Global Journal of Engineering and Technology Advances, 2020, 03(03), 020–030

Global Journal of Engineering and Technology Advances

Cross Ref DOI: 10.30574/gjeta

Journal homepage: http://www.gjeta.com

(RESEARCH ARTICLE)

Crucial barriers of building information modelling (BIM) in the Jordanian construction industry

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Publication history**:** Received on 06 June 2020; revised on 28 June 2020; accepted on 30 June 2020

Article DOI: https://doi.org/10.30574/gjeta.2020.3.3.0034

Abstract

The adoption of Building Information Modelling (BIM) has become essential in Jordan to improve the quality and reduce the challenges facing construction projects. Many studies conclude that implementing BIM in construction projects across the global improves quality, minimises errors and reduces project costs and time. In Jordan, adopting BIM will not be easy or smooth as a result of several barriers. Thus, it is essential to identify the crucial barriers to the adoption of BIM in the Jordanian construction sector. Both qualitative and quantitative methods, i.e. interview and questionnaire techniques, were used to achieve this objective. Interviews were conducted at the first stage of data collection, and the results formed the basis of the questionnaire, which was distributed across the Jordanian construction sector. Content analysis was used to analyse the interview responses, while factor analysis, correlation and the Severity Index (SI) were used to analyse the questionnaire results. The findings identified sixteen barriers which obstructing adoption BIM in Jordan. The sixteen barriers were classified into four main categories, namely finance, communication, people and project procurement, with sub-barriers in each category which are related to each other in significant ways and which affect each other.

Keywords: BIM; Construction; Jordan; Barriers; Adoption

1. Introduction

The Jordanian construction industry occupies a fundamental position in the national economy. The Jordanian construction sector was contributed 5% to 8% of Gross Domestic Product (GDP) over the period (1994-2010) and employed 20% of the total workforce in 2013 Alkilani et al. [1]. According to the Jordanian Construction Contractor Association annual report [2], the total value of the investment in public and private sectors was 1464 million Jordanian Dinar (2091.4 US Dollar). However, the construction industry faces significant challenges such as cost overrun, delay, disputes. Alshdiefat [3] said that the impact of lack of cooperation and collaboration between stakeholders reflects in increasing projects cost, delay in completion. Recently, there has been a tremendous increase in the awareness of the importance of Building Information Modelling (BIM) within the construction industry. According to Coates et al. [4,5], BIM is a 'medicine' for curing interdisciplinary inefficiencies in the construction industry. Furthermore, several countries as the UK has forced toward implementing BIM in their construction industry. In Jordan, Hamad [6] argues that there is a tremendous need to implement BIM in Jordan. But, there is a great gap to be seen between the adoption of BIM in the west and its uptake in the Jordanian construction industry, Al Awad, [7]. Furthermore, Alshdiefat and Aziz [8] suggested using BIM for reducing the causes of change orders in the Jordanian construction industry. Al Awad [7], concluded that the barriers to the adoption of BIM by Jordanian Small and Medium Enterprises (SMEs) are related to process, technology and people. Lack of awareness of BIM, low levels of education, a lack of knowledge and skills, and training and culture are the main obstructions that hindering adoption BIM in Jordan. Therefore, the current paper develops a deeper understanding of the barriers to the adoption of BIM in the Jordanian construction industry and to clarify the relationships between these barriers to determine which are the most significant.

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2. Literature Review

Despite the many benefits to be gained by using BIM for a project, many barriers are hindering the implementation of BIM in the construction industry. Aibinu and Venkatesh [9], in their research on the status of BIM adoption and the BIM experience of cost consultants in Australia, identified the following barriers; the cost of implementation, a lack of awareness of the benefits from a cost-benefit analysis perspective, a lack of demand by clients, a lack of trust in the integrity of BIM, a lack of standards for the description of BIM objects and a coding system, contract/legal issues and uncertainties, skills shortages, and the inability of firms to adapt to such a change because of cultural and financial factors.

In the context of Malaysia, Rogers [10] found that the main barriers to the adoption of BIM in Engineering Consulting Service (ECS) companies are; financial considerations, human resources, the change process and legal factors. Khosrowshahi and Arayici [11] concluded that the primary barriers to implementing stage 2 of BIM in many UK construction companies were as follows: firms not being sufficiently familiar with the use of BIM, reluctance to initiate new workflows or train staff, a view that the benefits of implementing BIM do not outweigh the costs and are not sufficiently tangible or offer enough of a financial gain to warrant its use, firms' lacking the capital to invest in hardware and software, BIM being seen as too risky from a liability standpoint to warrant its use, resistance to cultural change, and a lack of demand.

There have also been few studies which have explored the barriers to BIM in the Jordanian construction industry. Al Awad [7] investigated the barriers to the adoption of BIM by SMEs related to process, technology and people, which are lack of awareness of BIM, low levels of education, a lack of knowledge and skills, and training and culture. Matarneh and Hamed [12] said that the lack of support and incentives from construction policymakers, unavailable BIM standards and codes, lack of awareness, no client demand, the resistance of change, lack of a BIM specialist in Jordan, lack of necessary training, and the cost of BIM; software, hardware upgrade, training, and time, are the significant barriers that hindering adoption BIM in the Jordanian building industry. However, Matarneh and Hamed [12] did not investigate the relationships between BIM barriers. Thus, this paper focuses on identifying the significant barriers to the adoption of BIM to enable the construction industry to focus on these barriers to ensure that BIM is adopted effectively. Furthermore, this paper carries out a critical exploration by means of literature review, interviews and a survey across the Jordanian construction industry to ascertain the challenges facing BIM.

3. Methodology

Achieving the objectives of this paper requires the utilisation of reliable and suitable methodological research procedures. The procedures must be accompanied by effective data collection methods for identifying the barriers of adopting BIM in the Jordanian construction industry, and analysis it for achieving a meaningful research conclusion, which contributes to the existing knowledge. Therefore, this research utilised a mixed-method approach; qualitative followed by quantitative, which allows investigating the problem from inductive and deductive perspective. The combination of qualitative and quantitative research method is a very powerful way of gaining insights and results, as well as assisting in making inferences and drawing a conclusion. The qualitative approach is suitable for understanding the complex and specific social phenomena, Frankfort-Nachmias et al. [13]. So, it considers a suitable approach to understand and provide new information for the critical barriers of adopting BIM in the Jordanian construction industry. The quantitative approach provides objective, value-free findings which can be generalised and replicated, McMurray [14].

Consequently, the researchers used semi-structured interviews to collect data related to the research subject. The interviews were conducted with experts in the Jordanian construction industry and then was analysed through content analysis which provided a clear picture of the significant barriers that are obstructing adoption BIM in the Jordanian construction industry. The qualitative results formed the basis of the second stage of data collection. A questionnaire was used in the second stage, and it was designed based on the literature review and the interview results. A pilot study was used for the final draft of the questionnaire before it was distributed across the Jordanian construction industry. In this exercise, the researcher asks the pilot test respondents to complete the questionnaire and provide feedback on specific questions. The pilot shows whether the questionnaire is producing information that is related to the research subject, as well as providing feedback on the questionnaire design and content. The items in the questionnaire were thus pilot-tested for clarity and appropriateness in a self-administered pre-test with five experts in the Jordanian construction sector. They were asked to complete the questionnaire and identify any complexities, unclarities or ambiguities they had experienced in responding to the questions. The pilot tests were returned with comments, and some items were eliminated and others modified in the light of this feedback. Validation is essential for both qualitative

and quantitative research. In qualitative research, validation depends on factors such as honesty, the richness of the data, the depth of the research, triangulation and objectivity. In this research, the internal validity of the quantitative method was achieved by designing the questionnaire so that it was able to quantify what it was planned to quantify, which means that the findings represent the reality of the Jordanian construction industry in relation to BIM barriers. External validity was achieved by using a suitable number of participants representing different stakeholders in the Jordanian construction industry. To validate the qualitative results, the researcher used the four evaluation criteria proposed by Hammarberg et al. [15], namely trustworthiness, credibility, applicability and consistency. Finally, presenting a full description of the methodology used will address dependability (consistency).

4. Research Results

The research's findings provide a clear image of the main barriers which hindering adoption BIM in the Jordanian construction industry. Explore the significant barriers of adoption BIM in Jordan was that aim of the interviews. To get valuable information, participants were selected based on their knowledge, experience, management position, all participants are project managers. Thus, the researchers interviewed construction experts they represent different engineering firms; design and consultancy, contractors, the Ministry of Public Works and Housing, universities, Jordanian Engineering Association (JEA) and Jordanian Construction Contractors Association (JCCA). The diverse range of experts, 17 experts, enriched the data collection and gain a deep understanding with regards to the subject. Furthermore, the questionnaire was the second tool for data collection. The questionnaire was designed based on the literature review and interviews outcomes. The questionnaire was distributed online to people working and has experience in the Jordanian construction industry, and 155 questionnaires were completed and returned. The respondents must be involved in the construction industry as clients, engineers, first-class contractors and construction managers, as well as working in regulatory bodies (the JEA and JCCA) and the government. Therefore, respondents out of these categories were neglected. The questionnaire sought respondents' opinions on significant barriers of adopting BIM in the Jordanian construction**.** The questions were derived from the analysis of the interview. Respondents were asked to indicate their opinions on a Likert scale ("strongly disagree", "disagree", "neither agree nor disagree", "agree" and "strongly agree") for each question.

Table 1 The code, themes and sub-themes of the barriers to the adoption of BIM in the Jordanian construction industry

Barriers to the Adoption of BIM in the Jordanian Construction Industry		
Themes	Sub-Themes	Code
Products	Financial Considerations	software costs
		costs of upgrading hardware
		training costs
Individuals	Training	shortage of skilled and trained staff
Processes	Traditional Processes	current communication processes
		traditional work processes
	Culture	the reluctance of senior management
		dependence on unskilled staff
	Lack of Interest and Demand	lack of interest and demand
	Lack of Awareness	lack of awareness
	Legal Issues	lack of standards and regulations relating to BIM
		current approval system for new projects
	Low Budget for New Projects	low budget for new projects
		high competition
	Time Required	the time required for training
		the time required to prepare a suitable environment for the adoption of BIM

The interview identified sixteen barriers of adoption BIM in Jordan which are linked to the three main groups: products, individuals and processes. Acritical analysis of the interview indicated that the software cost, cost of upgrading

hardware, and training cost are the financial barriers which linked to the products. Shortage of skilled and trained staff is the training barrier related to the individual. current communication processes, traditional work processes, the reluctance of senior management, dependence on unskilled staff, lack of interest and demand, lack of awareness, lack of standards and regulations relating to BIM, current approval system for new projects, low budget for new projects, high competition, the time required for training, and time required to prepare a suitable environment for the adoption of BIM are the main barriers which linked to the process. Table 1 below shows the main barriers of adoption BIM in Jordan grouped according to the themes identified in the interviews.

The collected respondents of questionnaires were analysed descriptively and statically by Severity Index (SI), factor analysis, and correlation test. The Severity Index (SI) was used to rank respondents' ratings the 16 barriers which obstructing adoption BIM in the Jordanian construction industry. The Severity Index is recommended by Shash [16] for analyzing ordinal data where the mean and standard deviation are not suitable statistically for the overall ranking of variables. The Severity Index is illustrated in the following formula:

Severity Index (SI) $=\sum_i^5 (W_i * f_i) * (100\% / N)$
$Wi = i/N$
Where
SI = Severity Index; this is computed as the summation of importance ratings
i = the rating from 1 to 5
w_i = the weight of each rating
f_i = frequency of responses for a particular rating point
N = total number of respondents rating a particular factor in the survey.

4.1. Respondents' Backgrounds

Three questions asked participants to provide information about their background, and the responses illustrate the diversity of the sample. The majority of respondents (52) worked in engineering firms. This is followed by 40 respondents who are contractors. Construction management accounts for the smallest proportion of the sample, with only nine respondents. Sixteen are working in government, 12 in regularity bodies (the Jordanian Engineering Association (JEA), and Jordanian Construction Contractors Association (JCCA)), 11 in educational institutions, and 15 respondents are clients or developers. The highest proportion of participants (29.7%) had between 11 and 15 years' experience in the construction industry, while only 8.4% have five years of experience or less in the sector. 27.7 % have from 16 to 20 years' experience, followed by 20% who have more than 20 years, and 14.2% of the total has from 6 to 10 years' experience. Finally, the majority of participants (82.6%) work in the private sector, while only 17.4% work in the public sector.

4.2. Questionnaire Reliability

In this research, the reliability has to do with getting the same results if further data is collected by using the same procedure, Saunders et al. [17]. The Cronbach's alpha on a scale of 0% - 100% was used to evaluate the reliability where the higher values representing more consistent answers and indicating greater reliability. The minimum acceptable value is 0.70, which means that the answers are reliable. The SPSS software was used to apply Cronbach's alpha analysis to estimate the reliability of the responses in all the sections of the questionnaire, the Cronbach's alpha of the BIM barriers is 0.764. This means that the obtained data is reliable and consistent.

4.3. Questionnaire Results

The Severity Index was used to rank the sixteen barriers of BIM in the Jordanian construction sector. It found that the cost of training is the significant obstructing for adoption BIM where it has the highest Severity Index (SI), 94.74 %, while the high competition in the construction industry has the lowest Severity Index (SI), 62.24%. Table 2 below shows the Severity Index for the BIM barriers in Jordan, their ranking, mode, and median.

Table 2 Percentage of respondents, Severity Index (SI), median and mode for barriers to the adoption of BIM in the Jordanian construction industry**.**

No.	Barriers to the adoption of BIM in Jordan	Percentage of Participants							
		Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree	Severity Index	Median	Mode
1	Costs of training	0	1.3	2.0	18.4	78.3	94.74	5.00	5
2	The time required for training	0	0.7	1.3	30.3	67.8	93.03	5.00	5
3	Costs of BIM software	0	1.3	5.9	21.1	71.7	92.63	5.00	5
4	Dependence on unskilled staff	0	0	2.0	72.0	26.0	84.80	4.00	4
5	Costs of hardware	0	2.6	10.5	52.6	34.3	83.68	4.00	4
6	Shortage of skilled and trained staff	0	2.0	7.9	60.5	29.6	83.55	4.00	4
7	Reluctance on the part of senior management	0	3.9	7.9	58.6	29.6	82.76	4.00	4
8	Lack of awareness	0	3.3	15.1	72.4	9.2	77.50	4.00	4
9	Traditional processes	0.6	3.3	18.4	67.8	9.9	76.58	4.00	4
10	Lack of interest and demand	0	3.9	42.2	37.5	16.4	73.29	4.00	3
11	Lack of a legal framework for BIM	0.7	9.2	32.2	52.6	5.3	70.53	4.00	4
12	Approval system for new projects	0	8.6	33.5	55.9	2.0	70.26	4.00	4
13	Low budget for new projects	1.3	11.2	44.7	40.2	2.6	66.32	3.00	3
14	Weakness in communication between project parties	0.7	16.4	39.5	42.1	1.3	65.39	3.00	4
15	The time required for preparation of BIM infrastructure	0	6.6	66.4	26.3	0.7	64.21	3.00	3
16	High competition in the construction industry	2.0	19.7	45.4	30.9	2.0	62.24	3.00	3

To investigate the latent variable's effects, the factor analysis test was used. According to Field [18], factor analysis is used to measure the effects of latent variables. The SPSS software package was used to group the sixteen barriers of BIM, and dimension reduction (factor analysis) was run several times using absolute values of 0.50 and varimax rotation to the best reasonable causes correlated with the data. During the process, some barriers were eliminated while the others were grouped. This grouped the barriers to the adoption of BIM into four main groups, as well as eliminating some barriers, as shown in Table 3**.**

Table 3 Factor analysis test results for the barriers to the adoption of BIM in Jordan

Latent Barriers	Barriers to the adoption of BIM	Load			
Financial	Costs of BIM software	.850			
	Costs of hardware	.848			
	Costs of training	.781			
Communication	Weakness in communication between project parties		.785		
	Approval system for new projects		.730		
	Traditional processes		.572		
	Lack of legal framework for BIM		.763		
Human	Shortage of skilled and trained staff			.696	
	Lack of awareness			.569	
	Dependence on unskilled staff			.627	
	Lack of interest and demand			.673	
Project Procurement	Low budgets for new projects				.816
	High competition in the construction industry				.775

The factor analysis test for barriers to the adoption of BIM, as shown in Table 3, eliminates three barriers: training duration, reluctance on the part of senior management and the time required to prepare the infrastructure for BIM. However, the analysis grouped the 13 barriers to the adoption of BIM in the Jordanian construction industry into four groups, namely financial, communication, human, and project procurement. There are three barriers in the finance category: software costs, hardware costs and training costs. The results show that all these barriers are significant financial factors. Software costs are the barrier with the highest load (0.85). The communication category includes four barriers: current weaknesses in communication between project parties, the approval system for new projects, traditional work process and the lack of a legal framework for BIM. Weaknesses in communication between project parties have the highest load and are, therefore, a more significant barrier than the others. Human factors are the third category of barriers and include shortages of skilled and trained staff, lack of awareness, dependence on unskilled staff, and lack of interest and demand. The results show that shortages of skilled and trained staff, with a factor analysis load of 0.696, is the main barrier in this group. The final category, project procurement, has two barriers, the low budgets for new projects and high competition in the construction industry. The factor analysis load for both of these is more than 0.75, which means that both could explain the project procurement factor effectively.

Correlation is the relationship between two variables expressed in a single number called the correlation coefficient. This has a range from +1 to −1, and indicates the strength of the relationship and whether it is positive or negative. A correlation test was used to determine the relationship between the barriers of adoption BIM in Jordan. The test used was Spearman's rho correlation test, which is a two-tailed test of statistical significance at two different levels—highly significant where $\rho < 0.01$ and significant where $\rho < 0.05$. The results are presented in Table 4 below.

Table 4 Analysis of the correlation between the barriers to the adoption of BIM in Jordan

Barriers to the Adoption of BIM in Jordan	Software costs	Hardware costs	Shortage of skilled and trained staff	Training costs	The time required for raining	Weaknesses in communication between project parties	Approval system for new projects	Traditional processes	Dependence on unskilled staff	Reluctance on the part of senior management	Lack of interest and demand	Lack of Awareness	Lack of legal framework for BIM	Low budgets for new projects	High competition in the construction industry	The time required for preparation of BIM infrastructure
Software costs	1.000	.567**	.287**	.378**	.367**	.258**	.223**	.269**	0.091	0.135	.249**	.319**	0.159	0.152	0.129	0.094
Hardware costs		1.000	0.035	.531**	0.106	.162*	0.039	0.101	0.119	0.102	.416**	.240**	0.022	.170*	.385**	0.011
Shortage of skilled and trained staff			1.000	.251**	0.152	.169*	.188*	0.032	.491**	.354**	.219**	.545**	0.123	.207*	0.151	0.119
Training costs				1.000	0.159	.291**	.207*	0.000	0.061	0.068	.259**	.267**	0.105	0.031	.237**	0.131
The time required for training					1.000	.279**	.316**	.214**	.271**	.212**	0.095	.205*	.230**	.220**	0.111	0.093
Weaknesses in communication between project parties						1.000	.639**	.295**	0.155	.211**	-185*	.284**	.538**	.190*	0.112	0.070
Approval system for new projects							1.000	.279**	.177*	.281**	.176*	.330**	.501**	.225**	0.006	0.106
Traditional processes								1.000	.196*	.238**	0.002	0.085	.287**	.224**	0.098	.166*

Dependence on unskilled staff									1.000	.431**	.271**	.242**	.165*	.280**	.309**	.191*
Reluctance on the part of senior management										1.000	.223**	.196*	.459**	.242**	.297**	0.090
Lack of interest and demand											1.000	0.106	0.030	0.124	.359**	.272**
Lack of awareness												1.000	.162*	0.080	0.142	.254**
Lack of legal framework for BIM													1.000	.280**	0.015	0.052
Low budgets for new projects														1.000	.515**	.238**
High competition in the construction industry															1.000	.180*
The time required for preparation of BIM infrastructure																1.00

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

5. Discussion

The obtained results identified sixteen barriers which are hindering adoption BIM in the Jordanian construction industry. The barriers were classified into four main groups: financial, communication, human and project procurement. Each of these groups is made up of barriers which are significantly correlated with each other. These are training costs and the costs of software and hardware for BIM. Together, these are the main barrier to the adoption of BIM in the Jordanian construction industry, and each has a relatively high factor analysis load. Also, the Severity Index (SI) of each of the three barriers is significantly high, which ranks them among the main five barriers to the adoption of BIM in Jordan. Focusing on financial factors is thus essential as a first step in promoting the adoption of BIM in the Jordanian construction industry.

The human factor is the second main barrier to the adoption of BIM in Jordan. This includes a shortage of skilled and trained staff, dependency on staff who are not able to use BIM, a lack of interest and demand to, and a lack of awareness. The factor analysis load for all these barriers is over 0.5, which indicates that they are significant barriers in the Jordanian construction industry and each is highly representative of the human factor group as a whole. The questionnaire results supported this conclusion, and the Severity Index (SI) in each case is over 70%, putting them in the first 10 barriers to the adoption of BIM in Jordan. The barriers in this group are significantly correlated, which means that they mutually reinforce each other. Lack of interest and demand results in the employment of staff for work which is not related to BIM, so that they will develop only the skills they need for that work, which in turn means that there will still be no staff who have the knowledge and ability to implement BIM. Similarly, construction firms do not organize training courses for their staff for a variety of reasons, and so they continue to depend on skilled staff only for other types of work. Finally, the human factor is affected by levels of awareness of BIM. A poor understanding of the benefits can offer in the construction industry drives project parties to seek other options instead of BIM, which again minimizes the number of staff who can use BIM. The lack of awareness also means that construction firms depend on the available staff, and avoid running training sessions.

Communication is the third group of factors which prevent the adoption of BIM in the Jordanian construction industry. Weaknesses in communication between project parties, the lack of a legal framework for BIM, the approval system for new projects and traditional work processes all fall within this group. The relationships between these barriers are significant, which means that they work with each other as one body against the adoption of BIM in Jordan. The factor analysis shows a high load of more than 0.7 for all these barriers expect for traditional work processes, for which the load is 0.572. However, the Severity Index (SI) ranked only traditional work processes among the ten main barriers to the adoption of BIM in Jordan. Therefore, it can be concluded that the factors in the communication group are a real barrier to the adoption of BIM in Jordan, but their effect is moderate, and they come after financial and human factors, which are more important.

Project procurement is the last category of factors which prevent the adoption of BIM in the Jordanian construction industry. The traditional form of contract, design – bid - build, is common in the construction sector as a result of the competition between construction firms to get projects. Projects are awarded to the bid with the lowest price. That is why the low budget for new projects and high competition between construction firms have been classified as barriers in the project procurement category. The Severity Index (SI) for both these barriers is below 70%, which ranks them as 13th and 16th, meaning that these are less prominent than other barriers. However, the factor analysis load is relatively high (more than 0.75) for both barriers, so they have an important role in the project procurement category. There could be different views of the competition barrier. It could be seen as having a positive effect on the construction industry, in that it might push construction firms to try to improve their reputation and the quality of their work. But it could also work in the other way, by pushing firms to submit the lowest possible bid to secure the contract, which means that there is no budget for the implementation of BIM. This research shows that competition does push construction firms to offer the lowest price for projects and that this is, therefore, a barrier to the implementation of BIM. The correlation of these two barriers also supports this view, and can be expressed as follows: 'in Jordan, as the budget for projects decreases, competition between construction firms increases, which ultimately obstructs the adoption of BIM.'

Finally, the factor analysis test terminates a further three barriers: the duration of the training, reluctance on the part of senior management, and the length of time required for the preparation of infrastructure for BIM. These barriers were not classified under any group, which means that they do not work with other barriers. However, the duration of training was classified as the second main barrier, with a Severity Index of 93.03%. This shows the importance of the time required for training, as an individual barrier, in obstructing the adoption of BIM in the Jordanian construction industry, where most construction firms avoid offering training of appropriate duration. Moreover, this barrier could be seen in terms of the cost of training rather than the time it takes, and some organizations may consider that the time required for training results in a reduction of productivity and imposes costs on the organization, so the duration of

training could be categorized under training costs. Reluctance on the part of senior management is at an intermediate level in the barriers to the adoption of BIM in the Jordanian construction industry based on its Severity Index. Reluctance on the part of senior management is thus not an important barrier to the adoption of BIM, and presenting BIM to decision-makers will encourage the use of BIM in the Jordanian construction industry. Finally, the Severity Index ranked the length of time required for the preparation of infrastructure for BIM infrastructure as the last barrier to the adoption of BIM and was also apparent in the interviews, where one expert mentioned this barrier. The time it takes to prepare the infrastructure for BIM could, therefore, obstruct the adoption of BIM in the Jordanian construction industry, but it is not an important barrier.

6. Conclusion

Critically examined the barriers of adoption BIM in Jordanian construction industry identified sixteen barriers. These barriers are hindering adoption BIM in a different level. The descriptive analysis found training costs to be the main barrier to the adoption of BIM in the Jordanian construction industry, while the high level of competition was shown to be the weakest barrier. Furthermore, these barriers were ranked by their Severity Index (SI) as shown in Table 2. The factor analysis test identified three barriers which did not significantly hinder the adoption of BIM in the Jordanian construction industry, namely the time required for training, reluctance on the part of senior top management and the time required to prepare a suitable environment for BIM. Although these barriers individually might have a significant influence on the adoption of BIM, as a group they are not a major factor. The other 13 barriers were categorized into four groups, relating to finance, communication, human factors and project procurement. Each of these groups includes several sub-barriers as follows:

Financial factors: software costs, hardware costs and training costs;

Communication factors: current weakness in communication between project parties, the approval system for new projects, lack a legal framework and traditional work processes;

Human factors: the shortage of skilled and trained staff, dependence on unskilled staff in construction firms, lack of awareness and lack of interest and demand;

Project procurement: low budgets for new projects and high competition between construction firms.

The correlation test was conducted to determine the relationship between the barriers in each group to investigate their influence on each other. Table 4 presents the correlation of these barriers in detail. Finally, the future researches should be concentrated for reducing BIM barriers in the Jordanian construction industry through focusing on the root causes of these barriers.

Compliance with ethical standards

Acknowledgements

This research paper is made possible through the assistance and support from almost everyone. The authors would like to thank all people they effectively contribute to the research by their opinion and advice. Additionally, The authors would like to thank the reviewers anonymous for their significant comments. Finally, we would like to thank my colleagues for his more support and encouragement for giving us this research.

Disclosure of conflict of interest

All authors declare that there is no conflict of interest regarding the publication of this paper.

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How to cite this article

Alshdiefat A and Aziz Z. (2020). Crucial barriers of building information modelling (BIM) in the Jordanian construction industry. Global Journal of Engineering and Technology Advances, 3(3), 20-30.