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Building Information Modeling and Its Application in the State of Kuwait

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***Abstract*—**Recent advances of Building Information Modeling (BIM) especially in the Middle East have increased remarkably. Dubai has been taking a lead on this by making it mandatory for BIM to be adopted for all projects that involve complex architecture designs. This is because BIM is a dynamic process that assists all stakeholders in monitoring the project status throughout different project phases with great transparency. It focuses on utilizing information technology to improve collaboration among project participants during the entire life cycle of the project from the initial design, to the supply chain, resource allocation, construction and all productivity requirements. In view of this trend, the paper examines the extent of applying BIM in the State of Kuwait, by exploring practitioners' perspectives on BIM, especially their perspectives on main barriers and main advantages. To this end structured interviews were carried out based on questionnaires and with a range of different construction professionals.

The results revealed that practitioners perceive improved communication and mitigated project risks by encouraged collaboration between project participants. However, it was also observed that the full implementation of BIM in the State of Kuwait requires concerted efforts to make clients demanding BIM, counteract resistance to change among construction professionals and offer more training for design team members.

This paper forms part of an on-going research effort on BIM and its application in the State of Kuwait and it is on this basis that further research on the topic is proposed.

***Keywords*—**Building Information Modeling, BIM, construction industry, Kuwait.

I. Introduction

BUILDING INFORMATION MODELING (BIM) is a rapidly emerging concept in the area of construction project management, and the highly fragmented construction industry has been much affected by the advancement of BIM. Whilst there are now numerous software packages that support the concept of BIM, more and more companies are taking to applied research areas to reap the benefits from the implementation of BIM.

In some regions, construction labor productivity has declined by about 20% between 1964 and 2003, while other industries improved by more than 200% [1]. Implementation of BIM in the construction industry has been an issue of great importance in terms of enhancing the effectiveness of construction projects throughout their life cycle and across different construction business functions. This is because BIM focuses on applying information technology to increase collaboration among project participants during the entire lifecycle of any project [2]. Similarly, [3] identified that BIM involves applying and preserving the essential digital representation of all building information for different phases of the lifecycle of complex construction projects.

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Sacks et al. [2] uphold that BIM is far more than just a technological advance. The authors indicate that it requires a fundamental shift towards collaboration among project participants. Currently, BIM is utilized in Dubai to coordinate the design and build phase of mega and complex projects and it presents a framework for communication between different disciplines and stakeholders. This has brought about a shift in how projects are managed in Dubai making it a mandatory requirement for all stakeholders of large and complex projects to be carried out to use BIM [4]. This decision has put a lot of pressure on contractors as they are currently making a rapid transition to embrace BIM in order to meet client demands. In addition, since a lot of firms have multiple offices across the Middle East and with the emergence of mega and complex projects in various cities of the region, a further increasing adoption of BIM in construction across the region can be expected.

II. Background

A. BIM

Building Information Modeling (BIM) has been defined in different ways by different authors. Sacks et al. [2] defined BIM as "a verb or adjective phrase to describe tools, processes, and technologies that are facilitated by digital machine-readable documentation about a building, its performance, its planning, its construction, and later its operation". On the other hand, BIM was defined by Smith [5] as a "digital representation of the physical and functional characteristics of a facility. Its purpose is to serve as a shared knowledge resource for information about a facility and forming a reliable basis for decisions during its life-cycle from inception onward". BIM was also defined by the National Institute of Building Sciences [6] as "the act of creating an electronic model of a facility for the purpose of visualization, engineering analysis, conflict analysis, code criteria checking, cost engineering, as-built product, budgeting and many other purposes", while Penttilä [7] defined BIM as a set of interacting policies, processes and technologies used in generating a "methodology to manage the essential building design and project data in digital format throughout the building's life cycle". BIM is described as a three dimensional digital demonstration of a building with its intrinsic components and characteristics; made of intelligent building components which comprises of data attributes and parametric rules for each object [7].

B. The Application of BIM in Construction

Sacks et al. [2] has provided a detailed description of the uses of BIM in construction. These include visualization of form, collaboration in design and construction, Mechanical Electrical Plumbing (MEP) clash detection, and the rapid generation and evaluation of construction drawings, while Hannele et al. [8] emphasized that the first use of BIM should be in the design and planning phase of the construction project. During the planning phase different professional groups use BIM in architectural design, HPAC (heating, plumbing, and air-conditioning), electricity planning and structural design. Succar [9] argued that the most "mature" application of BIM is seen to involve collaboratively created, shared, and maintained models across the project lifecycle.

Abbasnejad and Moud [10] identified that BIM is being used at different maturity levels. The authors [10] discussed that at the first level, it is used as unmanaged CAD, in 2D, with paper or electronic paper data exchange; in the succeeding level it is utilized as managed CAD in 2D or 3D format with a collaborative tool that provides a common data environment with a standardized data structure and format. At this maturity level, commercial data is managed by standalone finance and cost management packages without integration with the CAD. Abbasnejad and Moud [10] indicated that in the third stage, BIM is used as a managed 3D environment with commercial data attached and this data will be managed by enterprise resource planning software, integrated by proprietary interfaces or bespoke middleware. At this level, BIM may utilise 4D construction sequencing or a 5D cost information in addition to the 4D or separately. The authors [10] stated that this was the highest level, and here BIM is considered to be fully integrated with the entire construction process. This level is empowered by "web services", is usually compliant with emerging Industry Foundation Class (IFC) standards, and BIM will utilize 4D construction sequencing, 5D cost information and 6D project lifecycle management information [10].

BIM is seen to offer the following advantages when applied to construction projects.

C. Advantages of BIM in the Construction Industry

Sacks et al. [2] give a comprehensive explanation on the advantages of using BIM:

1. Visualization of form (for aesthetic and functional evaluation) - all BIM systems enhance stakeholder participation by providing the ability to render the designs in 3D and making building designs more accessible to them.
2. Collaboration in design and construction - collaboration in design and construction is expressed in two ways, "internally," where multiple users within a single organization or discipline edit the same model simultaneously, and "externally," where multiple modelers simultaneously view merged or separate multidiscipline models for design coordination. Whereas in the internal mode objects can be locked to avoid inconsistencies when objects might be edited to produce multiple versions, in the external mode only no editable representations of the objects are shared, avoiding the problem but enforcing the need for each discipline to modify its own objects separately before checking whether conflicts are resolved.
3. Rapid generation and evaluation of construction plan alternatives - numerous commercial packages are available for four-dimensional (4D) visualization of construction schedules. Some automate the generation of construction tasks and modeling of dependencies and prerequisites (such as completion of preceding tasks, space, information, safety reviews, crews, materials, equipment, etc.) by using libraries of construction method recipes, so that changes to plans can be made and evaluated within hours.
4. Mechanical Electrical Plumbing (MEP) clash detection - MEP systems are extremely critical on technically challenging projects such as hospitals and pharmaceutical industries. Deciding the routing and the spatial arrangement of the MEP systems before construction execution hence plays an important role in the successful execution of a project. Architects and engineers (A/E) typically produce a schematic line diagram of the MEP system routing and the contractor relies on his specialty subcontractors to come up with the precise dimensions of the systems given the required specifications by the A/E. Failure to identify the spatial dimensions of the MEP systems and checking for potential clashes between the different MEP systems before construction can result in a lot of rework which can further lead to time and cost overrun.

D. Barriers to BIM in the Construction Industry

Despite these advantages of implementing BIM in construction projects, there are perceived barriers to the adoption of BIM and they slow down the adoption of BIM in the field of planning and scheduling especially in the developing countries. These barriers are caused by a number of technical and human obstacles, which can be classified as either internal or external barriers. The main obstacles are the cost and human related barriers, primarily the learning of new tools and processes [11]. Bernstein and Pittman [12] emphasized that the major barriers to the full adoption of BIM were transactional to the business process evolution: computability of the digital design information and meaningful data interoperability. In the same vein, Dabo Baba [13] grouped the barriers into cost, lack of training, lack of client demand, resistance to change and cultural issues, and interoperability:

1. Cost is related to the cost of new technologies in terms of changing in workflow and work process and most service

providers are not willing to make such investment unless they perceive long term benefits to their own organization and/or if the owner subsidizes the training costs.

2. Lack of training: Reference [14] identified that lack of training is one of the major obstacles in achieving a satisfactory level of BIM implementation.
3. Client demand: There is a need to standardize the BIM process and to define guidelines for its implementation. This has been a contentious issue among the AEC industry stakeholders (i.e. owners, designers, and constructors) regarding who should develop and operate the building information model and how the developmental and operational costs should be distributed.
4. Culture issues/resistance to change: BIM implementation has forced technology change and process change within the organizations and people are the main drive for success to achieve the goal of BIM implementation [4]. However, people are reluctant to accept changes and are not quick to adopt new technologies.
5. Interoperability: Interoperability is one of the common obstacles of BIM and it is mainly because of this reason that a single software tool is developed for meeting the requirements of different fields [15].

Regarding barriers to the implementation of BIM in the Middle East, Kiani et al. [11] identified obstacles to the implementation of BIM in the stage of planning and programming that included: lack of legal backing from authorities; lack of skilled BIM software operators; high price of software; benefits of using BIM are not tangible; not required by clients; longer time to develop a schedule; not requested by other team members; costly hardware; requested by clients in only some project phases; BIM tools difficult to learn; resistance to change; lack of available teaching.

III. Research Methodology

In order to identify the application of BIM approaches in Kuwait, questionnaire based interviews have been carried out. Since no complete list of BIM practitioners in Kuwait is available, two strategies have been followed to identify BIM practitioners. First, an internet based research led to the identification of organizations in Kuwait that have some type of connection with BIM, and some of them were helpful to get in contact with BIM practitioners. Second, personal networks in Kuwait were utilized to identify BIM practitioners. During the personal interviews, interviewees were asked to evaluate given statements (Table I) and to answer questions related to the demographics of the interviewees.

Statements number one and number ten (Table I) allowed elaboration on the interviews' personal perceptions of the main advantage and the main barrier of BIM, whereas the succeeding statements numbers two to nine, and numbers eleven to 16 respectively, were based on a 5-point response scale (5 – strongly agree, to 1 – strongly disagree). Alternative techniques, such as Fuzzy AHP, were not considered to lead to reliable responses within the given socio-economic context since they would have required significantly more time from the respondents and would have added complexity to the evaluation task, hence, would have further complicated the region specific difficulties in carrying out research [16], [17].

The shown main advantages and main barriers (Table I) were identified in earlier studies [18]-[20]. In order to increase the internal reliability, interviewees were encouraged to elaborate on the reasoning for their answers and a total of 22 usable interview responses were collected.

TABLE I
QUESTIONNAIRE (EXCERPT)

1.	The main advantage of using BIM is (please describe): …
2.	The main advantage of using BIM is "increased production"
3.	The main advantage of using BIM is "reduced project costs"
4.	The main advantage of using BIM is "better communication across stakeholders"
5.	The main advantage of using BIM is "less defective work on site"
6.	The main advantage of using BIM is "improved site layouts"
7.	The main advantage of using BIM is "improved construction and procurement programs"
8.	The main advantage of using BIM is "improved on site health and safety"
9.	The main barrier (challenge) of using BIM is (please describe): …
10.	The main barrier (challenge) of using BIM is "lack of client demand"
11.	The main barrier (challenge) of using BIM is "time required to train new users"
12.	The main barrier (challenge) of using BIM is "cost of training new users"
13.	The main barrier (challenge) of using BIM is "cost of investing in software and equipment"
14.	The main barrier (challenge) of using BIM is "not enough new users of BIM in order to make it beneficial" (e.g. not many clients are demanding it)
15.	The main barrier (challenge) of using BIM is "lack of knowledge about BIM"

The frequencies of the demographics related questions and of the two open answer questions were identified. Furthermore, the mean value, standard deviation and a resulting ranking were calculated for the answers that were obtained based on the 5-point response scale, and all results are presented in Section IV.

It has been found that it is imperative to calculate and present Cronbach's alpha coefficient [21] when using Likert-type scales in order to know the internal consistency reliability for the scales used. The formula for Cronbach's alpha [22] is

$$alpha = \frac{nr_{ii}}{1+(n-1)r_{ii}}$$

with n = the number of questionnaire items and r_{ii} = the average of all inter-item correlations.

For the case considered here, 13 questionnaire items are based on a 5-point response scale and r_{ii} has been found to be 0.367. This yields an alpha = 0.88, which is considered to be a highly reliable scale [22].

IV. Results

The demographic information of the interviewees is summarized in Table II. It can be seen that half of the interviewees (eleven) hold a civil engineering degree and most work as project manager, architectural designer or structural engineer. The interviewees' industry experience ranges from less than two years to more than 15 years, and all interviewees have more than two years' experience applying BIM. In their work situation, half of the interviewees (eleven) use BIM to prepare and manage project construction, followed by seven interviewees using BIM for engineering design. Regarding the time, the interviewees use BIM during their work time, the group of respondents is very diverse, ranging from less than 15% to more than 91% of their work time. Nine interviewees had no formal BIM training and seven benefited from in-house training that was offered in their organizations. Most of the interviewees' organizations focus on a design-build approach to project delivery.

TABLE II
SUMMARY DEMOGRAPHICS

Degree:	Civil	Arch.	Mech.	Elec.	Petrol.
Respondents:	12	8	2	0	0
	55%	36%	9%	0	0
Function:	Project Manager	Site Supervisor	Quantity Surveyor	Draftsperson	Designer
Respondents*:	7	2	0	0	7
	32%	9%	0	0	32%
Industry experience:	<2years	2<years<5	5<years< 10	10<years<15	>15 years
Respondents:	5	2	5	5	5
	23%	9%	23%	23%	23%
BIM experience:	<2years	2<years<5	5<years<10	10<years<15	>15 years
Respondents:	0	11	5	6	0
	0	50%	23%	27%	0
BIM usage (stage):	Design	Detailing	Element fabrication	Project construction	Facility Man.
Respondents:	7	1	3	11	0
	32%	5%	14%	50%	0
BIM usage (time):	0-15%	16-30%	31-60%	61-90%	91-100%
respondents:	4	7	4	4	3
	18%	32%	18%	18%	14%
BIM training:	None / self	Industry led	In house	College	Other
Respondents:	9	5	7	1	0
	41%	23%	32%	5%	0
Delivery Methods:	Design-Bid-Build	Design-Build	Gen. Con. /Con. Man.	Cost reimbursable	
Respondents:**	8	14	5	2	
	28%	48%	17%	7%	

(* 6 (27%) Structural Engineers; ** multiple choices possible)

The answers to the question regarding the perceived main advantage of BIM are summarized in Table III. The most common answer was "better communication across stakeholders", which made up 48% of all answers given by the interviewees. The second most common answer was "time saving" (20% of all answers). The third most common answer was "clash detection" (16% of all answers), followed by other answers, namely "better shop drawings" and "reduce cost and risk" (16% of all answers).

The respondents' assessment of the seven pre-defined main advantages that were derived from literature is shown in Table IV. "Better communication" was ranked highest with an average mean of 4.45, followed by "increased production" (4.32), "improved construction process" (4.23), "less defective work on site" (4.18), "improved site layout" (4.14), "reduced cost" (4.05) and "improved safety" (3.18). It is noteworthy that the mean values of six out of seven advantages are between "agree" and "strongly agree".

The answers regarding perceived main barriers to BIM application are shown in Table V. Half of the interviewees perceived a lack of knowledge as the main barrier to applying BIM, followed by a perceived resistance to change and a lack of client demand and other reasons (each 17% of interviewees).

The interviewees' assessment of main barriers based on the main barriers derived from literature is shown in Table VI. "Lack of knowledge regarding BIM" was ranked highest, followed by "cost of investing in software", "not enough stakeholders are using BIM", "time to train new users" and "lack of client demand" and "cost of training new users".

TABLE III
MAIN ADVANTAGES OF BIM APPLICATION (OPEN RESPONSES)

	Answer	**Frequency [% of all answers]**
First most common answer:	Better Communication across Stakeholders	48%
Second most common answer:	Time Saving	20%
Third most common answer:	Clash Detection	16%
Other answers:	Better Shop Drawings, Reduce cost and risk	16%

The presented results will be discussed in more detail in section V.

V. DISCUSSION

The focus of perceived benefits of BIM is on better communication with the involved stakeholders and the potential to save time. This might reflect the facts that, first, the organizations of most respondents focus on Design-Build or Design-Bid-Build delivery methods and, secondly, most respondents are involved in engineering design and project management activities. They are familiar with the consequences of poor communication as well as design changes that arise from poor coordination between stakeholders. The respondents seem to perceive BIM as an approach that helps mitigating these risks and contribute to increased production and an improved construction process. Respondents' perception based on the evaluation of pre-defined advantages mirrors in general their perception as articulated in their open answers.

In summary and based on the respondents considered here, BIM as applied in Kuwait has a positive effect on the delivery of construction projects, especially regarding improved communication between stakeholders. However, in order to benefit more from applying BIM, knowledge about BIM and its advantages needs to be made available to more construction professionals and clients should be encouraged to demand applying BIM on their projects.

TABLE IV
ASSESSMENT OF MAIN ADVANTAGES

Advantages:	Increased production	Reduced cost	Better communication	Less defective work	Improved site layout	Improved construction process	Improved safety
Mean:	4.32	4.05	4.45	4.18	4.14	4.23	3.18
Standard Deviation:	0.62	0.81	0.64	0.81	0.61	0.65	0.87
Ranking:	2	6	1	4	5	3	7

TABLE V
MAIN BARRIERS TO BIM APPLICATION (OPEN RESPONSES)

	Answer	**Frequency [% of all answers]**
First most common answer:	Lack of Knowledge	50%
Second most common answer:	Resistance to Change	17%
Third most common answer:	Lack of Client Demand	17%
Other answers:	Cost of Investing in Software, Misuse of BIM	17%

TABLE VI
ASSESSMENT OF MAIN BARRIERS

Barriers:	Lack of client demand	Time to train new users	Cost of training new users	Cost of investing in software	Not enough stakeholders use BIM	Lack of knowledge
Mean:	3.18	3.36	3.18	3.77	3.41	4.32
Standard Deviation:	0.87	0.96	1.05	0.83	0.64	0.80
Ranking:	5	4	5	2	3	1

VI. CONCLUSION

The purpose of this study was to identify the perception of construction professionals regarding main advantages and main barriers regarding the implementation of BIM in the State of Kuwait. Based on questionnaire based interviews, it was identified that the most important main advantage of applying BIM to construction projects lies in improved communication between the stakeholders that has potential to contribute to timely design and construction processes. The two most important main barriers that could be identified were a lack of knowledge regarding the full potential of implementing BIM and, secondly, a lack of demand from the client side.

Based on this exploratory study, more data will be collected in order to carry out a more comprehensive analysis of the situation in Kuwait. Anecdotal evidence shows that these results are representative to some extent for the whole region.

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