Journal of Scientific Research & Reports
11(5): 1-10, 2016; Article no.JSRR.26563
ISSN: 2320-0227

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Factors Affecting the Adaptability of Building Information Modelling (BIM) for Construction Projects in Anambra State Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author FOE initiated the idea, designed, carried out data acquisition and compiled the first draft of the manuscript. Author PUO was responsible for supervising every stage of the research and proof reading while author EN carried out the data analysis. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2016/26563
Editor(s):
(1) Luigi dell'Olio, School of Civil Engineering, Channels and Ports, University of Cantabria, Cantabria, Spain.
Reviewers:
(1) Alcinia Zita Sampaio, Technical University of Lisbon, Portugal.
(2) Syed Shujaa Safdar Gardezi, Universiti Teknologi PETRONAS (UTP), Malaysia.
Complete Peer review History: http://www.sciencedomain.org/review-history/15767

Original Research Article

Received 23rd April 2016
Accepted 11th July 2016
Published 12th August 2016

ABSTRACT

Aim: This study examined the factors affecting the adaptability of Building Information Modelling by the building construction professionals in Anambra State Nigeria.
Study Design: It was a survey research where questionnaires were distributed to core professionals in the Building Construction Industry.
Place and Duration of the Study: The study was conducted in Anambra State, Nigeria for a period of 3 months.
Methodology: A total of 84 questionnaires were administered to the respondents whereas 56copies were completed, returned and found useful, thus, giving a response rate of 67%. Data garnered were analysed and presented using mean score, percentages, relative importance index (RII), bar charts and pie charts.
Results: The study found that the level of BIM awareness among building construction professionals in the study area was 93%. The study revealed that 54% of the BIM users in the

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study area are beginner and 23% are moderate users. Also, the study revealed that 69% of the construction professionals are not yet prepared to embrace BIM technologies in the study area.
Conclusion: The study concluded that the level of readiness of Building Construction Industry in the study area towards embracing BIM is still poor. Therefore, it was recommended that institutional framework should be strengthened such that it can drive BIM adoption process in a systematic and participatory manner. The study further recommended that proper capacity building of the construction professionals on BIM should be pursed religiously in the study area.

Keywords: BIM; BIM adaptation; building construction industry; building projects; construction professionals.

1. INTRODUCTION

Construction industry is a well-known latecomer to the adoption of innovations compared to other sectors [1,2]. However, in the wake of this information and digital revolution, construction industry is facing a paradigm shift in the use of technologies aiming to increase productivity, efficiency, value, quality and sustainability and to reduce lifecycle costs [3-6]. Accordingly, BIM has been described as the next paradigm shift in the industry since it has shown the tendency of salvaging the present difficulties being witness in the industry [7].

Building Information Model is primarily a three dimensional digital representation of a building as well as its intrinsic characteristics that contains information like architectural design model, construction model, schedule model (4D), cost model (5D), fabrication model and operation model, useful within the construction project industry whereas Building Information Modelling (BIM) is the process and practice of virtual design and construction throughout its lifecycle [8,9]. Alternatively, BIM Building Information Model could been seen as a collection of interlinked domain models, sharing all the necessary information for design, construction and maintenance of the building while Building Information Modelling is not just a digital model but a process of creating and applying it to the design, planning and execution of construction work [10,6]. Simply put, BIM is a process of developing Building Information Model. Generally, BIM is more than drawings - it is a data repository for building design, construction and maintenance information combined in one convenient model to be share with all the stakeholders. It is a technology as well as a process and can display the entire life cycle of a building project [11].

Furthermore, previous studies have proven that BIM could help to improve productivity of the construction sector by ensuring an effective communication and collaboration between all project stakeholders from inception to completion of building projects [3,6,8,11-13]. Also, [14,15] highlighted that BIM applications has grown tremendously, from a tool to design in three dimensions and use of components, to a tool that is used for model analysis, clash detection, product selection, and the whole project conceptualization.

BIM being a new technology in Nigeria construction industry and in particular Anambra state is expected to deliver many benefits to the industry. However, a range of factors militate its widespread implementation in study area. Based on this premise, this research attempts to examine the factors affecting the adaptability of Building Information Modelling by the Building Construction professionals in Anambra State Nigeria. Also, the study considered the level of awareness and readiness/ preparedness of the construction professionals as regards BIM and its adaptability.

2. LITERATURE REVIEW

2.1 BIM and Construction Industry

Traditionally, buildings design and documentation has been paper based. In some cases, paper based documentation and communication often lacks the basis for collaboration and clear visualization of design. Thus, resulting to poor documentation, information mismanagement, design errors, estimate deficiencies, conflicts between design and construction and fragmented platforms which limit information flow throughout project lifecycle [5]. Therefore, [16] suggested that these problems could be solved with information and communication techniques/technologies. One of these ICT tools is BIM. Applying BIM to construction projects brings about improvement in communication between construction players, facilitates faster design decision, reduced time spent in design as well as decrease cost and duration of construction [10]. In addition, BIM can streamline business and project processes, improve site management, including complete facilitation of construction knowledge throughout building project lifecycle [6].

2.2 BIM Tools

BIM tools have been introduced in many types and functions. Some of these BIM software developer according to [17,18,16,8] are Naviswork, Tekla, Bentley, Autodesk and Vico. These BIM tools, including their developer and basic functions are illustrated in Table 1.

The selection of these tools according to [16] is based on four (4) features: Communication reliability, accuracy, usability and reliability of data exchange. However, [18] suggested that once a program has been selected, it is important to ensure that it is used correctly. The drawback in current BIM systems is the lack of integration between them. Thus, if BIM is to be used on a project, all stakeholders in that project need to invest in that chosen system and this, often, is not cost effective [18].

2.3 Factors Affecting the Use of BIM in Construction

The introduction and adoption of any new technology such as BIM usually requires that the factors which may affect its adoption by the relevant stakeholders be identified and addressed for the successful take up of the innovations and subsequent benefits to be derived thereof [5]. On this note, lots of researches have been conducted by different researchers and at different locations. These researches have established many factors affecting BIM adoption. However, the factors peculiar to the developing countries are:

2.3.1 Structure/culture of the industry

Adoption of BIM entails an entire shift in practice both in term of technology and culture. As observed by [3] cultural transformation poses more challenge than technology because culture is a product of many years and cannot change overnight. Since, construction sector in Nigeria has developed prior to the era of digital evolution; its adoption will change most construction practices [12]. On the other hand, top management support has been recognised as an important variable in innovation implementation [19]. When they are enlightened, it becomes easier for the firm to innovate. Hence, for any organisation to change its culture requires taking a bold step and such marks a turning point for that organisation to adopt BIM [19].

2.3.2 Level of knowledge and awareness index

Zahrizanetal [19] opined that one of the reasons why BIM is not popular in construction sector is the low level of awareness and knowledge of BIM among practitioners. Apparently, occasioned a situation where most construction practitioners don’t see how BIM benefit them [19]. Authors such as [16,20-22] have also identified lack of knowledge as one of the key impediment to BIM adoption in their respective countries.

Accordingly, [2] observed that presently BIM is well developed only in North America and Western Europe with Asia-Pacific growing fast. In United States of America and Europe for instance, RICS [23] observed that over 70% and 36% of the construction projects uses BIM respectively. Whereas, in Middle East, Asia and Africa the level of awareness of BIM is gradually improving but the extent of application is still poor. In Middle East, RICS [23] observed that about 80% construction practitioners are aware of BIM technology but only 25% projects are executed using BIM. In Iran, [7] observed that 29.5% of construction companies are involved in some level of BIM adoption; whereas 56.8% have had no exposure to BIM and 36.4% even do not have any plans to adopt BIM in the near future. [17] observed that 67% of construction practitioners in Nigeria were aware of BIM but none have used it. Although, [3] disagreed with [17] on the area of utilization by observing that most of the medium and larger scale firm in Nigeria are significantly catching up towards BIM practices and the level of adaption to BIM and digital technology at large are appreciable. Based on this, [2] observed that the few BIM applications in the developing countries were designed and developed by the western because; most of the construction professionals lack the capacity to work in BIM modes and platforms.

2.3.3 Availability of the appropriate technology and infrastructure

Appropriate infrastructure and technology augment the other factors affecting the adaptation of BIM technologies. If the structure/culture of a firm is flexible enough to accommodate changes without appropriate technology such changes will end up as utopia [19]. Meanwhile, [19] detected that unavailability of an appropriate infrastructure and technology is the major impediment towards adoption of BIM in the developing countries. Even when they are available, they tend to be expensive to install [18]. Hence, first time users of these technologies may feel a negative impact on their profitability at the initial time due to a new investment in technology and learning curve that comes with it [8].

2.3.4 Individual/personal disposition

Personnel's attitude toward new technology implementation shapes the extent of risks one could take when adjusting to a new technology [21]. So, most construction practitioners particularly in the developing countries have continued to nurse some fears as regards the use of BIM. Because, most, sees it as 'disruptive technology' that causes problems in the current construction processes [19]. Thus, changing working condition becomes a major barrier to the use BIM [19].

2.3.5 Presence of standards/guidelines

Without rules and guidelines, it's very difficult to achieve any meaningful changes. Therefore, [5,19,20] observed lack of Government support for the adoption of BIM, legal backing and national standard/implementation guideline are some of the major factors affecting the use of BIM. Hence, individuals develop guidelines without proper guidance from the expert. Consequently, the Level of Development/Details (LOD) varied from one organisation to another.

2.3.6 Business environment

The array of technologies available to today's designer or constructor creates process possibilities that far exceed norms of practice and well-understood business protocols [1]. Also, the inherent integration of design data in a model-based design-to-build process eliminates numerous potential conflicts, but addresses none of the underlying lack of basic business process integration. Without such integration, the processes themselves, supporting tools and data will fail to properly mature; because they lack clearly delineated work flow and data interactions [1]. Ironically, Nigeria construction industry business environment involves lots of paper-based protocols and often fragmented. This provides clear lines of business process that are now blurred by fluid digital information.

Amidst such process improvement potentials through BIM exists challenges in the form of resistance to change from entrenched business practices and fragmentation of the industry [22]. Based on this, [7] identified the most high ranked barriers to adoption of BIM are structure of the market, the nature of the construction industry, business environment, lack of attention by policy makers and the government.

2.3.7 Compatibility between software platforms

One of the biggest issues with early adaptors of BIM is the issue of inter-product compatibility. This interoperability issue is not limited to different software platforms; due to the rapid development of the BIM software industry, newer versions of programmes within the same platform can have interoperability issues and this is causing heartburn among industry players [24].

2.3.8 Cost

The use of BIM requires more initial investment cost such as staff time spent, hardware and software investment, cost for training with new cost in management and administration processes [25]. Also on the list of these initial capital outlays according to [26] are cost for updating software, hardware and the training of staff. Hence, [27] opined that cost of software and required hardware upgrade are considered significant. Furthermore, [28] studied Challenges for Implementation of Building Information Modelling (BIM) in Malaysian Construction Industry and observed that the main challenges facing the use of BIM in Malaysia are caused by factors which are driven by cost, market trends and organizational behaviours. Accordingly, [26] stressed that the implementation of new technologies is costly in terms of changing the work flows and processes. Therefore, most service providers are not willing to make such investment unless they perceive long term benefits to their own organization and/or if the owner subsidizes the training costs [26].

Table 1. BIM tools

Product name	Developer	Primary Function
Cadpipe HVAC	AEC Design Group	3D HVAC Modeling
Revit Architecture	Autodesk	Architectural Modelling and parametric design.
AutoCAD Architecture	Autodesk	Architectural Modelling and parametric design.
Revit Structure	Autodesk	Structural Modeling and parametric design.
Revit MEP, AutoCAD MEP	Autodesk	MEP Modeling
AutoCAD MEP	Autodesk	3D MEP Modeling
CADPIPE Commercial Pipe	AEC Design	Fabrication
DProfiler	Beck Technology	Conceptual 3D modeling with cost estimating and life cycle operational costs forecasting.
Bentley BIM Suite - Includes MicroStation, Bentley Architecture, Bentley Structural, Bentley Building Mechanical Systems, Bentley Building Electrical Systems, Bentley Building Electrical Systems for AutoCAD, Generative Design and Generative Components	Bentley Systems	Architectural, Structural, Mechanical, Electrical, and Generative Components Modeling – all within the 3D modelling environment
Fastrak	CSC (UK)	3D Structural Modeling
SDS/2	Design Data	3D Structural Modeling and Detailing
Fabrication for ACAD MEP	East Coast CAD/CAM	MEP detailed Modelling for Fabrication
Digital Project	Gehry Technologies	Digital Project Designer is a high- performance 3D modeling tool for architectural design, engineering, and construction. Designer provides an extensive set of tools for creating and managing building information throughout the building lifecycle.
Digital Project Designer	Gehry Technologies	CATIA based BIM System for Architectural, Design, Engineering and Construction Modeling
Digital Project MEP System Routing	Gehry Technologies	MEP Design
ArchiCAD	Graphisoft	Architectural Model Creation
MEP Modeler	Graphisoft	3D MEP Modeling
HydraCAD	Hydratec	3D Fire Sprinkler Design and Modeling
AutoSPRINK VR	M.E.P. CAD	3D Fire Sprinkler Design and Modeling
AutoSPRINK VR	M.E.P. CAD	3D Fire Sprinkler Design and Modeling
FireCad	Mc4 Software	Fire Piping Network Design and Modeling
CAD-Duct	Micro Application Package Ltd	3D Detailed MEP Modeling for Fabrication
Vectorworks	Nemetschek	3D Architectural Modeling
Duct Designer 3D, PipeDesigner 3D	QuickPen International	3D MEP Detailed Modeling
RISA	RISA Technologies	Full suite of analysis tools for steel, wood, concrete and masonry
Tekla Structures	Tekla	A Structural 3D Model Application
Affinity	Trelligence	A 3D Model Application for early concept design
Vico Office	Vico Software	5D Conceptual Model which can be used to generate cost and schedule data
Site Design, Site Planning	Eagle Point	Site Development

Adapted: [17]

3. METHODOLOGY

The population of this study constitutes the registered professionals particularly Architects, Builders, Structural Engineers and Quantity Surveyor in Anambra State Nigeria. Population of the registered professional obtained from the various secretariats of these professional bodies in the state is presented in Table 2. Therefore, the population of this study is 105.

Table 2. Population distribution

S/No	Professionals	Population size	Sample size
1	Architect	15	12
2	Builder	34	27
3	Quantity surveyor	25	20
4	Structural engineer	32	25
	Total	105	84

Source: Field survey, (2015)

Taro Yamani sample size method was employed to determine the appropriate sample size in this study.

Taro's formula is represented as:

$$i.e.\ n = \frac{N}{1+N(e)2}$$

Where "n" is the sample size, "N" is the population (103) and " e " is the level of confidence (i.e. 95%).
Thus, the sample size

$$n = \frac{105}{1 + 105\,(0.05)2} = 84$$

Data were collected through structured questionnaire administered to the selected professional. In addition, few interviews were conducted with some professionals to substantiate the validity of the result of this study (See Table 3 for questionnaire distributions and percentage returned).

Being a descriptive research, tables, line –chart, mean and histogram were used for data presentation. However, Relative Important Index (RII) was used for ranking and computed using:

RII =∑Fx/A*N

Where:

∑Fx = Weight given to each statement by respondents and ranges 1 – 5
A = Higher Response Integer
N = Total Number of Respondents

Table 3. Distribution of questionnaire and percentage response

Questionnaires	Frequency	Percentage (%)
Number of questionnaires returned	56	67.0
Number of questionnaires not returned	28	33..0
Total	**84**	**100**

Source: Field Survey (April, 2016)

4. RESULTS AND DISCUSSION

Fig. 1, revealed that 93% of the surveyed respondents are computer literate whereas 7% of the respondents are not computer literate. From the earlier research on BIM in the study area, it was observed that computer literacy level among construction stakeholder has appreciated from 68% observed by [29] to 93% observed by this study. Therefore, this entails that the construction sectors in the study area is gradually departing from analogy to digital.

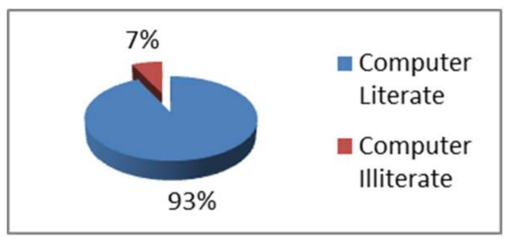

Fig. 1. Computer literacy status
Source: Field Survey (April, 2016)

Fig. 2 revealed that 54% of the respondents use 2D CAD only, 12% uses 3D CAD only and 20% and 14% for 2D and 3D CAD and No CAD respectively. According to [23, 24] 3D CAD is described as a starting point on the BIM journey. Based on this, figure 2 revealed that the number of 3D users in the study area is relatively low. When compared to India, for instances RICS [23] observed that 57% of the respondents uses 3D and 8.6% don't use CAD. Therefore, about 69% of the professionals are not ready to embrace BIM.

Table 4 revealed about 93% of the respondents are aware of the technology and 7% are not. In 2015 [17], observed that the level of awareness of BIM in the study area was 67%.

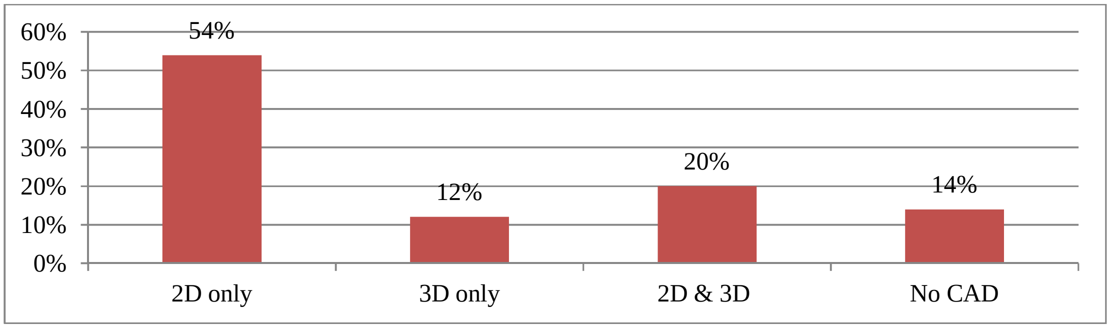

Fig. 2. Level of CAD usage by professional

Source: Field Survey (April, 2016)

Table 4, also revealed that 43% of the stakeholders that are aware of the BIM are not considering of using at the moment, whereas, 36% and 14% currently using it and actively using it respectively. The value for the category of the respondents that are not considering of using the BIM tool is also in agreement with the result of research work conducted in India [24]. Thus, this shows that most of the construction stakeholders are getting informed as regard BIM Technology.

Table 4. level of BIM awareness and utilization

BIM usage	Response in frequency	Response in percentage
Aware but not considering using it	24	43%
Aware and currently using it	20	36%
Aware and actively using it	8	14%
Not Aware	4	7%
Total	**56**	**100%**

Source: Field Survey (April, 2016)

Table 5 revealed that 54% of the respondents are beginners on the use BIM tools whereas 23% of the respondents are moderate users. None of the respondents belong to the category of Advanced and experts users; while 23% of the respondents don't belong to any category. This result strongly suggests the need for capacity building of the building construction professionals in the area.

Table 6 ranked the factors affecting the use of BIM technology in the study area. From the result it was observed that the compatibility between software platforms with a RII of 0.81 ranked first, closely followed by the Level of Knowledge and Awareness index with RII of 0.77. Structure/culture of the industry, Availability of the appropriate Technology and Infrastructure, Individual/Personal Disposition, Presence of Standards/Guidelines and Business Environment ranked 3rd, 4th, 5th, 6th and 7th respectively. Considering the RII values of the variables examined shows that the factors examined significantly affect the adaptability of BIM technology by the construction professionals in the study area.

Table 5. Respondents category of BIM usage

BIM usage	Response in frequency	Response in percentage
Beginners	28.00	50.00
Moderate user	12.00	23.00
Advanced user	-	-
Expert user	-	-
None	12.00	23.00
Total	**52.00**	**100.00**

Source: Field Survey (April, 2016)

The response in Table 7, indicates that Education and training programme (0.87) ranked first among the measures for improving BIM adaptability; closely followed by Incorporation of BIM to academic curriculum (0.85) and Enactment of BIM guideline and regulation (0.82). Also table 7 revealed that setting up BIM council/association (0.69) and BIM should be made compulsory for all procurement processes and contracts (0.71) ranked least. This implies that setting BIM committee/taskforce and making it mandatory for all procurement processes is not the key issue here rather proper capacity building through education, training, inclusion of BIM into the discipline academic curricula and provision of adequate infrastructure and technology will help salvage the present predicament.

Table 6. Respondents' perception on the factors affecting BIM usage

Factors	Frequency of occurrence				(∑F)	∑Fx	Mean	RII	Ranking
	1	2	3	4					
Structure/culture of the industry	00	17	15	20	52	159	3.06	0.76	3rd
Level of Knowledge and Awareness index	06	04	22	20	52	160	3.08	0.77	2nd
Availability of the appropriate Technology and Infrastructure	02	16	17	17	52	153	2.94	0.74	4th
Individual/Personal Disposition	05	13	18	16	52	149	2.87	0.72	6th
Presence of Standards/Guidelines	07	11	14	20	52	151	2.90	0.73	6th
Business Environment	19	03	18	12	52	127	2.44	0.61	8th
Compatibility between software platforms	04	00	28	20	52	168	3.23	0.81	1st
Cost of technology and its implementation	02	16	17	17	52	153	2.94	0.74	4th

1=Strongly Disagree, 2= Disagree, 3: Agree and 4= Strongly Agree, RII= Relative Importance Index

Source: Field Survey (April, 2016)

Table 7. Respondents' perception on the measures for improving BIM usage

Measures	Frequencies of occurrence				(∑F)	∑Fx	Mean	RII	Ranking
	1	2	3	4					
Setting up BIM council/ association	15	7	06	24	52	143	2.75	0.69	6th
Enactment of BIM guideline and regulation	00	08	22	22	52	170	3.27	0.82	3rd
Incorporation of BIM to academic curriculum	08	00	08	36	52	176	3.38	0.85	2nd
Education and training programme	04	00	16	32	52	180	3.46	0.87	1st
Provision of appropriate technology and infrastructure.	08	00	24	20	52	160	3.08	0.77	4th
BIM should be made compulsory for all procurement processes and contracts	05	12	22	13	52	147	2.83	0.71	5th

1= Strongly Disagree, 2= Disagree, 3: Agree and 4= Strongly Agree, RII= Relative Importance Index

Source: Field Survey (April, 2016)

5. CONCLUSION AND RECOMMENDATIONS

BIM has the potential to provide significant benefits to the Nigerian built environment sector. Considering the high volume of real estate and infrastructure construction activity Nigeria is witnessing; BIM, if deployed appropriately, can provide significant savings; enhance the quality of the built environment that gets delivered and allow the industry to make expected contributions to the growth of the country.

Hence, this study examined the application of BIM in Nigeria construction industry and in particular Anambra State and found that computer literacy status of construction professionals in the study area have appreciated same as the level of BIM awareness among construction professionals. Despite, this improvement, the level of readiness of construction professions to embracing BIM is still very poor.

The study, observed that compatibility between software platforms, level of knowledge and awareness, structure/culture of the industry, non-availability of the appropriate technology and infrastructure, cost of implementation, individual/personal disposition and lack of BIM standards/ guidelines are the reasons why most BIM potential remains untapped in the study area.

From the foregoing therefore, it is recommended that institutional framework for BIM should be established and strengthen to formulate and implement BIM policies, guidelines and standards in the study area. Adequate capacity building of the construction professionals should be pursed religiously through training, seminar, workshop and continuous professionals development programme by the various professional bodies regulating built environment indiscipline in the study area. Also, BIM should be infused into academic curricula of the built environment profession in the study area. Finally, BIM developers should ensure that each of BIM technologies could work in common data environment that will aid ease of data exchange among the technologies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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