Building Information Modelling and its Application in Building Construction Projects[1]

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ABSTRACT

Building Information Modelling (BIM), an emerging tool for collaboration within the Architectural Engineering and Construction industry, has been adjudged as one of the models for containing information within the nooks and crannies as well as the lifecycle of a building construction project.BIM has been proven to have contributed to the optimization of the construction process via, the collaboration and integration of all building information management processes necessary for ensuring that all project variables are delivered via a range of digital approaches. This study looked at the application of BIM in planning and controlling of building construction projects, BIM tools deployed by practitioners within Port Harcourt, Rivers State. Survey research design using structured questionnaires was deployed as means of data collection from construction professionals in some selected construction firms. A sample of 95 respondents was determined using Yamane's formula. Data for the study were presented using frequency table, percentage, charts. Key variables were analysed using Relative Importance Index (RII). The result from the study shows a general awareness of BIM with 97% of the respondents indicating a good knowledge and use of BIM. On enquiry about BIM tools used by respondents, AutoCAD Architecture was adjudged one of the most used BIM tool with 68% usage, followed by Revit Architecture and ArchiCAD with 46% and 45% respectively. Other tools had usage rate below 30%. The result of BIM application to construction processes revealed that BIM is mostly applied in design, visualisation and creation of digital mock-up as these processes had a RII of 0.85 and 0.79 respectively. Quantity take-off and estimation, and engineering analysis showed fair usage with RII of 0.55 and 0.50 respectively. Other construction processes tested all showed low usage with RII below 0.44.

Keywords: Building Information Modelling, Planning and Control, Building Construction Projects,

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INTRODUCTION

Construction projects are aimed at realizing predefined goals and objectives that are laced with risks, these risks are further compounded by the existence of some project constraints viz; time, cost, scope and the project delivery methods deployed (Foster, 2008). To maximize the twenty first century digitalized problem-solving opportunities of combating inefficiencies and reducing errors, omissions and wastages caused by the application of traditional methods of constructing, the construction industry must not be left out in the digitization crusade. As opined by Kiprotich (2014), the contributions of wider use of technology, digital processes and automation to our economic, social and environmental future cannot be overemphasized. BIM radically changes the way building designs are made, communicated and constructed (Isikdag, 2015). BIM is a technological advancement that has improved how building projects are planned, designed, communicated and constructed by integrating Architectural, Engineering and Construction (AEC) related practices that are traditionally fragmented (Cramer, 2010). Over the years, the use of paperwork has been the method of communication between key players in the built industry.

Building projects are designed as single units such that conflict, errors of omission that leads to alteration of a parameter automatically leads to alteration of related parameters and objects, including drawings, renderings, specifications and schedules. If such adjustment is made during the execution phase, the resulting effect could range from extension of project duration to incurring of extra costs. This therefore highlights the need for an integrated system that can foster collaboration of different stakeholders, giving them access to every information pertaining to the project as the need arises.

According to ASHREA (2009), a building information model, is a digital depiction of the physical and functional features of a facility which is accessible to all stakeholders and forms a reliable base for decision making throughout the life cycle of the facility. The notion of BIM emerged and was developed at the Georgia Institute of Technology in the late 1970s and it grew rapidly thereafter. BIM evolved from being a shared information resource to an information management strategy and further into becoming a construction management method (Isikdag, 2015).

According to Hassan and Yolles (2009), BIM follows a seven-dimensional process which can be portrayed thus: 3D – Modelling; 4D – Scheduling; 5D – Cost Estimating; 6D – Sustainable Design (Green Design); and 7D – Facility Management. This lends credence to the argument against the misconception that limits BIM to being a 3D Modelling tool and associate computer aided design (CAD) with 2D drawing. CAD technology also offers 3D renderings, the difference being that in CAD, building elements are represented by lines and geometric shapes, while in BIM, the elements hold specifications such as height, width, interior or exterior, fire rating, etc (Dastbaz, Gorse &Moncaster, 2017). BIM offers parametric integrity which relates to the connection and relation between elements which are maintained consistently even when the model is being manipulated (Succar, 2009). In the application of BIM, each party carries out its own responsibility while actively cooperating with other parties to ensure a smooth flow of work. (António& António 2014;Yanran, Guogang&Jingru, 2015). Yanran et al.(2015) further asserted that since BIM presents the physical and functional features of a construction work in a digital format, conflicts encountered while applying the traditional decentralized construction approach are easily observed and corrected while the project is yet in its planning phase.

Staub-French &Khanzode (2007) opined that the uniqueness of BIM is in its ability to integrate several disciplines and professions hence encouraging collaboration between Architects, Engineers, Quantity Surveyors, Contractors/Sub-Contractors, Facility Managers, Client and other stakeholders or consultants as the case may be. Hence, inefficiencies in form of errors or omissions which could inflate cost if observed only in the long run can be detected at the planning phase by studying the inputs of the different professionals (structural, electrical, etc.) and making necessary modifications without incurring extra cost.

BIM has two basic concepts: model a project in 3D (3 dimensional) reality rather than in a flat plane and provide this information just once in detail and very accurately in order to minimize problems. Building elements (operable walls for example) are not drawn into a project using "BIM": they are "placed" as an object or complete assembly into the model. Conflicts with other designs and trades become obvious and are corrected prior to bidding & building. Most importantly however is the "I" in "BIM" which denotes information and that is exactly what BIM is designed to do: deliver valuable, error free, up-to-date "information" on the product being considered for use in the building (Khalfan, Khan, & Maqsood 2015; Sullivan, 2012).

The performance of construction projects is usually evaluated using cost and schedule considerations. Hence, it is important that the construction manager focuses on time and control needs of the project. Involving construction professionals in the project's early phase and have them take proactive part in the development of the project plan helps ensure that the construction plan and schedule are sound. In a related study, Taku (1997) developed an automated and computerized system intended to control the manageability of the construction planning. The system had the ability to integrate the project design with planning, scheduling, and analysis. The user can then simulate the construction process. Popov (2016) asserts that with the advent of BIM came the possibility of having error free construction projects. He added that the traditional construction practices before the introduction of BIM had a high rate of extended project cost and schedule. This according to him was the major reason that led to the research into improved construction methods that reduce possibility of errors such as BIM.

The construction industry is fast embracing BIM as the future. This is true especially in developed societies but same cannot be said of sub-Saharan region of Africa where adoption of technological innovations is slow-paced. According to Agele (2012), the move for adoption of BIM among building professionals in Nigeria has been sluggish. Architects were said to have adopted it but basically for enhancing the visual quality of their presentations. This in essence is a gross underutilization of the vast potentials of BIM which was introduced to reduce to the barest minimum inefficiencies caused by adoption of traditional construction methods, especially such as relates to fragmentation and communication breakdown. Inefficiencies in construction works in Nigeria can be traced to individuality of professional's inputs as against collaborative efforts. The aftermath of this fragmentation is haphazard operations which further leads to uncontrolled project quality. More so, the recurrent communication breakdowns result in delays in project execution and increased project cost. Communication between project stakeholders in the construction industry was paper based with no basis for collaboration and clear visualization of the project design. This caused poor documentation and information management and stimulated fragmentation in the activities of the building industry. It further gave rise to errors and wastages, poor performance, low productivity and inefficiency in the construction industry. The many problems reported include design errors, estimate deficiencies, conflicts between design and construction and fragmented platforms which limit information flow throughout project lifecycle (Olatunji, Sher, Gu &Ogunsemi, 2010). This work aims at achieving the following objectives, viz:

To identify the extent of application of BIM in planning and controlling of construction projects in Port Harcourt, Nigeria and to identify the BIM tools currently deployed in building construction projects in the study area.

LITERATURE REVIEW

BIM as an innovation in architectural, engineering and construction industry is a modelling technology which incorporates AEC digital information throughout the life cycle of a facility. According to Succar (2009), digital data is integrated with policies, processes and technologies. The process of building digital models involves human activity of manipulating digital data using BIM software or related software, hardware and technologies. It can be deduced from the plethora of definitions, that BIM is a digital data presented in form of 3-dimensional model to create a better understanding for the construction team (Succar, 2009). While on the other hand, (Amuda, 2018), reiterated that BIM provides a platform that integrates exchange of information via a single model by minimizing design errors and omissions with significant reduction in design time.

Also, according to Eastman, Teicholz, Sacks & Liston (2011), BIM has been one of the greatest achievements of the architectural, engineering as well as building industry for the past century. BIM can be employed to conceptualize computer-generated models of a construction digitally. These digital models incorporate the right geometrical information of the construction elements as well as other vital information required for material purchases and construction activities. It also comprises of the numerous roles and prerequisites to model the lifespan of construction, thus providing the stage for fresh proposal as well as building competences (Eastman *et al.*, 2011). If all the data related to a project are made accessible from a single online system, the project could be firstly implemented in a virtual environment taking into cognizance dimensions of time (schedule) and cost in the simulation making it easy and almost instantaneous for cost-time-benefit analysis of the various options (Thompson & Miner, 2006).

The adoption rate of BIM the world over, has been on the increase over the past years especially by commercial contractors. The adoption rate in North America increased by 43% between 2007 – 2012 with contractors having the highest adoption rate (74%) as compared to the architects whose adoption rate is 70% and the engineers 64% (Benjamin, 2016). The British government in 2011 mandated the application of BIM in the United Kingdom (Ganiyu & Charles, 2018) and this caused an increase in the adoption rate from 60% to 95% within the last three years (Benjamin, 2016). In Malaysia, even though the adoption rate of BIM among construction organisations is only 5.2% from 2007 to 2013, the number will increase as the Construction Industry Development Board (CIDB) has piloted a good number of summits, talks and workshops regarding BIM adoption. According to Wong and Ko (2011) many firms across the world adopt BIM without having a clear direction of path they are moving to. Moreover, during the adoption, some organizations were hesitant to adopt BIM, while others thrived. Thus, the identification of BIM adoption is essential in assisting companies to continue adopting BIM in real life practices.

BIM AND THE BUILDING CONSTRUCTION INDUSTRY

According to Yan & Damian (2008), design of buildings in the past has been done using the traditional way with the use of simple tools such as pen, paper and ruler, until the advancement of mathematics and building material science which was set in motion around the mid nineteenth century resulting in engineers creating 2D CAD drawings using computers. According to Yan & Damian (2008), BIM is a powerful set of design management tools which possess substantial benefits over the entire building lifecycle, mostly design, and also construction and facility management. It is the platform on which collaboration amongst project stakeholders and improvement of project results are built. BIM has over the years attained widespread popularity among construction industry professionals globally. BIM is seen as a driver for the building industry to improve its productivity by ensuring effective communication and collaboration between all project stakeholders from inception to completion of building projects. According to Haron& Abel (2010), many design and construction organizations in different parts of the world are moving towards BIM adoption in their practices. Ayarici, Khosrowshahi, Ponting and Mihindu (2009) reported that in a recent past, many pilots and live projects have been completed and archived in Finland, Sweden, Norway, Germany, France, Singapore, UK and Australia, which established the capability of BIM application in the construction process. Though, Yan & Damian (2008) argued that not all companies are interested in its adoption, but still the future of BIM technologies in the industry looks bright with increasing efforts by researchers and industry stakeholders.

Thorpe (2009) opined that several benefits of BIM were claimed by its proponents to include changing the process of design and build to better, integration of building plans, sections, graphics and details in ways not possible in 2D CAD, providing synchronized information on performance and economic aspects of construction among others. This new technology that was introduced in the early 80s (Thorpe, 2009) has now proven its potentials in sanitizing the construction industry from its traditional and fragmented ways of operation with improved efficiencies and collaboration capabilities (Thorpe, 2009).

BIM TOOLS FOR PLANNING AND CONTROLLING BUILDING CONSTRUCTION PROJECTS

According to Cramer (2010), the idea and concept of BIM is not built around the ‘B’ (Building) or the ‘M’ (Modelling), rather it centres on the ‘I’ (Information). According to him, information is key and BIM’s ability to serve as a shared knowledge resource for information about a construction work providing a reliable platform for decision making throughout the lifecycle of the facility is its most important feature. Some BIM tools are employed to make possible interoperability and collaboration of different stakeholders at different phases of the facility's lifecycle. These tools make it possible for the stakeholders to access, modify or update information where and when necessary. Popov (2016) in his analysis of some BIM tools, highlighted the underlisted BIM tools.

ArchiCAD was originally named Radar CH after its creation in 1984. It was originally used for designing water systems but has become one of the most popular tools for building design. Revit was launched in 2000 and in 2002, Autodesk bought Revit Technology Corporation and in 2005 renamed the program Revit Building. Revit Structures (for structural design) and Revit MEP (for MEP designs) were both created in 2006, while Revit Architecture was created in 2007 for architectural designs (Cha & Lee, 2018; Nor, Abdul & Nor, 2016; Ruya, Chitumu&Kaduma, 2018).

Tekla has two variations namely; Tekla Structures and TeklaBIMsight.Tekla Structures is a modern tool for structural engineers, used for 3D structural modelling/detailing. While TeklaBIMsight is used for viewing building information model in native Tekla format or in Industry Foundation Classes (IFC), an object-based file format with a data model developed by building SMART. Solibri Model Viewer is a software for viewing building information model, it is used for quality assurance and quality control.

Zhang (2013) also highlighted some BIM tools which are also used by AEC industry professionals. Some of the tools include; Navisworks, manage and created by Autodesk and used for 3D model-based designs and clash detection. Digital Project Suite is a full featured suite used for design, review and information management, while Synchro Professional handles scheduling systems and planning simulations. A Gantt Chart created with Microsoft Professional can be linked to a 3D BIM model created with ArchiCAD using Synchro Pro such that modifications in the drawing results to real-time update of the schedule. Vico Office is a BIM tool for 3D model analysis for coordination, scheduling and estimating (António& António, 2014; Uduma, Umoh& Nwachukwu, 2018; Vico, 2011).

In a study by Zigurat (2018), some of the BIM tools highlighted for Planning and Controlling construction projects includes; AutoCAD (Architecture/Civil 3D/MEP); Synchro Professional; Navisworks; Solibri; Vico Office; Bentley Systems and Sketch Up. While tools like ArchiCAD, Revit, and Tekla Structures (Kalfa, 2018) most especially play important roles in the planning stage of a construction project as they are used to create realistic digital replica of the both physical and functional characteristics of the building, they also come handy throughout the lifecycle of the facility as there might be need for modifications.

Tools like TeklaBIMsight and Solibri Model Viewer although also used during the planning stage to view the digital models, detect clashes and identify missing components have gradually become important tools for control during project execution. They help in measuring the degree of conformity of the work in progress to the scope as defined in the planning stage.

BIM DIMENSIONS

1. PARAMETRIC 3D MODELLING (3D BIM)

3D BIM makes it possible to work in three dimensions, hence employing the same logic that applies during construction in a virtual environment. The implication being that changes made in any one part of the plan is automatically updated on other parts, eliminating the need to change them separately. Working in three dimensions from the beginning will enable all professionals and project stakeholders to have higher decision-making capacity and avoid changes during the execution phase of the project (Staub-French &Khanzode, 2007). According to Foster (2008), building components are analysed using clash detection tools to detect and resolve conflicts before proceeding with systems installation in the field. In all, the ability of the construction manager and the speciality contractors is to carry out 3D coordination before commencement of the construction work goes a long way in reducing design errors and gives a better understanding of the work to be done (Young, Stephen, Harvey & John, 2009).

2. BIM-BASED SCHEDULING (4D BIM)

The last decade has seen research efforts as relates to scheduling transcend from 3D CAD model-supported construction development to 3D BIM with improved information-based scheduling (time) (Harrison, & Thurnell, 2015; Liua, Lua & Al-Husseina, 2014). 4D BIM technology connects 3D BIM models to related activities following the guiding principle of the Critical Path Method (CPM), hence making it possible for users to run simulations of the project in order to identify and resolve space-time conflicts to improve project performance (Elghaish, Abrishami, Gaterell& Wise, 2018; Zigurat, 2018). According to Keegan (2010), integrating schedule into the virtual construction introduces the element of time which is the 4^{th} dimension (4D BIM). The Critical Path Method (CPM) is a common scheduling method that can be used to create 4D BIM. In CPM, activities are listed, linked according to their order of dependency and assigned duration. Interdependency between activities is such that the activities either act as predecessor or successor to another activity depending on planned order of execution.

3. COST ESTIMATION (5D BIM)

5D BIM technology comes with the capability of automating measurements and project cost. This is sometimes achieved by direct linking of modelling software to a cost control software. Since the budget is derived from the project design, cost values are obtained from actual measurements and not estimates from global variables or direct percentages (Zigurat, 2018). According to Elghaish et al. (2018), 5D BIM is also used for cost planning, and other such issues like bill of quantity (BoQ) preparation. According to Noor, Robin Scott and Robert (2016), BIM has a lot to offer in terms of improving cost estimating reliability, early schedule information, fast predictions of cost impact of design changes, proper understanding via improved visualization, as well as the possibility of accessing more information for purposes of documentation. Makenya and Ally (2018) opined that BIM enables estimators to identify and communicate the relationships between quantities, costs and locations, as well as distinguish how the various areas and components of a building construction project contributes to the total cost of the entire project.

4. GREEN DESIGN (6D BIM)

Improvement in energy efficiency and use of renewable energy has become a global imperative and the major reason why most governments support and enforce BIM adoption. More so, energy consumption has become a thing of great concern especially in homes as a result of steady increase in electricity, gas and water costs. This has become a motivating factor for building owners to consider integrating factors that will ensure low energy consumption. Energy analysis was unachievable with CAD programs. BIM tools integrate the technical properties (such as thermal transmittance, consumption of CO_2, etc.) of materials used in the project (Harrison, & Thurnell, 2015;Zigurat, 2018).

5. FACILITY MANAGEMENT (7D BIM)

The operational life of a building is estimated to be the most expensive part of its entire lifecycle. BIM offers greater control over information and documentation generated by the properties of a building and this is a major reason why public administrations are eager to replace old systems with fully functional BIM systems (Zigurat, 2018).

RESEARCH METHODOLOGY

This study made use of the quantitative (survey) research design method. The survey method was employed by the use of structured questionnaires in collecting quantitative data for the study. The reason for adopting this approach is that it is capable of yielding quantitative information which can be summarised via statistical analyses (Dempsey, 2003; Leedy& Ormrod, 2006).

The target population for this research consist of Architects, Civil Engineers, Project Managers, Mechanical Engineers, Electrical Engineers, Builders, Quantity Surveyors, Estate Surveyors, Land Surveyors, Geotechnical Engineers, Construction Consultants and any other related specialist within the built industry in Port Harcourt, Nigeria. These professionals were selected from five (5) indigenous construction companies in the study area. Their responses therefore are expected to be of valuable importance to this research.

The sample size was calculated using Taro Yamane's formula for calculating sample size from a population of one hundred and thirty (130) professionals as indicated below:

$$n = \frac{N}{1 + Ne^2}$$

Where; n = sample size, N = Total Population, e = Error tolerance = 0.05 at 95% confidence level.

$\square =$

$$\square = \frac{130}{1 + 130(0.050^2)}$$

Therefore, the sample size was 98.11 which was approximated to 98.

Out of the 98 questionnaires that were distributed, only 95 were retrieved and 92 were certified valid for the study.

The research data were obtained from two main sources viz;

Primary sources and secondary sources, the primary sources are materials which the investigators originated for the purpose of the inquiry at hand. They were obtained through structured questionnaires and personal interview (they are obtained through conversation with the respondent, hence they are semi-structured). They are considered appropriate for the study.

The questionnaires were self-administered and as such they allowed the respondents to give free and reliable answers at their own convenience without undue influence of the presence of the researchers. The questionnaire was grouped into four sections labelled A - D. The first section (Section A) simply captured the respondent's professional inclination and academic qualifications, while the remaining three sections (Sections B,C,D) were structured to capture issues around the research objectives which were rated using the Likert 5-point scale (1 = Strongly Disagree, 5 = Strongly Agree). The data gathered were subjected to quantitative analysis to ascertain its accuracy, reliability and relevance to the study.

The collected data were summarized and presented in tabular form. Frequency distributions tables and simple percentages were used to illustrate the results. Key variables were analysed and ranked in order to establish their criticality, relevance and level of influence. This was achieved with the aid of Microsoft Excel 2016 version. While Relative importance index method (RII) was used to determine the ranking of the items under consideration.
The relative importance index was computed as:

Relative Importance Index (RII) = $\frac{(\square_1 + \square_2 + ... + \square_\square)}{N \times A}$

Relative Importance Index (RII) = $\frac{\Sigma W}{N \times A}$

Where,
W = weighting as assigned on Likert's scale by each respondent
N = total number of respondents in the sample
A = highest weight (i.e. 5 in this case)

For easy calculation it was further simplified thus:

Relative Importance Index (RII) = $\frac{\sum fx}{\sum f} \times \frac{1}{K}$

Where,
$\sum fx$ = the total weight given to each attribute by the respondents.
$\sum f$ = the total number or respondents in the sample.
K = the highest weight on the likert scale (i.e. 5 in this case).

Ranking of the items under consideration are based on their RII values. The item with the highest RII value is ranked first (1) the next (2) and so on.

The RII value had a range from 0 to 1 (0 not inclusive), the higher the value of RII, the more impact the attribute has. However, RII doesn't reflect the relationship between the various items.

Decision rule:

DEGREE OF SIGNIFICANCE	RATING
Very Significant	0.76 above
Significant	0.67-0.75
Fairly Significant	0.45-0.66
Not Significant	0.44-below (Fadason et al., 2018).

DATA ANALYSIS AND PRESENTATION

Here, the researchers intend to present the data collected from the survey in form of tables, pie charts and combo charts. Out of 100 questionnaires distributed, only 95 were returned and 92 were certified valid and suitable for this research.

RESPONDENTS' PERSONAL DATA

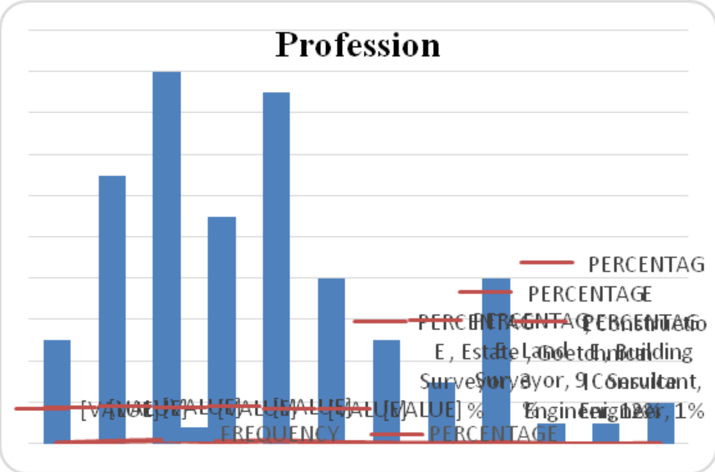

Fig 1: Respondents Profession (Source: Field Survey 2018)

The chart as shown above describes the distribution of respondents based on their area of professional practice. It shows that Civil Engineers have the highest number with 20% representation, followed by Builders with 18%, Architects with 14%, Quantity Surveyors with 12%, Electrical Engineers and Land Surveyors with 9%, Project Managers and Mechanical Engineers with 5%, Estate Surveyors with 3%, Construction Consultant with 2%, Geotechnical Engineers and Building Service Engineers with 1% representation. This shows that there was adequate representation of target professionals in the study.

Table 1: EDUCATIONAL QUALIFICATION OF RESPONDENTS

QUALIFICATION	FREQUENCY	PERCENTAGE
PhD	13	14%
MSc.	22	24%
HND/B.Sc/B.Tech	41	45%
OND	16	17%
Total	92	100%

(Source: Field Survey, 2018).

Table 1 shows the distribution of respondents based on the highest level of education attained. Top most on the list are the first degree holders (HND,B.Sc/B.Tech) with 45% representation, followed by M.Sc holders with 24%, OND holders with 17% and PhD with 14%.

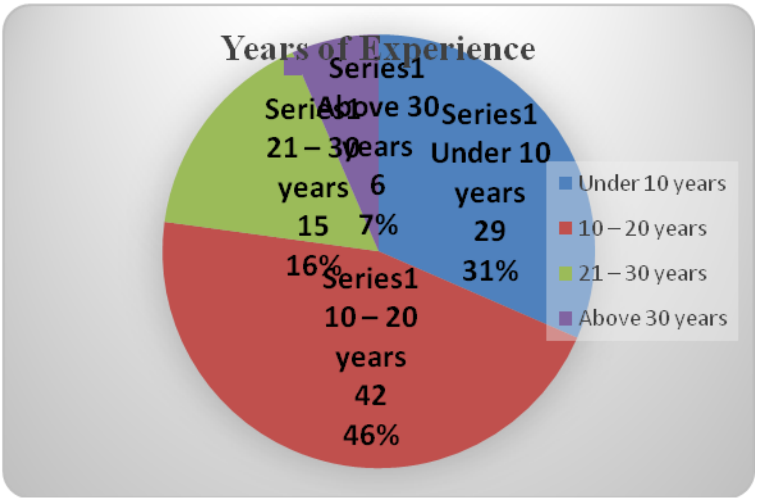

Fig 2: Years of Experience of Respondents (Source: Field Survey, 2018).

The chart describes the distribution of respondents based on their years of professional experience. Respondents with 10 – 20 years of experience dominated the chart with 46% representation, followed by those under 10 years with 31%, 21 – 30 years with 16% and above 30 years with 7%.

Table 2: BIM AWARENESS

	FREQUENCY	PERCENTAGE
Aware of BIM and currently using it	89	97%
Aware of BIM but have not used it	2	2%
Not aware of BIM	1	1%
Total	92	100%

(Source: Field Survey, 2018).

Table 2 shows that while 97% of those who took part in the survey were aware of BIM and are currently using it, 2% are aware of BIM but are not using it, while 1% is neither aware of nor using BIM. The 97% percent which is a total of 92 persons formed the valid data used in the study.

TABLE 3: EXTENT OF USE OF BIM TOOLS

BIM TOOL	Responses in ordinance scale					$\sum f$	$\sum fx$	Mean	RII	Rank
	1	2	3	4	5					

AutoCAD Civil 3D	26	15	20	17	14	92	254	2.76	0.55	3
Revit Architecture	26	14	16	20	16	92	262	2.85	0.57	2
ArchiCAD	22	20	17	23	10	92	255	2.77	0.55	3
Bentley Systems	69	12	5	4	2	92	134	1.46	0.29	11
Sketch Up	29	15	17	19	12	92	246	2.67	0.53	5
Digital Project Suite	73	10	6	1	2	92	125	1.36	0.27	14
AutoCAD MEP	44	22	12	9	5	92	185	2.01	0.40	7
Navisworks	60	14	9	7	2	92	153	1.66	0.33	9
Synchro Pro	77	7	4	3	1	92	120	1.30	0.26	15
AutoCAD Architecture	11	8	16	27	30	92	333	3.62	0.72	1
Revit MEP	49	17	14	7	5	92	178	1.93	0.39	8
Vico Office	71	10	4	4	3	92	134	1.46	0.29	11
Solibri	73	8	5	5	1	92	129	1.40	0.28	13
Tekla	71	8	7	2	4	92	136	1.48	0.30	10
Revit Structure	29	17	19	17	10	92	238	2.59	0.52	6

(Source: Field Survey, 2018).

Table 3 shows that the most BIM software used by respondents is AutoCAD Architecture with an RII value of 0.72 indicating that it is a very significant BIM tool that is widely used. Revit Architecture, ArchiCAD, AutoCAD Civil 3D, Sketch Up and Revit Structure are fairly significant BIM tools with RII rankings of 0.57, 0.55, 0.55, 0.53 and 0.52 respectively. AutoCAD MEP, Revit MEP, Navisworks, Tekla, Bentley Systems, Solibri, Vico Office, Digital Project Suite and Synchro Professionals all had RII below 0.44 which indicates low utilization and hence are not significant BIM tools currently used.

DISCUSSION OF RESULTS

The results from the study show a general awareness of BIM as well as the use of various BIM tools in improving the efficiency and successful delivery of building construction projects. While some of the tools are applied during the planning phase of the project, some are employed for monitoring and controlling purposes, while some play vital roles in both the planning and controlling phases of the project. This finding is at variance with that of Makenya and Ally (2018), who opined that awareness of BIM concept is low in Tanzania, and majority of quantity surveying professionals in the area are far behind understanding the concept of BIM in general. That the knowledge about BIM is also inadequate, as many firms are eager to adopt and implement BIM in their construction activities. One of the most deployed BIM tools used by professionals in the AEC industry is AutoCAD Architecture which ranked highest as the RII shows high level of significance. Revit Architecture, ArchiCAD, AutoCAD Civil 3D, Sketch Up and Revit Structure all had RII values which suggest a fair level of significance. This is an indication that not many AEC industry professionals use these tools. The rest of the tools listed which include Sketchup, AutoCAD Civil 3D, Revit Structure, AutoCAD MEP, Revit MEP, Navisworks, Tekla, Bentley Systems, Solibri, Vico Office, Digital Project Suite and Synchro Professionals are utilized by only a handful of the professionals.

On the analysis of BIM on construction processes, the findings show that BIM is predominantly employed as a tool for visualization and digital mock-up. It also shows slight usage in quantity take-off and estimation, engineering analysis, reduction of rework during construction and logistics/site utilisation planning. While showing that BIM is poorly utilised in constructability analysis, clash detection and coordination, information integration and collaboration of stakeholders, project cost estimation, construction scheduling and facility management. Although the outcomes of this findings is not in agreement with that of Nor et al.(2016) who were of the view that one of the essential features of BIM technology is to improve information and the reliability of cost estimating processes.These findings suggest that designers (architects) have the highest percentage of BIM adoption and use, this nonetheless, is in partial alignment with the findings of Benjamin (2016) which places contractors ahead of architects in BIM adoption rate, with a 70% and 64% adoption rate respectively in North America. The slight difference notwithstanding could be as attributed to differences in the population and area of study.

CONCLUSIONS

This work highlights three important findings which focus on the application of BIM in Planning and Controlling of Construction Projects. The study examined the extent of BIM application, and the BIM tools applied in the construction firms in Port Harcourt. The research findings show that about 97% of construction industry professionals are aware of BIM technology and familiar with at least one of the BIM tools listed. A proper examination of the most utilised tools and the dominant work processes where BIM is applied shows a trend which suggests that BIM application in the Port Harcourt construction industry is mostly deployed by architects and designers. This can be deduced from the high frequency of usage of AutoCAD Architecture, Revit Architecture and ArchiCAD as well the high frequency of application of

BIM in visualisation and creation of digital mock-ups as delineated in the research. The results further showed that AutoCAD Architecture is the most used BIM tool by professionals in the industry under study. The other tools listed are used by only a handful of professionals.

Nevertheless, the top three popular tools among construction industry professionals as observed in the results are AutoCAD Architecture, Revit Architecture and ArchiCAD. Also, analysis from the responses received while investigating the application of BIM to construction processes revealed that BIM technology is mostly employed as tool for visualisation and creating digital mock-ups a trend which suggests that BIM application is most popular among architects and designers. BIM application for such purposes as clash detection and coordination, constructability analysis, cost estimation, information integration and collaboration of stakeholders, construction scheduling and facility management is still very uncommon.

Based on the findings stemming from this research, we hereby recommend that the government in collaboration with top level management of AEC firms should facilitate BIM education across the industry. This can be achieved by conducting BIM skill development programmes, organising workshops to educate construction industry professionals on the benefits of BIM and integrating BIM education across built environment disciplines. This resolve borders on the premise that exposing construction professionals to proper BIM education cum information will eliminate most of other factors militating against its implementation. Government sponsorship should be made available for researchers in the built industry whose research works are BIM based. This can be in form of full/partial scholarships or grants; this will spike the interest of many young graduates towards delving into this area of research.

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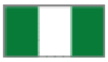

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