ASSESSMENT OF THE ADOPTION OF BUILDING INFORMATION MODELLING (BIM) IN THE NIGERIAN CONSTRUCTION INDUSTRY

Timothy Bamidele MONEJO[1] and Joseph Kolawole MAKINDE[2]

[1, 2] Dept of Project Management, Federal University of Technology Minna

ABSTRACT

Despite the use of BIM being an indicator of the maturity of a nation's construction industry as well as conferring several benefits on project stakeholders, researchers have noted that awareness of BIM among Nigerian construction professionals is low. This study aimed to assess the adoption of BIM on projects carried out by construction firms in the Nigerian Construction Industry (NCI). The study adopted a quantitative research design that was based the use of questionnaires. A convenience sample of relevant professionals in construction firms who could be accessed through an online survey was built up through a snowballing approach, which eventually yielded a total of 52 professionals. The data gathered from this sample through a questionnaire survey was analysed using descriptive statistical method (Mean Item Score and Standard Deviation) and the results were presented using tables and charts. The study found that BIM awareness and acceptance are at a medium level; only 'AutoCAD' BIM software enjoyed a 'High' frequency of use in the NCI. BIM adoption had a noticeable impact in four reviewed aspects of project performance; 'Greater control', 'Improved collaboration', 'Conflict resolution', and 'Reduction in labour'. The study concluded that BIM use in the NCI is still at a rudimentary level, although great potential for improvement exists, if the right environment (political, legislative, contractual, and technical) is provided. It was recommended that the Federal and State governments should devise an Implementation Strategy Plan for BIM; in addition, Clients could subsidise BIM costs through Preliminaries items on high-value construction contracts.

Keywords: adoption, Building Information Modelling, construction, technology.

INTRODUCTION

The construction industry is one of the major industries contributing significantly to national economies, in terms of GDP. Despite this fact, the industry is not maximising its full potentials. This has been attributed to some factors, among which is the fragmented process of design, procurement, construction, and project delivery (Khalfan and Anumba, 2000). The construction industry in Nigeria grapples with the challenges in form of time overrun, cost overrun, high level waste, high labour cost, variations/claims, inadequate control of the construction process, lack of seamless collaboration between agents, conflicts and clashes, as well as high level of errors and risks (Manza, 2016). Yusuf *et al*. (2015) cited the works of other authors that revealed that BIM has the potential to significantly change and improve performance and documentation in the construction industry. It is expected that the use of BIM will achieve decreased project costs, increased productivity and quality and reduced project delivery time.

Building Information Modelling (BIM) is a modern building delivery technology which is embraced by the construction industry globally (Yusuf, Ali & Embi, 2015). Internationally, the building industry is transforming rapidly with the introduction of BIM (Onungwa & Uduma-Olugu, 2016). BIM is a digital model full of information for the purpose of construction and management of the project throughout its life cycle (Yusuf *et al*., 2015); in fact, it is a digital representation of physical and functional characteristics of a facility (Building SMART, 2010).

Quite a number of studies on BIM in the Nigerian construction sector have been attempted; some of these studies focused on areas such as BIM and life cycle of the project (Onungwa & Uduma-Olugu, 2017), BIM and adoption factors for construction industry in Nigeria, (Mohammad *et al*, 2018), contractors' perception of BIM implementation in Nigeria (Abubakar, Ibrahim, Kado & Bala, 2014). This research is about relating the adoption of BIM to the effects it has on the Nigerian construction industry (NCI). The specific objectives are to (i) ascertain the level of BIM adoption in the Nigeria Construction Industry, and (ii) determine the effect of BIM level of adoption on the management of construction projects.

LITERATURE REVIEW

Building Information Modelling (BIM)

According to Autodesk, the developer of various Building Information Modelling (BIM) tools, "BIM (Building Information Modelling) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure" (Autodesk, 2017).

Building Information Modelling (BIM) is an innovative approach in architectural, engineering and construction industry as a modelling technology which encompasses AEC digital data throughout the construction life cycle (Mohammed *et al.*, 2018). Building information Modelling (BIM) is one of such innovative processes that is already bringing about continuous improvement and desired change in the construction industry by revolutionizing operational processes to achieve better collaboration between project parties. BIM stimulates the construction activities in a virtual environment. With BIM technology, an accurate virtual model of a building known as Building Information Model is digitally constructed and used to support the design, procurement, fabrication and physical site construction activities required to realize the structure (Abubakar *et al*., 2014).

BIM has also been described as the digital representation of the physical and functional characteristics of a facility, which serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle from inception onward (Building SMART, 2010). According to Ibrahim and Abdullahi, (2016), BIM is the most recent technological innovation developed to support designs, construction and operation of building and engineering projects in a virtual environment using intelligent objects. With BIM, both 2D and 3D drawings can be created as by-products of its design process. Design views can automatically be generated from single foundational database; and all other form of analysis such as clash detection, constructability analysis and more, can be undertaken in a BIM environment.

Globally, BIM has already existed for more than twenty years (Hadzaman, Roshana, & Nawawi, 2015). Many developed economies of the world have recorded impressive outcomes by implementing BIM in their construction practices (Abubakar *et al*., 2014). The idea of BIM was led by the United States (Smith, 2014). United Kingdom (Waterhouse and Philip, 2016); Norway, Finland and Denmark (Smith, 2014), are other leaders in BIM adoption and implementation.

There are so many professional BIM softwares available in the market today complying with all digital delivery requirements. Some of the BIM softwares are listed below:

Table 1: Some BIM software and their uses

BIM Software	Description of software
ARCHICAD	Architectural BIM CAD software that offers computer aided solutions for handling all common aspects of aesthetics and engineering during the whole design process of the built environment.
Vector works	2D drafting, 3D modelling, BIM and have rendering capabilities. A design software that delivers a flexible and collaborative design process to architecture, landscaping and entertainment professionals
Autodesk Revit	Revit is BIM software offering a multi – disciplinary and collaborative approach to design and construction projects. Revit empowers the AEC practitioners to produce a consistent, coordinated, and complete model – based designs for buildings and infrastructure
Navisworks	3D design review that combine design and construction data into a single model. Identify and resolve clash and interference problems before construction.
Sketch up	Premier 3D modelling computer programme for a wide range of drawing application
Allplan	3D BIM design and detailing software for precasters, rebar retailers and civil and structural engineers.
Others include	BricsCAD, Autodesk Ecotect Analysis, Microstation, Archibus, Green Building, Bentley Systems

Sources: Vectorworks.net, (2017); Autodesk.com, (2017)

The Levels of BIM

According to McPartland, (2014), the government of UK has recognised that the process of moving the construction industry to "full collaborative working" will be progressive, with distinct and recognisable milestones being defined within that process, in the form of "levels". They have been defined within the range from 0 – 3, and whilst there is some debate about the exact meaning of each level, the broad concept is as follows:

Level 0: describes unmanaged CAD (Computer Aided Design). This is likely to be 2D, with information being shared by traditional paper drawings, or in some instances, digitally via PDF, essentially separate sources of information covering basic asset information (bimblus.co.uk). Level 0 in its simplest form means no collaboration. 2D CAD drafting only is utilised, mainly for production information (RIBA Plan of Work, 2013 stage 4). Output and distribution is via paper and electronic prints, or a mixture of both. Majority of the industry is already well ahead of this now (Waterhouse, 2017).

Level 1: Involves managed CAD in 2D or 3D, it is a mix of 2D and 3D information using BS 1192 with a collaboration tool providing a Common Data Environment (CDE), (Mordue, 2019). BIM level 1 typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and production information (McPartland, 2014). CAD standards are managed to BS 1192:2007 and electronic sharing of data is carried out from a CDE often managed by the contractor.

Level 2: The concept of BIM levels and BIM level 2 compliance has become the accepted definition of what criteria are required to be deemed BIM-compliant, by seeing the adoption process as the next steps in a journey that has taken the industry from the drawing board to the computer and ultimately into the digital age (McPartland, 2014). This involves developing building information in a collaborative 3D environment with data attached, but created in separate descriptive models. (bim-level2.org, 2020) provides a one stop – shop access to the level 2 standards including PAS 1192. It is distinguished by collaborative working and requires an information exchange process which is specific to that project and coordinated between various systems and project participants.

Any CAD software that each party uses must be capable of exporting to one of the common files formats such as Industry Foundation Class (IFC) or COBie (Construction Operations Building Information Exchange). This is the method of working that has been set as a minimum target by the UK government for all work on public sector work. BIM level 2 involve a series of domain and collaborative federated model. The models consisting of both 3D geometrical and non – graphical data, are prepared by different parties during the project life cycle within the context of a common data environment. Using proprietary information exchanges between various systems, project participants will have the means necessary to provide defined and validated outputs via digital transactions in a structured and reusable form (bim-level2.org, 2020).

Level 3: Has yet to be defined in detail, but it is thought that it will include a single, collaborative, online, project model including construction sequencing, cost and management information. The latest Government Construction Strategy (GCS) by the UK government published in March, 2016 seeks to embed BIM level 2 across departments which will in turn enable departments to gradually move to BIM level 3 (bimplus.co.uk, 2020).

BIM Adoption and Implementation

BIM advancement in the Middle East is on the rise (Gerges *et al*., 2017). United States has recorded the most significant development in construction digitalization, Australia, United Kingdom and some other developed nations are also amongst promoters of BIM process and its development. Recently, developing countries like China and Malaysia are keying into the industry's digital shift, while very little move is seen in South Africa whose development is considered higher and perhaps leader in the digital transition amongst the African countries (Hamma – Adama & Kouieder, 2018). Countries have been adopting BIM at different levels and with different purposes, having different experiences (in benefits), depending on adoption level and possibly their challenges earlier to the adoption. According to Kori & Kiviniemi, (2015), countries like Finland, USA, UK, Australia, Netherlands, Singapore, Hong Kong Norway, Denmark among others have adopted BIM technologies and have experienced significant benefits in construction project delivery (Yan & Damian, 2008; Isikdag & Underwood, 2010; Nederveen *et al*, 2010; Sebastian & Berlo, 2010).

Despite the potentials and documented benefits, not much has been reported regarding its implementation in the Nigerian AEC industry. BIM concept can be traced mostly in Architectural practices than engineering practices in Nigeria. A superficial BIM practice is found to be at organizational level only and operating a model based - "BIM Level 1" (Abubakar *et al*., 2014).

BIM Benefits and Barriers

Some of the benefits of BIM technologies as claimed by its proponents are the provision of an efficient communication and data exchange system (Nederveen *et al.*, 2010), auto quantification, improved collaboration, coordination of construction documents, improved visualisation of design (Olatunji *et al*., 2010; Sacks et al., 2010), clash detection and cost reduction (Eastman *et al*., 2011) among others. Okereke, Chukwujindu and Emenike (2019) list the various benefits that can be derived from using BIM to include: better coordination, synchronization and sequencing of projects, and allowing all project participants to access and interrogate project information. At an advanced level, BIM enables better clash detection, ability to visualize what is to be built in a simulated environment, higher reliability of expected field conditions, allowing for opportunity to do more prefabrication of materials off site. The building design development can continue with the provision of automatic bills of material and generation of automatic shop drawings for everything from structural steel to sheet metal duct fabrication, to fire protection and piping fabrication, to electrical cabling and bus duct layouts. Some of the barriers to adoption of BIM in the construction industry in Nigeria are presented in Table 2.

Table 2: Barriers to adoption of BIM

Process Barriers	**Technology Barriers**
High cost of Training expenses and the learning curve are too expensive	Lack of trained professionals to handle the tools
Social and habitual resistance to change	Lack of BIM experts
Legal and contractual constraints	High Maintenance costs
Lack of enabling environment (Government policies and legislations)	High Cost of integrated software/models for all professionals
Clients not requesting the use of BIM on projects	Poor internet connectivity
No proof of financial benefits	frequent power failure
Lack of standards to guide implementation	
lack of awareness of the technology among industry	

Sources: Ahmed and Houque, (2018); Abubakar *et al.*, (2014); Ibrahim and Abdullahi (2016)

METHODOLOGY

This study adopted a questionnaire survey research design approach. A structured questionnaire was designed in three sections, using Likert-scale response options. Data was collected through a convenience sampling of the professionals in the construction firms in some states who were accessed remotely through electronic means. A total of 52 professionals were sampled. The study was limited to construction professionals who perform project design/supervision/management roles on building projects. It is believed that they have adequate knowledge about the state of BIM in building construction practice in Nigeria and can answer the questions of this study.

The questionnaire data was analysed using descriptive statistical method (Mean Item Score and Standard Deviation), which allowed the ranking of awareness, adoption and effects of BIM in building projects. A 5-item Likert scale was used to obtain perceptions of BIM adoption from respondents, from which Mean Item Scores (MIS) were computed. These MIS were then used to rank the different aspects of BIM adoption. For adoption of any aspect of BIM to be considered ‘high’, it must have an MIS of 3.50 – 4.49; to be considered ‘very high’, the MIS value must lie between 4.50 and 5.00. All of the results of these analyses were presented in tables.

RESULTS AND DISCUSSION

Results of Demographic Analysis of Respondents

Quantity surveyors were the most numerous of the professionals sampled, comprising 56% of the sample. Other major subgroups of professionals included architects (19% of the sample), builders (7%), engineers (6%) and project managers (4%). The implications of the spread of the professions of respondents in this study include the probability of the views of quantity surveyors dominating that of other professionals. It also shows that key professions in the actual building construction process were covered in the survey. This result is presented in Figure 1. The second pie-chart which is labelled Figure 2 provided information relating to the extent of experience acquired by the respondents. There were no respondents who had worked for less than 2 years; those who had worked for between 2 and 5 years comprised 29% of the sample. A further 40% of the sample had worked for between 5 and 10 years; respondents who had acquired between 10 and 15 years experience made up 21% of the sample. Very experienced professionals, possessing more than 15 years of work experience, comprised 8% of the sample. From these results it was apparent that the respondents were professionals who had worked sufficiently enough to have experienced the use of BIM if it had been adopted in the organizations.

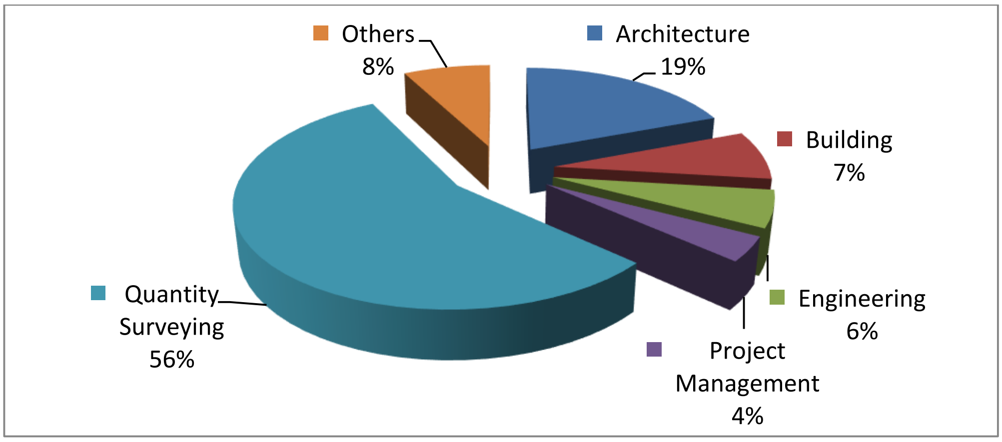

Figure 1: Respondents' professional area

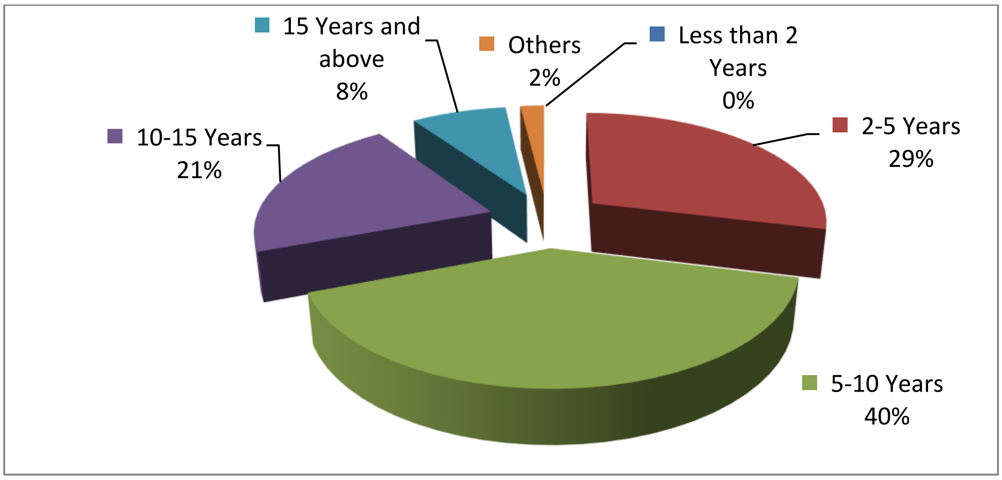

Figure 2: Respondents' years of experience

General level of BIM in the Nigeria Construction Industry

Level of BIM

The results of the analysis as presented in Table 3 revealed that within the sampled professionals in the NCI, BIM awareness and acceptance are at medium levels; this was inferred from Mean Score values of 3.10 and 2.70, which lay within the 'Medium' range (2.50 to 3.49). BIM adoption, implementation and investing in BIM are however at low levels, given observed Mean Score values ranging from 2.08 to 2.38. This implies that a lot still has to be done in the areas of awareness and acceptance, in order to improve the uptake of BIM technology. This needs to be done before efforts can be directed towards improving the adoption, implementation and investing in BIM. These results align with those of Hamma-Adama and Kouieder (2018) that very little movement in BIM matters is visible in Africa.

Table 3: Level of BIM

Level of BIM	Mean Score	SD	Rank	BIM Level
Awareness	3.10	1.52	1	Medium
Acceptance	2.70	1.52	2	Medium
Adoption	2.38	1.43	3	Low
Implementation	2.30	1.53	4	Low
Investing in BIM	2.08	1.52	5	Low

BIM software package(s) most commonly used

The use of BIM software packages was examined in this subsection. A total of seven different BIM software packages were examined in terms of frequency of use. Respondents opined that only one package, AutoCAD, was most commonly used, being subject to a 'High' frequency of use. Software packages that could be described as having a 'Medium' frequency of usage included Revit and ArchiCAD. SketchUp, another package was found to be of 'Low' frequency of use. Based on the results presented in Table 4, the most commonly used BIM software packages in the NCI, in order of use, are AutoCAD, Revit and ArchiCAD. In the UK, 41% of professionals in the construction industry use Autodesk Revit, while 14% AutoCAD (National BIM report, 2017).

Table 4: Frequency of use of BIM software packages

BIM software package(s) used	Mean Score	SD	Rank	Remark
Revit	2.73	1.73	2	Medium
AutoCad	3.83	1.23	1	High
Sketchup	1.95	1.66	4	Low
ArchiCad	2.67	1.76	3	Medium
Bentley	0.84	1.22	8	Very low
Tekla structure	0.97	1.46	7	Very low
Navis Works	1.30	1.54	6	Very low

Knowledge of the various levels of BIM

With respect to the knowledge possessed by respondents regarding the four levels of BIM, the results obtained showed that respondents had a 'Medium' level of knowledge about BIM level 0 and BIM level 1 (see Table 5). The corresponding level of knowledge for BIM level 2 and BIM level 3 was 'Low'. This agrees with the position by Kori and Kiviniemi (2015) that the NCI is still mostly at BIM Level 1.

Table 5: Respondents' knowledge of the various levels of BIM

knowledge of BIM levels	Mean Score	SD	Rank	Remark
BIM Level 0	2.75	1.42	1	Medium
BIM Level 1	2.55	1.39	2	Medium
BIM Level 2	2.28	1.37	4	Low
BIM Level 3	2.30	1.45	3	Low

Project life cycle stage where BIM was adopted

Analysis of the research survey data revealed that BIM is mostly applied in the 'Design' stage of construction projects (Mean Score 3.50, ranked 1st), as presented in Table 6. Other project lifecycle stages that are 'Medium' users of BIM include 'Detailing' and 'Budget and estimates' (Mean Scores 3.19 and 2.88, ranked 2nd and 3rd respectively). 'Medium' use is also made of BIM during the ‘Project management’, ‘Planning’, and ‘Delivery’ stages of projects. However it was discovered that the ‘Fabrication’ stage of projects involves the least use of BIM (Mean Score 2.27, ranked 8th). This is understandable in the light of the extremely low diffusion of any technology beyond BIM Level 1. BIM technologies higher than BIM Level 1 make use of object-oriented databases, which make it possible to automate the fabrication of component parts of construction projects. This is an area in which the NCI is still lagging behind; it is in this area that countries like Finland, USA, UK, Australia, Netherlands and Singapore have experienced significant benefits in construction project delivery (Kori and Kiviniemi, 2015) through the use of BIM Level 2 and 3.

Table 6: BIM in projects life cycle

Project life cycle stage where BIM was adopted	**Mean Score**	**SD**	**Rank**	**Remark**
Planning	2.61	1.73	5	Medium
Design	3.50	1.65	1	High
Detailing	3.19	1.85	2	Medium
Fabrication	2.27	1.68	8	Low
Construction	2.59	1.81	6	Medium
Budget and estimates	2.88	1.73	3	Medium
Project management	2.67	1.74	4	Medium
Delivery	2.53	1.88	7	Medium

Impact of BIM Adoption Levels in Construction Projects

<u>Benefits of BIM adoption on projects</u>

Projects performance in several key performance areas was computed before and after adoption of BIM, based on questionnaire responses. The results presented in Table 7 revealed that in four out of the eight aspects of project performance that were considered, BIM adoption apparently had a noticeable impact. These four aspects were ‘Greater control of the construction process’ (Mean Score 2.89, ranked 1st); ‘Improved collaboration between agents’ (Mean Score 2.87, ranked 2nd); ‘Conflict resolution and clash detection’ (Mean Score 2.63, ranked 7th); and ‘Reduction in labour’ (Mean Score 2.47, ranked 8th). All rankings refer to post-BIM performance. These findings agree with a previous study such as Nederveen *et al* (2010) that benefits of BIM technologies include the provision of an efficient communication and data exchange system.

Table 7: Benefits of BIM Adoption on projects

Benefits of BIM adoption on projects	**Pre-BIM**			**Post-BIM**			**Remark**
	Mean	**Rank**	**Level**	**Mean**	**Rank**	**Level**	
Waste reduction	2.74	1	Medium	2.85	3	Medium	Unchanged
Reduction in labour	2.70	4	Medium	**2.47**	**8**	**Low**	**Changed**
Reduction in deviations	2.73	2	Medium	2.80	4	Medium	Unchanged
Reduction in variations/claims	2.70	3	Medium	2.67	6	Medium	Unchanged
Greater control of the construction process	2.41	6	Low	**2.89**	**1**	**Medium**	**Changed**
Improved collaboration between agents	2.24	8	Low	**2.87**	**2**	**Medium**	**Changed**
Conflict resolution and clash detection	2.30	7	Low	**2.63**	**7**	**Medium**	**Changed**
Correction and error finding	2.66	5	Medium	2.70	5	Medium	Unchanged

Bold face type indicates significant changes in element due to BIM

Building Elements that frequently enjoy BIM adoption

Respondents were asked to indicate the extent to which BIM has contributed to the improvement of the elements of their building projects. The results are presented in Table 8; eight (8) building elements were involved. The results obtained revealed that BIM adoption has had 'Medium' influence on all eight building elements, although the ranking based on Mean Scores identified the most influenced elements as Doors, Roof, Windows and Walls.

Table 8: Influence of BIM Adoption on building elements

What elements of your projects are produced in 3D digital descriptions/representations?	Mean Score	SD	Rank	Remark
None	1.68	1.87	10	Low
Walls	3.18	1.83	4	Medium
Doors	3.32	1.72	1	Medium
Windows	3.19	1.78	3	Medium
Roof	3.24	1.79	2	Medium
Electrical installation	2.50	1.66	9	Medium
Mechanical installation	2.69	1.60	5	Medium
Reinforcements	2.66	1.78	7	Medium
Plumbing	2.69	1.68	6	Medium

Current BIM practices in execution of projects

A total of 14 practices were ranked by respondents, and the results are presented in Table 9. Only one (1) practice was ranked as occurring to a 'High' extent; this was 'CAD files (2D and 3D) are primarily used' (Mean Score 3.69, ranked 1st). Ten (10) other practices were carried out to a 'Medium' extent. The three least occurring practices which were only carried out to a 'Low' extent and were ranked 12th, 13th and 14th were 'File synchronisation at specific intervals carried out on projects'; Collisions effectively eliminated in the design phase and no clashes on the site'; and 'Collision detection by any BIM software'. This shows that project sites in Nigeria are yet to enjoy the full benefits of BIM which include clash detection and cost reduction (Eastman *et al,* 2011).

Table 9: Current BIM practices in execution of projects

What are the current practices in the execution of your projects?	Mean Score	SD	Rank	Remark
Traditional design methods	2.53	1.52	9	Medium
CAD files (2D and 3D) are primarily used	**3.69**	**1.44**	**1**	**High**
Construction site is provided with the traditional paper version of the documentation	3.33	1.52	2	Medium
Data coordination are conducted on BIM	2.82	1.55	4	Medium
CAE files BIM browsers are used, e.g. Autodesk *Navisworks*	2.71	1.33	6	Medium
Collision detection by any BIM software	2.27	1.50	14	Low
Projects have a central file on company's server with local files on PC's	2.50	1.72	11	Medium
File synchronisation at specific intervals carried out on projects	2.38	1.50	12	Low
Construction sites are provided with the traditional paper version of all documentation as well as with the BIM model	2.82	1.67	3	Medium
Collisions effectively eliminated in design phase and no clashes on site	2.38	1.48	13	Low
During design, fewer redesigns, revisions and changes	2.81	1.53	5	Medium
Accurate ordering of materials and elements	2.70	1.62	7	Medium
Quantity of materials consistent throughout the project duration	2.67	1.54	8	Medium
No unnecessary or incompatible elements	2.53	1.52	10	Medium

Bold face type indicates significant MS values

CONCLUSION

The paper assessed the adoption of Building Information Modelling (BIM) in the Nigerian Construction Industry (NCI). It has revealed that in the NCI both awareness and acceptance of BIM can be described to be in 'medium level' of knowledge within the range of BIM level 0 and BIM level 1. BIM software usage is dominated by 'AutoCAD' package and the most common BIM practice is distribution of contract or production information 'via paper or electronic form e.g. PDF', which is indicative of BIM Level 1. The paper has found that BIM adoption had a noticeable impact in four project performance aspects; use of BIM resulted in 'Greater control', 'Improved collaboration', 'Conflict resolution', and 'Reduction in labour'. The adoption of BIM has had a 'Medium' impact on no less than eight building elements. Based on the foregoing findings, it was concluded that BIM use in the NCI is still at a rudimentary level, but great potential for improvement exists, if the right environment (political, legislative, contractual, technical) is provided.

This paper recommended that the Federal and State governments should devise an Implementation Strategy Plan for BIM that will (i) explore how to make the use of BIM mandatory for all projects, (ii) support the use of BIM through incentives and (iii) fund BIM research and development (R&D). In addition, to increase BIM penetration among firms, Clients might offer some form of subsidies for BIM costs which could be included as items in the Preliminaries of construction contracts. It needs to be stated that these results have been obtained from analysis of a very limited sample of construction professionals. Further research could focus on validating these results through the testing of a larger sample of construction professionals.

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