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RESEARCH ARTICLE - CIVIL ENGINEERING

Building Information Modeling: Awareness Across the Subcontracting Sector of Saudi Arabian Construction Industry

Mahmoud Sodangi[1] · Ahmed Fouad Salman[1] · Muhammad Saleem[2]

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Abstract Studies related to BIM implementation status, awareness level, and implementation challenges and barriers in selected GCC have been well reported. Despite the vast Saudi Arabian economy and the volume of construction projects being undertaken in the Kingdom, there is no clear evidence for any such study conducted within the local construction industry. Thus, the authors make a pioneering attempt to first examine the level of subcontractors' awareness and preparedness for BIM implementation in construction projects in the Saudi Arabian construction industry. This is necessary because the subcontracting sector, which comprises mainly of the small- and medium-scale construction companies greatly outnumber the big construction companies in the local construction industry. Thus, industry wide survey was conducted to this effect. Findings of the study reveal a widespread lack of BIM knowledge across subcontracting sector of Saudi Arabian construction industry. Most of the subcontractors lack some basic understanding of the functions of BIM in the feasibility, construction and maintenance management stages of construction project. Other findings suggest reluctance among the subcontracting companies toward implementing BIM in construction projects. Thus, to maximize full advantages of BIM and to facilitate full adoption of BIM among the subcontracting sector, valuable recommendations were highlighted. It is anticipated that the findings of this paper could be valuable to regulators of the Saudi Arabian Construction Industry and serve as basis for urgent preparation of guidelines and policies to improve the general level of BIM adoption and expertise within the industry.

Keywords Building Information Modeling · BIM awareness · BIM readiness · BIM technology · Construction industry · Subcontractors

✉ Mahmoud Sodangi
misodangi@uod.edu.sa

Ahmed Fouad Salman
asalman@uod.edu.sa

Muhammad Saleem
mssharif@uod.edu.sa

1 Department of Construction Engineering, University of Dammam, Dammam, Saudi Arabia

2 Department of Basic Engineering, University of Dammam, Dammam, Saudi Arabia

1 Introduction

In today's globalized business environment, the construction industry still remains one of the best ways of stimulating economic activities, not just in the construction sector but across the economy as a whole. Construction industry activities remain essential to the provision of infrastructure and job creation all over the world. In terms of employment stimulation, construction industry is second to none. Abubakar [1] assert that the employment that construction industry provides benefits unskilled, lower skilled and young workers who have relatively few alternative opportunities. Many countries around the world are heavily reliant on construction jobs. Construction has always been the largest single sector in the GCC region [2,3].

However, Abubakar [1] emphasizes that despite the obvious significance of the construction industry to national economy of most countries, the global construction industry has been facing many criticisms due to its inefficiency and low productivity. These criticisms have been largely credited to the complicated process of construction procurement in the industry. To corroborate this, Hassan [2] also acknowledged that the Construction industry is generally perceived to be one of the most harshly criticized industries noting that the criticisms stem from problems related to poor performance in project delivery, low innovation level, inefficient collaborations as well as fragmented and adversarial nature of the industry. To this regard, the sector has proactively taken a systematic approach to improve construction efficiency, corporate and project levels quality performance, sustainability, increase clients and end-users satisfaction, decrease lifecycle costs, rework and construction wastages through efficient partnership between all stakeholders of construction projects. These pave way for an all-inclusive, collaborative, and integrated platform to address these problems. Thus, in an era of high advancements in information technology, the Building Information Modeling (BIM) is perceived to be the key element to rejuvenate the industry to the zenith of growth.

The rapid ongoing advancements in the information and technology sector are paving ways for the adoption of BIM technology in construction business [4]. There is evidence of considerable BIM adoption in construction in some large construction corporations in the UK and US. Nonetheless, the awareness and implementation across the entire construction industries in these countries remains relatively low despite signs of improvements.

Although BIM is being implemented in Saudi Arabia, it is still perceived to be in its early stages [5–7]. Nonetheless, it can be argued that BIM implementation in the Kingdom's construction industry remains relatively slow [8,9]. This is because only few project owners have started to appreciate the numerous benefits associated with BIM implementation like producing various design alternatives, the ability to conduct many tests on BIM model as well as its ability to provide for early detection of design errors to reduce reworks which are costly in nature. Issa [7] and Sodangi et al. [9] noted that in Saudi Arabia, the implementation of BIM in construction is mostly by the few big companies; the subcontracting sector which constitutes the majority of construction companies in the industry is still far left behind. The authors further noted that the few 'big' construction companies that use BIM in their major projects are typically confined to the most basic functionalities, suggesting an industry that is to some extent inexperienced in the application of BIM.

Considering the fact that BIM implementation in Saudi Arabia is only among the few top-ranking companies and the subcontracting sector, which comprises mainly of the small and medium-scale construction companies that dominate the local industry are yet to come to terms with BIM adoption; it became pertinent to come up with strategies that would ensure the adoption of BIM among the companies in this large sector of the industry. To start with, this paper takes a pioneering attempt to examine the subcontractors' awareness and preparedness level for implementing Building Information Modeling in construction.

2 Building Information Modeling (BIM)

The BIM as defined by the National Institute of Building Sciences [10] "is an automated illustration of the physical and functional features of a facility. Thus, it serves as a collaborative knowledge resource for information about a facility, establishing a consistent platform for making decisions during its service life from initial inception to demolition". BIM is one of such state-of-the-art processes that focus on bringing continuous quality improvement and much needed transformation in the construction sector. It also focuses on transforming the industry's practices toward attaining enhanced partnership among key project stakeholders and ensures efficient completion of construction projects [11]. By means of BIM knowledge today, a computer-generated model of a building structure can be created accurately and applied to help in the procurement, design, as well as project site tasks required to construct the facility. More so, the BIM can be adopted in the management of building maintenance during the post construction or occupancy stage upon completion [1]. Therefore, before making attempts to provide conceptual details of strategic plan that would help to prepare guidelines for decision-makers to implement BIM, it became pertinent to first present comprehensive assessment of subcontractors' awareness and preparedness level for implementing BIM in construction projects in Saudi Arabia, which is considered paramount.

BIM facilitates the building development, construction and building operation [12]. Mom and Hsieh [13] acknowledged that BIM is gradually changing how construction projects are being executed worldwide. With BIM's exclusive ability to enhance organization among operators, contractors and design teams; its implementation reduces project time, cost, material consumption and carbon emissions while improving contractors' productivity and quality performance [13]. The efficiency and economic benefits of BIM to the construction industry worldwide are generally recognized and increasingly well understood.

Apart from transforming management of data for building projects, this technology similarly supports an actual procedure of creating and handling building information throughout the project's life cycle. The BIM technology is not just a simple software replacement; but enhances quality of design using auxiliary input from the main project participants during design. It permits for the distribution of more information among constructors, owners, engineers, and designers. Above all, BIM emphasizes on both the processes as well as technology. Various projects have revealed exactly how BIM impacts on cost as well as time savings, greater efficiency, low rate of errors in design and better business prospects for clients and end-users of the constructed facilities. In essence, BIM is and remains the future of the construction industry.

3 Review of BIM Implementation in the Middle East

Developed nations in Asia, Europe and North America are now reaping the benefits of BIM adoption in ongoing asset management along with construction project delivery. However, in a study conducted by Gerges et al. [3] to determine the present status of BIM in the Middle East by exploring the extent of BIM implementation among stakeholders in the construction industry; the findings reveal that the state of BIM adoption in the Middle East is not satisfactory. The authors further affirmed that only 20% of construction companies are implementing BIM or are involved in BIM adoption process in any capacity, while the remaining 80% are neither applying it nor involved in its adoption process in whatever capacity.

Similarly, Hassan [2] conducted a study on the implementation of Building Information Modeling (BIM): practices and barriers in construction industry in GCC.

The author acknowledged the implementation of BIM in some construction projects in UAE and Kuwait though there are no published sources to ascertain the real status of BIM implementation in the entire GCC. Key among the findings of his study was the evidence of low implementation rate for BIM in construction projects in the GCC construction market and the lack of BIM awareness, and unwillingness of the stakeholders in accepting to change the existing work practices.

In a related attempt by Ahmed et al. [14], their study was aimed at evaluating the awareness and experience levels of 4D planning and BIM in the construction industry in Qatar in addition to identifying the likely challenges to the general implementation of BIM. The evaluation was undertaken through an industry wide survey administered to related experts in Qatar.

Still within the Middle East region, Hussein et al. [15] conducted similar study on the application of BIM technology and to identify the desired benefits and challenges that limit BIM adoption within the Iraqi construction industry. Findings of the study suggest a low BIM adoption among construction practitioners in Iraq.

A much earlier study was undertaken in the Middle East by Building Smart [5]. The target of the survey was to provide thorough knowledge of the construction market related to BIM and to determine competences, proficiencies and barriers to BIM implementation. The respondents to the survey were mostly project owners, contractors, project developers, consultants, and suppliers. Findings of the survey indicate that over 50% of the respondents do not use BIM, and about 20% were not familiar with BIM, which suggests a low awareness level. More so, the survey revealed that ‘availability of skilled staff’, ‘cost of software’, and ‘cost of implementation’ are the top-ranking challenges to BIM adoption in the region though the study did not specifically outline the countries covered in the survey and the countries the respondents came from.

From findings of the literature review highlighted before now, it is clear that studies related to BIM implementation status, awareness level, and implementation challenges and barriers in selected GCC countries have been well reported. However, considering the vast Saudi Arabian economy, which is one of the largest in the Middle East and the volume of construction projects being undertaken in the Kingdom, it would not be out of place if similar study is undertaken to provide an insight into the subject. Also, there is no clear evidence for any such study conducted within the Saudi Arabian construction industry.

Thus, the authors make a pioneering attempt to first examine the level of subcontractors’ awareness and preparedness for BIM implementation in construction projects in the Saudi Arabian construction industry. This is necessary because the subcontracting sector, which comprises mainly of the small and medium-scale construction companies outnumber the big construction companies in the local construction industry. It is anticipated that the findings of this paper would be valuable to regulators of the Saudi Arabian Construction Industry and serve as basis for urgent preparation of guidelines and policies to improve the general level of BIM awareness, preparedness, as well as adoption and to raise the general capabilities of the subcontracting sector of the local construction industry.

4 Methodology

A Saudi Arabian construction industry wide survey was conducted to examine subcontractors’ awareness and preparedness for implementing Building Information Modeling in their construction projects. Judgmental sampling was adopted in selecting the subcontracting companies for the survey. The sampling frame for the targeted subcontracting companies predominantly has their core business operations in the areas of architectural engineering, structural engineering, geotechnical engineering, and building services (mechanical and electrical works) was formed from a recent list made available to the researchers by the Saudi Arabian Ministry of Housing and Public Works. Initial information on the subcontractors was obtained from the Ministry. The targeted respondents were selected based on the consideration that their subcontracting trades may necessitate the use of BIM in construction projects. Thus, this would enable them to provide BIM models of their subcontracting trades and project operations which are tied to the BIM model of their main contractors operations. A total of one hundred and twenty-six questionnaires were distributed to the subcontracting construction companies. An e-mail-based questionnaire was chosen for the survey considering its reduced response time, better response quality, low costs and the respondents' access to the internet. An introductory e-mail containing the study aim was sent to the respondents in which the link for the questionnaire survey was provided. The respondents required not more than 15 min to respond to the questions online and their responses were collated in a Google supported database. The survey period lasted for 12 weeks.

In administering the questionnaires, the questionnaire was designed in two parts;

Part A contains questions that bring out information about the respondents' background. The questions in this section were closed ended but provisions were made, in case none of the options provided was appropriate to the respondents. Respondents were required to choose only one option from the various alternatives provided except where otherwise specified. The second part of the questionnaire was largely closed ended questions (see Tables 2 and 3), which assess the respondents' level of awareness and preparedness for implementing Building Information Modeling in their construction projects. Respondents rated their awareness and readiness levels according to a five-point Likert scale.

The scale for assessing awareness and readiness levels is as follows: 5 stands for very high extent; 3 for moderate extent and 1 for very low extent. In many previous studies, similar scales have been adopted by various authors [16–20]. Frequency analyses and severity index were used to rank the subcontractors' levels of awareness and preparedness for implementing Building Information Modeling in construction projects. The analysis of severity indices is a nonparametric statistical technique commonly used by researchers in the field of engineering and technology management to examine data obtained from questionnaire respondents concerning ordinal assessment of attitudes [20–23]. The analysis of severity indices involves using weighted percentage scores to compare and prioritize severity levels of the subcontractors' awareness and readiness under study.

After using the severity index to rank the subcontractors' levels of awareness and preparedness, reliability test was run to ascertain how reliable the research method was. Though questionnaires are widely considered as some of the approaches used for collecting data in survey research method, they are subject to measurement errors which could be systematic or random [24]. De Vaus [24] emphasized that when evaluating many items, the internal consistency method is the best technique to adopt as it does not encounter the problems of the test–retest method. The internal consistency is the most suitable and widely used internal consistency measures, which refers to how well the items that make up the questionnaire fit together [25]. This is because the strength of the coefficient gives the most thorough analysis of patterns of internal consistency by examining how groups of variables are related to groups of other variables.

More so, the coefficient does not depend on a single split-half coefficient but on the entire likely combinations of splits [24]. In general, this method indicates reliability using a coefficient ranging from 0.0 to 1.0; a higher value (0.7) of the coefficient is mostly considered as being the minimum level acceptable and indicates that the set of questions are highly reliable [26]. If the coefficient is less than 0.7, it signifies that the items are unlikely to be reliably measuring the same thing. A generally known rule for explaining internal consistency using Cronbach's coefficient alpha was established by George and Mallery [27] as follows: 0.90–1.00 is considered excellent; 0.80–0.89 is good; 0.70–0.79 is acceptable; 0.60–0.69 is questionable; 0.50–0.59 is poor, while a coefficient of less than 0.50 signifies unacceptable reliability.

5 Results Analyses

The survey data were analyzed using Microsoft Excel windows application package to produce descriptive, inferential and illustrative statistics. A total of one hundred and twenty-six questionnaires were distributed to local subcontracting construction companies. Fifty-four questionnaires were completed, received and analyzed for this paper. A reasonable explanation on why the whole completed questionnaires were useable was because the respondents are experienced. The fifty-four questionnaires returned signify 43% response rate. This is considered adequate for survey questionnaire. Like other surveys in the field of construction engineering and technology management undertaken by [17] suggest that a response rate of 21% is considered adequate, Aibinu and Jagboro [28] suggest 30–40%, while Enshassi [19] and Sodangi et al. [20] assert that 20% response rate could be accepted when using judgemental sample for a survey questionnaire. By and large, the response rate of 43% obtained from this survey is considered to be satisfactory. Reliability test was used by the authors to rely on the responses the questionnaire items gave; erase any doubt associated with analysis based on such data, and to indicate how reliable the questionnaire for this study is.

In the section of the questionnaire that covers demographic characteristics of the respondents, questions were addressed to the respondents to obtain information on their respective profiles. Purposely, this part identifies the respondents' professions, position in the company and level of experience in their present positions. Figure 1 shows distribution of respondents' profession. From the figure, it could be deduced that all the respondents are from recognized professional fields of construction engineering and project management. This

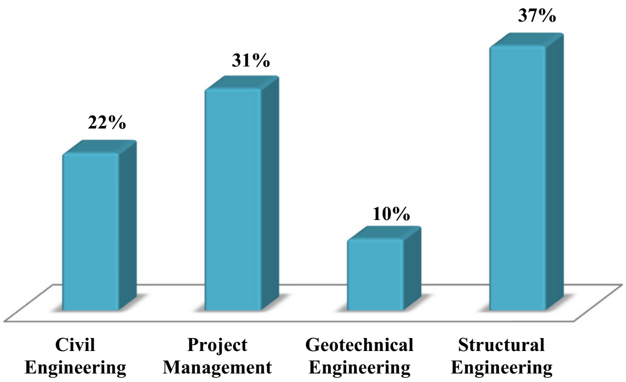

Fig. 1 Respondents' professions

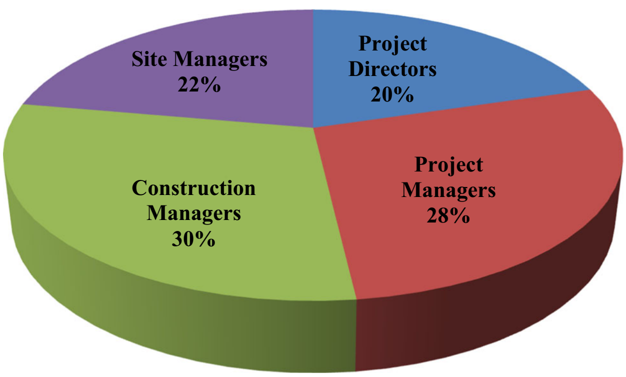

Fig. 2 Positions of respondents in the company

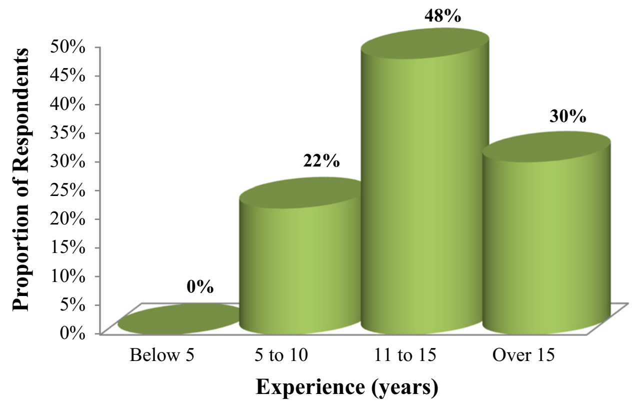

Fig. 3 Working experiences of respondents

seems to imply that the professionals (respondents) have the competences to give reliable and valid response to the survey questions.

Obviously, it could be seen from the distribution in Fig. 2 that all the respondents are key project party professionals that are indispensable in the management of construction projects. By virtue of their positions, these respondents are considered very significant because of their involvement in all project key decisions. Since BIM serves an information center to provide better communication among construction team members, the responses from these professionals in their respective positions would be valuable for the findings of this research.

Figure 3 presents working experience of the respondents in their respective positions in the construction companies. The most significant finding here is that about 80% of the professionals (respondents) have working experience of over 10 years in their present positions. These results strongly indicate that most of them have adequate experience to provide requisite information on awareness and preparedness of subcontractors in implementing BIM in construction projects. The required information provided by these experienced respondents is considered reasonably reliable and vital for this survey.

5.1 Determining Severity Index

Severity index was used to rank the factors for assessing awareness and readiness using frequency and severity index analyses. Idrus and Newman [29] and Chen et al. [30] noted that when using this method, analysis of frequency was first done to determine the response frequency for different factors being evaluated. Subsequently, the response frequencies were used to determine severity index for every factor using the formula below:

$$\text{S.I} = \sum_{i=1}^{5} w_i \times \frac{f_i}{n} \times 100 \Big/ (a \times 100) \tag{1}$$

where i is the point given to each criterion by the respondent, ranging from 1 to 5; ω_i is the weight for each point (=rating in scale of points, which "1" is the very low extent and "5" is very high extent); f_i is the frequency of the point i by all respondents; n is the total number of responses; and a is the highest weight, in this study $a = 5$. As pointed out by [29], the five levels indicating the awareness and readiness extent of the respondents are transformed to severity index values: very high awareness/readiness (0.80–1.00); high awareness/readiness (0.70–0.79); moderate awareness/readiness (0.50–0.69); low awareness/readiness (0.20–0.49) and very low awareness/readiness (0.0–0.19). This interpretation would later be used in prioritizing the severity level of the factors under the study.

5.2 Reliability Test

The overall Cronbach's alpha obtained from the reliability analysis is displayed in Table 1. As the results in the table show, the overall Cronbach's alpha for the items in two different sets of factors (level of BIM awareness and Level of preparedness) is 0.89 and 0.88, which is considered 'excel-

Table 1 Reliability test results

Factors under consideration	Cronbach's alpha	Number of factors under consideration
BIM awareness level	0.89	12
BIM readiness level	0.88	9

lent' by [27] and indicates very strong internal consistency among the eighteen items.

In essence, these test results indicate that professionals (respondents) who tended to assign high points for one factor also tended to assign high points for the other factors. Likewise, respondents who assigned low points for one factor also tended to assign low points for the other factors. Therefore, knowing the points for one factor would enable accurate prediction of the points for the other factors. However, this ability to predict scores from one item (factor) would not be possible when the Cronbach's alpha is low. Given that analyzing statistical data depends on measurements being both reliable and valid then the ability to obtain consistent responses makes a measurement reliable and a questionnaire item is reliable if it gives dependable and consistent responses from the respondents [24]. De Vaus [24] further emphasized that there is a need to rely on the responses that a questionnaire item gives in order to erase any doubt associated with analysis based on such data. Thus, it could be inferred that the responses obtained from the respondents are dependable and consistent and the items (factors used in assessing the awareness and preparedness level) are reliable and valid.

5.3 Discussion of the Severity Index Analysis

The valid percentage for scores of the respondents, summary of the severity indices and ranking of the factors used to assess respondents' level of BIM awareness is shown in Table 2.

From the transformed severity indices mentioned above, it could be inferred that the higher the severity index value for any factor, the higher level of awareness/readiness for that particular factor. Conversely, the lower the severity index value for any factor, the lower level of awareness/readiness for that particular factor.

A closer look at the table would show that 11 out of the 12 factors used for assessing BIM awareness within the four project stages (feasibility stage, design stage, construction stage, and in-use and maintenance stage) obtained low severity index values (0.20–0.49) from the rating done by the respondents, which indicates low BIM awareness among the respondents. The only factor that obtained moderate severity index value (0.50) is "awareness on the use of BIM to form better integration between designers and client", which was categorized under the feasibility stage of construction projects. Nonetheless, going by the weighted average values of all the factors' severity indices in each project stage in table, then it is clear that all the severity index values fall within the low severity range. This suggests low BIM awareness among the respondents in the entire project stages presented for the survey.

The respondents' BIM awareness in 'in-use and maintenance stage' has *low* aggregate severity level (29%), which indicates low awareness level of the subcontractors on the functions of BIM in building operation and maintenance activities. The implication here is that most of these subcontractors do not know the BIM's ability to reduce energy wastage based on the energy reading provided by BIM, obtain maintenance cost pre-estimation, carry out maintenance at the correct time and spot and to retrieve building data for renovation and replacement purposes. This finding is not surprising at all because the focus of BIM implementation in most big construction companies in the Kingdom's construction industry still remains strongly in design and construction stages of construction project. Since the early introduction of BIM, it has been claimed that BIM would bring significant benefits to building maintenance management. Though most of the familiar advantages of BIM are associated with design and construction, however, there is no much documentation of BIM benefits in building maintenance management activities.

Surprisingly, the subcontractors' awareness level on the functions of BIM in the 'construction stage' of construction project was rated as having *low* aggregated severity level (32%) despite the high emphasis being given to BIM implementation in the construction processes. This result also indicates very low awareness level of the subcontractors on the functions of BIM to reduce variation orders, construction wastage, disputes rates due to discrepancies, shorten the construction period and to ensure that the constructed facility meets client's requirements. Accordingly, it can be affirmed the subcontractors are not quite aware of the capabilities of the BIM to simplify and improve project-level construction processes and only a small group of the respondents are conversant with the powers of BIM application in construction industry.

In another related finding, the respondents' BIM awareness in 'feasibility stage' has *low* aggregated severity level of (47%), which is relatively much higher than in other project stages. This suggests near moderate level of awareness among the subcontractors on the functions of BIM to form better integration between designers and client and clients' use of the technology to make better decisions with projected design or model. The implication here is that only a small number of these subcontractors know the BIM's ability to showcase a model for the project during the feasibility stage in order to produce enhanced visualization to all concerned parties to the project. This great ability of BIM, which allows project owners and designers to easily make modifi-

Table 2 Level of BIM awareness among subcontracting construction companies

Construction Project Stages	Questions (Factors) for assessing BIM Awareness	Valid percentage (%) for score of					Severity index	Weighted average	Rank
		1	2	3	4	5			
Feasibility	Using BIM to form better integration between designers and client	25.9	24.1	33.3	7.4	9.3	**0.50**	**0.47**	**4**
	Using BIM by clients to make better decisions with projected design or model	29.6	37.0	18.5	11.1	3.7	**0.44**		
Design	Using BIM to convert 2D drawings into 3D models	40.7	37.0	11.1	5.6	5.6	**0.40**	**0.38**	**3**
	Using BIM as an information Centre to provide better communication among construction team members	50.0	33.3	5.6	5.6	5.6	**0.37**		
	Using BIM to reduce discrepancies between architect and engineer drawings; and between drawings and bill of quantities	40.7	53.7	0.0	1.9	3.7	**0.35**		
	Using BIM to reduce tendering duration by eliminating the taking off process	46.3	33.3	9.3	5.6	5.6	**0.38**		
Construction	Using BIM to reduce variation orders and construction wastage and also shorten the construction period	59.3	29.6	5.6	3.7	1.9	**0.32**	**0.32**	**2**
	Using BIM to reduce disputes rates due to discrepancies	35.2	59.3	5.6	0.0	0.0	**0.34**		
	Using BIM to ensure end product meets client's requirements	50.0	46.3	1.9	1.9	0.0	**0.31**		
In-use and maintenance	Using BIM to reduce energy wastage based on the energy reading provided by BIM	70.4	24.1	1.9	1.9	1.9	**0.28**	**0.29**	**1**
	Using BIM to obtain maintenance cost pre-estimation and to do maintenance at the correct time and spot	57.4	38.9	1.9	0.0	1.9	**0.30**		
	Using BIM to retrieve the building data for renovation and replacement purposes	57.4	38.9	3.7	0.0	0.0	**0.29**		

Bold values highlights the results obtained from the survey i.e. severity index and ranking

cations to the project model and analyze the subsequent cost implications accordingly is to a high extent not well known among the subcontractors.

On the other hand, it was not surprising to note the subcontractors' awareness level on the functions of BIM in the 'design stage'. Referring to Table 2, it could be seen that the awareness factors in this project stage still have *low* severity level (38%) signifying low awareness level of the subcontractors on the functions of BIM in this project stage. The implication here is that most of these subcontractors have poor knowledge of the BIM's ability to provide better communication among construction team members, reduce discrepancies between architect and engineer drawings, reduce discrepancies between drawings and bill of quantities and to decrease tendering duration by eliminating the taking off process. This finding obviously points to the fact that other important BIM's functions in the design stage of construction projects are not well known among the subcontractors.

Technically, these results have been expected as only the few 'big' construction companies in the Kingdom apply BIM in some of their major projects. Even the so-called big companies are typically confined to the most basic functionalities, suggesting that the Saudi Arabian subcontracting companies, which are predominantly local based companies, are to some extent inexperienced in the application of Building Information Modeling. Not that alone, nearly all the construction subcontracting companies in the Kingdom do not use BIM in their projects and are actually lagging behind due to lack of awareness and guidance.

The summary of the severity indices and ranks of factors used in assessing the respondents' level of preparedness in implementing BIM in construction project are presented in Table 3.

A closer look at the table would show that 8 out of the entire 9 factors used for assessing the respondents' readiness for BIM adoption within the four BIM implementation aspects (technology, people, process, and management

Table 3 Level of subcontractors' preparedness in implementing BIM

Implementation aspects	Questions (Factors) for assessing readiness for BIM implementation	Valid percentage (%) for score of					Severity index	Weighted average	Rank
		1	2	3	4	5			
Technology aspect	Extent to which the companies have adequate information technology infrastructure in place and use the infrastructure to improve communication and closer working relationship	25.9	24.1	33.3	7.4	9.3	**0.50**	**0.45**	**4**
	Extent to which the companies use the infrastructure to improve communication and closer working relationship	29.6	37.0	18.5	11.1	3.7	**0.44**		
	Extent to which the companies focus on ICT skills development and employ ICT experts	40.7	37.0	9.3	3.7	9.3	**0.41**		
People aspect	Extent to which the companies employees are willing to adopt innovative approaches and to use proven technologies, tools and practices	59.3	29.6	5.6	3.7	1.9	**0.32**	**0.34**	**2**
	Extent to which the companies provide specific training and technical assistance to their employees in implementing BIM	40.7	53.7	0.0	1.9	3.7	**0.35**		
Process aspect	Extent to which the companies have problems in adopting information systems and ICT into their work practices	46.3	33.3	9.3	5.6	5.6	**0.38**	**0.38**	**3**
	Extent to which the companies would conduct in-house self-evaluation before implementing BIM?	50.0	33.3	5.6	5.6	5.6	**0.37**		
Management aspect	Extent to which the companies would introduce BIM after planning and evaluation their capabilities to implement it	59.3	35.2	3.7	1.9	0.0	**0.30**	**0.28**	**1**
	Extent to which the senior managers of the companies would be willing to support the necessary maintenance costs during BIM implementation	70.4	29.6	0.0	0.0	0.0	**0.26**		

Bold values highlights the results obtained from the survey i.e. severity index and ranking

aspects) obtained low severity index values (0.20–0.49) from the rating done by the respondents, which indicates low level of readiness for BIM implementation in construction among the respondents. The only factor that obtained *moderate* severity index value (0.50) is "the provision of adequate information technology infrastructure in place and use the infrastructure to improve communication and closer working relationship", which was categorized under the technology aspect.

Nonetheless, going by the weighted average values of all the factors' severity indices in each implementation aspect in Table 3, then it is clear that all the severity index values fall within the low severity range. This suggests low level of readiness for BIM implementation in construction among the respondents. This could be linked to the fact that subcontractors are reluctant in adopting new practices either due to their sense of economics, business or some drawbacks to BIM implementation across subcontracting sector of Saudi Arabian construction industry. These drawbacks or difficulties could be related to poor knowledge of the BIM technology among the subcontracting companies; lack of obvious proof of financial benefits, high cost of training, shortfall on government guidelines and strategies, social and typical refusal to accept change and most importantly, construction clients are not demanding the usage of BIM on construction projects.

It is duly acknowledged here that this research was likely to be affected by some certain constraints and biases, which is common for survey based research works of this nature. The adoption of judgemental sampling method in selecting the sample also helps to reduce bias by offering the researcher some degree of control. As it was a structured questionnaire survey, evaluation of the factors' level of severity was limited to only the selected professional (respondents). Even though the size of the study sample may perhaps be relatively small, this study provides valuable information that can be used in providing better awareness and orientation to subcontractors in Saudi Arabia. This is pertinent in order to encourage the implementation of BIM in construction projects. Notwithstanding the limitations highlighted before now, it is the opinion of the authors that the entire factors used in assessing the awareness and preparedness level to apply BIM in construction projects, in the order of the ranking obtained from this study, satisfactorily represent the opinions of subcontractors in Saudi Arabian construction industry with regard to the assessment of subcontractors' awareness and preparedness level to implement BIM in construction projects.

6 Conclusion

This part presents the main conclusions from the preceding sections. It draws together the major themes of the paper. The level of awareness and preparedness of the subcontractors toward implementing BIM is not known. Remarkably, there has been no published work that aims at determining the level of subcontractors' awareness and preparedness for applying BIM in construction projects in the Saudi Arabian construction industry. For that reason, the paper presented comprehensive assessment of subcontractors' awareness and preparedness level for implementing Building Information Modeling in construction projects in Saudi Arabia. Twelve key factors were identified from the feasibility, design, construction and maintenance and operations stages of construction projects as being related to subcontractors' awareness assessment, while nine factors were identified in the aspects of subcontracting companies' preparedness, which include technology, people, process and management aspects. Questionnaire survey was conducted across the subcontracting sector of the construction industry to get data for the subject under study. Findings of the study reveal a widespread lack of BIM knowledge across subcontracting sector of Saudi Arabian construction industry. Most of the subcontractors lack the basic understanding of the functions of BIM to form better integration between designers and client, provide better communication among construction team members, reduce variation orders, reduce construction wastage, shorten the construction period, reduce disputes rates due to discrepancies and to ensure end product meets client's requirements.

While some of the big construction companies in the Kingdom's construction industry are making efforts to adopt BIM in operations and maintenance management stage, to a large extent, the subcontracting sector is still battling with BIM awareness. This suggests a possible wide gap exists between these two contracting sectors in the adoption of BIM in construction projects. BIM adoption depends on top down collaborative approaches involving the government (regulatory body) clients, and the subcontractors, and other relevant key players in the construction industry. The government being the biggest public client and the clear leader in project developments especially infrastructure projects has to take the initiative and lead by example in some of the following ways:

- The government may consider providing financial incentives to subcontractors who apply BIM in their construction projects. This would serve as one of the key motivations for BIM adoption.
- The government may consider reducing the levy and other project development administrative fees for small and medium contractors that implement BIM.
- Small and medium contractors that implement BIM may be given higher advance payments and lowering the percentage of retention for contractors' progress payments especially for public projects.
- BIM certification and clear evidence of BIM application in construction projects could be made a prerequisite for construction license renewals for small and medium contractors.

As for the subcontractors, top management of the companies should create organizational structure that will support BIM adoption, employ staff with high ICT literacy and mandate BIM training for staff.

Above all, this paper provides original contribution to knowledge through a methodical investigation of the awareness and readiness levels of the subcontracting sector of the Saudi Arabian construction industry in applying the functions of Building Information Modeling (BIM) technology in construction projects. Consequently, the current problems limiting the subcontracting sector from full adoption of BIM in construction projects were identified and valuable strategies were suggested to overcome the highlighted limitations. In essence, the paper presents a pioneering attempt and methodology that highlighted the poor knowledge and clear lack of will among the subcontracting companies to implement BIM in construction projects.

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