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BIM for construction safety improvement in Gaza strip: awareness, applications and barriers

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The objectives of this paper are to elicit the perception of contracting parties regarding building information modelling (BIM), the most important safety-related applications of BIM and the barriers to adopting BIM in the local construction industry. Data for this study were collected through a questionnaire survey. A total of 75 questionnaires were randomly distributed to contractors, owners and consultants, and 37 were returned, representing a 49% response rate. The findings indicated that 33% of the respondents had no knowledge of the concept of BIM, 28% of the respondents' organizations are not using BIM and if used it was implemented to a limited extent. The results indicated that 'hazard identification and minimization' and 'safety training and education' are the most important safety-related applications provided by BIM tools to improve safety performance in construction. Lack of universal use in the construction sector and insufficient training availability are the highest ranked barriers to adopting BIM in construction to improve safety. The research results may assist BIM developers to introduce the best applicable tools to improve safety performance in the construction industry. It is recommended that training courses be conducted regarding BIM concept and the benefits of its application in the construction industry.

Keywords: BIM; application; barriers; safety performance; construction

Introduction

The construction industry is considered one of the most dangerous industries for workers (Choudhry et al. 2008; Kamardeen 2010). Many characteristics resulted in growing concern for safety performance regarding this industry over the past decades, such as the dynamic work environments, the use of heavy equipment, and the seemingly unavoidable worker hazard interactions that contributed to the increased rates of injuries and illnesses (Khoshnava et al. 2012). Compared with other industries, the construction industry is often regarded as being slow to implement new ideas and technologies, which have the potential to make it a much more competitive, safe and productive industry (Newton & Chileshe 2012). Building information modelling (BIM) is one of the most valuable developments in the construction industry, encouraging collaboration and coordination between all different construction stockholders (Autodesk 2008; Abbasnejad & Moud 2013; Hussain & Choudhry 2013). BIM application in construction projects can reduce waste and safety problems in construction, leading to completion of quality projects (Latiffi et al. 2013). BIM facilitates precise documentation, faster decision making, improved communication between parties, and optimization of resources, more efficient workflow, increased productivity and decreased errors (NIBS 2007; Lu & Li 2011). Recently, there has been considerable interest in improving work site safety through the building life cycle using BIM (Kiviniemi et al. 2011; Chi et al. 2012).

Recent advancements of BIM technologies are providing decent starting points for the development of solutions for pro-active site safety planning and management (Godfaurd & Abdulkadir 2011). This means that the user is not just a passive observer of potential problems but has all necessary functions available as efficient solution enablers for improving working conditions (Sulankivi et al. 2010). Sulankivi et al. (2009) mentioned that there is still little research and experience considering the use of BIM technology in safety management and its potential for promoting safety.

A survey conducted in the Middle East included respondents from key construction companies operating in the United Arab Emirates (UAE), Saudi Arabia, Qatar, Oman, Bahrain, Kuwait and Jordan showed that 21% of the respondents were not aware of building information modelling and 54% of them were aware of BIM but not used it – a BIM adoption rate equal to 25%. These companies used BIM mainly for basic tasks such as 3D visualization, drawing extraction and rarely planning (BuildingSmart 2011). As part of the Middle East region, the Palestinian construction sector has not taken any steps to push the industry in the direction of BIM. Such efforts remain an individual initiative by academics and construction professionals depending on their BIM awareness and their willingness to adapt it. In Gaza Strip-Palestine, BIM applications in the construction industry have not been explored. Some fundamental issues related to the full extent of BIM adoption in this industry have yet to be fully investigated and addressed. This study is a starting point in exploring BIM awareness, identifying the most important safety-related applications of BIM and the barriers to adopting BIM in the

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Palestinian construction industry. This study aims to open the door for the construction industry to realize the importance of BIM adoption in improving the safety performance of projects and attract its attention to ways to apply it in construction work, especially in improving safety.

Literature review

The concept of BIM

The term BIM is used to refer two different things: the process of building information modelling, which was chosen for this study, and the resulting model. Building information modelling is the development and use of a computer software model to simulate the construction and operation of a facility (AGC 2006). Velasco (2013) conceived BIM as 'a working methodology that aims to improve the way in which information is generated, managed, transferred and visualized throughout the entire life cycle of a building'. It seeks to enhance communication between all parties involved in every single phase of the project (Azhar et al. 2012).

BIM applications in construction industry

Recently BIM has been named as the tool to improve the industry due to its ability to run '*n*-dimension' project information throughout the life cycle of a project (Benjaoran & Bhokha 2010). BIM has been utilized extensively to simulate and optimize designs in view of feasibility studies and stakeholder concerns, value analysis, constructability analysis, sustainability analysis, site operational efficiency and site layout, and facilities management (Kamardeen 2010; Hammad et al. 2012; Hussain & Choudhry 2013). The application of BIM technology in the field of building design simplifies the exchange of information and expertise between the different actors, both of the decision-aking process and of the constructive and facility management phases (Vozzola et al. 2009). BIM shows its power in the construction and operation phases – for example, BIM reduces the construction time and reduces the spending on operation and overhead costs. BIM improves the process of construction, project documents and the relationship between clients and architects (Yan & Damian 2009).

BIM knowledge enables all practitioners to make better decisions which may influence the project's performance (Dahlqvist & Winberg 2010). BIM has the potential for improving all stages of the construction life cycle of built assets including the pre-design, design, construction, maintenance and renovation or decommissioning (Furneaux & Kivit 2008; Azhar et al. 2012; Zhou et al. 2012). The benefits of BIM include providing better coordination for project teams; improving efficiency, accuracy and so on (Furneaux & Kivit 2008; Succar 2009). Construction players need to be aware of the benefits of BIM in helping them to improve implementation of construction processes (Latiffi et al. 2013).

BIM adoption in the construction industry

According to the SmartMarket Report 2012, the general BIM adoption of the construction industry in North America (US and Canada) has increased from 28% in 2007 up to 71% in 2012. In addition, the size of the firms is important: 91% of large firms have adopted BIM in North America against only 49% of small firms (McGraw-Hill Construction 2012). Another survey was conducted previously by McGraw-Hill Construction in 2010 across the industry in the United Kingdom, France and Germany, to which 948 industry professionals responded. The survey quantified the level of adoption within the UK as 35%, which was slightly lower than Germany and France at 36% and 38% respectively. When subdividing by industry discipline in the UK, architects were identified as using BIM the most at 60%, followed by engineers (39%) and contractors (23%) (McGraw-Hill Construction 2010).

In Asia, the Singapore government has been the leader in the BIM adoption process and is one of the few Asian countries that have implemented BIM in the public sector. In order to enhance productivity in the construction sector in Singapore, the Building Control Authority (BCA) has come up with a five-year plan to move the industry towards the adoption of BIM (Wong et al. 2009). On the other hand, the Middle East region has the lowest BIM adoption rate compared to the aforementioned developed countries. In fact, the public sector in the Middle Eastern countries does not seem to be taking steps towards mandating the use of BIM at least for public projects.

Using BIM for increasing safety performance

Currently, BIM in safety discussions is not common in the construction industry. To prevent injuries and save the lives of construction workers, there should be considerable interest in improving worksite safety through safer design and work method statements using BIM (Chi et al. 2012). BIM technology enabled new tools, communication chances and procedures addressing site safety aspects in an effective manner that can help to promote top quality site safety planning even in a highly multinational and dynamic environment (Kiviniemi et al. 2011). Leading general contractors are now using BIM visualization and analysis techniques to greatly enhance safety programmes during both pre-planning and construction phases (Puerto & Clevenger 2008).

Rajendran and Clarke (2011) indicated that worker safety training, safety planning, pre-task planning, job hazard analysis, site equipment planning, design for safety and accident investigations are major areas where Safety and Health (S&H) professionals can use BIM technologies. Hammad et al. (2012) investigated a new method for the automatic generation of Dynamic Virtual Fences (DVFs) as part of a BIM-based prevention programme and real-time safety management for construction safety. The DVFs, coupled with real-time location data of the workers can help in preventing accidents related to falling, collisions, etc. The study conducted by Wan et al. (2013) concluded that 78% of the members of the Society of Accredited Safety Auditor (SASA) in Hong Kong reported that there is benefit for using BIM for Safety Management System (SMS). Kamardeen (2010) developed the system architecture of an 8D modelling tool for BIM-based prevention through design (PtD). The tool is able to perform hazard audits on BIM models and then produces hazard profiles for elements rated at three levels of severity: critical, moderate and low. Ku and Mills (2010) suggested incorporating BIM for hazard recognition and designing optimization.

Puerto and Clevenger (2008) exemplified BIM applications to increase worker safety by investigating potential 'pinch-points' ahead of actual material installation through a 4D design review during the project planning phase. Kiviniemi et al. (2011) described the main ideas for using BIM for improving site safety such as safety planning, risk analysis, 3D and 4D visualizations in safety-related communication.

Barriers of adopting BIM in construction safety

A number of studies have reported on the reluctance of the construction industry to adopt new technologies. Although BIM promise to generate benefits and overcome problems in the design, construction and management of buildings, the barriers to its adoption cannot be neglected. Some primary barriers cited by studies include the lack of initiative and training, varied market readiness and reluctance to change the existing work practice (Khemlani 2006). Gambatese and Hallowell (2011) found that 'fear of change' is a major barrier to BIM application.

Gilligan (2007) reported that lack of need, lack of requests by owners and lack of qualified professionals are the most common reasons for not implementing the technology. Kassem et al. (2012) concluded that there are six common factors considered by consultants and contractors to be key limitations to the widespread use of 4D planning and BIM, including lack of tangible benefits for all parties involved or the understanding of the business value of BIM, lack of experience within the workforce, lack of universal use, resistance to change, contract type/project delivery method inhibiting technology adoption, and time and cost. Kumar and Mukherjee (2009) identified the barriers to incorporating BIM in their firms, which include complexity of BIM, inertia to explore new technology, lack of support from clients and contractors, unwillingness to change the traditional practice, lack of technical expertise, software too expensive, and uncertainty about the BIM platform.

The most important barriers to adopting BIM in the construction industry were reported to include major expenses associated with BIM, such as software to be purchased,staff training and the cost of new hardware, insufficient incentive for projects to implement it, the lack of BIM knowledge, the use of different software by the different stakeholders in the project, the current construction culture, insufficient computer skills among a lot of the employees in the construction industry that have utilized BIM (Winberg & Dahlqvist 2010). The most common barriers to BIM adoption in construction to improve safety are that the utilization of BIM technologies for safety management poses several challenges, such as additional cost involved for developing/enhancing BIM models, lack of knowledge of S&H personnel in using BIM, and technical issues such as non-availability of safety elements and equipment in the BIM software library. Human behaviour is a major challenge which cannot be changed quickly (Azhar et al. 2012; Azhar & Behringer 2013). Rajendran and Clarke (2011) mentioned that designers working with BIM often lack safety expertise and they are reluctant to consider construction safety during the BIM development process.

Methodology

Population and sample size

The population for this study was the three key stakeholders in construction projects: owners, consultants and general contractors. The targeted participants were those who had extensive construction experience and are on a key management

Table 1. Description of the distributed questionnaires.

Group	Population	Population (%)	Number of distributed questionnaires
Clients/owners	55	27	20
Consultants	59	29	22
Contractors	92	44	33
Total	206	100	75

Table 2. Description of the returned questionnaires.

Group	Number of distributed questionnaires	Number of returned questionnaires	Returned questionnaires (%)	Number of rejected questionnaires	Number of accepted questionnaires	Accepted questionnaires (%)
Clients/owners	20	13	65	2	11	55.00
Consultants	22	11	50	1	10	45.50
Contractors	33	19	58	3	16	48.50
Total	75	43	57	6	37	49.33

position in their firm. Contractors who are registered in the Palestinian contractors' union as first class, second class and third class were selected. Other classes were neglected because of their nominal size, and little experience in the construction industry, the total number of valid contractors from these three classes were 92 contractors. Consultants were selected from the engineering syndicate records which included 59 consultancy firms. There is no official number of owners in the Gaza strip. To overcome this problem, help was sought from experts and government officials who led to the identification of 55 clients (ministries, municipalities, non-governmental organizations [NGOs], United Nations [UN] agencies and international non-governmental organizations [INGOs]). The total aggregate for the population of this research is 206 from the three groups: clients, consultants and contractors.

The sample was selected from publicly available sources including the Palestinian Contractors Union, the engineering syndicate for consultants' records, and governmental and non-governmental organizations. The respondents were chosen as they are more likely to be leaders in the industry, adopting change more readily than other smaller, less recognized firms. It is assumed that members from these organizations have a greater understanding of BIM and can provide more meaningful information. The total number of the survey community was 75 organizations that are considered representative of the overall population. A stratified sampling technique was used to determine the number of respondents for distribution of the questionnaires (Kothari 2004). The number of questionnaires for each group was identified according to the proportion of the respondents in each group compared to the overall population: for the contractors group, which represents 44% (92/206) of the population, 33 questionnaires were distributed (44% of all 75 questionnaires); the same methodology used for the other two groups, as indicated in Table 1.

As illustrated in Table 1, 20 questionnaires were distributed to clients, 22 to consultants and 33 to contractors. Although 43 were returned, 6 were rejected because they were partially filled out. The non-response was traced to a significant lack of interest in or understanding of BIM and its potential benefits to their business, and the construction industry. The response rate (49.33%) was finally achieved after several efforts were made in terms of follow-up emails and calls. Table 2 describes the returned questionnaires.

Questionnaire design

The data collection process involved six stages:

The first stage: A study is conducted to assimilate all the relevant literature in understanding the study domain. The researchers reviewed the literature in order to distinguish what has been done and accomplished in the area of BIM, and what still needs to be learned and needs more attention.

The second stage: The collected data related to the objectives of this research such as the major applications of BIM related to safety and the barriers to adopting it for safety improvement in the construction industry were reviewed. Many ideas about the structure and content of the questionnaire were provided by the experts. Their suggestions were included

Table 3. Description of the study included in the questionnaire preparation.

No.	Organization	Position	Experience
1	Owner	Project planner/GIS expert	14
2	Consultant	Computer aided design expert	16
3	Consultant	Project manager	13
4	International organization	Construction project coordinator	11
5	Contracting company	Project manager	15

Table 4. Description of the pilot study personnel.

No.	Organization	Position	Experience
1	International organization	Project manager	11
2	Owner	Project planner	12
3	Academic	Statistician	10
4	Consultant	Structural designer	9
6	Contracting company	Site engineer	7
7	Contracting company	Project manger	16
8	International organization	Project director	15

in modifying the preliminary questionnaire. Table 3 shows the interviewed experts as they had extensive experience in the construction industry and knowledge about BIM.

The third stage: A preliminary questionnaire was prepared based on the information collected from the previous two steps in addition to the researchers' own experience. The questions were formulated in a way that introduces the concept to the participants simply and smoothly in order to gain the responses needed to answer the research questions and to achieve the research objectives.

The fourth stage: To examine the degree of understanding of the questionnaire among the respondents, eight Arabic versions of the questionnaire were sent to different professionals who had extensive experience in construction in the Gaza Strip. In general, the respondents agreed that the questionnaire is easily understood, designed well enough to achieve the research objectives, and covers the major ideas about the BIM and its topics related to safety. Nonetheless, some modifications to the Arabic wording were incorporated to make the questionnaire clearer to the respondents. The final questionnaire was prepared after taking the results of the pilot study into account and the questionnaire was ready for distribution to the selected sample. Table 4 provides a description of the professionals included in the pilot study.

The fifth stage: The final questionnaire was prepared taking into account pilot study results and was distributed to the study sample.

The sixth stage: The collected questionnaires were reviewed and analysed by the Statistical Package for the Social Sciences (SPSS) version 20, and the results are discussed in this paper.

Questionnaire contents

The proposed study questionnaire design was composed of four parts to accomplish the aim of this research. *The first part* of the questionnaire sought to identify the organization's and respondent's background and characteristics. *The second part* sought the respondents' perceptions of the BIM concept and its usage in the construction industry. *The third part* sought to rate the 23 identified safety-related applications of BIM and their importance from the viewpoint of the respondents to improve safety performance. *The fourth part* asked the respondents to rate the 17 identified key barriers that prohibit BIM adoption in construction safety. A cover letter (in Arabic and English) was attached to the front page of the survey questionnaire for each respondent in order to spot the objectives of the survey and to identify the concept of BIM and safety applications in this research. The respondents were asked to express their opinions about each statement on a 5 point Likert scale (1 = very low, 2 = low, 3 = moderate, 4 = high, 5 = very high).

Data processing and analysis

The aim of the analysis was to establish the relative importance of the various identified factors with respect to safety-related application of BIM and the barriers prohibiting BIM adoption in the construction industry to improve safety. The Relative Importance Index (RII) was calculated using the following formula (Enshassi et al. 2007, 2009):

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

Where:

'W' is the weighting given to each factor by the respondent, ranging from 1 to 5, ($n1$ = number of respondents for Very low, $n2$ = number of respondents for Low, $n3$ = number of respondents for Moderate, $n4$ = number of respondents for High, and $n5$ = number of respondents for Very high.

'A' is the highest weight (i.e. 5 in this study) and N is the total number of samples.

The relative importance index (RII) value ranges from 0 to 1. The group index is the average of the relative importance index of the identified factors.

Test of data normality (one sample K-S test)

The one-sample Kolmogorov-Smirnov (K-S) test is used to identify if the data follow normal distribution or not. This test is considered necessary in testing hypotheses, as most parametric tests stipulate data to be normality distributed. Test results are shown in Table 5, which clarifies that the calculated p-value is greater than the significant level which is equal to 0.05 (p-value > 0.05). This in turn denotes that data follows normal distribution.

Statistical validity of the questionnaire

Validity has a number of different aspects and assessment approaches. There are two ways to evaluate instrument validity: (1) sontent validity which included in the pilot study; (2) statistical validity, which include criterion-related validity and construct validity.

Criterion-related validity

The criterion-related validity of the questionnaire is the first statistical test that used to test the validity of the questionnaire. It is measured by a scouting sample, which consisted of 10 questionnaires from the collected questionnaires through measuring the correlation coefficients between each paragraph in one field and the whole field. Pearson correlation coefficients and p-values are used to test correlations. If significance level (p-value) for a paragraph is found to be between 0.01 and 0.05, this means that the correlation coefficient (α) is significant at $\alpha = 0.05$ and the paragraph is consistent and valid to measure what it was set for. On the other hand, if the p-value is less than or equals 0.01, this means that the correlation coefficient is significant at $\alpha = 0.01$ and the paragraph is valid to measure its target. It was found that the p-values were less than 0.05 or 0.01, the correlation coefficients of each item under any category were significant at $\alpha = 0.01$ or $\alpha = 0.05$. It indicated that the factors under each field were consistent and valid to measure what it was proposed for.

Construct validity

Structure validity is used to test the validity of the questionnaire structure by testing the validity of each category and the validity of the whole questionnaire. It measures the correlation coefficient between one category and all the categories of the questionnaire that have the same level of Likert scale. Table 6 shows the results of the correlation test, where the correction coefficient for all categories in the questionnaire are less than 0.05 or 0.01, so the categories are valid and can measure what they are proposed to measure.

Table 5. Data normality test (one sample K-S test).

Section	Z statistic	P-value
Safety-related applications of BIM	0.936	0.336
Barriers to adopting BIM	0.970	0.322

Table 6. Correlation coefficient between each field and all the fields.

No.	Section	Person correlation	Spearman–Brown coefficient
1	Safety-related applications of BIM	0.9540	0.000
2	Barriers to BIM adoption	0.9276	0.000

Table 7. Questionnaire reliability test by half split method.

No.	Section	Person correlation	Spearman–Brown coefficient	Sig. 2-tailed
1	Safety-related applications of BIM	0.9492	0.9740	0.000
2	Barriers to BIM adoption	0.8826	0.9377	0.000
	Total	0.9692	0.9844	0.000

The reliability of the questionnaire

Statistical methods were used to check the reliability of the questionnaire. These included Cronbach's alpha coefficient and the half-split method. Coefficients above 0.7 are considered satisfactory.

The half-split method

This method depends on finding the Pearson correlation coefficient between the means of odd rank questions and even rank questions of each field of the questionnaire. Then, correcting the Pearson correlation coefficients was done by using the Spearman–Brown correlation coefficient of correction. The consistency coefficient is between 0.0 and +1.0. As shown in Table 7, the general reliability of the safety-related applications and barriers to BIM adoption groups equal 0.9740 and 0.9377, respectively, the general reliability of all groups equals 0.9844, and the significant (α) is less than 0.05. Tests showed that all the corrected correlation coefficients were significant at $\alpha = 0.05$.

Cronbach's alpha coefficient

This method is used to measure the reliability of the questionnaire between each section and the mean of all the categories of the questionnaire. The normal range of Cronbach's alpha coefficient is between 0.0 and +1.0, and the higher values reflect a higher degree of internal consistency. As shown in Table 8, the Cronbach's alpha coefficient was calculated and the general reliability of safety-related applications and barriers to BIM adoption groups equal 0.9140, and 0.9276 respectively, and the general reliability of all groups equal 0.9702. This range is considered high, and greater than 0.70. Thus, the reliability of the questionnaire is assured.

Results and discussion

Part one: profile of the respondents

As shown in Tables 9 and 10, the survey respondents provided a broad and representative cross-section of the key parties in the construction industry including owners, consultants and contractors. The respondents held significant positions in

Table 8. Questionnaire reliability test by Cronbach's alpha coefficient.

No.	Section	No. of items	Cronbach's alpha
1	Safety-related applications of BIM	23	0.9140
2	Barriers to BIM adoption	17	0.9276
	Total	40	0.9702

Table 9. Distribution of respondents' organization type.

Respondents organization	Frequency	%
Client/owner	11	30
Contractor	16	43
Consultant	10	27

their organizations, and they had a good understanding of current practices and processes within their organizations and in the construction industry.

The survey participants had extensive experience in construction, and that was observed with the years of practice they had in the industry. Table 10 shows that 91% ($n = 10$) of all owners/clients participants, 69% ($n = 11$) of contractors, and 70% ($n = 7$) of consultants have more than five years of experience in construction. As far as education level is concerned, 30% ($n = 11$) of the respondents had postgraduate degrees, with 65% ($n = 24$) of them holding a bachelor degree.

Table 10. background and characteristics of the organizations and respondents.

	Client/owner		Contractor		Consultant		All respondents	
Item	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Experience of the organization (years)								
Less than 5 years	0	0	1	6	1	11	2	5
5–10 years	1	11	2	13	1	11	4	11
10–15 years	3	22	2	13	4	44	9	24
More than 15 years	7	67	11	69	4	33	22	59
Organization size (no. of employees)								
Fewer than 10 employees	0	0	1	6	3	30	4	11
11–30 employees	2	18	3	19	3	30	8	22
31–50 employees	3	27	5	31	4	40	12	32
More than 50 employees	6	55	7	44	0	0	13	35
Value of executed projects during the last five years ($m)								
less than US$5 million	2	18	3	19	3	30	8	22
US$5–10 million	2	18	5	31	4	40	11	30
US$10–15 million	4	36	6	38	2	20	12	32
More than US$15 million	3	27	2	13	1	10	6	16
Job title of the respondent								
Company owner	0	0	1	6	0	0	1	3
Director/vice director	0	0	3	19	2	20	5	14
Project manager	6	55	5	31	4	40	15	41
Site/office engineer	4	36	5	31	3	30	12	32
Safety engineer	1	9	2	13	1	10	4	11
Education level of the respondent								
Diploma	1	9	1	6	0	0	2	5
Bachelor	7	64	11	69	6	60	24	65
Postgraduate studies	3	27	4	25	4	40	11	30
Respondent years of experience in the line of work								
1–3 years	0	0	1	6	2	20	3	8
3–5 years	1	9	4	25	1	10	6	16
5–10 years	7	64	6	38	4	40	17	46
More than 10 years	3	27	5	31	3	30	11	30

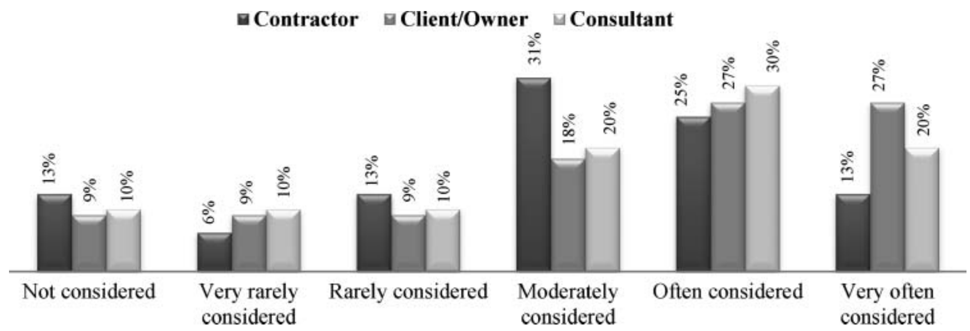

Figure 1. Consideration level of safety in the organization.

Part two: building information modelling perceptions

1. Safety considerations in construction firms

By introducing BIM in construction, organizations can improve safety and health in construction projects. The results shown in Figure 1 indicate that safety is an important issue for the respondents' organizations – for example 69% of the contractors, 72% of the owners and 70% of the consultants considered safety as of moderate or high importance in their projects. The owners/clients (27%) very often considered safety in their organization, which is more than the contractors (13%) and consultants (20%). Generally, the clients/owners are leading the implementation of safety measures in construction projects in the Gaza Strip. High safety consideration levels indicated that safety issues are an integral part of the participant organizations' safety management.

2. Organizations' commitment to adopting new technologies to improve safety

Figure 2 depicts the respondents' answers to the question about their organization's commitment to adopting new technologies to improve construction safety. This commitment is important in providing and purchasing these technologies and providing the training for their employees on these new technologies. About 69% of contractors, 60% of owners and 60% of consultants had low commitment in adopting new technologies to improve their safety performance. These results indicated that many organizations in the construction industry do not generally appear to have appreciated the positive changes and benefits that the new technology provides to safety performance. As BIM is one of these new technologies, it is not often used in the construction industry as a result of very low commitment of the construction firms to adopting new technologies to improve safety.

3. Respondents' satisfaction regarding the use of technologies for construction safety

The results shown in Figure 3 revealed that most respondents were not satisfied with the technologies currently used for safety in their organizations. At 79% the contractors expressed the highest dissatisfaction, compared with 54% of the clients/owners and 70% of the consultants. The high and very high satisfaction (27%) of the respondents from the owner group resulted from the continual development of technology adopted in some organizations and the high degree of consideration of safety in these organizations.

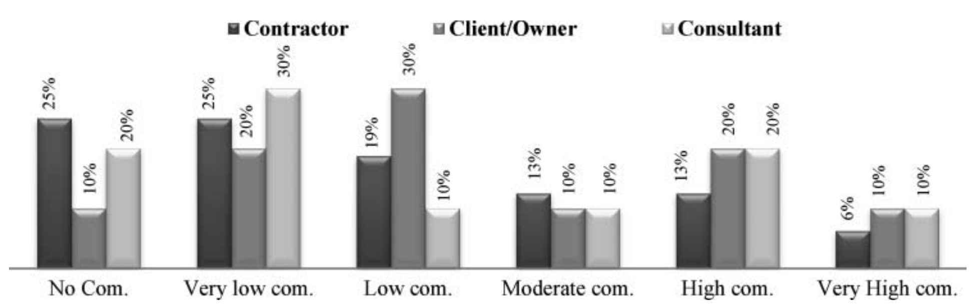

Figure 2. The level of the organization's commitment to adopting new technologies to improve construction safety.

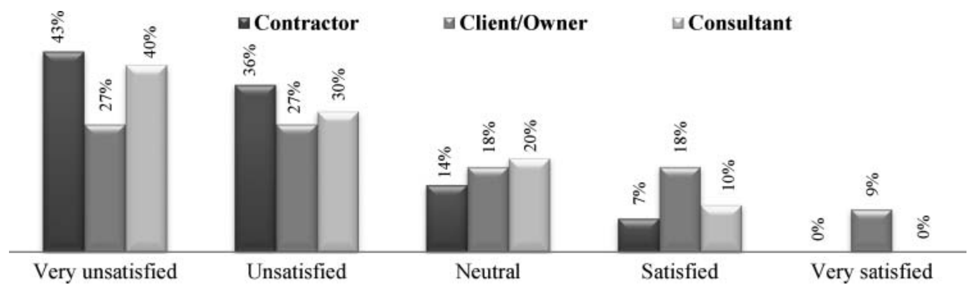

Figure 3. The degree of the respondents' satisfaction about the current technologies used for construction safety in the organization.

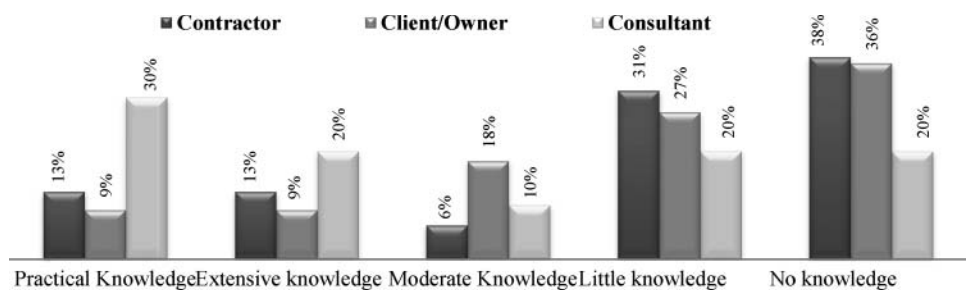

Figure 4. The degree of knowledge about building information modelling (BIM) technology.

4. *Respondents' knowledge of BIM technology*

Figure 4 illustrates that owners and contractors accounted for the highest percentages of the respondents who had no knowledge of BIM. About 38% of the contractors, 36% of the owners and 20% of the consultants claimed that they knew nothing about BIM. The results obtained are in line with the survey results conducted in the construction sector in the Middle East (Jordan, Saudi Arabia, Qatar, Oman, Bahrain and Kuwait) which showed that 21% of the participants were not familiar with BIM (BuildingSmart 2011). However, 30% of the surveyed consultants had a practical knowledge. A high percentage of the respondents from contracting companies (38%) had no knowledge of BIM, which reflects the lower level of employees' education, and their low commitment to use BIM.

5. *Sources of knowledge about BIM technology*

Figure 5 depicts the way BIM knowledge is gained by the respondents. They had some knowledge about BIM. Sixty per cent (60%) of the contractors, 43% of the owners and 50% of the consultants revealed that their knowledge about BIM was obtained from the educational knowledge. These results are inconsistent with the results of the study conducted in UK by Kassem et al. (2012), who found that the working/practical knowledge is the most dominant source of BIM awareness for UK consultants and contractors. The BIM concept is widely used in the UK, and it provides more opportunities for the construction employees to gain increased knowledge in their work. But in the Gaza Strip, education is considered as the

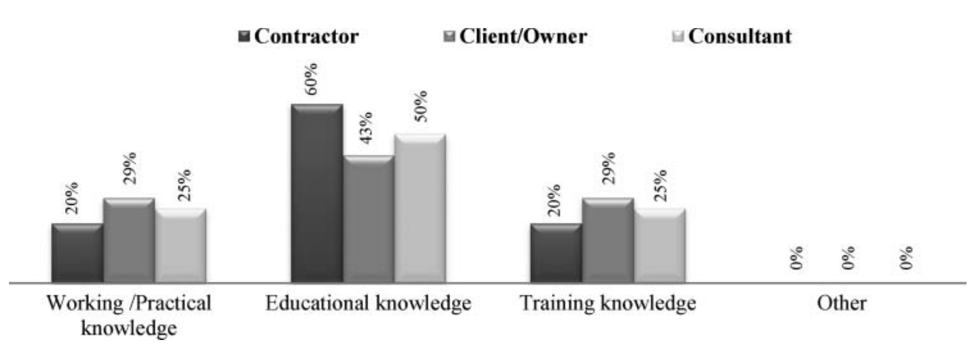

Figure 5. Sources of knowledge about BIM technology.

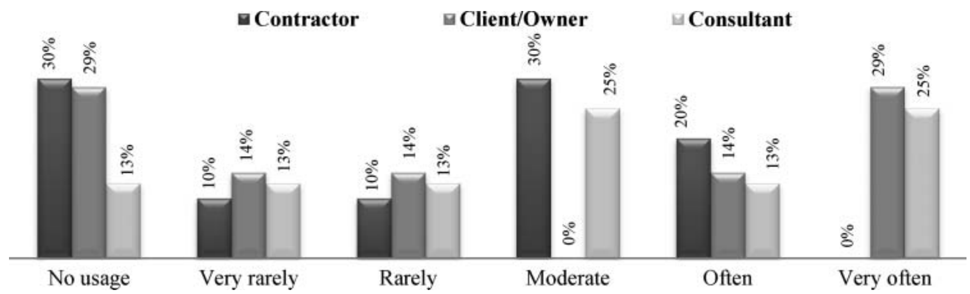

Figure 6. Response to the level of usage of BIM technology in the organization.

main source of knowledge about new technologies, including university education, self-education from the internet or other means available.

6. *The level of BIM technology usage in the respondents' organization*

Figure 6 shows the extent of BIM implementation in the respondents' organizations. The results reveal that BIM is deemed to have been implemented to a limited extent within the respondents' organizations. The contractors were not using BIM in their projects, as explained by 30% of the respondents who had BIM knowledge. Furthermore, consultants and owners mentioned that their organizations have implemented BIM to a greater extent than contracting companies regardless of the low usage rates for all groups. It is notable that 29% of the owners and 25% of the consultants indicated that their organizations have frequently implemented BIM. Survey results indicated that most firms engaged with BIM were in an early adoption phase and were typically using BIM in its most basic form. These results are in the line with the results obtained by BuildingSmart (2011) conducted in the Middle East.

7. *Future plans to adopt BIM*

The survey results shown in Figure 7 reveal that the majority of respondents who are aware of BIM did not have any plans to use it in the future. About 50% of the respondents from contracting companies, 57% of the respondents from clients/owners' organizations, and 75% of the respondents from the consultants' organizations did not have any plans to adopt BIM in their works in the future. The lack of in-depth knowledge and the respondents' perception of the importance, applications and the benefits of BIM led to these results. The study conducted in the US and UK by Yan and Domain (2009) are consistent with these results.

8. *The impact of BIM adoption on construction safety performance*

Figure 8 explains the extent to which the implementation of BIM could contribute to an improvement in safety performance. It indicated that there is generally strong agreement that BIM is to bring benefits to construction safety. Consultants have the most positive view of BIM, when 50% of them mentioned that it has a very positive effect on the safety performance. In UK, about half of study respondents stated that BIM brings benefits to construction health and safety (Gibb 2013). In addition, 40% of the contractors, 43% of the owners and 25% of the consultants didn't know the effect of BIM

Figure 7. Response to do you have any plans to adopt BIM technology in the future.

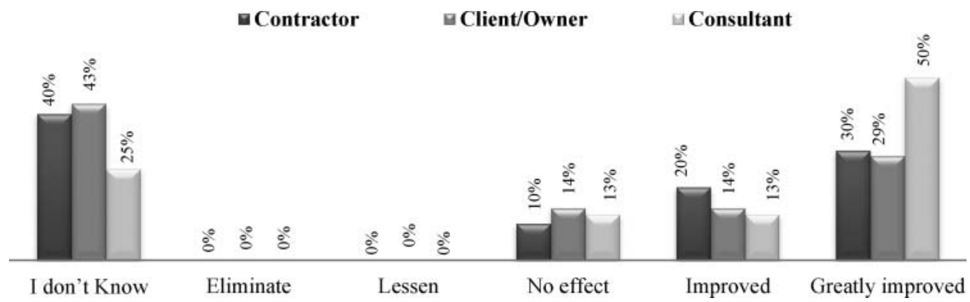

Figure 8. Impact of BIM adoption on construction safety performance.

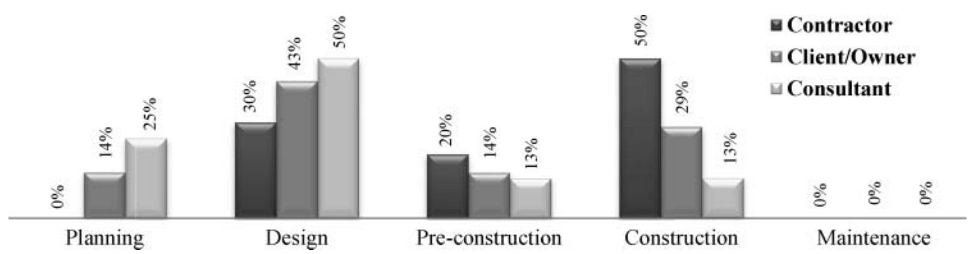

Figure 9. The most important phase to implement BIM for safety performance.

adoption on construction safety. This was traced to little knowledge and usage of BIM. This is not in the line with Wan et al., (2013) study on safety performance in Hong Kong who revealed that 78% of the respondents realized benefits for using BIM. Suermann and Issa (2007) indicated that only 46% or less than half of the respondents thought that construction safety was improved through BIM.

9. The most important phase to implement BIM for safety performance

Figure 9 shows that most respondents in this study opined that the greatest value from BIM occurred during the design, pre-construction and construction phases. About 40% of the contractors considered that the construction phase is the most important time to implement BIM tools for construction safety performance. The consultants (50%) considered the design phase the most important time for BIM implementation for construction safety. Owners indicated that both design (43%) and construction phases (29%) are the most important times to implement BIM for construction safety. BIM is not seen as particularly valuable for safety during planning and maintenance phases. These results are inconsistent with the conclusion of Azhar and Behringer (2013), who conducted their study in the USA. The study revealed that BIM provides the most effective measures to improve construction safety in the project planning phase.

Part three: safety-related applications of BIM

Table 11 illustrates 23 safety-related applications of BIM technology that can lead to improvements in safety.

'Hazard identification and recognition' with RII = 91% was first in the overall ranking of the safety-related applications to be provided by BIM tools for improving safety in construction projects. Owners ranked this application in the first position (RII = 93%), contractors put it in second place (RII = 90%) whereas the consultants ranked it in the fourth position (RII = 92%). This result indicates that improvements in the safety of construction projects requires the BIM tools and techniques to be used systematically and properly by the project team to analyse and identify the hazards related to the project. Puerto and Clevenger (2008) discussed specific examples where BIM can be used for hazard identification and elimination and its importance for improvement in the safety of construction projects.

'Safety training and education' was second in the overall ranking, with (RII = 89%). Owners ranked this application in the first position (RII = 93%), contractors put it seventh (RII = 84%) whereas consultants placed it second (RII = 94%). These results explain the importance of using BIM tools to enhance construction employees' education and training related to safety issues. The awareness of contract parties towards safety, health and their working environment are considered important aspects which improve construction safety in construction projects. Lack of safety training and education

Table 11. RII and rank for safety-related applications of BIM.

	Contractors		Owners		Consultants		Overall rank	
Safety-related application	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Hazard identification and recognition	0.90	2	0.93	1	0.92	4	0.91	1
Safety training and education	0.84	7	0.93	1	0.94	2	0.89	2
Site layout planning	0.83	9	0.91	3	0.92	4	0.88	3
Falling prevention planning	0.86	4	0.85	11	0.92	4	0.88	3
Planning of work tasks that include remarkable safety risks	0.78	19	0.91	3	0.98	1	0.87	5
On-site safety monitoring and control	0.89	3	0.85	8	0.82	18	0.86	6
Visualization of construction sequences	0.84	7	0.87	7	0.88	11	0.86	6
Provide and communicate mitigation plans to the workers	0.85	6	0.85	11	0.88	11	0.86	6
Automatic checking system for safety regulations and rules	0.80	14	0.87	7	0.92	4	0.85	9
Design revision	0.76	21	0.91	3	0.94	2	0.85	9
Provide site specific emergency action plan with the HASP	0.81	13	0.87	7	0.90	9	0.85	9
Provide safety warnings for on-site workers when necessary	0.86	4	0.82	16	0.86	14	0.85	12
Visualizing and simulating construction safety measures	0.83	9	0.89	6	0.82	18	0.84	13
Temporary structures and equipment planning (scaffolding, frameworks)	0.91	1	0.76	20	0.82	18	0.84	13
Safety programme cost evaluation	0.79	16	0.85	11	0.92	4	0.84	13
Detections of special conflicts	0.79	16	0.87	7	0.88	11	0.84	16
Accident investigation	0.83	9	0.80	16	0.86	14	0.83	17
Risk analysis	0.76	21	0.84	15	0.9	9	0.82	18
Safety assessment	0.78	19	0.82	16	0.86	14	0.81	19
Provide communication and collaboration between all project participants at all stages	0.83	9	0.75	14	0.84	17	0.81	20
Information extraction and coordination	0.79	16	0.82	16	0.76	22	0.79	21
Management of hazardous equipment and materials	0.80	14	0.67	23	0.80	21	0.76	22
Modelling of off-site fabrication	0.70	23	0.69	22	0.72	23	0.70	23

was identified as a key factor contributing to accidents on construction site (Sulankivi et al. 2010). In recent years, many construction firms have recognized the importance of the establishment of a good safety culture and improving their workers' attitude towards safety. Contractors ranked this factor in the seventh position (RII = 84%) because of the temporary employment of workers and local contractors' inability to fund their workers' training. It appears that contractors are looking for more tangible applications related to safety when they choose the BIM tool. This result is in line with Wan et al. (2013), who found that safety training effectiveness can be enhanced by using BIM tools.

'Site layout planning' and *'Falling prevention planning'* were ranked third in the overall ranking with (RII = 88%). Owners ranked *'Site layout planning'* in the third position (RII = 91%) and *'Falling prevention planning'* in the eleventh position (RII = 85%). Contractors put *'Site layout planning'* ninth (RII = 83%) and '*Falling prevention planning'* fourth (RII = 86%), while consultants ranked '*Falling prevention planning'* and *'Site layout planning'* in fourth place (RII = 92%). Construction companies in the Gaza Strip are using traditional methods, techniques and tools to develop site layout plans and to prevent accidents in their projects. The significance of these two applications encouraged them to search for more developed methods to enhance safety performance. BIM based site plan are related to the potential for conducting safety planning and connecting safety plans to product planning (Kiviniemi et al. 2011). Falling from a height was considered the most common type of accident in construction projects. In the Gaza Strip, in the current planning practice, a plan for protection from falling is not created in all projects and detailed prevention planning is not carried out at an

Table 12. RII and rank of the barriers to adopt BIM for construction safety.

Barrier	Contractors		Owners		Consultants		Overall rank	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Lack of universal use in local construction sector	0.95	1	0.95	1	0.94	1	0.95	1
Insufficient training available	0.89	5	0.93	2	0.88	2	0.90	2
Not enough demand from clients and/or other firms on projects	0.91	2	0.91	4	0.86	4	0.90	2
Uncertainty of the safety benefits of BIM implementation	0.91	2	0.89	8	0.86	4	0.89	4
Lack of guidelines and standards of how BIM should be implemented for construction safety	0.86	7	0.93	2	0.88	2	0.89	5
Lack of knowledge of safety Engineering in using BIM	0.89	5	0.89	8	0.86	4	0.88	6
High costs related to the BIM software, hardware and training	0.91	2	0.87	13	0.84	8	0.88	6
The lack of sufficient time to evaluate BIM and its training	0.85	8	0.91	4	0.82	10	0.86	8
Shortage of BIM tools and applications related to safety	0.85	8	0.91	4	0.80	13	0.85	9
Complexity of BIM	0.85	8	0.89	8	0.78	14	0.84	10
Management does not believe in BIM and its use for safety	0.85	8	0.89	8	0.76	15	0.84	11
Social and habitual resistance to change	0.75	13	0.89	8	0.82	10	0.81	12
Traditional methods of contracting	0.69	15	0.91	4	0.84	8	0.79	13
Lack of safety expertise of BIM users	0.76	12	0.80	14	0.82	10	0.79	14
Safety improvement is not a priority of the local construction sector	0.73	14	0.80	14	0.86	4	0.78	15
Low computer skills among a lot of participants in the construction industry	0.68	16	0.69	16	0.74	16	0.70	16
Current construction safety technology is enough	0.60	17	0.47	17	0.70	17	0.59	17

early phase of the construction project. A BIM-based falling prevention plan can support communication related to arrangements for protection from falling. Consistent with these results, Sulankivi et al. (2010) piloted BIM-based procedures in real on-going building projects and identified further testing and development needed for the potential of the BIM-based falling protection plan to support construction work on sites and to improve site safety.

'Modelling of off-site fabrication' was ranked in the last position in the overall ranking of the safety-related application of BIM (RII = 70%). BIM tools enable modelling of prefabrication off-site because the BIM model contains all the important details of every component in the construction. Furthermore, an error in offsite fabrication, compared to onsite fabrication, has a smaller impact on safety.

Part four: barriers to adopting BIM for construction safety applications

Table 12 illustrates 17 barriers to adopting BIM technology for safety-related applications to improve construction safety.

The results in Table 12 highlight an agreement among the respondents that the most important barriers to adopting BIM for safety-related applications in the construction industry were *'Lack of universal use in the construction sector'* (RII = 95%), *'Insufficient training available'* (RII = 90%), *'Not enough demand from clients and/or other firms on projects'* (RII = 90%) and *'Uncertainty of the safety benefits of BIM implementation'* (RII = 89%). These barriers are related to the level of BIM knowledge provided and construction participants' awareness about the techniques for using it in their profession. *'Lack of universal use in the construction sector'* was ranked first in the overall ranking of the barriers (RII = 95%) to the construction industry adopting BIM technology for safety-related applications in the Gaza Strip. Owners, contractors and consultants rated this barrier with an RII of 95%, 95% and 94%, respectively. Most contractors and designers are not familiar with the use of BIM. This result indicated that BIM technology did not have a significant place and usage in the construction industry. To be implemented successfully, BIM requires all parties in the construction project to increase their knowledge about its applications and be able to use it for construction safety. In line with this result, Kassem et al. (2012) stated that this barrier was considered one of the six most common barriers limiting the widespread use of BIM in the construction industry.

'Insufficient training available' and *'Not enough demand from clients and/or other firms on projects'* were ranked second (RII = 90%). Owners put *'Insufficient training available'* in the second rank (RII = 93%) and *'Not enough demand from clients and/or other firms on projects'* in the fourth rank (RII = 91%). Contractors put *'Insufficient training available'* fifth (RII = 89%) and *'Not enough demand from clients and/or other firms on projects'* second (RII = 91%), whereas consultants placed '*Insufficient training available'* second (RII = 88%) and *'Not enough demand from clients and/or other firms on projects'* fourth (RII = 86%). Insufficient training is jeopardizing the success of organizational change and the ability to use new technologies. The results show the importance of education and training to provide knowledge about new technologies and to adoption of BIM.

The study participants indicated that *'Not enough demand from clients or other firms'* prevents them from adopting BIM. Respondents were looking for owners and other firms to take the initiative on whether the technology is to be utilized for safety performance on a project. Respondents indicated that BIM should be mandated on construction projects. Mandating BIM could be the strongest driver of BIM adoption. From this result, it is clear that clients and other influential construction firms play an important role in the use of BIM within the industry. BIM should be adopted as a mandatory provision in order to improve safety in construction projects. However, clients and other firms in the construction sector lack the knowledge and do not realize the benefits of using BIM in projects. Consistent with this result, the McGraw-Hill (2010) survey indicated that the primary reason non-users give for not implementing BIM is the lack of client demand: 55% of non-users surveyed revealed that this was the number one reason.

'Current construction safety technology is enough' was ranked last in the overall ranking from the listed barriers with (RII = 59%). Owners, contractors and consultants considered this barrier as the lowest barrier to adopting BIM in the construction sector, with RII of 47%, 60% and 70% respectively. The participants did not realize the benefits of BIM adoption for construction safety and most of them did not know about any BIM tools used for safety improvement. The respondents indicated that existing problems on construction safety performance are not related to BIM technology adoption but they are related to the methods and the level of using existing technologies.

Conclusions and recommendation

BIM is an innovative concept to manage construction projects by simultaneously storing and visualizing construction data. Due to its benefits, numerous research studies have been conducted regarding BIM integration for different purposes. This paper has presented the perceptions of the primary construction industry stakeholders in the Gaza Strip regarding the awareness, usage, safety-related applications of and barriers to adopting BIM to improve construction safety performance.

The study results revealed that a significant proportion of the respondents have little or no knowledge and understanding of the concept of BIM. The respondents revealed that BIM usage was very low in their organizations, and the majority of respondents did not have plans to use BIM in the near future. The respondents felt that BIM is most likely to positively impact on construction safety. Several safety-related applications in construction can be developed by adopting BIM technology that can improve construction safety. From the viewpoint of the respondents, the most important safety-related applications of BIM are related to the potential for using BIM in hazard identification and minimization, safety training and education, site layout planning and fall prevention planning.

Despite rapid international development and implementation of BIM, it is not widely adopted in the the construction industry to improve safety. Major barriers are identified regarding the implementation of BIM technology in the Gaza Strip's construction industry, especially for safety. The main barriers to the application of BIM were lack of universal use in the construction sector, insufficient training available, not enough demand from clients and/or other firms on projects, and uncertainty of the safety benefits of BIM implementation. The results give a snapshot of the benefits related to safety and the barriers affecting BIM implementation in the industry which are useful in developing a holistic strategy to increase the adoption of BIM in the industry. There is a need to improve awareness of the BIM concept through education and training, both formal and informal, including more information and provision of expertise about BIM that can enhance the levels of adoption.

Government and decision makers in the the construction industry need to support the establishment of a training board that can provide subsidized courses targeting the industry stockholders to educate them about the role that BIM can play in the industry and especially in safety management. Construction organizations need to make constant efforts to expand their workers' knowledge about BIM and should consider it a basic criterion for hiring safety professionals. There is a need for greater assessment within companies and project teams to have the ability to adopt BIM for their projects. It is recommended that training courses regarding the BIM concept and the benefits of its application in the construction industry be conducted. Development of BIM is needed for a workable and efficient hazard identification process in construction projects. Safety professionals should be hired based on their knowledge of BIM. Clients and other construction firms should mandate BIM as a contractual requirement for construction projects.

Disclosure statement

No potential conflict of interest was reported by the authors.

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