Revista Ingeniería de Construcción RIC
Vol 31 Nº2 2016 www.ricuc.cl

ENGLISH VERSION

An investigation of building information modelling functions in the Palestinian construction industry

Investigación de las funciones del modelado de la información de construcción en la industria de la construcción en Palestina

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Fecha de Recepción: 09/02/2016
Fecha de Aceptación: 10/05/2016
PAG 127-138

Abstract

The objective of this paper is to investigate the importance of Building Information Modelling (BIM) functions in the construction industry from professionals' views in the Gaza Strip-Palestine. A questionnaire survey was employed in this study and 270 professionals in the construction industry have responded to the questionnaire; data were analyzed using exploratory factor analysis. The study findings indicated that BIM functions are significantly needed and important for professionals in the construction industry in Gaza Strip. Findings of this study revealed three components of BIM functions: data management and utilization in planning, operation and maintenance, visualized design and analysis, and construction and operation. Energy optimization was found as the highest important function of BIM of the first component as there is a high demand for sustainable building and sustainable development. A functional simulation in order to choose the best solution for lighting and energy was the highest important function of the second component. This function will assist in identifying methods to reduce resources consumption and increase on-site renewable opportunities. Model-based cost estimation was found the highest important function in the third component. Professionals in the construction industry will benefit from the findings presented in this paper by understanding the BIM functions which will encourage them to apply BIM tools that will lead to a substantial improvement in the performance of construction projects.

Keywords: *BIM, functions, professional, construction*

Resumen

El objetivo de este artículo es investigar la importancia de las funciones del Modelado de la Información de la Construcción (BIM, por sus siglas en inglés) en la industria de la construcción desde el punto de vista de los profesionales, en la Franja de Gaza, Palestina. Se utilizó una encuesta tipo cuestionario respondido por 270 profesionales de la industria. Los datos fueron analizados usando el análisis factorial exploratorio. Los hallazgos del estudio indicaron que las funciones del BIM son muy necesarias e importantes para los profesionales de la industria de la construcción en la Franja de Gaza. Los hallazgos de este estudio revelaron tres componentes de las funciones del BIM: (1) Gestión de datos y utilización en la planificación, operación y mantenimiento; (2) Diseño y análisis visualizados y (3) Construcción y operación. La optimización de la eficiencia energética resultó ser la función más importante de la primera componente del BIM ya que existe alta demanda por una construcción y desarrollo sustentables. En cuanto a la segunda componente, la simulación funcional destinada a elegir la mejor solución para la iluminación y energía resultó ser la función más alta. Esta función ayuda a identificar los métodos para reducir el consumo de recursos e incrementar las oportunidades de energías renovables en el sitio. La estimación de costos basada en el modelo demostró ser la función más alta en la tercera componente. Los profesionales de la industria de la construcción se verán beneficiados con los hallazgos presentados de este estudio al poder comprender las funciones del BIM que los impulsarán a aplicar sus herramientas con el fin de mejorar sustancialmente la realización de los proyectos de construcción.

Palabras clave: Modelado de la información de la construcción (BIM), funciones, profesional, construcción

1. Introduction

BIM can be defined as the development and the use of a computer software model to simulate the construction and operation of a facility. Dzambazova et al. (2009) defined BIM as the management of information throughout the entire life cycle of a design process, from early conceptual design through construction administration. BIM has been in use internationally for several years, and its use continues to grow. It is one of the most promising developments in the Architecture, Engineering, Construction (AEC) industry and it has the potential to become the information backbone of a whole new AEC industry (Eastman et al., 2011; Cheng and Ma, 2013; Stanley and Thurnell, 2014). BIM is continuously developing as a concept because the boundaries of its capabilities continue to expand as technological advances are made (Joannides et al., 2012). BIM is now considered the ultimate in project delivery within the AEC industry (Azhar et al., 2008). It is motivating an extraordinary shift in the way the construction industry functions. This fundamental change involves using digital modeling software to more effectively design, build and manage projects (Nassar, 2010).

BIM reflects the current heightened transformation within the construction industry offering a host of benefits from increased efficiency, accuracy, speed, coordination, consistency, energy analysis, project cost reduction etc., to various stakeholders from owners to architects, engineers, contractors and other built environment professionals (Mandhar and Mandhar, 2013). BIM has far reaching benefits in the construction industry in supporting and improving business practices compared to traditional practices that are paper-based or two-dimensional (2D) CAD (Eastman et al., 2011). BIM is becoming more and more important to manage complex communication and information sharing processes in collaborative building projects. BIM serves all the

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stakeholders, (e.g.: designer, contractor, owner and facility manager), in designing, constructing, forecasting and budgeting (Weygant, 2011). A growing number of design, engineering and construction firms have made attempts to adopt BIM to enhance their services and products (Sebastian and Berlo, 2010; Aibinu and Venkatesh, 2013). The objective of this study is to investigate the importance of BIM functions in the construction industry from professionals' views in the Gaza Strip-Palestine. This paper starts with an extensive review of related literature. The methodology of this study is then presented followed by reporting the results. The paper then closes with conclusion and recommendations.

2. Literature review

The adoption of BIM by the development community indicates an acceptance of its use and acknowledgement of its potential to improve the integration between procurement decisions and actual operational issues (Lorch, 2012). BIM comprises collaboration frameworks and technologies for integrating process and object-oriented information throughout the life cycle of the building in a multi-dimensional model (Sebastian and Berlo, 2010). Utilization of BIM requires collaboration among the contracting parties such as owner, architects, engineers, contractors, and facilities managers (Eastman et al., 2011). The use of BIM can increase the value of a building, shorten the project duration, provide reliable cost estimates, produce market-ready facilities, and optimize facility management and maintenance (Eastman et al., 2011). Sarno (2012) explored in greater detail how various activities, grouped under the term 'project lifecycle management' can be consistently linked to the BIM. By integrating BIM with construction project management and infrastructure lifecycle management solutions, project stakeholders can gain new efficiencies across the entire project lifecycle. In addition to that, BIM model helps owners to achieve more control and more savings through the use of BIM in project design and construction (Eastman et al., 2011).

BIMs contain a rich information model related to the life cycle of a facility, and enable enhanced communication, coordination, analysis, and quality control (McGraw-Hill Construction, 2008). BIM will reduce the waste of materials during construction and building management and eventually assist in sustainable demolition. Energy modeling can also minimize energy use over a building's life (Kolpakov, 2012). BIM models allows for a previously unimaginable array of collaborative activities; integrated inter-disciplinary design review, multi-model coordination and clash detection, and real time integration with other specialist disciplines for cost estimation, construction management etc. (Karlshøj, 2012). Many new terms, concepts and BIM applications have been developed such as 4D; 5D; six-dimensional (6D); and seven-dimensional (7D). The (D) in the term of 3D BIM means "dimensional" and it has many different purposes for the construction industry. Wang (2011) explained BIM types as the following:

- *3D: three dimensional means the height, length and width.*
- *4D: 3D plus time for construction planning and project scheduling.*
- *5D: 4D plus cost estimation.*
- *6D: 5D plus site. This would require the integration of geographic information system (GIS) and BIM. With the integration of GIS, all the items in the site model would carry the exact location and elevation information (X, Y, Z) as they are in the real construction world.*
- *7D: BIM for life cycle facility management.*

Recent advances in BIM have disseminated the utilization of multidimensional nD CAD information in the construction industry (Eastman et al., 2008; Jung and Joo, 2011). In addition to the parametric properties of 3D BIM, the technology also has 4D and 5D capabilities. Recent advancements in software have allowed contractors to add the parameters of cost and scheduling to models to facilitate value engineering studies; estimating and quantity take offs; and even simulate project phasing (Holness, 2006). At its most basic level, BIM provides three-dimensional visualization to owners. It used too as a marketing tool for potential clients and designers can employ this technology to demonstrate design ideas (Azhar et al., 2008). Weygant (2011) viewed BIM as a tool that is used for model analysis, clash detection, product selection, and whole project conceptualization.

Ashcraft (2008) presented how BIM is being used as follows: single data entry, multiple uses; design accuracy; consistent design bases 3D modeling; conflict identification and resolution; take-offs and estimating; shop and fabrication drawing; visualization of alternative solutions and options; energy optimization; constructability reviews and 4D simulations; control fabrication costs and errors; facilities management; and functional simulations. Becerik-Gerber et al. (2011) recognized the application areas of FM that BIM could be implemented and beneficial: locating building component; facilitating real-time data access; visualization and marketing; and checking maintainability. Maintainability can address the following areas: accessibility, sustainability of materials, and preventive maintenance; creating and updating digital assets; space management; planning and feasibility studies for non-capital construction; emergency management; controlling and monitoring energy; and personnel training and development.

Ku and Taiebat (2011) found that companies utilize BIM in the following domain areas of construction management: constructability and visualization, where constructability tasks included clash detection for trade coordination; site planning; database information management; model-based estimating; cost control; and 4D scheduling. Gray et al. (2013) reported BIM uses which included: design visualization; design assistance and constructability review; site planning and site utilization; scheduling and sequencing (4D); cost estimating (5D); integration of subcontractors and supplier models; systems coordination; layout and fieldwork; prefabrication; and operations and maintenance. Lee et al. (2014) summarized tasks that grounded under the construction industry and can utilize BIM as follows: 3D visualization; clash detection; feasibility studies; model-based quantity take-off and estimation; visualized scheduling 4D management; environmental analysis or LEED certification; creation of shop drawings and schedule management for installation of rebar/steel frame/curtain wall; visualized constructability review; visual and geospatial coordination for construction of atypical shapes; and creation of as-built model for facility management.

Based on the above, it can be said that BIM has a broad range of application: right cross the design; construction; and operation process. It is often impractical for any single BIM user to have expertise in all areas, nevertheless, it is important to be aware of the areas of application and thus be able to select which BIM functions are most applicable to one's own business (Baldwin, 2012). BIM is transforming the way architects, engineers, contractors, and other building professionals work in the industry today (Mandhar and Mandhar, 2013).

3. Methodology

A quantitative survey approach involving professionals (Architects, Civil engineers, Mechanical engineers, Electrical engineers, and any other and any other related specialization) in the construction industry in Gaza Strip, Palestine has been adopted. The research was carried out in Gaza Strip, which consists of five governorates: the Northern governorate, Gaza governorate, the Middle governorate, KhanYounis governorate and Rafah governorate.

3.1 Target population and sampling of the questionnaire

Research population includes professionals (Architects, Civil engineers, Mechanical engineers, Electrical engineers, and others) in the construction industry in Gaza strip, Palestine as a target group. Convenience sample was chosen as the type of sample. Convenience sampling is a type of nonprobability sampling in which respondents are approached simply because they are "convenient" sources of data for researchers (Lavrakas, 2008). In other words, they are selected because of their convenient accessibility and proximity to the researcher (Dillman et al., 2000). A total of 275 copies of the questionnaire were distributed and 270 copies of the questionnaire were returned from the respondents with respondents' rate of 97.8 %. Personal delivery for the whole sample helped to increase the rate of response and thus the representation of the sample.

3.2 Questionnaire design and development

A self-administered questionnaire was used for data collection. First draft of the questionnaire was revised through three main stages, which are: face validity, pre-testing the questionnaire, and pilot study.

Face validity

Face validity was important to see whether the questionnaire appears to be a valid or not. The questionnaire was presented to 12 experts in the construction industry with an average experience of 20 years, and their valuable comments regarding modification, clarity, addition or deleting some of the questions were taken into consideration.

Pre-testing the questionnaire

Pre-testing the questionnaire was done to make sure that the questionnaire is going to deliver the right data and to ensure the quality of the collected data (Lavrakas, 2008). The pre-testing was conducted in two phases and each phase has been tested with 6 professionals in construction industry in Gaza Strip. The first phase of the pre-testing resulted with some amendments to rephrasing some words in the questions, and to add further explanation to some items to facilitate the understanding of the question. The questionnaire was modified based on the results of the first phase of the pre-testing. After that, the second phase was conducted with the same 6 professional and it was sufficient to ensure success of the questionnaire, where there were no any queries from any professional and everything was clear.

Pilot study

After the success of the second phase of the pretesting of the questionnaire, a trial run on the questionnaire was done before circulating it to the whole sample in order to get valuable responses and to detect areas of possible shortcomings (Thomas, 2004; Naoum, 2007). A sample of around 30-50 people is usually enough to identify any major bugs in the system (Thomas, 2004). According to that, 40 copies of the questionnaire were distributed conveniently to respondents from the target group (professionals in the construction industry in Gaza Strip). All the copies were collected, coded, and analyzed through Statistical Package for the Social Sciences IBM (SPSS) version 22. Two tests were conducted: statistical validity of the questionnaire/ criterion related validity and reliability of the questionnaire by Half Split method and the Cronbach's Coefficient Alpha method.

Statistical validity of the questionnaire

In quantitative research, validity is the extent to which a study using a particular tool measures what it sets out to measure. To insure the validity of the questionnaire, two statistical tests were applied. The first test is criterion-related/internal validity test (Pearson test) which measures the correlation coefficient between each item in the field and the whole field. The second test is structure validity test (Pearson test) that used to test the validity of the questionnaire structure by testing the validity of each field and the validity of the whole questionnaire. It measures the correlation coefficient between one field and all the fields of the questionnaire that have the same level of similar scale (Garson, 2013).

Internal validity test

Internal consistency of the questionnaire was measured by the scouting sample (the sample of the pilot study), which consisted of 40 questionnaires. It was done by measuring the correlation coefficients (Pearson test) between each item in one field and the whole filed (Garson, 2013). The results revealed that the P-values are less than 0.05, so the correlation coefficients of each field are significant at $\alpha = 0.05$. Thus, it can be said that the items of each field are consistent and valid to be measured what it were set for.

Structure validity test

Structure validity is the second statistical test that used to test the validity of the questionnaire structure by testing the validity of each field and the validity of the whole questionnaire. It measures the correlation coefficient between one field and all of the other fields of the questionnaire that have the same level of numerical rating scale (Garson, 2013). 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 fields are valid to be measured what it were set for to achieve the main aim of the study.

Reliability test

Reliability is the degree of consistency or dependability with which an instrument (questionnaire for this study) measures what it is designed to measure (Field, *2009; Garson, 2013). Two tests were used to measure the reliability: Half Split method and Cronbach's alpha coefficient test.*

Half split method

It was found that the correlation coefficient value is 0.87 and P value is less than 0.05. Thus, it can be said that the studied fields were reliable according to the Half Split method.

Cronbach's Coefficient Alpha (Cα)

This method is used to measure the reliability of the questionnaire between each field and the mean of the whole fields of the questionnaire. The normal range of Cronbach's coefficient alpha (Cα) value is between 0.0 and +1.0, and the higher value reflects a higher degree of internal consistency (Field, 2009; Garson, 2013). The results 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.

As a result of the pilot study, some items have been selected; other items have been modified, while others have been merged, as well as some items have been added. Out of 45 functions that were derived from a thorough literature review, 16 functions were selected to be investigated in this study. Analysis of the data was undertaken using IBM SPSS Statistics (Statistical Package for the Social Sciences) Version 22(IBM).

4. Results and discussion

Factor analysis is a generic term which is concerned with the reduction of a set of observable variables in terms of a small number of latent factors. It has been developed primarily for analyzing relationships among a number of measurable entities. The underlying assumption of factor analysis is that there exist a number of unobserved latent variables (or "factors") that account for the correlations among observed variables. In other words, the latent factors determine the values of the observed variables (Doloi, 2008; Doloi, 2009; Hardy and Bryman, 2004; Larose, 2006; Liu and Salvendy, 2009; Field, 2009). The main applications of factor analytic techniques are: to reduce the number of variables; and to detect structure in the relationships between variables, that is to classify variables.

Exploratory factor analysis (EFA) is used to identify complex interrelationships among items and group items that are part of unified concepts (Field, 2009). The researchers make no "a priori" assumptions about relationships among factors. Factor weights are computed in order to extract the maximum possible variance, with successive factoring continuing until there is no further meaningful variance left. The factor model must then be rotated for analysis (Field, 2009). Factor analysis was used to examine the pattern of inter-correlations between the 16 items/variables of BIM functions in attempt to reduce the number of them. It is used also to group items/variables with similar characteristics together. In other words, it identified subsets of items/variables that correlate highly with each other, which called factors or components.

Appropriateness of factor analysis

The data was first assessed for its suitability to the factor analysis application which includes the following steps:

Validity of sample size

The reliability of factor analysis is dependent on sample size. Factor analysis can be conducted on a sample that has fewer than 100 respondents, but more than 50 respondents, and the sample size for this study was 270. Further, the common rule is to suggest that sample size contains at least 10–15 respondents per item/variable. In other words, sample size should be at least 10 times the number of variables and some even recommend 20 times (Field, 2009; Zaiontz, 2014). BIM functions contain 16 items and the sample size was 270. With 270 respondents and 16 items/ variables (BIM functions), the ratio of respondents to items/variables are 17: 1, which exceeds the requirement for the ratio of respondents to items/variables.

Validity of correlation matrix (Correlations between items/variables)

Table 1 show the correlation matrix for the 16 variables of BIM functions. It is simply a rectangular array of numbers which gives the correlation coefficients between a single variable and every other variable in the investigation (Field, 2009; Zaiontz, 2014). As shown in Table 1, the correlation coefficient between a variable and itself is always 1; hence the principal diagonal of the correlation matrix contains 1s. The correlation coefficients above and below the principal diagonal are the same. PCA requires that there be some correlations greater than 0.30 between the variables included in the analysis. For this set of variables, that most of the correlations in the matrix are strong and greater than 0.30. Correlations have been satisfied with this requirement.

Kaiser-Meyer-Olkin (KMO) and Bartlett's Test

The Kaiser-Meyer-Olkin (KMO) sampling adequacy test and Bartlett's test of Sphericity were carried out. The results of these tests are reported in Table 2. The value of the KMO measure of sampling adequacy was 0.92 (close to 1). It was considered acceptable because it exceeds the minimum requirement of 0.50 and it is above 0.90 (`superb' according to Kaiser, 1974; Field, 2009; Zaiontz, 2014). Moreover, the Bartlett test of Sphericity was another indication of the strength of the relationship among variables. The Bartlett test of Sphericity was 2707.30 and the associated significance level was 0.00. The probability value (Sig.) associated with the Bartlett test is less than 0.01, which satisfies the factor analysis requirement. This indicated that the correlation matrix was not an identity matrix and all of the variables are correlated. According to the results of these two tests, the sample data of (BIM funstions) were appropriated for factor analysis.

Measures of reliability for the whole items/ variables

Cronbach's alpha test was performed on the items/ variables in the field of BIM functions. The value of Cronbach's alpha (Cα) could be anywhere in the range of 0 to 1, where a higher value denotes the greater internal consistency and vice versa. An alpha of 0.60 or higher is the minimum acceptable level. Preferably, alpha will be 0.70 or higher (Field, 2009; Garson, 2013). As shown in Table 2, the value of calculated Cα for 16 items/variables of the field of (BIM functions) is 0.94 which is considered to be high.

Table 1. *Correlations between items/ variables of BIM functions*

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
F1	1															
F2	0.72**	1														
F3	0.62**	0.69**	1													
F4	0.52**	0.57**	0.62**	1												
F5	0.48**	0.46**	0.47**	0.56**	1											
F6	0.43**	0.46**	0.48**	0.51**	0.74**	1										
F7	0.49**	0.51**	0.47**	0.46**	0.54**	0.54**	1									
F8	0.53**	0.45**	0.56**	0.45**	0.47**	0.48**	0.74**	1								
F9	0.38**	0.39**	0.35**	0.42**	0.49**	0.56**	0.37**	0.33**	1							
F10	0.48**	0.52**	0.43**	0.44**	0.52**	0.54**	0.56**	0.50**	0.60**	1						
F11	0.46**	0.48**	0.51**	0.45**	0.46**	0.41**	0.50**	0.53**	0.39**	0.66**	1					
F12	0.46**	0.44**	0.48**	0.43**	0.46**	0.47**	0.54**	0.56**	0.33**	0.56**	0.63**	1				
F13	0.50**	0.48**	0.50**	0.38**	0.39**	0.39**	0.54**	0.60**	0.28**	0.48**	0.63**	0.66**	1			
F14	0.40**	0.41**	0.39**	0.44**	0.54**	0.55**	0.50**	0.48**	0.42**	0.42**	0.43**	0.56**	0.48**	1		
F15	0.40**	0.44**	0.47**	0.44**	0.47**	0.47**	0.53**	0.60**	0.36**	0.48**	0.53**	0.59**	0.58**	0.66**	1	
F16	0.48**	0.47**	0.49**	0.44**	0.43**	0.37**	0.51**	0.50**	0.38**	0.47**	0.49**	0.51**	0.48**	0.49**	0.62**	1

***. Correlation is significant at the 0.01 level (1-tailed).*

**. Correlation is significant at the 0.05 level (1-tailed).*

Table 2. *KMO and Bartlett's test for BIM functions*

KMO and Bartlett's test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.92
Bartlett's Test of Sphericity	Approx. Chi-Square	2707.30
	df	120
	Sig.	0.00
Cronbach's Alpha (*Cα*)	0.94	

Communalities (common variance)

Communalities represent the proportion of the variance in the original items/variables that is accounted for by the factor solution. The factor solution should explain at least half of each original item's/variable's variance, so the communality value for each item/variable should be 0.50 or higher (Field, 2009; Zaiontz, 2014). Table 3 shows that all of the communalities for all items/variables satisfy the minimum requirement of being larger than 0.50, so items/ variables were not excluded any on the basis of low communalities and all of the 16 items/ variables of BIM functions were used in this analysis.

Table 3. *Communalities of BIM functions*

No.	BIM function	Initial	Extraction
F1	Three-dimensional (3D) modeling and visualization	1	0.73
F2	Functional simulations in order to choose the best solution (*such as Lighting, energy, and any other sustainability information*)	1	0.78
F3	Change management (*any modification to the building design will automatically replicate in each views such as floor plans, sections and elevation*)	1	0.75
F4	Visualized constructability reviews/ Building simulation (*a 3D structural model as well as a 3D model of Mechanical, Electrical and Plumbing (MEP) services*)	1	0.63
F5	Four-dimensional (4D) visualized scheduling and construction sequencing	1	0.71
F6	Model-based cost estimation (Five-dimensional (5D))	1	0.76
F7	Model-based site planning and site utilization	1	0.60
F8	Safety planning and monitoring on-site	1	0.65
F9	Model based quantity take-offs of materials and labor	1	0.66
F10	Creation of as-built model that contains all the necessary data in order to manage and operate the building (*facility management*)	1	0.59
F11	Future expansion/extension in facility and infrastructure	1	0.60
F12	Maintenance scheduling via as-built model	1	0.69
F13	Energy optimization of the building	1	0.71
F14	Issue reporting and Data archiving via a 3D model of the building	1	0.62
F15	Managing metadata (*provide information about a certain item's content*) via a 3D model of the building	1	0.69
F16	Interoperability and translation of information (*between professionals*) within the same system/program	1	0.53

Total variance explained

Using the output from iteration 1, there were three eigenvalues greater than 1 (Figure 1). The eigenvalue criterion stated that each component explained at least one item's/variable's worth of the variability, and therefore only components with eigenvalues greater than one should be retained (Larose, 2006; Field, 2009). The latent root criterion for number of factors to derive would indicate that there were 3 components (factors) to be extracted for these items/variables. Results were tabulated in Table 4. The three components solution explained a sum of the variance with component 1 contributing 52.60%; component 2 contributing 7.41%; and component 3 contributing 6.77%.

The three components were then rotated via varimax (orthogonal) rotation approach. This does not change the underlying solution, or the relationships among the items/variables. Rather, it presents the pattern of loadings in a manner that is easier to interpret components (factors) (Reinard, 2006; Field, 2009; Zaiontz, 2014). The rotated solution revealed that the three components solution explained a sum of the variance with component 1 contributing 28.21%; component 2 contributing 19.36%; and component 3 contributing 19.20%. These three components (factors) explained 66.77% of total variance for the varimax rotation.

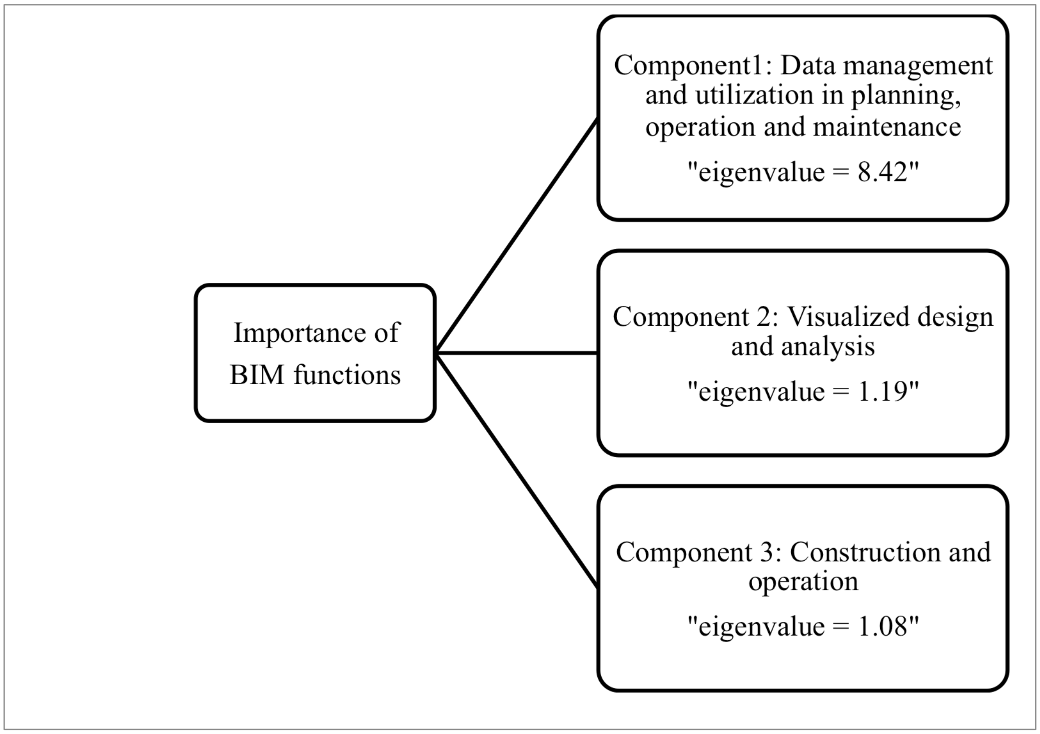

Figure 1. *Components of BIM functions*

Table 4. *Total Variance Explained of BIM functions*

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.42	52.60	52.60	8.42	52.60	52.60	4.51	28.21	28.21
2	1.19	7.41	60.01	1.19	7.41	60.01	3.10	19.36	47.57
3	1.08	6.77	66.77	1.08	6.77	66.77	3.07	19.20	66.77
4	0.81	5.04	71.82						
5	0.69	4.29	76.11						
6	0.60	3.72	79.83						
7	0.51	3.20	83.03						
8	0.43	2.70	85.73						
9	0.39	2.44	88.16						
10	0.36	2.24	90.40						
11	0.34	2.12	92.52						
12	0.31	1.92	94.44						
13	0.28	1.75	96.19						
14	0.22	1.39	97.59						
15	0.21	1.33	98.91						
16	0.17	1.09	100						

Scree plot

The scree plot below in Figure 2 is a graph of the eigenvalues against all the factors. This graph can also be used to decide on number of factors that can be derived. The point of interest is where the curve starts to flatten. It can be seen that the curve begins to flatten between factors 3 and 4. Note also that factor 4 has an eigenvalue of less than 1, so only three factors have been retained to be extracted.

Rotated component (factor) matrix

Table 4 shows the factor loadings after rotation of 15 items/variables (from the original 16 items/ variables) on the three factors extracted and rotated. The pattern of factor loadings should be examined to identify items/variables that have complex structure (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/ a variable has complex structure, it should be removed from the analysis (Reinard, 2006; Field, 2009; Zaiontz, 2014). According to that, it was necessary to remove item/ variable "Issue reporting and data archiving via a 3D model of the building" (F14) because it demonstrated complex structure. It was loaded under two components (component 1 and component 3) in the same time with a factor loading of 0.60 under component 1 and a factor loading of 0.51 under component 3. As shown in Table 4, factor loading for each remaining item/variable is above 0.50 and all items/variables had simple structure.

Measures of reliability for each component (factor)

Once factors have been extracted and rotated, it was necessary to cross checking if the items/ variables in each factor formed collectively explain the same measure within target dimensions (Doloi, 2009). If items/variables truly form the identified factor (component), it is understood that they should reasonably correlate with one another, but not the perfect correlation though. Cronbach's alpha (Cα) test was conducted for each component (factor) The higher value of Cα denotes the greater internal consistency and vice versa. An alpha of 0.60 or higher is the minimum acceptable level. Preferably, alpha will be 0.70 or higher (Field, 2009; Garson, 2013). According to results which were tabulated in Table 5, Cα for factor 1 is 0.90; Cα for factor 2 is 0.86; and Cα for factor 3 is 0.84. They are considered to be excellent.

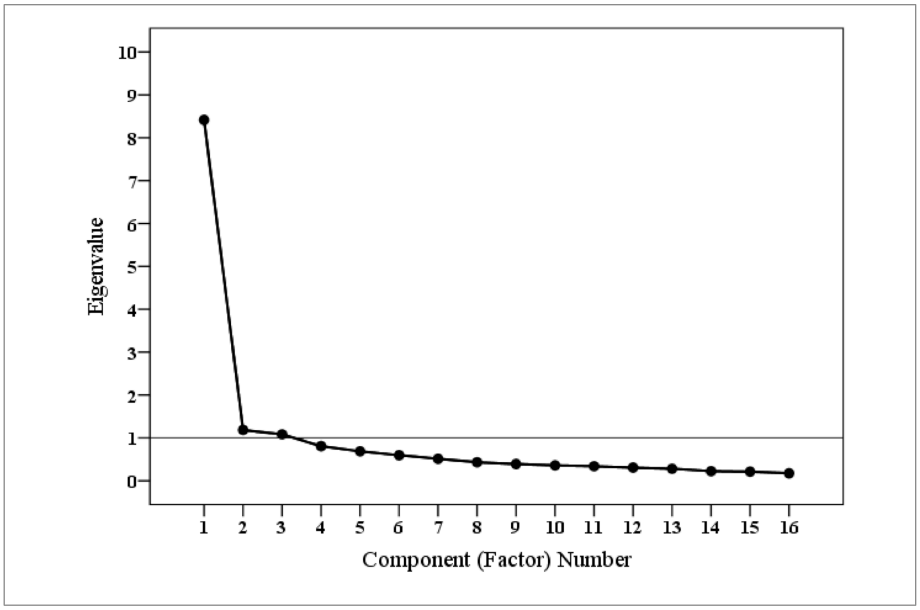

Figure 2. *Components of BIM functions*

Table 5. *Results of factor analysis for BIM functions*

No.	Factors/ Components of BIM function	Factor loading	Eigenvalues	variance% explained	Cronbach's Alpha (Cα)
Component/ Factor one : *Data management and utilization in planning, operation and maintenance*					
F13	Energy optimization of the building	0.78	8.42	52.60	0.90
F12	Maintenance scheduling via as-built model	0.76			
F15	Managing metadata (*provide information about a certain item's content*) via a 3D model of the building	0.76			
F8	Safety planning and monitoring on-site	0.69			
F11	Future expansion/extension in facility and infrastructure	0.66			
F7	Model-based site planning and site utilization	0.61			
F16	Interoperability and translation of information (*between professionals*) within the same system/program	0.61			
Component/ Factor two: *Visualized design and analysis*					
F2	Functional simulations in order to choose the best solution (*such as Lighting, energy, and any other sustainability information*)	0.80	1.19	7.41	0.86
F3	Change management (*any modification to the building design will automatically replicate in each views such as floor plans, sections and elevation*)	0.77			
F1	Three-dimensional (3D) modeling and visualization	0.77			
F4	Visualized constructability reviews/ Building simulation (*a 3D structural model as well as a 3D model of Mechanical, Electrical and Plumbing (MEP) services*)	0.62			
Component/ Factor three: *construction and operation*					
F6	Model-based cost estimation (Five-dimensional (5D))	0.79	1.08	6.74	0.84
F9	Model based quantity take-offs of materials and labor	0.78			
F5	Four-dimensional (4D) visualized scheduling and construction sequencing	0.74			
F10	Creation of as-built model that contains all the necessary data in order to manage and operate the building (*facility management*)	0.53			

5. The extracted factors

The next section will interpret and discuss each of the extracted components (factors) as follows:

5.1 Component 1: Data management and utilization in planning, operation and maintenance

First component named data management and utilization in the planning, operation and maintenance explains 52.60 % of the total variance and contains seven items/ variables. The majority of items/variables had relatively high factor loadings (≥ 0.61). The seven items/ variables are as follows:

- *Energy optimization of the building (F13), with factor loading = 0.78.*
- *Maintenance scheduling via as-built model (F12), with factor loading = 0.76.*
- *Managing metadata (provide information about a certain item's content) via a 3D model of the building (F15), with factor loading = 0.76.*
- *Safety planning and monitoring on-site (F8), with factor loading = 0.69.*
- *Future expansion/extension in facility and infrastructure (F11), with factor loading = 0.66.*
- *Model-based site planning and site utilization (F7), with factor loading = 0.61.*
- *Interoperability and translation of information (between professionals) within the same system/program (F16), with factor loading = 0.61.*

Data management is the process of controlling the information generated during a project. Throughout the lifecycle of a project or asset (from design, construction and handover to operations) the number of assets that need to be documented, exchanged and referenced is enormous. Finding the right solution that can help to improve secure collaboration and control between all stakeholders, while increasing compliance, mitigating risk, and integrating with core processes can be a challenge (Eastman et al., 2011; Baldwin, 2012). BIM, data management solutions have proved great ability for maintaining data consistency and context as well as supporting more efficient processes across the project lifecycle (Choi, 2010; Lee et al., 2009; Lee et al., *2007; Smart Market Report, 2012) (cited in Lee et al., 2014). As shown from results, the item/variable with the highest loading of this first component (factor) is "Energy optimization of the building" (F13), and the item/variable with the lowest loading of this first component (factor) is "interoperability and translation of information (between professionals) within the same system/program" (F16).*

"Energy optimization of the building" (F13) is the highest item/ variable of component 1 of BIM functions with factor loading of 0.78. It is an important function of BIM, where the demand for sustainable buildings with minimal environmental impact and efficient energy use is increasing. Energy modeling can minimize energy use over a building's life (Kolpakov, 2012). From a cost perspective, designing a building for efficient energy usage is more expensive in the early design and construction phases, but it reduces building costs over the entire lifecycle. BIM model monitors building's life cycle costs and optimizes cost efficiency. BIM model incorporates a large part of what facilities management (FM) would require to operate and maintain the building from an energy usage perspective. Sensors can feed back and record data relevant to the operation phase of a building, enabling BIM to be used to model, evaluate, control, and monitor energy efficiency (Ashcraft, 2008; Eastman et al., 2008; Becerik-Gerber et al., 2011; Ku and Taiebat, 2011). Upon to energy savings, Park et al. (2012) in Korea sought to build a BIM based system that can assess the energy performance of buildings. It is strongly required to enhance the energy efficiency through intelligent operation and/or management of Heating, Ventilation and Air Conditioning (HVAC) system by dealing with the BIM based energy performance analysis.

"Interoperability and translation of information (between professionals) within the same system/ program" (F16) is the lowest item/ variable of factor 1 of BIM functions with factor loading of 0.61. This function of BIM can facilitate collaborative working in the construction industry. The result is consistent with Baldwin (2012) and Gray et al. (2013). "Interoperability and translation of information" is an important thing when adopting BIM in the work, where it facilitates accurate information mobility between all parties in construction industry.

5.2 Component 2: Visualized design and analysis

Second component named visualized design and analysis explains 7.41% of the total variance and contains four items/variables. The majority of items/ variables had relatively high factor loadings (≥ 0.62). The four items/variables are as follows:

- *Functional simulations in order to choose the best solution (such as Lighting, energy, and any other sustainability information) (F2), with factor loading = 0.80.*
- *Change management (any modification to the building design will automatically replicate in each views such as floor plans, sections and elevation) (F3), with factor loading = 0.77.*
- *Three-dimensional (3D) modeling and visualization (F1), with factor loading = 0.77.*
- *Visualized constructability reviews/ Building simulation (a 3D structural model as well as a 3D model of Mechanical, Electrical and Plumbing (MEP) services) (F4), with factor loading = 0.62.*

In design phase and through BIM, collaboration takes place among all design consultants from the beginning of a project so every aspect of the design can be coordinated whether it is architectural, structural, engineering, etc. Because BIM is linked to a database, any change to one design is reflected throughout the model; thus, eliminating oversights and saving time changing design models and drawings. Also, BIM can be employed on projects of any size and portions of projects. The 3D depictions/visualization helps the owner and the entire team in visualizing the project which makes design decisions easier. It is easier to do complex design in BIM because architects/engineers can document the complexity better in the drawings. Errors/ clashes in design among the disciplines can be spotted and resolved easily (Ashcraft, 2008; Eastman et al., 2008; Becerik-Gerber et al., 2011; Ku and Taiebat, 2011; Baldwin, 2012; Gray et al., 2013; Lee et al., 2014). BIM can also be used for improving analysis, where BIM model is used for determining the most effective engineering method based on design specifications. Development of information is the basis for what will be passed on to the owner and/or operator for use in the building's systems (i.e. energy analysis, structural analysis, emergency evacuation planning, etc.). These analysis tools and performance simulations can significantly improve the design of the facility and its energy consumption during its lifecycle in the future (Baldwin, 2012; Lee et al., 2014). As shown from results, the item/ variable with the highest loading of this first component (factor) is "Functional simulations in order to choose the best solution (such as Lighting, energy, and any other sustainability information)" (F2), and the item/ variable with the lowest loading of this first component (factor) is "Visualized constructability reviews/ Building simulation (a 3D structural model as well as a 3D model of Mechanical, Electrical and Plumbing (MEP) services)" (F4).

"Functional simulations in order to choose the best solution (such as lighting, energy, and any other sustainability information)" (F2) is the highest item/ variable of factor 2 of BIM functions with factor loading of 0.80. It is an important BIM function, where extending BIM to analysis can help in identifying ways to reduce resource consumption, increase on-site renewable opportunities, increase investor confidence, improve employee morale, and meet requirements for sustainable design and energy efficiency. Ashcraft (2008), Eastman et al. (2008), Baldwin (2012), and Lee et al. (2014) pointed to the importance of this function. Simulations of lighting, energy, and any other sustainability information would really affect the strength and the quality of the design and hence the operation of the building effectively.

"Visualized constructability reviews/ Building simulation (a 3D structural model as well as a 3D model of Mechanical, Electrical and Plumbing (MEP) services)" (F4) is the lowest item/ variable of component 2 of BIM functions with factor loading of 0.62. This function of BIM can assist in completing building at the optimal level through effective understanding of the design and hence choosing the best method for construction. In other words, understanding the significance of quality design and completing a project efficiently leads to the use of BIM to manage the coordination of MEP/architectural design on renovation and new construction projects. This function of BIM can effectively integrate the construction knowledge into the conceptual planning, design, construction, and field operations of a project to achieve the overall project objectives in the best

possible time and accuracy at the most cost-effective levels (Ashcraft, 2008; Eastman et al., 2008; Ku and Taiebat, 2011; Gray et al., 2013; Lee et al., 2014).

5.3 Component 3: construction and operation

Third component named construction and operation explains 6.77 % of the total variance and contains four items/variables. The majority of items/variables had relatively high factor loadings (≥ 0.53). The four items/variables are as follows:

- *Model-based cost estimation (Five-dimensional (5D)) (F6), with factor loading = 0.79.*
- *Model based quantity take-offs of materials and labor (F9), with factor loading = 0.78.*
- *Four-dimensional (4D) visualized scheduling and construction sequencing (F5), with factor loading = 0.74.*
- *Creation of as-built model that contains all the necessary data in order to manage and operate the building (facility management) (F10), with factor loading = 0.53.*

Moving beyond design, BIM models can facilitate materials purchasing, the bidding process, and the construction stage of the project. Linking the contractor's model to the design model can allow stakeholders to actually pre-build the project before actual construction and provide information for better staging and scheduling. On the other hand, BIM supports collaboration; operation of a facility; and management of a virtually building model within a building life cycle (AGC, 2005; Smith, 2007; GSA, 2007; State of Ohio, 2010; NBIMS-US, 2012; Ahmad et al., 2012). BIM is the future of construction and long-term facility management, where BIM controls time and operation and maintenance costs. It optimizes facility management and maintenance strategy (Ashcraft, 2008; Eastman et al., 2008; Becerik-Gerber et al., 2011; Ku and Taiebat, 2011; Baldwin, 2012; Gray et al., 2013; Lee et al., 2014). As shown from results, the item/ variable with the highest loading of this first component (factor) is "Model-based cost estimation (5D)" (F6), and the item/ variable with the lowest loading of this first component (factor) is "Model based quantity take-offs of materials and labor" (F10).

"Model-based cost estimation (5D)" (F6) is the highest item/ variable of component 3 of BIM functions with factor loading of 0.79. It is very important function of BIM for professionals in the construction industry. This is in line with Eastman et al. (2008), Baldwin (2012), and Gray et al. (2013). Nassar (2010) found that BIM will increase the precision and accuracy of the quantity aspect of the estimate. Cost estimating, 5D in BIM supports the entire lifecycle of a facility from the cradle to the grave. By using a building information model instead of drawings, the takeoffs, counts, and measurements can be generated directly from the underlying model. Therefore the information is always consistent with the design. And when a change is made in the design (a smaller window size, for example), the change automatically ripples to all related construction documentation and schedules, as well as all the takeoffs, counts, and measurements that are used by the estimator. Cost estimating, 5D via BIM can save time, cost, and reduces the potential for human error.

"Creation of as-built model that contains all the necessary data in order to manage and operate the building (facility management)" (F10) is the lowest item/variable of component 3 of BIM functions with factor loading of 0.53. This function was mentioned in the literature review as an important function of BIM according to the studies of Ashcraft (2008), Eastman et al. (2008), and Lee et al. (2014). BIM model that created by designers and updated throughout the construction phase, can have the capacity to become an "as built" model, which also can be delivered to the owner or facility manager. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions regarding the operation and the maintenance of the building.

6. Conclusion

The findings of this paper indicated that BIM functions are significantly needed and important for professionals in the construction industry in Gaza Strip. The results obtained from factor analysis have clustered BIM functions in three components, which are: (1) Data management and utilization in planning; operation and maintenance; (2) Visualized design and analysis; and (3) Construction and operation. Education and training are strongly recommended to increase BIM awareness and interest among architects and engineers. Universities and Engineers Association are recommended to promote the adoption of BIM by providing technical training courses and workshops in BIM functions and its application in the construction industry. Academic institutions and universities have to take the initiative to facilitate modern and innovative methods to engage BIM in the construction industry and suggest BIM courses for students. Alumni Association of engineering faculties should take an active part in BIM awareness and shed light on the field of BIM and the possibility of its application in the Palestinian construction industry.

The relationship between academia and professionals in the construction industry should be activated through the establishment of dialogue, which encouraged the exchange of knowledge, experiences and ideas. Implementing BIM approach should be slow and steady to avoid negative impacts to already existing workflow processes. In other words, change should be gradual and steady by adopting BIM on a project- by-project basis (as an example, but not as a limitation). Thus, it would be easier breaking down any psychological, social, and financial barriers for BIM adoption. The government must take progressive steps to apply BIM in the construction industry in Gaza Strip. It should generate a simplified implementation roadmap/plan for the implementation of BIM entailing issues that require consideration for organizations to progress on the BIM maturity ladder.

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