1874-8368/19

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RESEARCH ARTICLE

Limitation Factors of Building Information Modeling (BIM) Implementation

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Abstract:

Background:

Building Information Modeling (BIM) has been recommended as the best tool to improve construction processes by many researchers. However, most construction companies do not adopt BIM because there are many limitations slowing BIM adoption.

Objective:

The aim of this paper is to investigate the factors that limit BIM implementation in the construction industry.

Methods:

To investigate the research objectives, a quantitative approach was adopted and a structured questionnaire was designed. A total of sixty-eight copies of the questionnaire were distributed and sixty-five of them were satisfactorily completed, making the total response rate = 95.58%. Snowball sampling method helped to obtain a high rate of response and thus increase accuracy.

Results and Conclusion:

BIM limitation factors were divided into five categories. The results illustrated that the personnel category was ranked as the most important, while the legal category was ranked as the least important. Findings showed that requirement of large culture change within the organization, lack of senior management support, lack of knowledge on how to implement BIM, lack of staff experience and skills, and need to change in workflows to comply with the new requirements were ranked as the most important factors that obstruct BIM implementation.

Keywords: Building Information Modeling (BIM), Limitation factors, Construction industry, Gaza strip, Quantitative approach, Structured questionaire.

Article History	Received: May 16, 2019	Revised: July 19, 2019	Accepted: July 26, 2019

1. INTRODUCTION

The construction industry requires to investigate techniques to decrease project cost, reduce project duration, increase productivity, and improve quality [1]. BIM has been accepted in the construction industry as a new approach to achieving these objectives [2]. Autodesk, the developer of various Building Information Modeling (BIM) tools, defined BIM as following "BIM is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infra-structure" [3]. Another definition of BIM is a computer-aided technology for managing the information of a construction process focusing on communication, production, and analysis of building information models [2].

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BIM can define connections between attributes to reflect any change in elements of building into the information of building arrangement. BIM provides foreseeable information related to material, schedule, and amount, and it can also analyze data depending on the environment and structure to predict unforeseeable information [4].

J. Harris [5] stated that Building Information Modeling (BIM) theoretically appeared and developed at Georgia Institute of Technology in the late 1970s and then grew quickly because of construction firm increasing interest to use BIM to integrate and manage information through several phases of the construction project. The first BIM software was introduced in 1984 by "Standards for the Exchange of Product Model Data" (STEP) and Archi CAD for Mac computers [6]. Implementation of BIM has been widely used over the past decade, in these days BIM implementation is considered one of the most important technological improvements in the

DOI: 10.2174/1874836801913010189, 2019, *13*, 189-196

construction industry [7]. However, it is reported that the implementation of BIM is limited to large companies which have the capability [8]. In this section, BIM definitions and types will be presented.

2. LITERATURE REVIEW

BIM has significant benefits to construction projects through the project lifecycle. However, unfortunately, most projects do not achieve these benefits because of not adopting and implementing BIM [9]. There are many limitations that slowed BIM implementation [10] and BIM application is still in the beginning stage to some degree [11].

After reviewing a number of articles related to limitation factors for BIM implementation (Table **1**), the researchers found various types of classification. The classification by C. Sun *et al*. [12] has been used in this research. C. Sun *et al*. [12] said that all limitation factors are classified into five categories: technology, cost, management, personnel, and legal. The researchers chose this classification because it is the most recent one and it includes all the categories that were reported in previous works. Fig. (**1**) shows the BIM limitation categories. In the following section, these categories will be discussed.

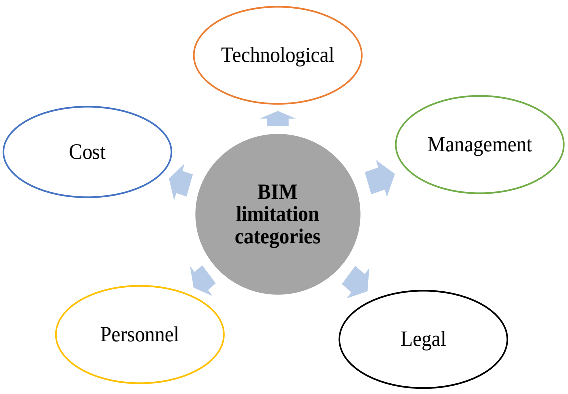

Fig. (1). BIM limitation categories.

2.1. Technological Factors

The technological factors refer to BIM-based software packages limiting factors [12]. Lack of BIM software packages is stated as one of the limiting factors that prevent BIM adoption [13]. Many software firms are cashing in on BIM programs that only treat quantitative aspects and do not treat all process [1].

The capability to transfer and reuse information in the graphical model should be included by BIM, therefore, a lack of information sharing could consider a limitation factor to BIM implementation [14 - 16]. D. Bryde *et al.* [15], P. G. Bernstein and J. H. Pittman [17], and N. Post [18] suggested that the lack of data interoperability defined as the biggest limiting factor to BIM implementation. Interoperability is defined by A. Geraci *et al*. [19] as “the ability of two or more systems or components to exchange information and to use the information that has been exchanged”. The interoperability problem may be caused by horizontal fragmentation between members at any construction project phase and this fragmentation can be caused by the variety of computer software programs [20]. C. Sun *et al*. [12] and P. G. Bernstein and J. H. Pittman [17], however, argued that the digital design data should be computable.

2.2. Cost Factors

The high cost of BIM implementation has been reported as a major barrier in the construction industry [1, 10, 21 - 24]. The implementation of BIM in construction firms requires the purchase of relevant software and hardware as well as train the staff to use it effectively which increases overall project cost [6, 7, 10, 12, 15, 23]. Software packages need periodic updates, so it is essential to add updates costs to the whole BIM implementation cost [25].

2.3. Management Factors

Management factors related to the procedure and organization-related factors that limit BIM implementation include lack of senior management support, lack of client demand, cultural misfits, fragmented nature of the construction process, change the workflow, time-consuming, and lack of knowledge [12]. There are many reasons that make the top manager of an organization dissenting to implementing new technologies and process to their organization, for instance, when the technology is comparatively new, there is no sufficient information and feedback about it from previous construction projects [15, 26]. Some managers are worried that the learning curve required with BIM may influence their business. Lack of knowledge about the process needed to go beyond traditional methods was identified as an obstacle to BIM implementation [14].

BIM implementation requires huge changes in business practices [27]. This requires a large culture change within the organization [28]. Introducing new processes into an organization requires changing the organization's culture [10, 29]. BIM eliminates the traditional borders between companies and allows the sharing of project information in a more collaborative environment [12]. This means that members must change their roles and change the workflow of their firm to comply with the requirements of BIM application [6, 12, 30]

J. D. Goedert and P. Meadati [31] said that using BIM to develop 3D as-built drawing consumes more time than using traditional methods to develop 2D as-built drawing. Also, many activities need more time to be adopted to successfully implement BIM such as: changing in file management, client billing, deliverables, and organizations [18]. Fragmentation is a vital negative factor influencing the efficiency and productivity of construction projects [20, 32]. Most projects members are not interested to adopt BIM tools exactly because of the fragmented nature of the construction process [12, 33 - 36]. To confirm the effective implementation of BIM, all stakeholders must have knowledge of BIM and the lack of this knowledge was pointed as a significant limitation to implement BIM [2, 6, 26]. Adoption of BIM involves a collaborative effort from all the stakeholders, otherwise, a conflict may rise [12, 15, 26].

Any faults and errors in project information can relatively be seen as a lack of collaboration between designers and site personnel, not as faults in the software [37]. More clients do not have awareness about the value of BIM process, so, they do not need to adopt BIM [38, 39]. R. Matarneh and S. Hamed [6] and S. Liu *et al*. [7] asserted that government clients are interested in BIM implementation but private sector clients are less demanding [15, 39]. Therefore, it is important to deal with management issues for BIM benefits to be achieved [40].

2.4. Personnel Factors

BIM development is based on education and training [41, 42]. So the lack of sufficiently trained BIM specialists has slowed down BIM implementation in the AEC industry [15, 43]. C. Sun *et al*. [12], N. Bui *et al*. [13], M. R. Hosseini *et al*. [30] and G. Aouad *et al*. [44] stated the lack of skilled BIM workers and IT educated persons in the industry as a major barrier to BIM implementation. Skill gap has increased due to BIM implementation [45]. To fully adopt BIM technology inside the company, the company should be hiring new staff that has good knowledge about BIM usage or retraining the current staff to support the organizational and behavioral changes [46]. Staff resistance to change old methods and adopt new processes can also state as a significant obstacle to implement BIM in the construction industry [6, 12, 24, 26, 34, 39]. M. R. Hosseini *et al*. [30] and B. K. Giel *et al*. [22] suggested that the financial value of BIM implementation was difficult to identify even with an expert senior manager. H. W. Ashcraft [47] asserted that designers and engineers need to adopt and exploit the new technology more than the clients. However, for numerous designers and engineers, BIM benefits are not obvious [47]. H. Yan and P. Demian [10] concluded that the reason why the AEC industry is not ready to invest in BIM is the shortage of case study evidence of the benefit of BIM.

2.5. Legal Factors

To have a successful implementation of BIM, the team should protect the privet data of BIM model from loss and misuse, but this may cause some a significant risk [12, 40, 48]. There are many legal issues with BIM, for example, the duty of care including ownership and intellectual property [7, 12, 15, 49, 50]. If the owners pay for the design of construction projects, they may claim that they own this design. Conversely, designers may claim that the design still their own intellectual property [7]. Determining who has the ownership is not a simple process, particularly as the construction industry moves towards fully-integrated Level 3 BIM [51]. In fact, If the model is a collaborative work, then ownership may not be vested in a single party [42].

Another legal issue is the reliance of data, how to determine who has control of this data, who would take decisions and assign resources based on the data and be responsible for any problem, and this aspect could lead to substantial risks [23, 42]. To manage this risk, the BIM protocol should make each party liable for errors in its contributions [51]. The BIM Model may be legally viewed as a product because of the probability of repeated and unrestrained use of design documents by clients, this led to product liability risks [42]. That means the contractor or designer could be liable for any defect in the BIM model [51].

One of the most important legal issues is the authenticity of users when using electronic methods to share information, because it is relatively simple to fake the digital records, or amend dates, times, or other data [48, 52]. If any party litigates, the other court may disregard all evidence or put less weight on it than on paper evidence [52]. S. Christensen *et al*. [48] stated that if an email is sent over a BIM system or extranet, and then verified to have been sent from a specific machine, it is not so easy to verify which person actually sent it. So there is a need to deal with these legal issues in the construction contract in order to reduce the substantial risks [48].

Table 1. Summary of BIM limitation factors.

Code	BIM Limitation Factor	Reference No.
A. Technological Factors		
LF 1	Lack of BIM software packages	[13]; [1]
LF 2	Lack of information sharing	[14 - 16]
LF 3	Lack of ability of two or more systems or components to exchange information and interpret them then use the information (Interoperability)	[12]; [15]; [18]; [17]; [20]
LF 4	Lack computable digital design data	[12]; [17]
B. Cost Factors		
LF 5	High software costs	[1, 21 - 23]; [6]; [7]; [15]; [25]; [10]; [12]
LF 6	High hard ware costs	[1, 21 - 23]; [6]; [7]; [15]; [25]; [10]; [12]
LF 7	High training costs	[1, 21 - 23]; [6]; [7]; [15]; [25]; [10]; [24]; [12]
C. Management Factors		
LF 8	Lack of senior manager support	[12]; [40]; [14]; [15]; [26]
LF 9	Lack of client demand	[38]; [6]; [39]; [15]
LF 10	Required a large culture change within the organization	[27]; [28]; [10, 29]
LF 11	Lack of collaboration between project practitioner	[12]; [15]; [26]; [37]
LF 12	Lack of knowledge on how to implement BIM	[14]; [6]; [1]; [2]; [26]; [53]
LF 13	Need to change in workflows to comply with the new requirements	[12]; [6]; [30]; [2]; [45]; [18]

(Table 1) contd.....

Code	BIM Limitation Factor	Reference No.
LF 14	Fragmented nature of the construction process	[12]; [34]; [33]; [35]; [36]; [20]
LF 15	Time-consuming	[31]; [18]
D. Personnel Factors		
LF 16	Lack of staff experience and skills.	[12]; [6]; [30]; [15]; [44]; [45]; [43]; [41]; [13]
LF 17	Staff resistance to change.	[12]; [6]; [26]; [39]; [34]; [24]
LF 18	Lack of awareness of BIM benefits.	[12]; [30]; [22]; [47]
E. Legal Issues		
LF 19	Lack of contractual arrangements to protect the privet data of BIM model from loss and misuse.	[12]; [40]; [42]; [52]; [48]
LF 20	Difficult to determine who is have intellectual property to design.	[12]; [7]; [40]; [49]; [42]; [50]; [51]
LF 21	Determine who has a full control of the data (Reliance of data).	[12]; [51]; [42]; [23]
LF 22	Contractor or designer could be liable for any defect in the BIM model (Product liability risks).	[12]; [51]; [54]
LF 23	Simple to fake the digital records, or amend dates, times or other data (Authenticity).	[40]; [52]; [48]

3. RESEARCH METHODOLOGY

This study engaged quantitative data to perform research aim, a structured questionnaire was designed for data collection and analysis. The questionnaire was distributed to 68 engineers who have some experience about BIM applications in the construction industry in the Gaza Strip in Palestine.

3.1. Questionnaire Design

The questionnaire is divided into two sections. In the questionnaire cover page, the researchers explain why this questionnaire was developed and identified research aim and objectives as well as mentioned the main sections of the questionnaire. The first section is about respondents' personal information and is divided into five questions about the respondent's gender, education level, nature of work, position, and work experience, respectively.

The second section contains twenty-three questions about limiting factors faced by respondents' company in BIM implementation and these factors are divided into five categories as follow: technological factors, cost factors, management factors, personnel factors, and legal factors.

The Relative Importance Index (RII) method has been extensively applied in construction management studies for determining attitudes with regards to surveyed factors. Numerous studies [55 - 63] have used the RII in their analysis. The participants were requested to assess the identified interface problems on a five-point Likert scale between "1" for the strongly disagree and "5" for the strongly agree. Based on the survey response, RII was calculated using the following equation:

$$\text{Relative Importance Index} = \frac{\sum w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where, W is the weighting specified to every factor by the participant between 1 and 5, n1 = number of participants for strongly disagree, n2 = number of participants for disagree, n3 = number of participants for neutral, n4 = number of participants for agree, n5 = number of participants for strongly agree, A is the highest weight (5 in this study) and N is the total number of samples.

3.2. Questionnaire Verification

3.2.1. Face Validity

The validity of the questionnaire designed was tested by presenting the first draft of the questionnaire hardcopy by hand or softcopy by email to 6 experts with academic knowledge in BIM. These experts made a very helpful and important modification to the questionnaire such as: clarify some technical expressions, add some questions, and audit Arabic and English language. These modifications helped to develop the final version of the questionnaire.

3.2.2. Pilot Study

The size of the pilot sample depends on the actual sample size. According to S. J. Thomas [64], a sample of around 30-50 people should be enough to identify any substantial bugs in the system. As a result of that, 30 copies of the questionnaire were distributed conveniently to respondents from the target group. All copies were collected, coded, and analyzed by using Statistical Package for the Social Science IBM (SPSS) version 22.

3.3. Population and Sample

The questionnaire was formed and distributed in March 2019. The target population of the questionnaire includes civil engineers, architects, electrical engineers, and mechanical engineers who have some experience about BIM applications in the construction industry in the Gaza Strip in Palestine. Snowball sampling method was conducted as a sampling method in the research. In this sampling method, the initial respondents are chosen by non-probability methods and then other respondents are suggested by the initial respondents [65]. Because the number of people who are familiar with BIM implementation is limited and there is limited source for finding engineers who have experience in this specific topic, snow-ball sampling method can be the best technique to create a network of professional contacts [66]. In the questionnaire distribution stage, face-to-face and a web-based survey were used. A total of sixty-eight copies of questionnaire were distributed and sixty-five of them were satisfactorily completed, making the total response rate (65/68) × (100) = 95.58%. Snow-ball sampling method helped to obtain a high rate of response and thus increase accuracy.

4. RESULTS

4.1. Personnel Category

This category composes of three factors. Table **2** illustrates that "Lack of staff experience and skills" was ranked in the first position by the respondents under this group with RII equals (80.62%). This result illustrates the influence of lack of staff experience and skills on the implementation of building information modeling in the construction industry. This happens because BIM is a new technology and it has not known in the Gaza Strip yet. Further, there is no support from the engineering association to present new training courses related to BIM application to increase staff experience and skills. Some BIM experts chose to work in more developed countries where this technology is used. M. R. Hosseini *et al*. [30] and R. Eadie *et al*. [39] reported that lack of staff experience and skills is the most major limitation factors that were faced organization in BIM implementation.

Table 2. RII's and test values for all categories.

No.	Limitation Factors	Mean	Std. Dev	RII (%)	T value	P value Sig.	Rank
Technological Category Factors							
LF 2	Lack of information sharing	3.49	1.21	69.85	3.27	0.002	1
LF 3	Lack of ability of two or more systems or components to exchange information and interpret them then use the information (Interoperability)	3.40	1.10	68.00	2.93	0.005	2
LF 4	Lack of computable digital design data	3.17	1.17	63.38	1.17	0.247	3
LF 1	Lack of BIM software packages	2.97	1.22	59.38	-0.20	0.840	4
Cost Category Factors							
LF 5	High software costs	3.18	1.13	63.69	1.32	0.193	1
LF 6	High hardware costs	3.11	1.16	62.15	0.75	0.457	2
LF 7	High training costs	3.05	1.10	60.92	0.34	0.735	3
Management Category Factors							
LF10	Requirement of large culture change within the organization	4.42	0.90	88.31	12.69	0.000	1
LF8	Lack of senior manager support	4.06	0.92	81.23	9.34	0.000	2
LF12	Lack of knowledge on how to implement BIM	4.05	1.02	80.92	8.25	0.000	3
LF13	Need to change in workflows to comply with the new requirements	4.00	0.94	80.00	8.62	0.000	4
LF9	Lack of client demand	3.83	0.96	76.62	6.97	0.000	5
LF11	Lack of collaboration between project practitioner	3.49	1.05	69.85	3.79	0.000	6
LF14	Fragmented nature of the construction process	3.46	1.05	69.23	3.55	0.001	7
LF15	Time consuming	2.18	1.18	43.69	-5.55	0.000	8
Personnel Category Factors							
LF 16	Lack of staff experience and skills.	4.03	0.68	80.62	12.15	0.000	1
LF 17	Staff resistance to change.	3.92	0.85	78.46	8.72	0.000	2
LF 18	Lack of awareness of BIM benefits.	3.89	1.08	77.85	6.68	0.000	3
Legal Category Factors							
LF 19	Lack of contractual arrangements to protect the private data of the BIM model from loss and misuse.	3.52	1.08	70.46	3.92	0.000	1
LF 20	Difficulty in determining who has design intellectual property rights.	3.03	1.09	60.62	0.23	0.821	4
LF 21	Difficulty in determining who has full control of the data (Reliance of data).	3.12	1.07	62.46	0.93	0.356	3
LF 22	Contractor or designer could be liable for any defect in the BIM model (Product liability risks).	3.40	1.10	68.00	2.93	0.005	2
LF 23	Easy to fake the digital records, or amend dates, times or other data (Authenticity).	2.40	1.10	48.00	-4.39	0.000	5

"Lack of awareness of BIM benefits" was ranked in the last position by the respondents under this group with RII equals (77.85%). The sign of the test is positive, so the mean of this factor is significantly greater than the hypothesized value. This result demonstrates the influence of lack of awareness of BIM benefits on the implementation of building information modeling in the construction industry. This may be related to the shortage of case study evidence about the benefits of BIM implementation in the Gaza Strip. Universities also have not provided official courses to their students to increase their knowledge of BIM benefits. In addition, the government has not encouraged BIM-related researches. This outcome agreed with the results of Hosseini *et al*. [30] and O. E. Ogunmakinde and S. Umeh [67].

4.2. Management Category

This category contains eight factors. Table **2** shows that "Requirement of large culture change within the organization" was ranked in the first position by the respondents under this group with RII equals (88.31%). This result illustrates clearly the influence of this factor on the implementation of BIM in the construction industry. This is because all construction companies in the Gaza Strip are familiar with implementing the construction process by using traditional methods to avoid new risks and challenges. The result obtained aligns with the findings of R. Eadie *et al*. [40] that scale of culture change required limited BIM implementation and it was ranked in the first positions by respondents.

"Time-consuming" was ranked in the last position by the respondents under this group with RII equals (43.69%). This result illustrates that members of the study sample do not agree with this paragraph, which indicates that time-consuming do not affect the implementation of BIM in the construction industry. This means that BIM does not consume time in construction projects. Actually, BIM consumes time to develop 3D as-built drawing more than using the traditional method to develop 2D. However, BIM saves more time in the later stages of construction projects. Thus, this result confuses with the outcomes of J. D. Goedert and P. Meadati [31].

4.3. Technological Category

This category composes of four factors. Table **2** shows that "Lack of information sharing" was ranked in the first position by the respondents under this group with RII equals (69.85%). This result illustrates clearly the influence of the lack of information sharing on the implementation of BIM in the construction industry. This related to the failure of coordination and collaboration between project team in some of the project stages. Also, difficulties in the transfer and reuse of information in the graphical model could affect information sharing. Research findings of D. Bryde *et al*. [15] support this result.

"Lack of BIM software packages" was ranked in the last position by the respondents under this group with RII equals (59.38%). This is because many software firms are cashing in on BIM and developed much software to facilitate BIM implementation in construction projects. This result is in line with the conclusions of S. Azhar [1] which indicate that software issues are not considered a great deal.

4.4. Cost Category

This category consists of three factors. Table **2** shows that "High software costs" was ranked in the first position by the respondents under this group with RII equals (63.69%). This result illustrates the influence of high software costs on the implementation of BIM in the construction industry. This means that construction firms should assign some of their income to purchase related software. Software firms also should invest more and more to introduce high-quality software at a lower development cost. This agreed with the study findings of O. E. Ogunmakinde and S. Umeh [67] which indicated that high software costs were ranked in the first position by respondents. The results of S. Liu *et al*. [7] also show that high software costs were ranked in the third position by respondents.

"High training costs" was ranked in the last position by the respondents under this group with RII equals (60.92%). In other words, practitioners tanning cost will not affect the BIM implementation in the Gaza Strip. The reason for this is the importance of BIM at reducing overall project cost so training cost is not very important. This outcome disagreed with studies conducted by O. E. Ogunmakinde and S. Umeh [67] and S. Liu *et al*. [7].

4.5. Legal Category

This category consists of three factors. Table **2** shows that "Lack of contractual arrangements to protect the private data of BIM model from loss and misuse" was ranked in the first position by the respondents under this group with RII equals (70.46%). This result illustrates obviously the influence of lack of contractual arrangements to protect the private data of the BIM model from loss and misuse on the implementation of BIM in the construction industry. This occurs as a result of the lack of meetings from engineers' associations to deal with this new technology. The government also does not support investments to make a new contractual arrangement. Similar results were conducted by O. E. Ogunmakinde and S. Umeh [67] which indicate that lack of contractual arrangements to protect the private data of BIM model from loss and misuse considers on of the most major factors that face organization in implementing BIM.

"Easy to fake the digital records, or amend dates, times or other data (Authenticity)" was ranked in the last position with RII equals (48.00%). The sign of the test is negative, so the mean of this factor is significantly smaller than the hypothesized value. This result illustrates that it is not easy to fake the digital records, or amend dates, times, or other data. This may be related to the high quality of software and the ability of this software to save important information in a well-closed security system. This agrees with the outcomes of O. E. Ogunmakinde and S. Umeh [67] and R. Eadie *et al* [39]. that ranked authenticity in the last position by respondents.

In order to determine the most important limitation category and the least one faced by organizations in the BIM implementation, RII of each category was measured. Table **3** illustrates that the personnel category with RII of (78.97) was ranked the most important while the legal category with RII of (61.91) was ranked the least important. Management factors were second-ranked with RII (73.73%). Technological factors were third-ranked with RII (73.73%). The fourth-ranked category was the cost factor category with RII (62.26).

Table 3. Rank of groups that limit BIM implementation.

Factors	**Average RII**	**Rank**
Limitation Factors		
1. **Personnel factors**	78.97	1
2. **Management factors**	73.73	2
3. **Technological factors**	65.15	3
4. **Cost factors**	62.26	4
5. **Legal factors**	61.91	5

Personnel and management categories had RII score above 68% that indicates the necessity for critical actions to breakdown those limiting factors.

CONCLUSION

This study identified twenty-three limitation factors to

BIM implementation in the construction industry. These factors were summarized in five categories (technological, cost, management, personnel, and legal categories) and then the factors were ranked in order of importance. Of these categories, personnel and management factors are the most and least factors to the adoption of BIM, respectively. The study explains the importance of limitation factor determination to implement BIM in the construction industry as a tool to gain BIM significant benefits to the construction projects through the project lifecycle. It revealed that the requirement of large culture change within the organization, lack of senior management support, lack of knowledge on how to implement BIM, lack of staff experience and skills, and need to change in workflows to comply with the new requirements were the most important limiting factors to BIM implementation.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The data used to support the findings of this study are included in the article.

FUNDING

The authors declare no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

Declared none.

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