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RESEARCH ARTICLE

Critical Success Factors for Building Information Modelling Implementation

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Abstract

This paper expounds the Critical Success Factors (CSFs) for BIM implementation and explore their ranking and underlying relationships. A total of 28 CSFs was identified from the review of previous studies on success factors. Survey questionnaire containing these 28 factors was used to collect data from industry practitioners in Nigeria. Benchmark metrics was developed to rank the success factors. The topmost five success factors for BIM implementation in order of importance are: standard platforms for integration and communication; cost of development; education and training; standardization (product and process); and clear definition and understanding of users' requirement. Analysis of variance shows that significant differences exist in the pattern of rating for the topmost CSFs based on turnover. Factor analysis was further adopted to group the 28 CSFs into five components, using rotated component matrix method. The five components extracted are: (i) industry stakeholders' commitment and knowledge of BIM, (ii) capacity building for technology adoption, (iii) organisational support, (iv) collaborative synergy among industry professional and (v) cultural orientation. The rankings of the CSFs have practical implication as it provides basis for refining the most significant factors that industry stakeholders should focus attention for successful implementation of BIM. In addition, the underlying relationships among the success factors identified in this study, will assist industry stakeholders to determine best strategy to adopt in implementing BIM at industry level.

Keywords

Building Information Modelling, Critical Success Factors; Practitioners, Stakeholders, Standardisation.

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Introduction

Building Information Modeling (BIM) has been variously described as a methodology to integrate digital descriptions of all the building objects and their relationships to others in a precise manner, so that stakeholders can query, simulate and estimate activities and their effects on the building process as a lifecycle entity (Augenbroe, 2009; Baldwin, et al., 2009; Boon & Prigg, 2012; RICS, 2015). BIM is said to be different from the conventional 2-dimensional CAD in the sense that 2D drawings are graphical representations of objects, which are independent of each other. For example, there is no link between plans, elevations and sections in 2D views, and any change in Plans will require all other views to be updated (Ramilo & Embi, 2014). On the other hand, BIM provide a platform for integrated information exchange through a single model. It reduces design errors and omissions with significant reduction in design time (Aibinu & Ventkatesh, 2014).

According to Arayici, et al (2012) BIM is not limited to three-dimensional graphical model; it possess the capability to exchange and reuse the information embedded in the graphical model. In addition, it has the potential to significantly reduce workloads, errors and overcome the challenges of collaboration in the construction industry of developing countries (Bui, et al., 2016). Technology of BIM facilitates collaboration working of project stakeholders through the use of 3D models between planning and design phases (Goedert & Meadati, 2008). The four – dimensional (4D) models refers to 3D models linked to a schedule and is used for interference analysis and space conflict identification (Arayici, et al., 2012). The five – dimensional (5D) model integrates a 3D drawing with time and cost estimates and could help in accelerating design process and ensuring that client's budget is not exceeded (Boon & Prigg, 2012; RICS, 2014). However, collaboration is essential if the potential benefits of BIM are to be realised as those involved in a project will need to contribute to and access the BIM model, and 3D Computer –aided design (CAD) software is intended to facilitate this (Gelder 2013). The process of collaborative working may include informal networks, alliances or partnering to full integration and can last for a fixed length of time or can form a permanent arrangement (Augenbroe, 2009; Eadie, et al., 2013; RICS, 2015). Baldwin, et al., (2009) said that effective collaborative working in service-based operations needs to bring together the four key resources of people, process, technology and data.

Kori & Kiviniemi (2015) examined the prospect of BIM adoption in Nigerian construction industry by focusing primarily on the Architectural practices in four major cities in Nigeria and found that most of the medium and large-scale firms are significantly catching up towards the BIM practice and that the level of technological workforce toward BIM and digital technology of large Architectural firms was found appreciable. Abubakar, et al., (2014) observed that there is lack of awareness of BIM technology among industry practitioners, and identified the potential barriers to BIM adoption as resistance to change, legal and contractual constraints, lack of integrated software for practitioners, lack of enabling environment and lack of trained professionals. These studies have not specifically addressed the issue of Critical Success Factors (CSFs) for BIM implementation in the country and some of the issues identified related to the level of awareness and potential barriers to BIM adoption in the Nigeria construction industry.

Accordingly, there is need to explore the CSFs for the implementation and adoption of BIM in the context of a developing economy such as Nigeria. Although several studies have been conducted on the Critical Success Factors (CSFs), which (Morlhon, et al., 2014) considered as elements that are seen as essential and that facilitates successful implementation of new systems in the construction industry. However, there is a noticeable dearth of research that focuses on CSFs for BIM implementation in construction industry so as to understand what the main CSFs of BIM implementation are. This research seeks to fill this gap in knowledge and the aim is to explore industry's practitioners' perception on the CSFs in the implementation and adoption of BIM in the context of Nigerian construction industry. This study has drawn from research projects carried out to identify CSFs in ICT adoption in construction (Gichoya, 2005; Ugwu & Kumaraswamy, 2007; Woo, 2007) with, the difference that, this research is applied to BIM implementation in a developing economy. The rationale for considering IT studies in addition to BIM related research is that BIM is considered as an extension of IT adoption in the construction industry (Anumba, et al., 2002; Augenbroe, 2009; Boon & Prigg, 2012). The specific objective of the study is to evaluate CSFs that could influence the implementation of BIM in the Nigerian construction industry.

Critical Success Factors

Studies that have been conducted on Critical Success Factors (CSFs) described it as elements that are seen as essential and that facilitate successful implementation of new systems (Morlhon, et al., 2014). According to Pinto & Slevin (1989) CSF can be defined as certain rules, executive procedures and environmental conditions which are felt to have an important impact on whether or not a project will succeed. Similarly, within the concept of risk assessment and management practices Chileshe & Kikwasi (2014) defined CSF as drivers or enablers for successful risk assessment and management practices. By way of clarification between drivers and enablers, Gichoya (2005) defined drivers as the factors that encourages or reinforce the successful implementation of IT project such as: vision and strategy; government support; external pressure and donor support; rising consumer expectations; technological changes; modernisation; and globalisation.

While enablers according to Gichoya (2005) are considered as the active elements present in society which helps overcome the potential barriers to ICT system implementation. Examples of this includes: effective project coordination and change management; and good practice. Therefore for the purpose of this study, CSFs is considered as drivers or enablers whose presence can cause success and their absence can cause failure in the implementation and adoption of Building Information Modeling in Nigerian construction industry.

Based on a case study of a Chinese company Woo (2007) examined the experiences of a manufacturing enterprise in enterprise resource planning (ERP) implementation. The study grouped the CSFs into four as follows: top management support; project team; process change; education and training and communication. Panuwatanich and Peansupap (2013) researched into factors affecting the current diffusion of BIM through a qualitative study of online professional network. The study found that the critical issues influencing the diffusion of BIM by the construction industry professionals include: the difficulty for organisations in adjusting traditional culture and workflow processes to accommodate the adoption of BIM; the misconception of BIM that led to user's disappointment and eventual abandonment of BIM; and the implementation of BIM for short term gains by industry stakeholders.

There are several CSFs identified from the various taxonomies of CSFs in literature. This paper aims to verify the identification of the 28 factors earlier identified by Ugwu and Kumaraswamy (2007) as CSFs to IT adoption in the construction industry of emerging economies. This is further explained in Table 1.

Table 1 Critical success factors for BIM adoption

Critical Success Factors	Explanation	Authors
Business process reengineering	This refers to the ways in which current business processes are reviewed and implemented to capture current workflows and ways of doing things in a BIM oriented manner.	(Ugwu & Kumaraswamy, 2007); (Morlhon, et al., 2014)
Standardization (product & process)	Introduction of standards and metadata to better handle information and to tend towards an industry wide paradigm about BIM use.	(Ugwu & Kumaraswamy, 2007); (Arayici, et al., 2012)
Stakeholders involvement	Stakeholders include: Client, Consultants, Contractors, Other participants in the supply chain that can be affected by BIM adoption	(Ugwu & Kumaraswamy, 2007)
Education and training	Education and training of industry practitioners and organization staff is one of the critical success factors for the successful BIM implementation.	(Woo, 2007) (Bui, et al., 2016)
Communication of BIM objectives	Education of the in-house team members on the use of the different tools that made up BIM and the rationale for adopting them to improve practices.	(Morlhon, et al., 2014) (Eadie, et al., 2013)
Top management support (Leadership)	Strong commitment from top management is crucial for successful the BIM implementation.	(Ugwu & Kumaraswamy, 2007); (Eadie, et al., 2013)
Cost of development	This refers to cost of software, cost of branded hardware, cost of infrastructure to support computerization and cost of support services by computer professionals in relation to earning capacity of organisations.	(Morlhon, et al., 2014); (Bui, et al., 2016)
Appropriate hardware technology	Availability of essential hardware necessary for wide adoption of BIM	(Ugwu & Kumaraswamy, 2007); (Panuwatanich & Peansupap, 2013)
Ease of use	Refers to the degree of ease with which a building information model can be perceived and used properly by any industry player for design, construction and maintenance of a construction project.	(Ugwu & Kumaraswamy, 2007); (Eastman, et al., 2011)
Appropriate software	Availability of Software that capture user's requirement for interoperability in BIM model environment is significant for BIM implementation	(Ugwu & Kumaraswamy, 2007); (Bui, et al., 2016)

Table 1 continued

Clear definition and understanding of users' requirements	There is need for end-user driven system development to ensure that user requirements are correctly captured. User needs would need to be simplified after they are presented with various available options, possibly with unbiased guidelines to help them towards realistic choices.	(Ugwu & Kumaraswamy, 2007); (Morlhon, et al., 2014)
End-user involvement	Awareness and education of the end-users in the development and capability of BIM adoption for information management at both industry and organization level.	(Ugwu & Kumaraswamy, 2007); (Bui, et al., 2016)
Change management at organisation level	This denotes the extent to which an organization has developed a documented methodology for changing its business processes.	(Ugwu & Kumaraswamy, 2007); (Morlhon, et al., 2014)
General perception of BIM as improving productivity	Perception of BIM as a tool for enhancing productivity by eenabling practitioners to effectively control schedule, budget and quality, and to reduce risks is key to wide adoption in the industry.	(Ugwu & Kumaraswamy, 2007)
Human resource consideration	The emphasis here is on human resource management. The most important issues here include corporate power and motivational strategies to create an enabling environment for the workforce to be committed to the organizational objectives in implementing ICT systems.	(Ugwu & Kumaraswamy, 2007)
Employee training needs and staff competence	Education and training of the internal members of the organization about information management practices and philosophy.	(Ugwu & Kumaraswamy, 2007).
Evolutionary Development	This refers to step by stem implementation. An evolutionary approach to technology uptake is essential.	(Ugwu, et al., 2006) (Ugwu & Kumaraswamy, 2007)
Return on investment	Anticipated return on investment by firms as a result of investing in BIM would have significant impacts in the decision to use BIM	(Ugwu & Kumaraswamy, 2007); (Bui, et al., 2016)
Standard platforms for integration & communication	Introduction of standards and metadata to promote interoperability for an industry wide paradigm about BIM use.	(Morlhon, et al., 2014); (Kori & Kiviniemi, 2015)
Interpersonal skills	A standardized interaction between practitioners at industry level and employee within organizations to share BIM knowledge and skills to other so as to create enabling working environment.	(Ugwu & Kumaraswamy, 2007); (Bui, et al., 2016).

Table 1 continued

Externalities	These include other industry participants in the construction supply chain such as small and medium enterprises that often have limited resources for investments and/or skill training in ICT, government policies, macro and micro-economic environments that impinge on revenue streams,	(Ugwu & Kumaraswamy, 2007)
Clear communication with staff (Trust and Openness)	Staffs need to be unbiased for the organizational change and willing to learned new technology	(Ugwu & Kumaraswamy, 2007); (Morlhon, et al., 2014);
BIM competence of in-house team	BIM evolution require changes in responsibility being allocated to a specific role (s) and, ultimately, will impact on the way projects are procured. Therefore, the individual competency requirements for the changing role of Project Model is significant for effective BIM uptake.	(Morlhon, et al., 2014) (Singh, et al., 2011)
Outsourcing	Adoption of BIM would require input from external sources, particularly consultants to provide operational guidelines, knowledge structures and skills necessary for BIM uptake at both industry and organization levels. outsourcing support services could be the best option for firms who do not have the resources to set-up in-house team	(Ugwu & Kumaraswamy, 2007); (Morlhon, et al., 2014); (Arayici, et al., 2009)
Company turn over	Turnover of companies will determine their capability for BIM uptake.	(Ugwu & Kumaraswamy, 2007); (Bui, et al., 2016)
Adoption of BIM by other project team members	Adoption of BIM by stakeholders and participants in the construction supply chain is critical to successful implementation at industry level. This will force electronic transfers of information and prohibit paper-based models for communicating design and construction information.	(Rogers, et al., 2015) (Bui, et al., 2016)
Industry culture	Cultural change is an important factor that will affect the success of BIM adoption because most of the end-users are already used to the traditional paper-based working. This means that BIM requires a transition from old ways of doing things, as well as a shift in technical mindset.	(Ugwu & Kumaraswamy, 2007)
Legal aspects	The legalities of the contribution to BIM model by various professionals will require much debates and discussion to ensure development of effective and contractually binding arrangement for dispute resolutions.	(Ugwu & Kumaraswamy, 2007); (Arayici, et al., 2012) (Bui, et al., 2016)

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RESEARCH METHOD

In order to identify the critical success factors for implementation and use of Building Information Modelling, a structured questionnaire survey to a target population of professionals which include: architects, engineers, quantity surveyors engaged in contracting firms, consulting firms, public and private clients' organisations. A sample target population was selected through snowballing, reference to the list of registered engineers with the Nigerian Society of Engineers, the Nigerian Institute of Architects and the Nigerian Institute of Quantity Surveyors, as well as list of registered contractors with clients' organisations. This is to ensure that a large number of individuals with BIM experienced are covered.

The validity of the questionnaire designed was tested in a pilot study of 5 industry practitioners and 2 senior academics. The questionnaire comprises of 5 questions on demographics of respondents, and contained 28 CSFs. Respondents were requested to rate the CSFs they perceived necessary for the implementation of BIM, on a five-point Likert-scale (1=strongly disagree, 2 = disagree, 3 = neutral, 4=agree, and 5 = strongly agree). A bi-media approach was adopted for the distribution of the questionnaire. This comprises of face to face administration and a web-based questionnaire survey. A total of 307 copies of questionnaire were emailed out of which 151 responded as shown in Table 2. The responses were received in the period between June 2015 to November 2016.

Table 2 Questionnaires Distribution and Responses

Professional background	No of questionnaire sent	Percentage to all questionnaires sent (%)	No of responses	Percentage of responses (%)
Architect	68	22.1	23	33.8
Engineer	89	29	41	46.1
Quantity Surveyor	107	34.9	78	72.3
Builder	43	14	9	20.9
Total	307	100	151	49.2

Analysis of Respondents Characteristics

Out of the total number sampled, 52% are Quantity Surveyors, 27% Engineers, 15% Architects and 6% Builders. About 55% are working in consulting organization, 33.8% in contracting organization and 11.3% client. In terms of professional qualification, 63.6% are Associate Members, while 29.8% are Fellows, the rest (3.3%) respectively are probationer and other qualifications. About 32% have practiced between 16-20 years, 23% between 11-15 years, 21% above 20 years, 15% below 5 years and 10% between 6-10 years. For number of employees by the various organizations, results show that 43 organizations employed between 11-30, 34 organizations employed <10 while 19 organizations respectively employed between 31-50,51-100 and 101-250. A total of 17 organizations employed more than 250. Again, results show that 58 organizations had between 11-50 million Naira as turnover annually, 28 organizations between 51-100 million Naira, 25 between 101- 250 million, 14 <1 million and 2 > 250 million.

DATA ANALYSIS AND KEY FINDINGS

In this section, the basic statistics (Mean and standard deviation) in Table 3 show that the mean value of the 28 items ranged from 4.5 to 2.8 while standard deviation ranged from 1.1 to 0.5. Item 4 (Education and training) recorded the highest mean of 4.5 while item 18 (Return on investment) had the lowest (2.8). That majority of the items in Table 2 have their mean scores ranging between 3 and 4 suggests that respondents perceived them as being moderately important and important to BIM adoption in Nigeria.

Table 3 Characteristics of CSFs for BIM adoption in Nigeria

Code	Key enablers of BIM	Mean	Std. Deviation
CSF1	Business process reengineering	3.8675	.93577
CSF2	Standardization (product & process)	4.3775	.67074
CSF3	Stakeholders involvement	4.3642	.68783
CSF4	Education and training	4.5232	.63071
CSF5	Communication of BIM objectives	4.3179	.78631
CSF6	Top management support (Leadership)	3.3444	1.12574
CSF7	Cost of development	4.5298	.67140
CSF8	Appropriate hardware technology	4.2914	.63864
CSF9	Ease of use	4.0861	.57666
CSF10	Appropriate software	3.1722	1.07556
CSF11	Clear definition and understanding of users' requirements	4.3907	.68287
CSF12	End-user involvement	4.1656	.82809
CSF13	Change management at organisation level	2.9007	1.29489
CSF14	General perception of BIM as improving productivity	2.8808	1.07658
CSF15	Human resource consideration (people dimension)	3.9007	.82264
CSF16	Employee training needs and staff competence	3.5232	1.10051
CSF17	Evolutionary Development (i.e step by step implementation	4.2450	.66299
CSF18	Return on investment	2.8609	1.11976
CSF19	Standard platforms for integration & communication	4.6026	.55473
CSF20	Interpersonal skills	4.0795	1.01668
CSF21	Externalities (Government ordinances, and Macro and micro-economic policies)	4.1589	.90254
CSF22	Clear communication with staff (Trust and Openess)	3.1126	.81276
CSF23	BIM competence of in-house team	3.0000	.90185
CSF24	Outsourcing (use of consultants)	3.2649	1.08137
CSF25	Company turn over	3.7881	1.21989
CSF26	Adoption of BIM by other project team members	4.1722	.99841

Table 3 continued

CSF27	Industry culture	4.0861	.92333
CSF28	Legal aspects	4.0795	.95585

Based on Likert Scale (1= Not important, 2 = Slightly important, 3= Moderately important, 4=Important, 5=Very Important)

BENCHMARK METRICS FOR RANKING THE ITEMS

Having examined the descriptive statistics of the items in Table 3, the main thrust of this section is to benchmark metrics for CSFs for BIM adoption in Nigeria. In analyzing the data, rankings obtained from the respondents about the key CSFs that they perceive could facilitate BIM adoption in Nigeria were used to develop a "BIM benchmark index" (BIM_{bi}). In calculating the $BIM_{bi,}$ all the numerical scores for the key enablers in Table 2 were transformed in SPSS to access their relative rankings as postulated by Love and Irani, 2004. Thus, the BIMbi was calculated using the formula:

$$BIM_{bi=} = \frac{\sum w}{AN}, (0 < BIMbi < 1)$$

Where,

W = weighting assigned to each item by the respondent, which ranged from 1 = Not important, 2 = Slightly important, 3= Moderately important, 4 = Important, 5 = Very Important

A = Is the highest rating which is 5 and

N = Total number of respondents.

Leaning upon this, the BIM bench mark index (BIM_{bi}) in Table 4 was calculated.

Table 4 Benchmark Metrics of Key Enablers for BIM Adoption in Nigeria

Code	Critical Success Factors	BIM_{bi}	Rank
CSF 19	Standard platforms for integration & communication	.92	1
CSF7	Cost of development	.91	2
CSF4	Education and training	.90	3
CSF2	Standardisation (product & process)	.88	4
CSF 11	Clear definition and understanding of users' requirements	.88	5
CSF3	Stakeholders involvement	.87	6
CSF5	Communication of BIM objectives	.86	7
CSF8	Appropriate hardware technology	.86	8
CSF17	Evolutionary Development (i.e step by step implementation	.85	9
CSF12	End-user involvement	.83	10
CSF21	Externalities (Government ordinances, and Macro and micro-economic policies)	.83	11
CSF 26	Adoption of BIM by other project team members	.83	12
CSF9	Ease of use	.82	13

Table 4 continued

CSF20	Interpersonal skills	.82	14
CSF27	Industry culture	.82	15
CSF28	Legal aspects	.82	16
CSF15	Human resource consideration (people dimension)	.78	17
CSF1	Business process reengineering	.77	18
CSF25	Company turn over	.76	19
CSF16	Employee training needs and staff competence	.70	20
CSF6	Top management support (Leadership)	.67	21
CSF24	Outsourcing (use of consultants)	.65	22
CSF10	Appropriate software	.63	23
CSF22	Clear communication with staff (Trust and Openess)	.62	24
CSF23	BIM competence of in-house team	.60	25
CSF13	Change management at organisation level	.58	26
CSF14	General perception of BIM as improving productivity	.58	27
CSF18	Return on investment	.57	28

Source: Analyses of Survey data

Based on the results in Table 4, the top 10 ranks in descending order are: Standard platforms for integration & communication (CSF19), Cost of development (CSF7), Education and Training (CSF4), Standardisation (product & process) (CSF2), Clear definition and understanding of users requirements (CSF11), Stakeholders involvement (CSF3), Communication of BIM objectives (CSF5), Appropriate hardware technology (CSF8), Evolutionary Development (i.e step by step implementation (CSF17) and End-user involvement (CSF12).

TURNOVER AND BIM ADOPTION

In this section, ANOVA test was conducted to see how the different turnover groupings rated the top 10 CSFs for BIM adoption. The pattern of rating for the top 10 key CSFs for BIM adoption based on turnover of firms was examined in this section. Results in Figures 1 to 10 would be the basis for discussion. For the item that ranked 1st (CSF 19), results show a progressive pattern in rating as turnover increases. Respondents from those firm whose turnover is above 250 million Naira recorded the highest mean score (5.0). What this result shows is that they see Standard platforms for integration & communication as very important factor for BIM adoption in Nigeria. For the item that ranked 2nd, the reverse was the case in terms of rating, as respondents from firms with high turnover recorded the least mean score. As could be seen, those from firms that their turnover is >250 million recorded the least score (3.0).

In view of this, it could be said that those from firms with high turnover perceived cost of development (CSF7) as being moderately important when talking about key enablers for BIM adoption. This is normal because they can afford to purchase any software or technology needed, hence the less importance attached to cost. However, for those firms with low turnover cost of development must be addressed to ensure smooth implementation of BIM. For the third in rank (CSF4), respondents from firms with turnover <1 million and >250 million Naira recorded the least mean score while those whose turnover ranged between 51- 100 million Naira scored the highest (4.82). In other words, they perceived Education and training (CSF4) as important for BIM adoption while those from firms with low and high turnover see it as being moderately important. The pattern of rating exhibited for the 4th factor in the rank is in increasing order with respondents from firms with large turnover recording the highest mean score (5.0). Going by this, it could be said that respondents from firms with large turnover view Standardisation (CSF2) as very important for BIM adoption. For the 6th rank (CSF3), the pattern of rating showed that those from firms with large turnover (>250 million) recorded the highest mean score (4.92) while those whose turnover ranged between 101-250 million Naira recorded the least (3.94). Again, respondents from firms with large turnover see stakeholders' involvement as important for BIM adoption.

Communication of BIM objectives (CSF5) the 7th in rank has its highest mean rating (4.80) from respondents in firms that their turnover ranged between 51-100 million Naira while those with large turnover (250 million and above) recorded the least (3.82). Looking at how respondents rated the 8th factor in the rank (CSF8), those from firms with large turnover recorded higher compared to others, which implies that appropriate hardware technology (CSF8) is seen by them as an important factor for BIM adoption. For evolutionary Development (i.e step by step implementation) CSF17 which ranked 9th, respondents from firms whose turnover ranged between 51-100 million Naira recorded the highest mean score (4.89) and a similar pattern exist for the 10th rank (CSF12) End-user involvement. In general, respondents from firms with large turnover recorded highest mean score in four (CSF19, CSF2, CSF3, CSF8) out of the top 10 key enablers of BIM adoption identified and lowest in three factors (CSF11, CSF5, CSF7).

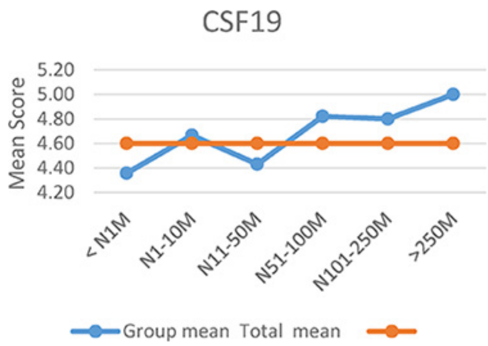

Figure 4 Company Turnover and CSF 19.

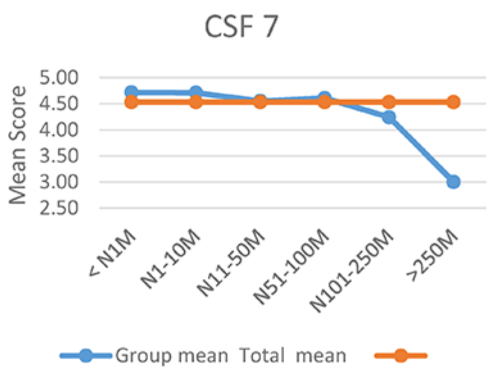

Figure 5 Company Turnover and CSF 7.

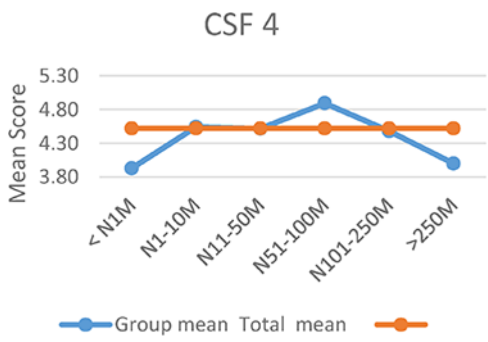

Figure 6 Company Turnover and CSF4.

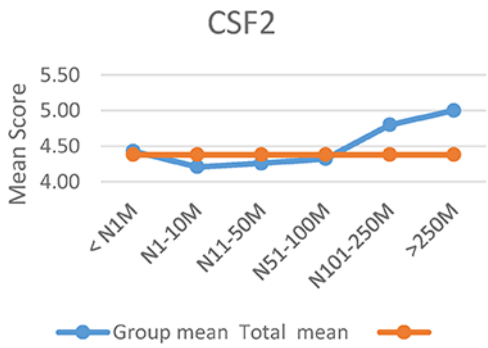

Figure7 Company Turnover and CSF2.

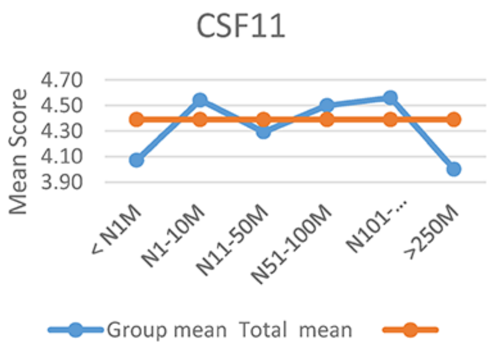

Figure 8 Company Turnover and CSF11.

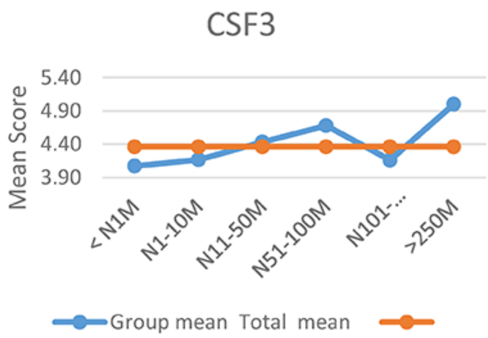

Figure 9 Company Turnover and CSF3.

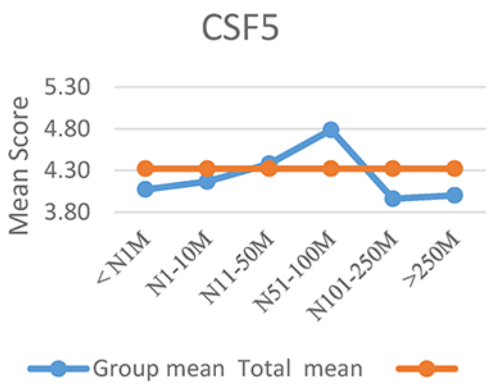

Figure 10 Company Turnover and CSF5.

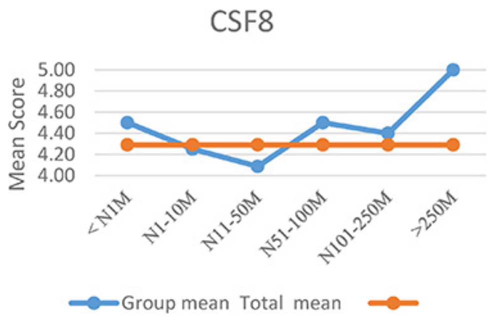

Figure 11 Company Turnover and CSF8.

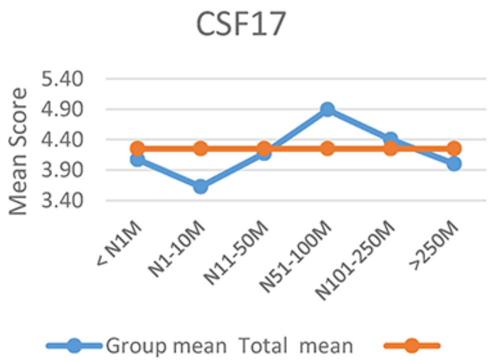

Figure 12 Company Turnover and CSF17.

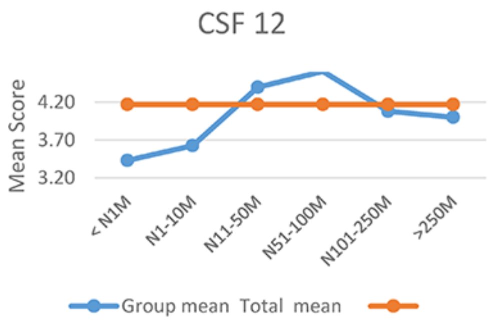

Figure 13 Company Turnover and CSF12.

Factor Analysis of the CSFs

Factor analysis was conducted on the 28 items. This is in line with Aksorn & Hadikusumo (2008) that suggested the need to group CSFs so as to reveal the important factors representing a wide variety of issues. However, Prior to conducting any statistical test, it is expected that the researcher should conduct a test to know whether the data in question is normally distributed or not. The strength of relationships among the factors were determined using the test of normality. The results of the normality test revealed that the data used for this study are normally distributed because the values obtained for both kurtosis and skewness, all the items (CF-CF28) meet the proposed level of -2 to +2. Results from the reliability test shows that all the items have Cronbach's alpha value > 0.7, thus confirming that they are reliable.

Factor analysis is employed to determine a relatively small number of factor groupings that can be used to represent relationships among sets of many interrelated variables (Li, et al., 2005). Five factors were extracted from the rotated component matrix as shown in Table 5. Since this is an exploratory factor analysis, naming of the factors was based on the researchers underlying knowledge of the phenomenon under study (Proverbs, et al., 1999). The discussion on the factor analysis is provided in the ensuing section.

Table 5 Extracted factors

	Rotated Component Matrix[a]					
CODE	ITEMS	Component				
		1	2	3	4	5
CSF1	Business process reengineering	.832				
CSF3	Stakeholders involvement	.765				
CSF4	Education and training	.819				
CSF5	Communication of BIM objectives	.773				
CSF6	Top management support (Leadership)			.702		
CSF7	Cost of development			-.793		
CSF9	Ease of use					.689
CSF10	Appropriate software		.734			
CSF11	Clear definition and understanding of users' requirements		.647			
CSF12	End-user involvement		.612			
CSF13	Change management at organisation level		.801			
CSF14	General perception of BIM as improving productivity			.818		
CSF15	Human resource consideration (people dimension)	.658				
CSF16	Employee training needs and staff competence			.526		
CSF18	Return on investment					-.729
CSF20	Interpersonal skills		.542			

Table 5 continued

CSF23	BIM competence of in-house team			.666		
CSF24	Outsourcing (use of consultants)				.814	
CSF25	Company turn over				.689	
CSF26	Adoption of BIM by other project team members	.773				
CSF27	Industry culture					.625
CSF28	Legal aspects				.605	

Extraction Method: Principal Component Analysis; Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 11 iterations.

DISCUSSION OF FACTOR ANALYSIS

Component 1(C1): Industry Stakeholders Commitment and Knowledge of BIM

Of great importance in factor analysis is that name given to any factor must be able to convey meaning of what the items that loaded in a factor represents both theoretically and practically. Against this backdrop, the First factor was named *Industry Stakeholders Commitment and Knowledge of BIM*. Six constructs loaded onto one factor. These constructs are shown in Table 6 (CSF1, CSF3, CSF4, CSF5, CSF15 and CSF 26). The first component, "C1" shows that industry stakeholders must be committed to the implementation of new innovative technology such as BIM. The factors under C1 indicates that particular attention must be paid to re-engineering the entire process of doing business in the construction industry to accommodate the evolution of transformative BIM technology. Thereby requiring education and training of the industry practitioners to understand how the technology works. This is in line with Lee & Sexton (2007) findings that education and training is still the most successful means of knowledge and technology gain for adoption of new technology. Similarly, BIM objectives must be communicated to users before it can be deployed routinely in the industry. These findings are in line with previous studies that government agencies in several countries like the UK, USA, Singapore and South Korea have already established plans for the Mandatory use of BIM for public projects (Arayici, et al., 2012; Eadie, et al., 2013; Gelder, 2013; Cao, et al., 2015).

Component 2 (C2): Capacity Building for Technology Adoption

The second factor was named (*Capacity Building for Technology Adoption*). Five constructs (CSF 10, CSF11, CSF 12, CSF13 and CSF 20) loaded in this factor. Capacity building is sine qua non for adoption of any new technology especially in the ICT industry. Capacity building in terms of using the appropriate software, understanding of end user requirements and other interpersonal skills. In order to encourage incremental use of BIM by industry practitioners, gap caused by non-availability of trained professionals to handle BIM tools and software availability and affordability must be addressed to ensure smooth implementation. The 5 constructs encapsulate the people and technology aspect of information technology adoption, it also highlighted change management at organisation level which is an integral part of innovation adoption in the construction industry (Lee & Sexton, 2007). This includes understanding of how to use appropriate software to meet the requirements of end-users in BIM model. Existing literature is replete with studies (Teo & Heng, 2007; Arayici, et al., 2012) that reported a strong correlation between capacity building and adoption of technology.

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Component 3 (C3): Organisational Support

Third factor (*Organisational Support*) has five items that loaded under it. The factors are: CSF6, CSF7, CSF14, CSF16 and CSF 23. What this suggests therefore is that the support received by the professionals in the building and construction from their various organization is very critical for BIM implementation in the country. The support could come from the management through employee trainings and investment in areas that could promote BIM adoption. Again, when the organization has the general perception that BIM adoption could enhance productivity and efficiency, more support is given to attain such goal. Gambatese & Hallowell (2011) considered that top management support was one of the most significant enablers of innovation implementation in construction firms. This factor is also in line with Ugwu, et al. (2006) standpoint that any construction organisations that create an enabling environment for their workforce through approriate management interventions are likely to implement successful IT and knowledge management.

Component 4 (C4): Collaborative Synergy Among Industry Professional

Fourth factor (*Collaborative Synergy Among Industry Professional*) has three items that loaded on it (CSF 24, CSF25 and CSF 28). To address the challenge of fragmentation in the construction industry, there is need for collaborative synergy among the industry professionals in areas that relate to legal aspects and outsourcing (use of consultants). This finding is also in line with previous studies such as Succar, (2009); Singh, et al., (2011); RICS, (2015) that pointed out that the higher the level of integration of team members at the early design stages of a construction project, the greater the opportunities to get maximum benefits from the use of BIM.

Component 5(C5): Cultural-Orientation

Lastly, the fifth factor (Cultural-Orientation). Similar to the fourth factor, three items loaded on the fifth factor (CSF9, CSF18 and CSF 27). Culture is a way of life of a people (i.e. the way people have been doing things in their traditional setting). Taking this to construction industry, professionals have been thought over the years to approach their work from their own perspective without taking into much consideration input of others. But in reality, this has created problems, as there is an overlap between one profession and the other throughout the lifecycle of construction projects. Humans are rigid in terms of adoption of new ideas they think is at variance with the old ways they have been doing things and this is one major problem militating against BIM adoption and must be overcome for successful BIM implementation

Conclusions

This study has presented results of a questionnaire survey with the main aim to identify critical success factors to BIM implementation in Nigeria, explore their rankings and underlying associations among the factors. As a means of determining significant CSFs in this study, 28 factors were identified through literature review and pilot studies. Questionnaire survey was adopted to administer the questionnaire to industry practitioners. BIM benchmark metrics was developed and used to rank the success factors and the topmost 5 success factors in order of significance are: standard platforms for integration and communication; cost of development; education and training; standardization (product and process); and clear definition and understanding of users' requirement. However, analysis of variance shows that significant differences exist in the pattern of rating for the 10 most important CSFs based on turnover of firms. For instance, firms with higher turnover (>250m) perceived cost of development as moderately important while firms with low turnover considered cost to be very important. The results obtained from factor analysis have shown that the items that loaded in each of the identified factors have high proportion of variance in common. This study has contributed towards understanding and stablishes relationships between key CSFs for BIM implementation in the construction industry of developing economies. Although this study was conducted in Nigeria, the results can be extrapolated to other developing countries since BIM maturity and adoption level in the construction industry of these countries are generally low. It is important for researchers and practitioners in these countries to also note that the critical success factors adopted for this study were obtained from previous studies on IT adoption in emerging economies. The rankings of the CSFs have practical implication as it provides basis for refining the most significant factors that industry stakeholders should focus attention for successful implementation of BIM.

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