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Research Article

An Appraisal of the Benefits of Building Information Modelling (BIM) in Architecture

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Abstract

Building Information Modelling (BIM) represents the development and use of computer-generated n-dimensional (n-D) models to simulate the planning, design, construction and operation of a facility. Architectural designs were communicated through the medium of 2-dimensional hand drawings and written specifications produced by applying ink or pencil to a medium of paper. With the help of BIM, projects can be completed faster and within budgeted limits. Proposals are understood through accurate visualization. Reworks can also be minimized due to better understanding of project. The purpose of this research is to develop a clear understanding about BIM and identify the benefits of BIM leading to it being considered in projects by architects in Nigeria. Relevant literatures were reviewed and practising architects in architectural firms were interviewed to analyse their knowledge and/or usage of BIM. The findings reveal that while the awareness of BIM amongst architects is high, the usage is relatively low.

1. Introduction

Housing Construction projects have always been complex and continue to be more complex with increase in sophistication in the world. As the desires of man continue to expand, so do the interests of the stake holders in the architectural, engineering and construction (AEC) industry. The vast advances in Information and Communication Technology (ICT) have brought about research on approaches and applications to reduce the burdens of the AEC. One of these new advances is BIM.

During much of modern history, architectural designs were communicated through the medium of 2 dimensional hand drawings and written specifications. These technical drawings were produced by applying ink or pencil to a medium of paper. The 1990's brought the advent of computer-aided design (CAD) as the popular medium to draw a building. At the dawn of the 21st century, BIM was introduced to the architecture

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and engineering professions as the latest medium for designing and drawing a building (Fox 2016). In spite of the evolution of technology over the years, construction disputes continue to occur.

In the earliest stages of a project, particularly during the schematic and preliminary stages, critical design decisions are made that largely dictate the economics of the project. BIM provides both the owner and the management organization with detailed specific information about the building (Kreider and Messner 2013). BIM supports collaboration; operation of a facility; and management of a virtual building model within a building life cycle (Smith, 2010; Ahmad et al., 2012).
The principal difference between BIM and 2D Computer Aided Design (CAD) is that the latter describes a building by independent 2D views such as plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated, a process prone to mistakes, which is one of the major causes of poor documentation. In addition, data in these 2D drawings are graphical entities only, such as lines, arcs and circles, in contrast to the intelligent contextual semantic of BIM models, where objects are defined in terms of building elements and systems such as spaces, walls, beams and columns (CRC Construction Innovation, 2007).

In addition to the parametric properties of 3D BIM, the technology also has 4D and 5D capabilities (cost and scheduling) to models to facilitate value engineering studies;

Wang (2011) explained BIM types as the following:

- 3D: three-dimensional means the height, length, and width.
- 4D: 3D plus time for construction planning and project scheduling.
- 5D: 4D plus cost estimation.
- 6D: BIM for life-cycle facility management

Figure 1: 3-D architectural model; showing the relationship between the building and the site.

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At its most basic level, BIM provides three-dimensional visualization to owners. It is also used as a marketing tool for potential clients and designers and can be employed to demonstrate design ideas (Azhar et al., 2008, Weygant 2011) viewed BIM as a tool that is used for model analysis, clash detection, product selection, and whole project conceptualization. The different uses of BIM in construction as the followings:

- 3D model

Clash detection; Architects and contractors can go through the model and make adequate and agreeable corrections before proceeding to the construction site. BIM enables potential problems to be identified early in the design phase and resolved before construction begins.

Project visualization provides a very useful and successful marketing tool which can show the owner what the building will look like when completed.

- 4D time

BIM tools can be used to enhance planning and monitoring. Schedule visualization; by watching the schedule visualization, project members will be able to make decisions based upon multiple sources of accurate real-time information.

- 5D cost

BIM model includes information that allows a contractor to accurately and rapidly generate an array of essential estimating information, such as materials; quantities and costs; size and area estimates. As changes are made, estimating information automatically adjusts, allowing greater contractor productivity. Cost data can be added to each object enabling the model to automatically calculate a rough estimate of material costs.

- 6D facilities management (FM)

Data Capture; sensors can provide feedback and record data relevant to the operation phase of a building, enabling BIM to be used to model and evaluate energy efficiency, monitor a building's life cycle costs and optimize its cost efficiency.

2. Why BIM

(Hardin 2009) agreed with (Smith and Tardiff 2009) and said that BIM is a revolutionary CAD technology, and building process that has transformed the way buildings are designed, analysed, constructed, and managed. BIM model ties all the components of a building together as objects embedded with information that tracks its manufacture, cost, delivery, installation methods, labour costs, and maintenance (Smith and Tardiff, 2009). Therefore, BIM can be said to have emerged to improve the process of design and enhance the design and construction output, thereby, increasing efficiency.

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In a survey conducted in Egypt, 19% firms require the knowledge of BIM basics in newly recruited staff even though BIM have only been in use there for five (5) years. (Khodeir and Nessim 2017)

2.1 Advantages and Disadvantages of BIM to Architects

Mineer (2015) stated the advantages of BIM as follows:

2.1.1 Advantages

- **Better planning and design**: completed buildings with all its components are visualized before mobilizing to site.
- **Fewer reworks**: potential problems are seen and fixed before errors are committed. Thereby, reducing the need for costly reworks and renovations.
- **Savings on materials**: helps to estimate exactly what one needs, thereby, eliminating wastages
- **Support for prefabrication**: prefabrication of components offsite saves time and money

2.1.2 Disadvantages

(Kuehmeier 2008) stated the following as disadvantages of BIM:

- **Garbage in garbage out**: will suppliers be held accountable for incorrect data from the data base or will the architect be blamed for not cross checking
- **No standard BIM contract documents:** if standards are not developed, reciprocal interaction with others will not be efficient
- **Electronic data transfer:** architects are always reluctant to provide digital data to contractors for fear of modification.
- **Interoperability:** when a BIM is opened by a different program, who checks to ensure that the data is still correct from the one transferred as BIM cannot interface with other programs yet.

2.2 BIM Acceptability

(Arayici et al. 2009); (Khosrowshahi and Arayici 2012); (Elmualim and Gilder 2013); and Aibinu and Venkatesh (2014), concluded that there is poor knowledge of BIM and its advantages in the construction industry. They found that there is a lack of expertise that professionals need to have for using the BIM

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software as well as ignorance of how to implement the BIM software to be helpful in construction processes.

According to (Gu et al. 2008), BIM is quite ill-understood across the board. Only 54% of the architectural practices are currently aware of BIM (NBS, 2013).

(Newton and Chileshe 2012), (Mitchell and Lambert 2013), (Löf and Kojadinovic 2012), on their part found out that there is little understanding of the concept of BIM, and the usage was found to be very low in South Australia, Australia and Sweden respectively. (Kassem et al. 2012) found that in the UK there is an overall lack of knowledge and comprehension of BIM.

Jung and Lee (2015) investigated the use of BIM on the six (6) continents and summarized their findings as shown in figure 2 below:

	Overall	*North America*	*Europe*	*Oceania*	*Asia*	*Middle East and Africa*	*South America*
3D Coordination	85.0%	95.5%	92.9%	100.0%	70.3%	91.7%	60.0%
Cost Estimation	75.0%	95.5%	92.9%	66.7%	56.8%	58.3%	80.0%
Existing Conditions Modeling	74.3%	81.8%	60.7%	88.9%	67.6%	66.7%	80.0%
Design Authoring	63.4%	63.6%	71.4%	88.9%	73.0%	83.3%	0.0%
Structural Analysis	60.0%	90.9%	78.6%	88.9%	51.4%	50.0%	0.0%
Maintenance Scheduling	30.1%	54.5%	57.1%	33.3%	18.9%	16.7%	0.0%
Building System Analysis	33.4%	72.7%	53.6%	11.1%	37.8%	25.0%	0.0%

Fig. 2 Use frequencies of BIM services used in each continent (Jung and Lee 2015)

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2.3 BIM Software

Table 1; showing some BIM soft wares, Manufacturers and their uses

Product Name	Manufacturer	Primary Function
Revit Architecture	Autodesk	3D Architectural Modelling and Parametric Design
Revit Structure	Autodesk	3D Architectural Modelling and Parametric Design
DProfiler	Beck Technology	3D Conceptual Modelling with real time cost estimating
Bentley BIM Suite (Micro Station, Bentley Architecture, Structural, Mechanical , Electrical Generative Design)	Bentley Systems	3D Architectural, Structural, Mechanical, Electrical and Generative Components Modelling
	Graphisoft	3D Architectural Modelling
Vectorworks Designer	Nemetschek 3D Architectural Modelling	3D Architectural Modelling

Architects can gain from going beyond the traditional 2D CAD approach throughout the different stages of pre-design, design and post-design. BIM is an innovative way to preconstruction, design, construction, and post construction of a building project in comparison to the traditional way of drawing (Eastman et al., 2011). A dearth of knowledge regarding BIM has led to a slow uptake of this technology and ineffective management of adoption (Mitchell and Lambert, 2013).

Table 2: shows the application of BIM in the design phase.

Schematic Design	Detailed Design	Construction Detailing
• Options Analysis (to compare multiple design options) • Photo Montage (to integrate photo realistic images of project with its existing conditions)	• 3D exterior and interior models • Walk-through and fly-through animations • Building performance analyses (e.g. energy modelling) • Structural analysis and design	• 4D phasing and scheduling • Building systems analysis (e.g. clash detections) • Shop or fabrication drawings

Source: Azhar, S et al. (2012)

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Figure 3

Figure 4

Figures 3 and 4: 3D architectural models.

Figures 3 and 4 above is showing 3D architectural models. Proposals are understood through accurate visualization, better production quality – documentation output is flexible and exploits automation.

Figures 2 and 3 are 3-D architectural models of the same building. Options for the colour of the paint, building element or even the shrubs for landscaping can be proposed and agreed on from the model. Where a proposal is made and there is the need for adjustments, documentation output is flexible and exploits automation. This saves the client, contractor and the architect the stress of having to redo an aspect of the building after it has been constructed, thereby, saving cost and time. Proposals are better understood through accurate visualization. Cost estimates are easily extracted and updated with changes made.

The basic difference in the building element between figure 3 and 4 is the use of hardwood as fascia board in the former and concrete fascia in the latter. The 5D aspect of BIM i.e. costing automatically realises this and changes the specification and cost of fascia board in the former to that of concrete fascia in the latter. By so doing, chances for mistakes and/or omissions in specifications and detailing are eliminated. On the 4D aspect, the time allotted for construction of fascia board is also automatically changes to the time for concrete fascia. If it will take longer to construct concrete fascia, it will increase the total time of construction by the time difference. Figure 4 shows and example of the 5D aspect of BIM.

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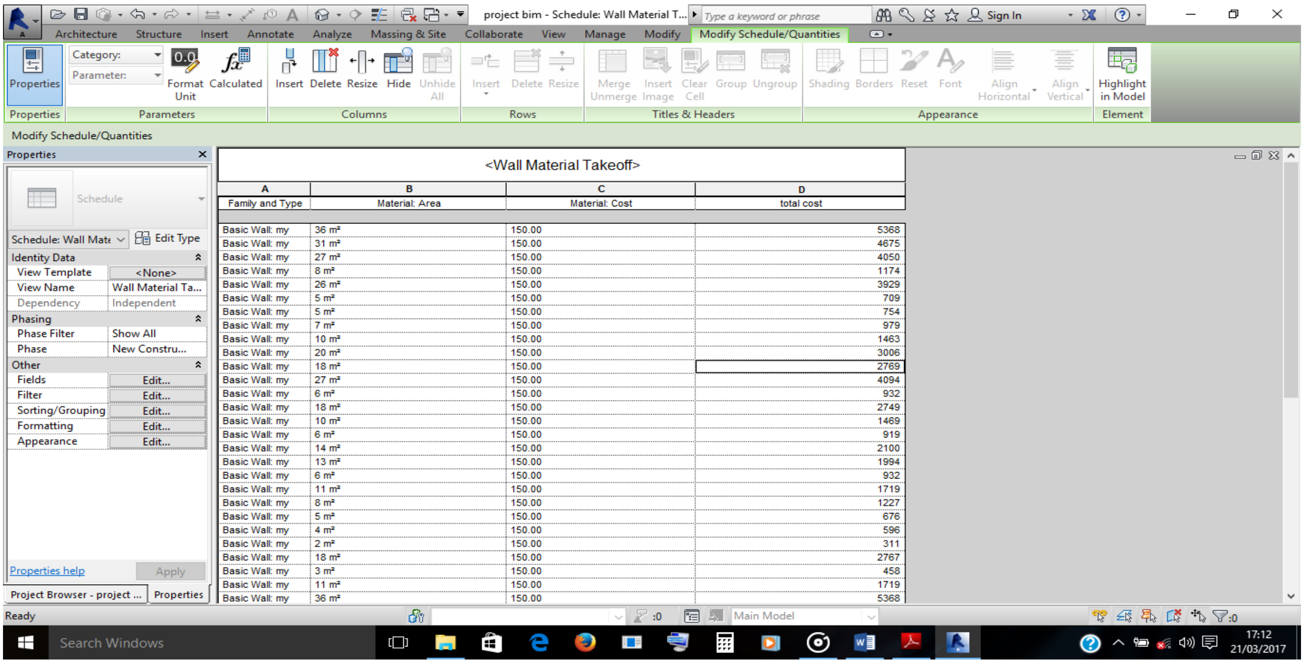

Figure 4: showing the final material take off with cost and total cost of walls in Autodesk Revit Architecture 2014

3. Methodology

Interviews were carried out amongst architectural firms in Nigeria. The sample population constitutes forty (40) registered architectural firms. Since the usage of BIM is being considered, firms that have been involved in design and construction were sampled.

4. Results and Findings

The following data were obtained from the respondents:

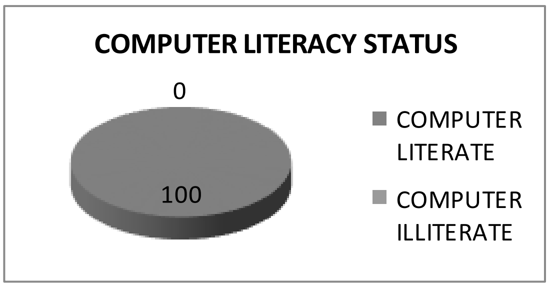

Figure 5: Computer literacy

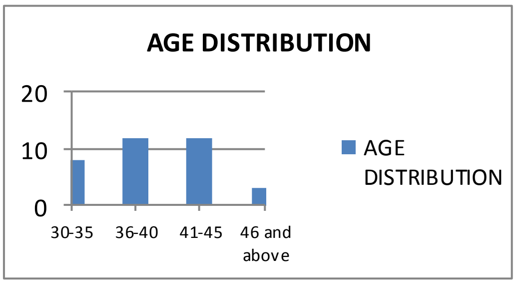

Figure 6: age distribution of personnel using CAD

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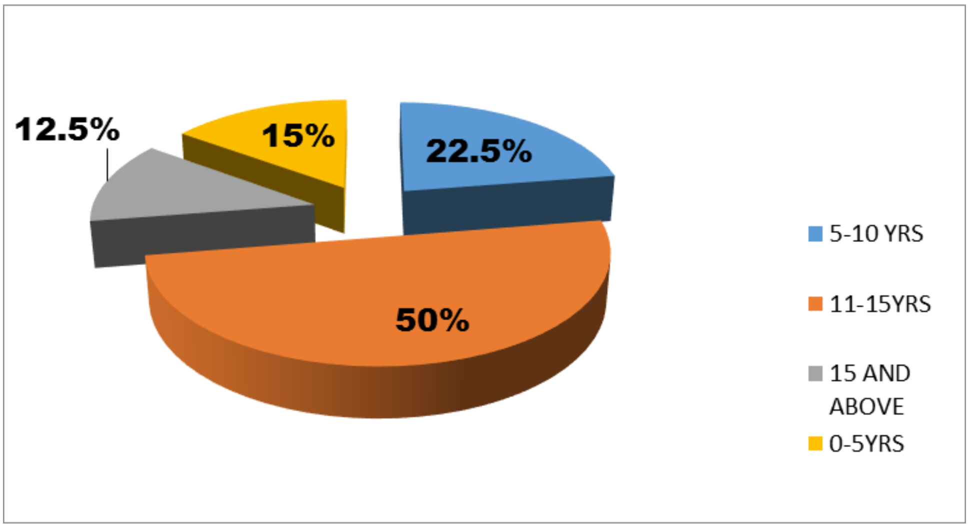

Figure 7: Practice experience of architectural firms

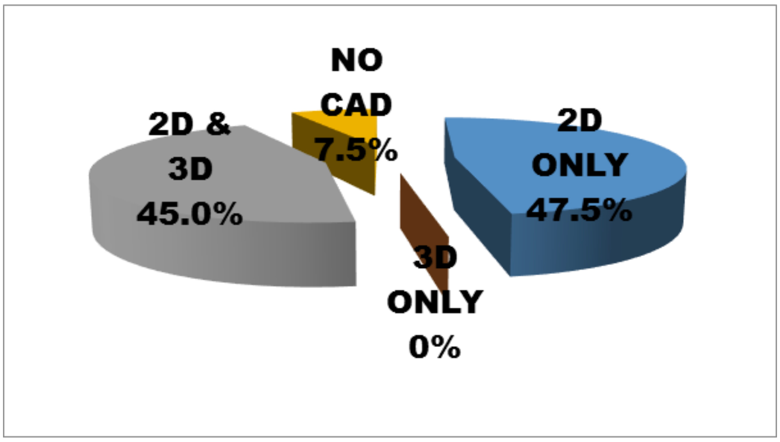

Figure 8: Level of CAD usage of personnel

Table 3: Level of BIM awareness and usage

Bim Usage	Response In Frequency	Response In Percentage
Aware and currently using it	1	02.5%
Aware and actively using it	0	00.0%
Aware and considering it	26	65.0%
Aware but not considering it	10	25.0%
unaware	3	07.5%

Figure 5 shows that 100% of the respondents are computer literate. This shows that computer literacy is appreciated in architecture as a profession. Figure 6 shows that twenty four (24) of the personnel using CAD in the architectural firms are between the ages of thirty six (36) and forty five (45). This shows the age bracket actively practising architecture in Nigeria. Figure 7 shows that the architectural firms have been practising for at least 5 years. 2D architectural software is mostly used by architectural firms as shown in figure 8 with forty five percent of the respondents using both 2D and 3D architectural software.

Table 3 shows that the awareness of BIM was high amongst respondents with only 7.5% of the respondents unaware about it. It also reveals that the usage of BIM was very low as only one architectural firm used it. While probing further to know why the usage is low despite awareness being high, some respondents say the unavailability of the software was a factor. It was learnt that the cost of the software is high and there was an unavailability of pirated copies which is what is mostly used because of its affordability. Where pirated copies were available, they were incompatible with other BIM software

5. Conclusion

Cost of BIM software should be subsidised such that is becomes affordable to enable more architects use it as it is clear from the results presented that the willingness to use BIM high. As the usage of BIM increases, architects will naturally become more interested in it. Just as Computer Aided Design (CAD) started as 2D then evolved to 3D, it will develop and continue to evolve to BIM 6D and continue to n-D.

From the results obtained in this research, sixty five percent (65%) of the personnel using CAD are between the ages of thirty five (35) and forty five (45) years. This shows that the youth should be targeted in BIM education. Hence, BIM should be thought in higher institutions of learning to enhance its usage at ages earlier than thirty five years. Just as 19% of firms in Egypt require the knowledge of BIM in newly recruited staff it will gradually become a requirement in most firms as time evolves.

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