Studying the Benefits of Building Information Modeling (BIM) in Architecture, Engineering and Construction (AEC) Industry in the Gaza Strip

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ABSTRACT

The objective of this study is to identify and evaluate the potential benefits of using BIM in architecture, engineering and construction (AEC) industry in Gaza Strip, Palestine. A questionnaire survey was utilized and distributed to 270 construction professionals. Data were analyzed using Exploratory Factor Analysis (EFA). The results revealed the forming of four components (i.e., four factor structures) of BIM benefits; those are: (i) life cycle cost control and environmental issues, (ii) effective construction process, (iii) design and quality improvement and (iv) decision-making support. The results show that the most important individual BIM benefits among the main four components are: improving management and operation of buildings, controlling the whole life cycle cost, reducing change orders, increasing coordination between contract parties, improving communication, improving safety, improving quality and improving decision-making process. Professionals and engineers are urged to utilize BIM in designing and constructing buildings and infrastructure projects in the Gaza Strip, in order to improve effectiveness, efficiency, productivity and quality of construction projects. This paper provides an insight into the benifits of using BIM in construction industry at the Gaza Strip. It contributes to the overall body of knowledge relevant to advocating the benefits of BIM among construction organizations in developing countries, where there are limited studies in this area.

KEYWORDS: BIM, Benefits, Architecture, engineering and construction (AEC) industry, Construction, Life cycle.

INTRODUCTION

Building Information Modeling (BIM) is an innovative technology and process, which transformed the way of pre-construction, design, construction and post-construction of a building project (Eastman et al., 2008, 2011). In recent years, AEC industry started to implement BIM in projects. In particular, research emphasized the significant role of BIM for sustainable development in AEC industry (Cheng and Ma, 2013). However, despite the promising benefits of using BIM in the AEC industry, the adoption of the new technology of BIM is still slow in both developed and developing countries (Azhar et al., 2008b; Enshassi et al., 2009; Gu and London, 2010; Sebastian, 2011; Both and Kindsvater, 2012).

AEC industry is regarded as one of the most important sectors in Gaza Strip in Palestine. Nevertheless, AEC industry suffers from many complex problems, which make the achievement of the construction and reconstruction processes more difficult. For example, construction projects in Gaza Strip suffer from the fragmented nature and lack of knowledge sharing as well as lack of communication among different stakeholders. In addition, the rising

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costs of construction projects remain the greatest problem that construction industry in Gaza Strip is currently facing. Further, there are other factors that affect directly and negatively AEC industry, such as delay, waste and lack of interest in maintenance of buildings. There is a clear evidence from literature that confirms the benefits of using BIM to overcome similar challenges and problems faced by AEC industry in Gaza Strip. In particular, research emphasized the role of BIM to enhance both productivity and efficiency of construction industry, as well as the ovrall performance of the project. However, the adoption of BIM by AEC firms in Gaza Strip is still in its beginning (Enshassi et al., 2007; Enshassi et al., 2009). The objective of this paper is to identify and evaluate the potential benefits of using BIM in AEC industry in Gaza Strip in Palestine, which would convince professionals in AEC firms to adopt BIM.

Potential Benefits of Using BIM

BIM technologies provide a new shift in the way buildings are designed, constructed and maintained (Elmualim and Gilder, 2013). BIM helps owners visualize the spatial organization of the building as well as understand the sequence of construction activities over project duration (Eastman et al., 2011). Schade et al. (2011) proposed a decision-making framework using a performance-based design process in the early design phase based on BIM. It is developed to support decision-makers to take informed decisions regarding the life cycle performance of a building. The benefits of this BIM-based design include that such information as building geometry, structure, materials, installation and functional use is stored in the BIM model. This reduces time and cost for the analysis of energy performance of the building (Park et al., 2012).

Contractors are also using BIM to support various construction management functions (Nepal et al., 2012; Ahmad et al., 2012). Farnsworth et al. (2014) emphasized that BIM has become an integral part of commercial construction processes in recent years. Research found that the advantages of using BIM during the construction phase include improving communication, providing accurate scheduling, improving coordination, improving visualization, detecting clashes, providing more accurate cost estimation and performing quantity takeoffs accurately. Weygant (2011), Succar (2009), Hardin (2009) and Eastman et al. (2008, 2011) agreed that 4D and 5D modeling helps clients and contractors to make informed decisions, by estimating, coordinating and scheduling the construction process. Nassar (2010) reported that BIM will increase the precision and accuracy of the quantity aspect of the estimate and may affect the precision and accuracy of the productivity aspect.

BIM is also used in managing existing facilities, by fully modeling and linking the structure to the virtual model. In this way, energy consumption and operational faults can be detected from the model for management purposes (Ahmad et al., 2012). Allen Consulting Group (2010) has highlighted the potential benefits from the adoption of BIM technology, which include: improved information sharing, enhanced productivity through time and cost savings, improved quality, increased sustainability, support of decision making and market improvements. Aibinu and Venkatesh (2013) found that time saving is the most important perceived benefit by the respondents to a quantity survey in Australia. Newton and Chileshe (2012) summed up the benefits of BIM in: (a) improved constructability, (b) improved visualization, (c) improved productivity and (d) reduced clashes as the highest ranking benefits associated with BIM adoption.

METHODOLOGY

A quantitative approach facilitated by a questionnaire survey was used for this study. The targeted population includes professionals (i.e., architects, civil engineers, mechanical engineers, electrical engineers and others) in construction industry of Gaza Strip, Palestine. Convenience sampling method was adopted. A total of 275 copies of the questionnaire were distributed and 270 were returned from the respondents with a response rate of 97.8%. Personal delivery for the whole sample helped increase the rate of response and thus the representation of the sample.

A total of 26 benefits were selected from an extensive literature review to be investigated in this study. Respondents were asked to rate each idenitified BIM benefit by using a five-point Likert scale, where 1 represents "lowest benefit scale" and 5 represents "highest benefit scale". To insure the validity of the questionnaire, two statistical tests were applied following Field's (2009) criteria. The first test is criterion-related/internal validity test. The second test is structure validity test (i.e., Pearson test) used to test the validity of the questionnaire structure The results revealed that the *P*-values are less than 0.05; thus, the correlation coefficients of the questionnaire are significant at $\alpha = 0.05$. Structure validity test is the second statistical test used to test the validity of the questionnaire structure. It was found that the *P*- value is less than 0.05, which indicates that the correlation coefficient is significant at $\alpha = 0.05$. Thus, it can be said that the questionnaire is valid and suitable for distribution. To measure the reliability of the questionnaire, Cronbach's coefficient alpha (Cα) test was used. The result showed that the Cronbach's coefficient alpha (*Cα*) was 0.89, which is above 0.7 (Field, 2009). Thus, the result ensures the reliability of the questionnaire.

Analysis of the data was undertaken using Statistical Package for Social Sciences (SPSS) V.22. Exploratory Factor Analysis (EFA) was used for data analysis. The rationale for using EFA is based on this study's nature; i.e., exploratory research,which aims at exploring and investigating the most ignificant benefits for using BIM by AEC industry in Gaza Strip, where no prior assumptions were available to identify the relationships between the items (barrires). Therfore, EFA aims to examine the pattern of inter-correlations between the 26 BIM benefits. In addition, it is used to group benefits with similar characteristics together.

The data were tested for main assumptions for the suitability of using EFA, including: data distribution, validity of sample size, Kaiser-Meyer-Olkin (KMO) test, Bartlett's test and reliability using Cronbach's alpha. The validity of factor analysis is dependent on sample size. Principal Component Analysis (PCA) can be conducted on a sample that has fewer than 100 respondents, but more than 50 respondents. The common rule is to suggest that sample size contains at least 10-15 respondents per BIM benefit. The sample size should be at least 10 times the number of variables and some even recommend 20 times (Field, 2009; Zaiontz, 2014). BIM benefits contain 26 items and the sample size was 270. With 270 respondents and 26 items/ variables (BIM benefits), the ratio of respondents to items/variables is about 10: 1, which exceeds the requirement for the ratio of respondents to items/variables.

The results of the Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of sphericity are reported in Table (1). The value of the KMO measure of sampling adequacy was 0.95 (close to 1), which is considered acceptable, since it exceeds the minimum requirement of 0.50 (Kaiser, 1974; Field, 2009; Zaiontz, 2014). The result of Bartlett's test of sphericity was 4754.45 and the associated significance level was 0.00. The probability value (Sig.) associated with the Bartlett's test is less than 0.01, which satisfies the PCA requirement. According to the results of these two tests, the sample data of BIM benefits were appropriate for factor analysis.

Cronbach's alpha test was performed on BIM benefits. The value of Cronbach's alpha (*Cα*) could be anywhere in the range of 0 to 1, where a higher value denotes greater internal consistency and *vice versa*. An alpha of 0.6 is the minimum acceptable level. Preferably, alpha should be 0.70 or higher (Field, 2009; Garson, 2013). As shown in Table (1), the value of calculated *Cα* for 19 BIM benefits is 0.96, which is considered high.

Table 1. KMO test and Bartlett's test for items of BIM benefits

KMO test and Bartlett's test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.95
Bartlett's Test of Sphericity	Approx. Chi-Square	4754.45
	df	325
	Sig.	0.00
Cronbach's Alpha (*Cα*)	0.96	

RESULTS AND DISCUSSION

Participants' Background Information

As shown in Table (2), 35.2% of the participants had working experience of less than 5 years in AEC industry, 32.6% had experience from 5 to 10 years and 32.2% had more than 10 years experience in AEC industry of Gaza Strip. Respondents for this study had a good understanding of consulting and construction works in AEC industry. In terms of the nature of their workplace, the majority of the respondents (30%) were working as consultants, 24.4% as contractors, 19.3% in the governmental sector, 15.6% in NGOs and 10.7% in other places, such as Jordan Engineers Association (JEA). Based on this information, the participants' views and responses may be noteworthy and reliable.

Factor Analysis Results

Through an iterative trimming process, EFA test results show that seven out of the poroposed 26 BIM benifit variables (i.e., items) were incostintent due to their low factor loadings. Further, they are cross-loaded onto other components. Specifically, the trimming process included examining the pattern of factor loadings to identify items/variables that have complex structure (i.e., *complex structure occurs when one item/variable has high loadings or correlations (0.50 or greater) on more than one factor/component).* If an item/ variable has complex structure, it should be removed from the analysis (Reinard, 2006; Field, 2009; Zaiontz, 2014). Accordingly, it was necessary to remove seven BIM benefits, because they demonstrated complex structure. Each variable of the removed benefits was cross-loaded onto two components with factor loadings that exceed 0.5. As shown in Table (3), the factor loading for each remaining item (i.e., BIM benefits) is above 0.5 and all items/ variables have simple structure (i.e., with no considerable cross-loading onto other components).

Table 2. Participants' background- general information

General information about respondents	Categories	Frequency	Percentage
Gender	Male	222	82.2%
	Female	48	17.8%
Educational qualification	Bachelor	195	72.2%
	Master	71	26.3%
	Ph.D.	4	1.5%
Specialization	Civil	129	47.8%
	Architect	83	30.7%
	Electrical	41	15.2%
	Mechanical	14	5.2%
	Others (Electromechanical engineer, Environmental engineer and GIS engineer)	3	1.1%
Nature of the workplace	Consultant	81	30%
	Contractor	66	24.4%
	Governmental	52	19.3%
	NGOs	42	15.6%
	Others (Jordan Engineers Association)	29	10.7%
Location of workplace	Gaza	204	75.6%
	Rafah	23	8.5%
	North	21	7.8%
	KhanYounis	14	5.2%
	Middle	8	3%
Current field -present job	Designer	73	27%
	Supervisor	64	23.7%
	Site engineer	54	20%
	Others (office engineer)	46	17%
	Project manager	33	12.2%
Years of experience	Less than 5 years	95	35.2%
	From 5 to less than 10 years	88	32.6%
	10 years and more	87	32.2%

Upon the removel of the inconsistent items/variables, four factor structures (i.e., components) in EFA analysis have emerged. Those four components account jointly for 65.47% of the total explained variance. This was further supported by the eigenvalues of the four components, which range from 1.10 to 13.13. The first factor (i.e., component) is "life cycle cost control and environmental issues", which includes nine variables. The second factor/component is "effective construction process", that includes four variables. The third factor/component is "design and quality improvement", with four variables and the fourth factor/component is" decision making support", which includes two variables. The extracted four factors are discussed below.

Table 3. Factor structure and loading for BIM benefits

No.	BIM benefit components	Factor loading	Eigenvalues	Variance % explained	Cronbach's alpha (Cα)
Component/ Factor one: *Life cycle cost control and environmental issues*					
BE 20	Improving the management and operation of the building to maintain its sustainability by supporting decision-making on matters relating to the building	0.70	13.13	50.48	0.92
BE 24	Controlling the whole-life costs of the asset effectively	0.70			
BE 19	Ease of information retrieval for the entire life of the building through as built 3D model	0.70			
BE 15	Reduction of change/variation orders in the construction stage	0.69			
BE 21	Increasing coordination between the different operating systems of the building (such as security and alarm system, lighting, air conditioning,… etc.)	0.65			
BE 23	Improving maintenance planning (preventive and curative)/ maintenance strategy of the facility	0.60			
BE 22	Enhancing energy efficiency and sustainability of the building	0.59			
BE 14	Improving communication between project parties	0.55			
BE 18	Improving the implementation of lean construction techniques to get sustainable solutions for reducing waste of materials during construction and demolition	0.55			
Component/ Factor two: *Effective construction processes*					
BE 9	Enhancing work coordination with subcontractors and suppliers (supply chain)	0.66	1.69	6.50	0.85
BE 7	Improving the selection of construction components carefully in line with quality and costs (such as types of doors and windows, coverage type of the exterior walls,… etc.)	0.66			
BE 6	Improving safety design	0.63			
BE 8	Improving understanding the sequence of construction activities	0.57			
Component/Factor three: *Design and quality improvement*					
BE 4	Improving design quality (reducing errors/redesign and managing design changes)	0.64	1.11	4.27	0.84
BE 5	Improving sustainable design and lean design	0.64			
BE 12	Increasing the accuracy of scheduling and planning	0.62			
BE 10	Increasing quality of prefabricated (digital fabricated) components and reducing its costs	0.54			
Component/ Factor four: *Decision making support/ Better customer service*					
BE 2	Supporting design decision making by comparing different design alternatives on a 3D model	0.80	1.10	4.22	0.83
BE 1	Improving realization of the idea of a design by the owner *via* a 3D model of the building	0.80			

Component/Factor 1: Life Cycle Cost Control and Environmental Issues

The first factor named "life cycle cost control and environmental issues" explains 50.48% of the total variance and contains nine items/variables. The majority of the BIM benefit items corresponding to this factor had relatively high factor loadings ranging from 0.55 to 0.70. The name of this factor has been chosen according to the characteristics of these nine benefits. Life cycle costs refer to the total costs of ownership over the life of an asset. Costs considered include financial cost, which is relatively simple to calculate, as well as environmental and social costs, which are more difficult to quantify and be assigned numerical values. Typical areas of expenditure which are included in calculating the whole-life cost include planning, design, construction, operation, maintenance, rehabilitation and cost of finance and replacement or disposal. The BIM model can be used to understand and predict the environmental performance of a building and its life cycle costs during the management period of the facility. BIM data can be exploited during the facility management, ensuring that procurement decisions are taken based on whole-life costs and cultural fit and not solely on short-term financial criteria. Proposals are better understood through accurate visualization of life cycle data requirements. Design, construction and operational information can be used in facility management of the building (CRC Construction Innovation, 2007; Azhar et al., 2008a; Azhar et al., 2008b ; Eastman et al., 2011; Ku and Taiebat, 2011; BIFM, 2012).

The results revealed that "BE 20- *Improving the management and operation of the building to maintain its sustainability by supporting decision-making on matters relating to the building*" is the highest BIM benefit corresponding to this component with a factor loading of 0.70. Decisions early in the design process have a big impact on the life cycle performance of a building and with the rising cost of energy and growing environmental concerns, the demand for sustainable buildings with minimal environmental impact is increasing (Schade et al., 2011; Azhar, 2009). There is tremendous advantage in the integration of green (sustainability) and BIM processes (Kolpakov, 2012). BIM can be used as a decision-making framework in the early design phase. It supports decision makers to take informed decisions regarding the life cycle performance of a building (Schade et al., 2011).

The findings show that *"BE 18-Improving the implementation of lean construction techniques to get sustainable solutions for reducing waste of materials during construction and demolition"* is the lowest item/variable of component 1 of BIM benefits with a factor loading of 0.55. This BIM benefit was mentioned in the literature review as a valuable benefit of BIM according to the studies of Kjartansdóttir (2011), Khosrowshahi and Arayici (2012), Kolpakov (2012) and Cheng and Ma (2013). Lean construction techniques are incorporated throughout the BIM workflow. In other words, BIM application enables the full effect of lean principles. Value maximization and waste reduction (benefits of BIM) are in line with the benefits that lean construction promises. When BIM and lean construction principles are used together, the construction process becomes even more enhanced. The project team becomes more able to tackle complex dynamic and challenging target goals to deliver a project (Eastman et al., 2008; Eastman et al., 2011; Kjartansdóttir, 2011).

Component 2: Effective Construction Processes

The second factor named "*effective construction processes"* explains 6.50% of the total variance and contains four items/variables. The majority of items/variables had relatively high factor loadings, ranging from 0.57 to 0.66. BIM helps professionals save time and money. It enables more effective integrated through-life information management, as well as stronger business continuity. BIM is a coordinated set of processes, supported by technology, that add value by creating, managing and sharing the properties of an asset throughout its life cycle. BIM ensures more controlled conditions for weather, quality, improved supervision of labor and fewer material deliveries. In addition, BIM can increase worker safety through reduced exposure to inclement weather and better working conditions (Karlshøj, 2012).

The results in Table (3) show that *"BE 9- Enhancing work coordination with subcontractors and suppliers (supply chain)"* is the highest item/ variable of this component with a factor loading of 0.66. It is a valuable BIM benefit, where BIM is a collaborative approach that improves communication means between client, design professionals, contractors, suppliers and sub-contractors. Consultants, contractors, suppliers and sub-contractors all benefit from sharing project information through BIM model. Sub-contractors can adopt BIM and stop suffering from additional expenses for having to use various models. BIM promises significant cost savings for sub-contractors and suppliers (Ahmad et al., 2012; Khosrowshahi and Arayici, 2012; Lorch, 2012; Farnsworth et al., 2014; Stanley and Thurnell, 2014).

On the other hand, *"BE 8- Improving understanding the sequence of construction activities"* is the lowest item/ variable of component 2 of BIM benefits with a factor loading of 0.57. Although this benefit was ranked low by the respondents, BIM can assist in completing building at the optimal level through effective understanding of the sequence of construction activities. 4D BIM modeling provides a powerful visualization and communication tool that gives project teams a better understanding of project milestones and construction plans. 4D simulation can help teams in identifying problems well in advance of construction activities, when they are much easier and less costly to resolve. BIM models can be linked with construction activity schedules to explore space and sequencing requirements. Additional information describing equipment locations and material staging areas can be integrated into the project model. This can facilitate and support site management decisions, enabling project teams to effectively generate and evaluate layouts for temporary facilities, assembly areas and material deliveries for all phases of construction (Eastman et al., 2011; Newton and Chileshe, 2012; Aibinu and Venkatesh, 2013; Farnsworth et al., 2014).

Component 3: Design and Quality Improvement

The third factor named "*design and quality improvement*" explains 4.27% of the total variance and contains four items/ variables. The majority of items/ variables had relatively high factor loadings (≥ 0.54). Early evaluation of design alternatives using analysis/ simulation tools increases the overall quality of the building. The use of BIM to support digital prototyping has spurred a design revolution allowing for innovations in architectural industry. By applying BIM models to buildings, project teams can understand a project digitally prior to being built. BIM delivers higher-quality designs. Making changes or adjustments to a virtual model can be accomplished more quickly, more easily and exponentially more cost effectively than waiting until a fully mobilized workforce is involved. BIM allows models to be tested for clashes and conflicts throughout the development of the design. By integrating fabrication information, the shop drawing process can be streamlined or eliminated. BIM digital model resolves coordination issues and increases the use of pre-fabricated components, thus improving quality and reducing material and labor waste (Eastman et al., 2008; Eastman et al., 2011; Lorimer, 2011; Elmualim and Gilder, 2013).

The results show that *"BE 4- Improving design quality (reducing errors/redesign and managing design changes)"* is the highest item/ variable of component 3 of BIM benefits with a factor loading of 0.64. Successful implementation of BIM would result in a better quality design. The use of BIM prevents expensive delays due to inaccurate drawings. The adoption of BIM can also help civil engineers in quickly analyzing and comparing several design alternatives. BIM model is linked to a database and any change to one design is reflected throughout the model; thus eliminating oversights and changing design models and drawings. BIM facilitates doing complex design and can resolve easily errors/ clashes in the design among the disciplines. BIM ensures verifying consistency to the design intent easily, which prevents expensive delays and eliminates conflicts (Holness, 2006; Eastman et al., 2008; Eastman et al., 2011).

On the other hand, *"BE 10-Increasing quality of prefabricated (digital fabricated) components and reducing their costs"* is the lowest item/ variable of component 3 of BIM benefits with a factor loading of 0.54. BIM allows fabrication of many types of building components to occur efficiently offsite. These building components include steel framing, curtain walls, facades and building envelope designs, as well as mechanical and piping assemblies. These precisions of building components reduce waste, condense construction time and save costs. The reduction in labor schedules due to offsite prefabrication diminishes onsite interferences and decreases lead times, thus facilitating faster erection and placement of building components on a project. Furthermore, prefabricated (digital fabricated) components allow for enriched quality *via* information extracted directly from the BIM project model, reducing errors caused by miscommunication or misinterpretation of the design. The quality of fabricated components generated in controlled settings is superior to those generated onsite. More importantly, the use of digital fabricated components allows for enhanced coordination amongst architects, fabricators and contractors, allowing for the theory of the BIM model to be successfully achieved (Eastman et al., 2008; Eastman et al., 2011; Gray et al., 2013).

Component 4: Decision Making Support/ Better Customer Service

The fourth factor named "*decision-making support/ better customer service"* explains 4.22% of the total variance and contains two items *(BE 2- Support of design decision making by comparing different design alternatives on a 3D model*") and (*BE 1- Improving realization of the idea of a design by the owner via a 3D model of the building*") with a factor loading of 0.80 for both items. BIM is used to generate and manage information about a building or piece of infrastructure over its entire life span. At every stage of the project life cycle, from design through to decommissioning, BIM provides information that helps owners make informed choices. It makes design, construction, operation and decommissioning processes more efficient. Stebbins (2009) agreed that BIM is a process rather than a piece of software. He clearly identified BIM as a business and management decision. BIM implementation is strongly related to managerial aspects of professional practices for different working styles and cultures (cited in Ahmad et al., 2012). More precisely, BIM is a mechanism to share knowledge between design professionals for improving decision-making through better project understanding (Schade et al., 2011). Building information models become shared knowledge resources to support decision-making about a facility from earliest conceptual stages, through design, construction, operational life and eventually, demolition.

CONCLUSION

This paper identified the most significant potential benefits of using BIM in AEC industry in Gaza Strip. The study findings indicated that BIM benefits are significantly valuable for professionals and practitioners in AEC industry in Gaza Strip. Results obtained from EFA analysis have clustered BIM benefits into four components: life cycle cost control and environmental issues, effective construction process, design and quality improvement and decision-making support/ better customer service.

The results identified the most important individual potential benefits of using BIM; those are: improving management and operation of buildings, controlling the whole life cycle cost, reducing change orders, increasing coordination among contract parties, improving communication, improving safety, improving quality and improving decision-making process. Professionals and engineers are urged to utilize BIM in designing and constructing buildings and infrastructure projects in the Gaza Strip, in order to improve effectiveness, efficiency, productivity and quality of construction projects. This paper provides insight into the benefits of using BIM in construction industry in the Gaza Strip. It contributes to the overall body of knowledge relevant to advocate the benefits of BIM among construction organizations of developing countries, where there are limited studies in this area.

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