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Examining the Positive Impact of BIM on the Gaza Strip's AEC Sector

Adnan Ali Ahmed and Suhair Alkilani

Department of Civil Engineering,

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ABSTRACT

The research team behind this project in Gaza Strip, Palestine set out to find and assess the possible advantages of building information modeling (BIM) in the AEC sector. A total of 270 construction industry experts were polled using a questionnaire. Exploratory Factor Analysis (EFA) was used for data analysis. The results showed that the four main advantages of building information modeling (BIM) may be broken down into the following: (i) a more efficient construction process; (ii) better design and quality; and (iv) assistance with decision-making. Among the four primary components of building information modeling (BIM), the results highlight the following as the most significant individual benefits: better building management and operation; better control of whole life cycle costs; fewer change orders; better coordination between contract parties; better communication; better safety; better quality; and an improved decision-making process. Engineers and professionals in the Gaza Strip are strongly encouraged to use building information modeling (BIM) when planning and executing infrastructure and building projects. This will greatly enhance the projects' efficiency, quality, effectiveness, and productivity. The advantages of building information modeling (BIM) in the Gaza Strip construction sector are explored in this research. Given the paucity of research in this field, it adds to what is already known about the value of building information modeling (BIM) and how to convince construction companies in developing nations of its merits.

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

INTRODUCTION

An innovative technique and technology, Building Information Modeling (BIM) changed the way a building project was planned, built, and maintained (Eastman et al., 2008, 2011). Building information modeling has been increasingly used in the AEC sector in recent years. According to Cheng and Ma (2013), BIM plays a crucial role in the AEC industry's sustainable development efforts. Developed and developing nations alike are sluggish to embrace the new technology of building information modeling (BIM), despite the many advantages it offers the architecture, engineering, and construction (AEC) sector (Azhar et al., 2008b; Enshassi et al., 2009; Gu and London, 2010; Sebastian, 2011; Between and Kindsvater, 2012).

Among the several vital industries in the Palestinian territory of Gaza, the AEC industry stands out. However, the building and repair procedures are more difficult to accomplish due to the AEC industry's numerous complicated challenges. For instance, in the Gaza Strip, building projects are often disjointed and characterized by a lack of communication, information exchange, and overall coordination among all parties involved. Another major issue that the Gaza Strip building sector is now dealing with is the increasing expenses of development projects. In addition, the AEC sector is directly impacted by issues like tardiness, inefficiency, and disinterest in building upkeep, among others. The research

provides strong evidence that building information modeling (BIM) may help the AEC sector in the Gaza Strip solve comparable issues. Research has focused on the importance of building information modeling (BIM) in improving the overall performance of a project and the efficiency and productivity of the construction sector. However, according to Enshassi et al. (2007) and Enshassi et al. (2009), AEC businesses in the Gaza Strip are only starting to use BIM. In order to persuade experts in AEC businesses to embrace BIM, this article seeks to identify and assess the possible advantages of using BIM in the AEC sector in the Gaza Strip in Palestine.

Potential Benefits of Using BIM

The use of building information modeling (BIM) technology has brought about a paradigm change in the building industry (Elmualim and Gilder, 2013). Building information modeling (BIM) aids owners in visualizing the building's spatial structure and comprehending the project's sequential construction processes (Eastman et al., 2011). A performance-based design method was suggested by Schade et al. (2011) as a decision-making framework for the early design phase that relies on building information modeling (BIM). For the purpose of helping decision-makers make educated choices about a building's life cycle performance, it is being developed. One advantage of building information modeling (BIM) is the ability to retain data on a building's geometry, structure, materials, installation, and functional usage. According to Park et al. (2012), this helps to decrease the time and expense associated with analyzing the building's energy performance. Additionally, BIM is being used by contractors to bolster a range of responsibilities related to construction management (Nepal et al., 2012; Ahmad et al., 2012). According to Farnsworth et al. (2014), building information modeling (BIM) has recently grown in importance in commercial building operations. Using building information modeling (BIM) throughout the construction phase provides several benefits, according to research. These include better communication, more precise scheduling, better coordination, better visualization, conflict detection, more accurate cost prediction, and accurate quantity takeoffs. By aiding in the estimation, coordination, and scheduling of the building process, 4D and 5D modeling allows customers and contractors to make educated choices (Weygant, 2011; Succar, 2009; Hardin, 2009; Eastman et al., 2008, 2011). The quantity component of the estimate will be more precise and accurate thanks to BIM, according to Nassar (2010), however the productivity component may be affected.

Existing facility management also makes use of BIM, which completely models and links the physical building to the digital model. According to Ahmad et al. (2012), this allows for the detection of operational defects and energy usage inside the model, which is useful for management. Some of the possible advantages of building information modeling (BIM) technology that have been outlined by Allen Consulting Group (2010) include better information sharing, more productivity (due to reduced costs and more efficiency), higher quality, more sustainability, better decision-making assistance, and better market performance. According to a 2013 study by Aibinu and Venkatesh, the perceived advantage that Australian respondents valued most was the time savings. According to Newton and Chileshe (2012), the top four advantages of building information modeling (BIM) are: (a) better constructability, (b) better visualization, (c) increased productivity, and (d) fewer conflicts.

METHODOLOGY

This research used a quantitative method, which was made possible by the use of a questionnaire survey. Members of the building sector in the Gaza Strip, Palestine, including architects, civil engineers, mechanical engineers, electrical engineers, and others, are the intended recipients. The researchers used a convenience sampling technique. A response rate of 97.8 percent was achieved when 270 out of 275 questionnaires were returned by the respondents. The rate of response and, by extension, the sample's representation, were both boosted by the personal delivery of the whole sample. This research aims to evaluate 26 benefits that were chosen after a thorough literature assessment. On a five-point Likert scale, with 1 indicating "lowest benefit scale" and 5 indicating "highest benefit scale," respondents were asked to rank each identified BIM advantage. Two statistical tests were conducted in accordance with Field's (2009) standards to guarantee the questionnaire's validity. Internal validity, which is connected to criteria, is the first test. The second step is to ensure the questionnaire's validity by conducting a structural validity test, also known as a Pearson test. At $\alpha = 0.05$, the correlation coefficients of the questionnaire are significant, since the findings showed that the P-values are less than 0.05. As a second

statistical check, the structural validity test ensures that the questionnaire is well-designed. The correlation coefficient is significant when α = 0.05, since the P-value is smaller than 0.05. It follows that the questionnaire meets all criteria for validity and dissemination. The reliability of the questionnaire was assessed using Cronbach's coefficient alpha (Cα) test. Field (2009) found that the Cronbach's coefficient alpha (Cα) was 0.89, which is more than 0.7. Our results confirm this. As a consequence, the validity of the survey is confirmed.
Statistical Package for the Social Sciences (SPSS) V.22 and Exploratory Factor Analysis (EFA) were used to analyze the data. Due to the exploratory nature of this study, which seeks to identify the most significant benefits of BIM for the AEC industry in the Gaza Strip, where no prior assumptions were available to identify the relationships between the items (barrires), EFA is a reasonable method to use. Therefore, the purpose of EFA is to investigate the inter-correlation pattern of the 26 BIM advantages. Also, it's a great way to organize advantages that share certain traits.

Distribution of data, validity of sample size, reliability using Cronbach's alpha, and the Kaiser-Meyer-Olkin (KMO) test were among the key assumptions assessed to ensure the data was suitable for EFA. Factor analysis's reliability is proportional to the size of the sample. Even if your sample size is less than 100 but more than 50, you may still do Principal Component Analysis (PCA). The general consensus is that for every BIM benefit, a minimum of ten to fifteen respondents should be included in the sample. According to Field (2009) and Zaiontz (2014), the sample size need to be ten times more than the number of variables, with some sources even suggesting twenty times. The sample size was 270, and BIM benefits comprise 26 elements. The ratio of respondents to items/variables is roughly 10:1, which surpasses the criteria, with 270 respondents and 26 items/variables (BIM benefits).
Table (1) displays the outcomes of the Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO) sample adequacy test. As it surpasses the minimal criteria of 0.50 (Kaiser, 1974; Field, 2009; Zaiontz, 2014), the KMO measure of sample adequacy has a value of 0.95 (near 1), which is deemed acceptable. The related significance level was 0.00, while the result of Bartlett's test of sphericity was 4754.45. The PCA condition is satisfied since the Sig. value associated with Bartlett's test is less than 0.01. These two analyses confirmed that the BIM benefit sample data was suitable for factor analysis.
BIM advantages were subjected to Cronbach's alpha testing. A higher value of Cronbach's alpha (Cα) indicates better internal consistency, whereas a lower number indicates less internal consistency. The range of possible values is from 0 to 1. The bare minimum for an alpha to be considered acceptable is 0.6. It is recommended that alpha be 0.70 or more (Field, 2009; Garson, 2013). The computed Cα value for 19 BIM benefits is 0.96, which is deemed high, as shown in Table (1).

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

In the AEC industry of the Gaza Strip, 35.2% of the participants had fewer than 5 years of experience, 32.6% had 5 to 10 years, and 32.2% had more than 10 years, according to Table (2). The AEC industry's consulting and building processes were well-understood by the study's respondents. Consultants made up 30% of the respondents, contractors 24.4%, government employees 19.3%, non-governmental organizations 15.6%, and other organizations including the Jordan Engineers Association (JEA) 10.7%. This suggests that the opinions and replies of the participants could be significant and trustworthy.

Summary of Factor Analysis

The EFA test findings reveal that seven out of the twenty-six proposed BIM benefit variables (i.e., items) were unintentional since they had low factor loadings. This was determined via an iterative pruning procedure. Additionally, additional components are cross-loaded with them. In order to find items or variables with complex structure, which is defined as having high loadings or correlations (0.50 or more) on more than one component or factor, the pattern of factor loadings was examined throughout the trimming process. According to Reinard (2006), Field (2009), and Zaiontz (2014), it is recommended to exclude items or variables with complicated structures from the analysis. As a result, seven BIM benefits had to go since they showed too much structure. With factor loadings greater than 0.5, each variable of the eliminated benefits was cross-loaded onto two components. All items/variables have simple structures (i.e., without significant cross-loading onto other components), and the factor loading for each remaining item (i.e., BIM benefits) is over 0.5, as indicated in Table (3).

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%
	Gaza	204	75.6%
	Rafah	23	8.5%

Location of workplace	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			

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	1.69	6.50	0.85
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).

CONCLUSION

In this article, we outlined the top advantages that the AEC sector in the Gaza Strip stands to gain from using BIM. According to the results, anyone working in the AEC sector in the Gaza Strip may greatly benefit from using BIM. Life cycle cost management and environmental challenges, an efficient construction process, design and quality improvement, decision-making support/better customer service—these are the four main advantages of building information modeling (BIM) that have been identified via environmental factor analysis (EFA). Building information modeling (BIM) has several potential advantages, but the most important ones were highlighted by the results. These include better building management and operation, better control of whole life cycle costs, fewer change orders, more coordination among contract parties, better communication, safer projects, higher quality, and better decision-

making. Engineers and professionals in the Gaza Strip are strongly encouraged to use building information modeling (BIM) when planning and executing infrastructure and building projects. This will greatly enhance the projects' efficiency, quality, effectiveness, and productivity. This article delves into the advantages of building information modeling (BIM) in the Gaza Strip construction sector. Given the paucity of research in this field, it adds to the existing body of information that is pertinent to promoting the advantages of BIM among building organizations in developing nations.

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