. Finally, this study was restricted to Jordan; further studies can be performed including the surrounding countries.

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