Upgrading from the use of 2D CAD systems to BIM technologies in the construction industry: consequences and merits

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Abstract- *The highly competitive and tight market in the construction industry has compelled contracting firms to sort ways of improving work productivity and meeting project owners' expectations. The use of building information modeling (BIM) is to improve the quality characteristics of construction outputs and create potential impact in the industry. Most developing countries are propagating for the use of BIM in project implementation but the existing procurement routes have restrained easy transformation to BIM technologies. The paper investigates the impact of upgrading from 2D CAD to BIM technologies in the Nigerian construction industry. The study adopts quantitative survey with a total number of 418 valid responses for the analysis. The findings reveal a high level of awareness of BIM technologies and a very slow level of BIM skills acquisition. The most critical challenges confronting the upgrade are identified as lack of clarity on legal and contractual issues, unsuitable framework for adopting BIM and inadequate knowledge/training. The most important benefits of BIM usage are identified as improved collaboration among parties, reduction in re-work and effective procurement strategy. The paper recommends the need to incorporate the knowledge of BIM in the university teaching syllabus for students and continuing education courses for practitioners. The government agencies, associations and researchers should also enforce the practice through standards and policies.*

Keywords — *Building information modeling (BIM), 2 dimensional computer-aided design (2D CAD), Nigerian construction industry and architecture, engineering and construction (AEC).*Introduction

I. INTRODUCTION

The nature of construction industry is changing and it is driven by commoditisation of construction services, this might eventually drive some contractors out of business while others who survived the change will master and remodel the system (FMI, 2012). The highly competitive and tight market has forced some contracting firms to diversify their construction services to provide better opportunities for them to have competitive edge over others. This has led to acquiring of different mixes of skills, capabilities and technical specialities to meet the global demands from project owners. The construction industry has contributed massively in providing social requirements as well as economic growth globally but regardless of these, the industry is still faced with several challenges relating to economic, regulatory and environmental issues (Azis *et al.,* 2012). Most developed and developing countries have since initiated several agencies at various levels of socio-economic development to facilitate continuous improvement in the construction industry. This has contributed to improved performance, but in most cases there is a need for comprehensive review of the state of the construction industry and the culture of the project environment in order to effectively restructure the industry (Ofori, 2012).

Most developing countries still operate their construction activities based on the traditional procurement arrangement inherited from the Western countries (Ofori, 2012). The use of traditional procurement route has remained predominant in the Nigerian construction industry than other integrated routes. Dada (2012) identified the major factors contributing to the use of traditional procurement route as technical issues, administrative matters and personality issues. Regardless of these, traditional procurement route has created a high level of fragmentation resulting in project delays and cost overrun. Public awareness of environmental issues has increased the demand for sustainable construction in Nigeria which focuses not only on tradition design but environmental, economic and social effects of a building project as a whole. Sustainable construction has paved way for progressive improvements through increased project efficiency, reduced construction waste, energy saving, it provides enabling platform for adoption of new technologies such as lean, BIM and many others (Azis *et al.,* 2012). Project owners are demanding for more project visibility at lower cost and better risk management and this has increased the demand for new technologies in project implementations. There is a global call for the use of building information modeling (BIM) and green technologies to improve the quality characteristics of the construction industry's outputs and create potential impact on the industry. Therefore, avoiding the concept of change in the construction sector can be naïve and extremely dangerous for any organisation's continuing existence (FMI, 2012).

The introduction of BIM is a dramatic step forward from 2D CAD which is a technology used for design and construction to a new collaborative workflow of intelligent objects such as 3D models, unstructured and structured data as well as scheduling and cost information using 4D and 5D (Boutwell, 2008). The paper assesses the impact of upgrading from 2D CAD to BIM technologies in the Nigerian construction industry. To achieve this aim, the following objectives are considered: a) identifying the possible challenges confronting BIM technologies transfer and b) evaluating consequences and merits of such transfer in the Nigerian construction sector.

II. LITERATURE REVIEW

A. *The introduction of BIM technologies into AEC projects*

Since the 21st century, the need for project improvements and efficiency through the application of information technology to meet the increasing challenge of knowledge sharing has remained paramount to the architecture, engineering and construction (AEC) sector. This necessities the introduction of diverse set of technological tools and resources to manage information sharing in the sector which are categorised as information communication technologies (ICTs). Ikediashi and Ogwueleka (2015) defines ICTs as tools implanted in networks and services to aid the flow of construction information data during the whole life of a construction project. The concept of information islands has remained a major challenge in construction projects where the existing management systems have restrained the sharing of information on the building life cycle and also cooperation among the contracting parties (Liu *et al.*, 2011). In order to improve the effective flow of information data, two aspects of construction informatisation was introduced namely: a) digitalisation of engineering design, construction and management process and b) interface the communication process amongst contracting parties (Liu *et al.*, 2011). From the earliest documentations, construction industry practitioners and academia have sought for ways to communicate ideas, concepts and actions through graphical illustrations (from prehistoric drawings to drafting standards). The drafting standards of 2D illustrations was introduced in 20th century consisting of two dimensions of individual views on a paper work (Cory, 2001). The concept of 2D illustrations was regarded as more accurate and descriptive type of engineering graphic, although it is confronted with several challenges such as difficult to visualise, required interpretation and limited usage (Cory, 2001). The quest for digitalisation of technologies led to the introduction of computer-aided design (CAD) to 2D graphics to improve the productivity of engineers and drafters in the mid 1960 (which was officially commercialised in 1969) (Weisberg, 2008).

The introduction of 2D CAD has created an incredible step in work productivity and processes but it is limited to one aspect of construction informatisation which is digitalisation. The purpose of managing the entire lifecycle of a construction project through the sharing of digital information among the stakeholders led to the formation of BIM technology which is based on virtual architectural design. The concept of BIM technology was first proposed by Professor Chuck Eastman in 1970 (Eastman *et al.*, 2008). In the mid-year of 2000, BIM technology was formally adopted in the AEC projects and the United States of America was the first country to embrace it (Latiffi *et al.*, 2013). The concept of BIM was explained as "a digital representation of physical and functional characteristics of a facility. It is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition" (CSQ, 2014, citing The National BIM Standard Project Committee). The digitalisation process of BIM provides three dimensional illustration of the entire building lifecycle from inception and design to demolition and materials re-use. This creates an opportunity for project team members to detect and fix conflicts before inception and also provides functional and operational guides to project owners on how to manage the facility, demolish after use and re-use of materials.

B. *Simulation of BIM technologies in both developed and developing countries*

The need to implement BIM technologies is driven by the increasing demands and complexities of modern design projects. BIM technology has been vigorously promoted in the USA construction industry with an increase of 75 percent utilisation rate in the last two years where one-third of construction firms adopt the technology in more than 60 percent of their projects (Peng and Ruan, 2014). Other countries such as UK, Australia, Netherlands, Singapore, Finland, Norway, Germany and many others have responded rapidly to the use of BIM technology in the construction industry, this has created digital revolution through combined efforts of people, process and technology in project environment (Wong *et al.*, 2010; Isikdag and Underwood, 2010; Nederveen *et al.*, 2010; Sebastain and Berlo, 2011). The effective implementation of BIM technology has been restricted by improper training/education and unsuitable framework to regulate the work process involving various participants, this might result in the liability risk of infringing third part intellectual property rights (Elhag and Al-Sharifi, 2014). Arayici et al. (2012) investigated on how BIM technology was effectively introduced in a UK-based construction company where the contracting parties were remote from each other. Initially, 2D drawings of the proposed construction projects were already produced

and BIM models with associated plans, sections and elevations were later developed. For effective transition to the implementation of BIM models, the company staff and stakeholders were trained on four aspects which are basic operation skills, modeling standards, methodology of model construction and work relationship with other parties. The study identified the merits of sematic information of building objects through BIM application as: a) effective information sharing and re-use amongst the parties, b) consistency and accuracy for procuring site material at the right time, c) effective design and technical review of projects, and d) efficiency in quality, cost and time management practice.

The use of BIM technology in Australia and New Zealand has dramatically increased project efficiency and affordability amongst the large AEC firms with one third of them fully participated in its implementation while 51 percent adopt BIM in more than 30 percent of their projects (AECOM, 2014). Barriers associated with BIM implementation were identified as: a) industry culture, b) liability amongst stakeholders, c) lack of clarity on individual roles and responsibilities, and d) inadequate knowledge and training (Alabdulqader *et al.,* 2013). The perceived benefits were identified as: a) cost and time saving, b) reduction in re-work and c) improved collaboration (Alabdulqader *et al.,* 2013). The implementation of BIM technologies has not being well utilised in Germany when compared to other developed countries and this has been attributed to the fine granular organisational structure of the AEC market (Both and Kindsvater, 2012). Notwithstanding, several steps have been taken for effective implementation of BIM technologies in Germany as well as the publication of BIM guideline in 2004 (see ARGE BIM-Leitfaden AEC3 & OPB, 2013). Common barriers to BIM implementation were identified as technological issues and education (Both and Kindsvater, 2012).

The study conducted by Liu *et al*. (2011) identified the challenges confronting BIM application in China as: a) difficulty in adapting to change, b) fragmented construction processes, c) non-compliance of the foreign software to domestic standards, d) unwillingness of project owners to adopt BIM technology, e) undefined application risks, and f) demarcation of legal responsibilities amongst contracting parties. The study further emphasises that despite these challenges, the BIM application has provided more accurate cost evaluation, easy access and proper coordination of building information, relevant information for building usage and its application in 4D has improved construction quality. Khemlani (2012) reported on the implementation of BIM technology in India which is still a developing country. The case study organisation was familiar with the use of AutoCAD but the transition to BIM technology faced several challenges. Such challenges are: a) skepticism regarding the ability to deliver smoothly; b) timelines in usage; c) ability to address design issues and d) achieving the desired quality of output. To address these challenges, a BIM consultant was employed to develop the first model project while training sessions were conducted to bridge the learning gaps. The organisation has achieved several merits from BIM application such as: a) easier visualisation and efficiency with 50 to 60 views taken to develop the initial design; b) repetitive tasks like multiple sectioning take less time and are more accurate; c) increased accuracy and speed of BOQ computation and d) designs with complex geometrics have especially benefitted from improved integrity of information flows and workflows in general. The highest barrier to the implementation of BIM was identified as high cost of software.

Nigeria is the biggest economic powerhouse in Africa with great expectation of construction boom but the use of advanced technology in the construction industry has not witnessed much significant improvement as compared to the anticipated growth rate in the industry. The construction industry is labour-intensive where most stakeholders are not willing to invest in advanced technology due to relative cheaper cost of labour. Cultural change is identified as an important factor to consider when implementing BIM technology (Lane, 2011). This provides the need to assess the impact of BIM implementation based on cultural and project environmental settings. The literature survey reveals numerous challenges and merits associated with BIM implementation in both developed and developing countries and these measures were compiled for investigation in the Nigerian construction industry.

III. RESEARCH METHODOLOGY

A. Questionnaire design

The paper investigates the impact of upgrading from 2D CAD to BIM technologies in the Nigerian construction industry. To achieve this aim, the study adopted both quantitative approach in data collection where the survey was carried out using questionnaires which was found effective because of the relative ease of obtaining standard data required. A questionnaire survey was used to gather information needed from respondents in order to assess the key objectives of the study. Based on the challenges and benefits of BIM technologies identified in the literature review, a draft questionnaire was prepared and shown to professional experts and academics in the field. Amendments were made on the drafted questionnaire based on the suggestions of the reviewers.

B. Characteristics of respondents

The targeted study population comprises project participants who have participated in the execution of both commercial and public infrastructure projects in the three major cities in Nigeria, namely: Abuja, Lagos and Port Harcourt. Abuja is the Federal capital territory of Nigeria and it is regarded as the most populous city in Nigeria with highest record of construction activities and where most multinational companies have their headquarters as well as construction associations and outfits. Lagos is the former capital of Nigeria which is regarded as the economic hub of the nation while Port Harcourt is the second largest commercial city in Nigeria where most oil multinationals have their operating bases. The accessible population includes registered consultants and construction companies operating in the three selected cities. The numerous and unclassified databases prompted the use of non-probability sampling first to identify the sample population and second, the stratified probability was adopted to select the respondents of sample size from the sample frame. Neuman (2006) emphasises that choosing a large sample size alone does not guarantee a representative sample. Saunders *et al.* (2009) further stipulate that in choosing a sample size, there are three factors to be considered which are: a) the level of certainty that the characteristics of data collected will represent the characteristics of the total population; b) the margin of error that can be tolerated; c) the type of analysis to be used; and d) the size of the population. Based on these recommendations and Yamane's formula (1967), a total number of 1240 construction professionals were selected for the study. Respondents were drawn from consultants/advisors/designers that are registered members of Council of Registered Builders of Nigeria (CORBON), Architects Registration Council of Nigeria (ARCON), Quantity Surveyors Registration Board of Nigeria (QSRBN) and Council of Registered Engineers of Nigeria (COREN) and registered construction companies who operate in building and civil engineering sector (grades A to C with FMW&H). The survey was carried out from mid-January to April 2015; a total number of 418 valid responses were computed for the data analysis with a response rate of 33 per cent. Waris *et al.* (2014, citing Dulami et al., 2003) emphasise that the response rates of postal survey in the construction industry are usually within the ranges of 20 to 30 per cent. Thus, the response rate of this survey is good enough to make meaningful analysis and interpretations.

C. Measures

Part one of the questionnaire focused on demographic information of respondents, part two assessed the level of awareness of BIM technologies in the construction industry. Part three investigated the possible challenges and benefits of BIM technologies in the Nigerian construction industry. Respondents were asked to rank their responses in part three using a 5-Likert scale of 1-completely disagree; 2-partially disagree; 3-neither agree nor disagree; 4-partially agree; 5-completely agree.

IV. DATA ANALYSIS AND INTERPRETATION

The demographic data of respondents (part one) and part two were analysed using descriptive statistic such as frequency count and percentage. Table 1 reveals that 46 percent of the respondents were from consulting firms while 54 percent were from construction companies, the result shows that each profession is well-represented. Majority of the respondents have 21 to 30 years of work experience while 88 percent have above 10 years of work experience. Respondents in managerial positions represent 25 percent, 21 percent of respondents are in middle management positions while 54 percent are in operational positions. The collected data for part three were analysed using relative importance index of items' rating for each group of respondents (consultancy firms and construction companies) to reveal the perceptions of each group. Relative importance index (RII) for each group is computed using this formula:

$$RII = \frac{\sum w}{AN} \quad (1)$$

Where w represents the weighting allocated to each factor by respondents, which ranges from 1 to 5, A is the highest weight (5 for this study), and N is the total number of respondents.

Table 1: Demographic data of respondents

Demographic information	F	P	CP
Organisation type			
Consulting firms	192	46	46
Construction companies	226	54	100
	418	**100**	
Profession			
Architects	94	22	22
Project/construction managers	89	21	43
Engineers	137	33	76
Surveyors	98	24	100
	418	**100**	
Work experience			
1 to 10 years	50	12	12
11 to 20 years	108	26	38
21 to 30 years	168	40	78
Above 30	92	22	100
	418	**100**	
Job description			
Managerial position	104	25	25
Middle management	88	21	46

position			
Operational (skilled/unskilled)	226	54	100
	418	**100**	

F=frequency; P=percentage; CP=cumulative percentage

A. *Awareness of BIM technologies amongst construction professionals*

To explore the level of awareness of BIM in the construction industry, the respondents were asked to indicate their knowledge the use of BIM technologies. Table 2 reveals 5 per cent of respondents have no idea of BIM, 42 per cent have basic understanding of BIM technologies, 50 per cent have formal understanding of BIM technology and its application, and 3 per cent have formal training on its usage. This implies that majority of the respondents (95%) are aware of BIM technologies even though 3 per cent have formal training on the usage.

Table 2: What is the degree of your knowledge on BIM applications?

BIM application	Total score	Percentage
No idea	20	5
Basic understanding of BIM	178	42
Formal understanding of BIM technology and its application	207	50
Formal training on its usage	13	3

B. *Implementation of BIM technologies in the Nigerian construction industry*

The paper investigated into the possible challenges and prospects of upgrading from 2D CAD to BIM technologies in the Nigerian construction industry. Table 3 reveals the RII scores for each group and the total scores of all groups. From the analysis, respondents from the construction companies agreed that the most critical challenge confronting the upgrading to BIM technologies is "inadequate knowledge and training". "Lack of clarity on legal and contractual issues" is ranked as the most critical challenge confronting the upgrading to BIM technologies by respondents from consulting firms. The weighted average RIIs for all groups reveal that "lack of clarity on legal and contractual issues" (RII = 0.908), "unsuitable framework for adopting BIM" (RII = 0.893) and "inadequate knowledge and training" (RII = 0.881) are the three most critical challenges confronting the upgrading to BIM technologies. Reliability analysis reveals the Cronbach's alpha of 0.84 (N of items = 12) for all groups, this indicates a high level of internal consistency for the scale with the sample.

RII scores for each group and all groups in relation to the prospects of BIM application in the Nigerian construction industry are presented in Table 4. The analysis reveals that "improved collaboration among contracting parties" (RII = 0.938) is rated as the highest benefits of BIM usage by respondents from both construction companies and consulting firms. The second rated benefit by all groups is "reduction in re-work" (RII = 0.894) while "improved visualisation and space management" (RII = 0.876) is rated as the third highest benefit. Reliability analysis reveals the Cronbach's alpha of 0.76 (N of items = 11) for all groups, this indicates a high level of internal consistency for the scale with the sample.

V. DISCUSSIONS

The Nigerian construction industry is dominant with the use of different software tools in project implementation. Two-dimensional CAD design software programs are commonly used by architects and engineering consultants to produce drawings to convey the building information to clients and contractors. There are several software tools used by different professions in the Nigerian construction sector to carry on their work activities such as PDMS 12.0 & 11.6, Primavera P6, AutoCAD, Staad Pro, Aspen HYSYS 7.0 and Orion 15 & 16. These programs do not promote integration of information among the parties and this might result in misinterpretations and disputes. Even though they do have their advantages, information stored in a conventional drawing may lead to redundancy and create confusion in interpretation (Masood et al., 2014). The use of BIM enables a master model to be produced where all stakeholders can retrieve and generate information to streamline project life cycle processes (Ding et al., 2014).

The results reveal that a high level of awareness of BIM technologies in the Nigerian construction industry with a rating of 95 per cent while 3 per cent of the respondents have formal training on BIM usage. This implies that BIM is not a new concept in the industry therefore upgrading from 2 CAD to BIM can be easily actualised. In order to ascertain how to effectively implement BIM, the paper further investigated the possible challenges and benefits of BIM usage. The most critical challenge of upgrading is identified as "lack of clarity on legal and contractual issues", most respondents agreed that legal obligations in the existing contract documents will be difficult to support the legal implications of working with BIM. The novel issues that can cause legal consequences are contractual relationship among parties, model management/relationships, intellectual property rights/data management, liability of errors or omissions, and owner of the work process (Udom, 2012). Therefore it is required to tackle the novel

issues in a contractual agreement to achieve efficiency in the BIM work process.

The second most critical challenge is identified as "unsuitable framework for adopting BIM", most respondents agreed that the use of framework in BIM work process will promote easy integration of parties and improve labour productivity. The nature of the Nigerian construction industry is characterised as labour intensive where informal sector are predominant in the industry. The concept of integration may be difficult to achieve within this sector because most project team members rely on purpose-built models. Commercial and public sectors are more formalised but they are also faced with challenges in relation to contract-splitting, poor budgeting and corruption. These cultural problems can be resolved through developing a strategy that can bridge the gap of cultural transformation by integrating the existing method into the BIM work process. This will allow for easy simulation of knowledge by encouraging the participation of project team members throughout the transformation process. "Inadequate knowledge and training" is rated as the third most critical challenge; this is similar with the study conducted by Alabdulqader et al. (2013) where it was identified as a major barrier to adopting BIM in the Australian AEC industry. Panuwatwanich et al. (2013 citing Azhar et al., 2008) emphasise that employees with formal education in BIM are considered more advantageous in the construction industry over those who lack such knowledge.

"Improved collaboration among contracting parties", "reduction re-work" and "effective procurement strategy" are rated as the three most important benefits of BIM application in the industry. Traditional procurement strategy has remained the most predominant route for procuring construction projects in Nigeria; this has created remoteness of project team members resulting in misinterpretations and re-works. Most respondents believed that the use of BIM technologies can resolve these challenges associated with the existing traditional procurement strategy thereby promoting best practice among the stakeholders. The paper further propose a framework for adopting BIM in the Nigerian construction industry with the view to aid easy transformation and resolve the identified challenges in the BIM work process (see figure 1).

VI. CONCLUSIONS

Upgrading from 2 CAD to BIM wouldn't be easy in the Nigerian construction industry, organisational culture has a significant role to play in upgrading and this may require a gradual process of integrating the existing method into the BIM models. The proposed framework provides a systematic process which will enable effective integration and transfer of BIM knowledge within a project cycle. This allows for project team members to be actively involved in the transformation process where BIM skills can be easily acquired within a project cycle. The process offers the opportunity to incorporate the national building standards into BIM models and the legal responsibilities of all team members are stipulated in a contract document.

Risks of using BIM are far outweighed by its benefits therefore proper understanding of its application can promote its efficiency. This provides the need to incorporate BIM in the University teaching syllabus to equip students on the concepts and skills required and also develop continuing education courses of BIM to transfer such knowledge to industry practitioners. The paper recommends the need for the Federal government of Nigeria, construction and building associations/agencies and researchers to enforce policies and standards to promote BIM implementation within the construction sector.

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Table 3: Possible challenges confronting the adoption of BIM technologies.

Possible challenges	**Construction companies**		**Consulting firms**		**All groups**	
	RII	R	RII	R	RII	R
Inadequate knowledge and training	0.874	1	0.888	3	0.881	3
Lack of clarity on legal and contractual issues	0.871	2	0.945	1	0.908	1
The industry is not clear about BIM	0.543	12	0.765	10	0.654	11
Poor change management	0.852	4	0.855	5	0.854	4
Undefined risks in usage	0.745	9	0.774	9	0.760	7
Unsuitable framework for adopting BIM	0.862	3	0.923	2	0.893	2
Non-compliance with domestic standards	0.766	8	0.722	12	0.744	9
Inappropriate knowledge about BIM by stakeholders	0.798	6	0.834	6	0.816	5
High cost of software	0.811	5	0.808	7	0.810	6
Skepticism regarding the efficiency of BIM technology	0.678	11	0.755	11	0.717	10
Lack of incentive or requirement to adopt BIM	0.721	10	0.794	8	0.758	8
Data protection issues	0.755	7	0.876	4	0.816	5

Table 4: Prospects of BIM applications in the construction sector.

Benefits of BIM usage	**Construction companies**		**Consulting firms**		**All groups**	
	RII	R	RII	R	RII	R
Increased accuracy in BOQ computation	0.765	8	0.875	5	0.820	7
Improve visualization and space management	0.844	4	0.908	3	0.876	3
Effective procurement strategy	0.874	3	0.855	7	0.865	4
Cost saving/accurate cost evaluation	0.825	5	0.828	8	0.827	6
Effective building information sharing and re-use	0.745	9	0.921	2	0.833	5
Reduction in re-work	0.889	2	0.898	4	0.894	2
Effective design and technical review of projects	0.722	10	0.867	6	0.795	9
Time saving	0.809	6	0.805	9	0.807	8
Improved collaboration among contracting parties	0.942	1	0.934	1	0.938	1
Effective conflict management	0.718	11	0.765	11	0.742	11
Improved construction quality	0.789	7	0.799	10	0.794	10

Figure 1: Proposed framework for adopting BIM technology in the Nigerian construction industry