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Building Information Modelling (BIM) for Quantity take – off and Visualization of Building Construction Projects in Akwa Ibom State, Nigeria

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Abstract
This study aimed to investigate the extent to which Building Information Modelling (BIM) is applied for quantity take-off and visualization of building construction projects in Akwa Ibom State. In line with the specific purposes of the study, two research questions and two hypotheses guided the study. The study employed a descriptive survey research design. The population of the study was 401 building construction practitioners in Akwa Ibom State with a sample size of 114, drawn using cluster and simple random sampling techniques. The instrument for data collection was a structured questionnaire titled 'Building Information Modelling for Quantity take-off and Visualization Questionnaire (BIMQVQ)' which contained a total of 40 items built in two clusters to address the research questions. The instrument was validated by three experts, two in the Department of Industrial Technology Education (Building technology option) and one in the Department of Measurement and Evaluation, all from the University of Uyo, Uyo. The reliability of the instrument was determined by trial testing the instrument on twenty (20) practitioners in the building industry in Akwa Ibom State who were not part of the Study. The Cronbach Alpha procedure was used to compute the estimate of internal consistency of the instrument and yielded the reliability coefficient of 0.85. Some questionnaires administered were retrieved on the spot while some were retrieved a day after with the help of three research assistants. The data collected were analysed using descriptive and inferential statistics. The Mean and Standard Deviation were used to answer the research questions, while one sample t – test was used in testing the hypotheses at 0.05 level of significance. Findings revealed that the extent of application of BIM in quantity take – off and visualisation of building construction projects in Akwa Ibom State is low and not significant.

Key Words: Building, Information, Modelling, Quantity Take-off, Visualization

Introduction

Building Information Modelling (BIM) is a digital representation of the physical and functional characteristics of a facility throughout its life cycle from inception to completion. BIM model gives the digital representation of the intended project in a virtual environment. The BIM software is a software designed to give a precise digital model of how a facility is digitally constructed. The BIM model can be employed to display the complete details of building from inception to completion. BIM represents a new concept in Architectural, Engineering and Construction (AEC) industry that promotes collaboration of relevant stakeholders on a project. As opined by Buyle *et al.* (2013), BIM has the ability to encourage better efficiency and coordination among the project team members who see themselves as adversaries in the past. BIM is a novel project delivery process that integrates systems, people and business practices in a collaborative manner to minimize waste and maximize efficiency throughout the project lifecycle. A project lifecycle can be defined as the process that involves different phases of work from inception to completion.

BIM serves as a shared knowledge resource for information about a facility and provides a reliable basis for decisions during the entire life cycle of the project. According to Xiao and Noble (2014), BIM is an innovative design tool which has changed a lot in the construction industry. As reported by Bryde, *et al.* (2013), BIM is a suitable tool for management of various phases of the construction projects such as project procurement, execution, and facility management. As opined by Nasila and Cloete (2018), BIM is used in pre-construction, construction, and post construction stages of building projects. In pre – construction stage, BIM is used for designing, scheduling, quantity take – off, and visualization of building construction projects. At the construction stage, they assert that BIM is useful in clash detection, constructability analysis, and risk control, while being used at post construction stage in facility management of building construction projects. This study will however focus on the use of BIM for quantity take-off and visualization of building construction projects.

Quantity take-off is one of the key tasks in the construction process since it is the foundation for several other tasks. The building elements are measured, and these quantities are then used to estimate their cost and the relevant workload. Quantity take-off can be a measurement of the building's schematics or of the work done on site. This information is assembled in what is traditionally called a Bill of Quantities. This type of document structures and organizes the information about measurements, productivities and costs, according to the construction task and respecting the actual construction order. According to Cheung *et al.* (2014), Quantity take-off is applied throughout the construction process. In the early stages, it provides the base for a preliminary cost estimate for the project; in the tendering stage it is used to assist in the estimation of the project's cost and duration of the construction activities; before the

construction stage it is used to forecast and plan the construction activities; and during the construction stage it is used for the economic control of the project.

An accurate quantity take-off is decisive for the economic balance of the contractor's finances as it is the only way of achieving a thorough analysis of the productivity and of the different types of costs in a particular project. Traditionally, quantity take-off is a manual process that involves measuring the different design elements, namely, floor plans, elevations, cross sections and other similar documents. Since it is based on human interpretation this approach is very error prone (Monteiro and Martins, 2013). Furthermore, according to Monteiro and Martins (2013), 2D-based documents, whether they are designed by hand or with the help of CAD tools, are also error prone. 2D documents are designed based on other 2D documents developed by a manual process; wrong inputs and interpretations are therefore very common since it is very hard to process complex situations, in particular, connections between various building elements (e.g. a cross section of the connection of a beam, a column, a wall and a slab) in a 2D frame. A further complication is the coordination of different project specialties while avoiding clashes between different elements, all of which makes the manual production of 2D documentation even harder.

Application of BIM in quantity take – off and estimation of building construction projects involves the use of Information models to generate accurate cost estimates at a faster rate of modelled materials. Here the model is linked to a cost database, which then computes a cost estimate. Kjartansdóttir and Snæbjörnsson (2015) avers that BIM can be used to provide more accurate cost information to the owner during the early decision making phase of building design and throughout the lifecycle of the building, including changes during construction. It allows estimators to focus on more value adding activities in estimating such as: identifying construction assemblies, generating pricing and factoring risks, which are essential for high quality estimates. According to Kjartansdóttir and Snæbjörnsson (2015), added to a construction schedule (such as a 4D Model), a BIM developed cost estimate can help track budgets throughout construction and help reduce time on quantity take-offs and cost estimations.

Based on the technicalities involved in quantity take – off in building construction projects, scholars including Firat *et al*. (2016) and Balah and Akut, (2015) reported the application of BIM in quantity take – off of building construction projects among building construction practitioners to be very low. This again, points to the poor state of Vocational and Technical education in the country to provide adequate manpower needs for the built sector. According to Ntegwung and Njoku (2022), how far the successive democratic government in Nigeria has pursued the issue of vocation technical education and training for the manpower needs of the country visa-a-visa the unemployment situation affecting the Nigeria youths remains a big question yet to be answered.

Visualization refers to the physical or mental representation of an object, situation, or information as an image. The construction industry relies heavily on visualization to investigate and communicate complex situations and objects, in particular relating to

the design and construction of buildings and other built assets. It is widely used as part of the design process, and as a way of describing constructionworks and components to contractors, subcontractors and suppliers. It is also used to communicate proposed solutions to clients, local authorities and other stakeholders (Gerrish *et al.*, 2017).

Visualization can range from very simple block diagrams at the early stages of a project, to highly-technical representations of construction information or visually realistic representations that can be useful for communicating to non-expert stakeholders..

Traditionally, visualizations were prepared by hand as sketches, diagrams, technical drawings and 3D renderings. The development of computers resulted in the emergence of Computer Aided Design (CAD) techniques that allowed two-dimensional visualisations to be create, changed and duplicated more easily. More recently, as noted by Abdelalim et al. (2017),

Building Information Modelling has allowed 3D modelling of design proposals, constructed parametrically and including 4D (time), 5D (cost) and 6D (facilities management) information. In visualization, BIM can be used in design review for purpose of clash detection, work planning to enable task scheduling, progress tracking, energy analysis and facility management. As opined by Ivson *et al.* (2020), designing facilities with 3D CAD models enables automated checking of physical inconsistencies. For example, geometry overlaps can cause severe delays and rework during construction and also increase the overall project costs. BIM systems help engineers locate these physical overlaps using some kind of visual feedback over the 3D CAD model. In addition, the experts need to identify which components are involved, their degree of inconsistency, and corresponding engineering specifications.

Visualization for Task Scheduling in virtual construction planning has always been the major use case of BIM. It consists of 4D animations (3D + time) that indicate the sequence of activities in the job site. Combining temporal with spatial information allows engineers to avoid many scheduling problems, such as inconsistent assembly ordering and workspace conflicts. It also improves understanding of work plans among designers, planners, and field personnel. Slightly more information is displayed in Chart views than 3D CAD views, with only a few exceptions using a 2D CAD view. Main techniques include: Gantt Chart, Visibility Animation, Table, and Annotation. Gantt charts plot time using a spatial dimension in an intuitive graph-like view (Shalabi and Turkan, 2017). Regarding the 3D CAD view, the most popular 4D visualization is the Visibility Animation. In this scheme, facility components not yet built remain invisible. As simulation time progresses, geometries suddenly turn visible to indicate their construction has commenced. Similarly, predecessor/successor relationships are deduced by the sequence of appearing geometries.

Visualization in BIM use also help in tracking work progress. Project managers need to closely follow construction execution to make sure activities remain in accord with the original schedule. Main challenges include tracking many ongoing activities and calling attention to problems and delays. Traditionally, project management uses the same methods and tools for planning and controlling work execution. Many schedule analysis systems already have the ability to track task delays by enriching their visualizations. According to Ivson *et al.* (2020), Although Chart and 3D CAD views are still predominant, tables are now the most prominent mechanism of conveying information, closely followed by Gantt Charts, Highlight, and then Visibility Animations. Tables continue to convey mostly textual information related to task execution. Meanwhile, Gantt Charts are seldom employed in the current use case. One reason could be a lack of adequate progress tracking tools within BIM visualization systems (Rahmani *et al.*, 2015). In the 3D CAD view, most information is visualized using Highlight Animations. These are more frequent when compared to "Task Scheduling". This is probably because task delays can be easily highlighted using colors.

Visualization is also used for energy analysis in building construction projects due to a growing trend in sustainable design using BIM. Today's governments face environmental pressure from several factors such as global warming studies, increasing costs of fossil fuels, and elevated pollution in large metropolis. Ever stricter regulations are forcing construction companies to improve their practice. Certificates systems such as the Leadership in Energy and Environmental Design (LEED) were created to promote and award efficient buildings (Rahmani *et al.*, 2015). As an added benefit, energy efficient designs also contribute with cost savings during operation phase.

Another use of BIM for visualization is in facilities management. One of the main activities during "Operation" is maintaining a facility's physical integrity. Structures suffer continuous degradation from exposure to elements. Hydraulic, mechanical, and electronic systems lose efficiency and can malfunction over time. Facility managers employ several different maintenance strategies. Each has varying task and data requirements, as well as different implementation costs. Sicat *et al.* (2018) asserted that information are visualized mainly with 3D CAD and Chart views, with a few exceptions using 2D CAD. Within the 3D CAD view, Annotation is the main visualization. It conveys three major types of information: maintenance problems, sensor readings, and component specifications. This visualization combines several Marks and Channels to make evident the logical relationships among facility components (Chandler *et al.*, 2015).

Application of BIM for Visualization involves the use of BIM to represent design and review construction activities through pictorial model, 3D models and virtual reality. As affirmed by Eastman *et al.* (2018), BIM is used to visualize permanent and temporary facilities on site during multiple phases of the construction process. As part of the communication purpose of BIM Uses, using BIM to visualize a facility is very powerful. It is especially powerful for those

who have not been trained within the design and construction industry but are critical stakeholders and decision makers. The visualization purpose of BIM Uses include those BIM Uses which are implemented to form a representation of the facility or facility elements. Often this visualization can be very realistic and detailed in nature.

Visualization according to Kreider and Messner (2013) is often used to support decision making about the facility's design or construction as well as support marketing efforts. It can include walkthroughs, renderings, and schedule visualizations. The fact that the visualization is a by-product of other BIM processes improves the ability of individuals to share facility information in a more effective manner with much additional effort. Information models are used to visualize permanent and temporary facilities on site during multiple phases of the construction process. The model can also be linked with the 4D schedule to convey space and sequencing requirements on site. Furthermore, information on labour resources, materials with associated deliveries and equipment location can be obtained using BIM.

In visualization, BIM according to Wong and Zhou (2015), Cheung *et al.* (2014), and Barati *et al.* (2013) is useful in the following areas: Efficiently generate site usage layout for temporary facilities, assembly areas, and material deliveries for all phases of construction; Quickly identify potential and critical space and time conflicts; Accurately evaluate site layout for safety concerns; Select a feasible construction scheme, Effectively communicate construction sequence and layout to all interested parties; Easily update site organization and space usage as construction progresses; and Minimize the amount of time spent performing site utilization planning. Ntegwung and Usoro (2023) however, noted that BIM has not been fully maximized by building construction practitioners in visualization of building construction projects due to dearth of skilled personnel and the cost implications.

Application of BIM in building construction projects has gone far in some developed countries. However, there remain a long way to go in the developing countries especially Nigeria. There is a very limited awareness and knowledge of BIM technology in Nigeria (Onungwa *et al*., 2017); and this is generally associated with lack of awareness of the concept, or lack of trained staff on the BIM tools or both (Abubakar *et al*., 2013; Onungwa *et al*., 2017). In view of the varied benefits and usefulness of BIM to the construction industry and the challenges to its application in Nigeria, it becomes imperative to determine the extent to which BIM is applied in quantity take-off and visualization of building construction projects in Akwa Ibom State, Nigeria.

Statement of the Problem

It is worrisome that the relationship among various practitioners in the construction industry in Nigeria over the years has been poor according to research reports. Not only has this situation resulted in haphazard implementation and uncontrolled quality of projects, the frequent break-downs in communication have also led to increased costs, prolonged project execution time and most times, abandoned projects. The alarming cases of collapsed buildings and

abandoned construction projects in Akwa Ibom only point to the sub-optimal constructions which fall short of global standards with the use of BIM.

Observation and interactions with building construction practitioners reveal that the BIM concept seems relatively new in Akwa Ibom State. This suggests that the construction industry in Akwa Ibom State may still be struggling to adopt and fully maximize the potentials and gains of BIM to develop the sector. It was therefore imperative to ask: to what extent do building construction practitioners in Akwa Ibom State apply BIM in quantity take-off and visualization of building construction projects? Providing answer to this question necessitate this study.

Purpose of the Study

The general purpose of this study was to determine the extent to which Building Information Modelling (BIM) is applied for project management by building construction practitioners in Akwa Ibom State. Specifically, the study sought to:

1. determine the extent to which BIM is applied for quantity take – off of building construction projects by building construction practitioners in Akwa Ibom State.
2. determine the extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State.

Research Questions

The following research questions guided the study:

1. What is the extent to which BIM is applied for quantity take – off of building construction projects by building construction practitioners in Akwa Ibom State.
2. What is the extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State?

Research Hypotheses

The following null hypotheses were formulated for the study and tested at 0.05 level of significance.

1. The extent to which BIM is applied for quantity take – off of building construction projects by building construction practitioners in Akwa Ibom State is not significant.
2. The extent to which BIM is applied for Visualization of building construction projects by building construction practitioners in Akwa Ibom State is not significant.

Methodology

This study employed a descriptive survey design. The use of this design is considered appropriate because it will establish the opinions of building construction practitioners on the extent of application of BIM for quantity take-off and visualization of building construction projects in Akwa Ibom State. The study was conducted in Akwa Ibom State. Akwa Ibom is one

of the 36 states in Nigeria, located in the coastal southern part of the country. Akwa Ibom State was considered as the area of the study because of its terrain as a coastal area and the recent industrialization drive by the state government which will usher in civilization with the concomitant effect of the upsurge of building construction projects in the state.

` The population of this study was 401 building construction practitioners. This consisted of registered professionals in the building construction industry in Akwa Ibom State, obtained from the directories of professional bodies in Nigeria. (https://www.vconnect.com › Akwa Ibom). The sample size for this study was One Hundred and fourteen (114). A cluster and simple random sampling techniques was adopted in selecting the sample. The population was grouped into three clusters to represent three senatorial districts of Akwa Ibom State namely: Uyo, Ikot Ekpene, and Eket. A Simple random sampling technique was adopted to select the sample size of 38 from each cluster. This was to ensure that each member of the population has equal chances of being selected for the study. Questionnaire titled Extent of Application of Building Information Modelling for Quantity Take-off and Visualization of Building Construction Projects Questionnaire (EABIMQVBCPQ*)* was used for data collection. The questionnaire was developed by the researchers based on the research questions. The questionnaire contained a total of 40 items built in two clusters: A and B with 20 questions in each cluster to address the research questions. The two clusters therefore consisted of items structured to address the two research questions that guided the study. A five-point rating scale was provided in each of the clusters for the respondents to make their responses as follows: Very High extent (VHE), High Extent (HE), Moderate (M), Low Extent (LE), and Very Low Extent (VLE). The scale was weighed 5, 4, 3, 2, and 1 respectively.

The reliability of the instrument was determined by trial testing of the instrument on twenty (20) practitioners in the building industry in Akwa Ibom State who were not part of the sample of the Study. The Cronbach Alpha statistic was used to compute the estimate of internal consistency of the instrument so as to determine the reliability coefficient. The instrument yielded the reliability coefficient of 0.85. This showed that the instrument was reliable to be used for the study. The data collected were analysed using descriptive and inferential statistics. The Mean and Standard Deviation were used to answer the research questions, while one sample t – test was used in testing the hypotheses at 0.05 level of significance. The mean value of 3.0 was used as a decision rule in answering the research questions. Any item with the mean value below 3.0 was considered as low, while the mean value of 3.0 and above was considered as high.

Results

Research Question 1: What is the extent to which BIM is applied for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State.?

Table 1: **Extent to which BIM is applied for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State**

Variables	N	$\bar{X}$	SD	Weighted mean	Remark
Building construction practitioners	114	25.36	2.89	2.53	Low extent

Source: Field data 2024

In Table 1, the result revealed that the mean rating of building construction practitioners on the extent to which BIM is applied for quantity take–off of building construction projects is 25.36 and the weighted mean of items is 2.53. Since the weighted mean of items is less than the benchmark of 3.0, it is regarded as low extent. This implies that the extent to which BIM is applied for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State is low.

Research Question 2: What is the extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State?

Table 2: **Extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State**

Variables	N	$\bar{X}$	SD	Weighted mean	Remark
Building construction practitioners	114	26.45	2.32	2.64	Low extent

Source: Field data

In Table 2, the result revealed that the mean rating of building construction practitioners on the extent to which BIM is applied for visualization of building construction projects is 26.45 and the weighted mean of items is 2.64. Since the weighted mean of items is less than the benchmark of 3.0, it is regarded as low extent. This implies that the extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State is low.

Null Hypothesis 1: Extent to which building construction practitioners do apply BIM for quantity take–off of building construction projects in Akwa Ibom State is not significant.

Table 3: **Summary of one sampled t-test on Extent to which building construction practitioners do apply BIM for quantity take–off of building construction projects in Akwa Ibom State**

Variable	$\bar{X}$	SD	df	t	P=0.05	Decision
quantity take–off	25.36	2.89	113	93.58	.560	Not Sig.

Source: Field data

The result in Table 3 revealed that the calculated t = 93.58 and p =. 560 at 113 degree of freedom. Since the p value is greater than 0.05 level of significance the null hypothesis which stated that the extent to which building construction practitioners do apply BIM for quantity take–off of building construction projects in Akwa Ibom State is not significant is retained. This implies that the extent to which building construction practitioners do apply BIM for quantity take–off of building construction projects in Akwa Ibom State is not significant

Null Hypothesis 2: Extent to which building construction practitioners do apply BIM for visualization of building construction projects in Akwa Ibom State is not significant.

Table 4: **Summary of one sampled t-test on Extent to which building construction practitioners do apply BIM for visualization of building construction projects in Akwa Ibom State**

Variable	$\bar{X}$	SD	df	t	P=0.05	Decision
visualization	26.4570	2.32	113	121.24	.054	Not Sig.

Source: Field data 2024

The result in Table 4 revealed that the calculated t = 121.24 and p = .054 at 113 degree of freedom. Since the p value is greater than 0.05 level of significance, the null hypothesis which stated that the extent to which building construction practitioners do apply BIM for visualization of building construction projects in Akwa Ibom State is not significant is retained. This implies that the extent to which building construction practitioners do apply BIM for visualization of building construction projects in Akwa Ibom State is not significant.

Summary of Findings

1. The extent to which BIM is applied for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State is low.
2. The extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State is low.

Discussion of Findings

Extent to which BIM is applied for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State.

Table 1 presents the result on the extent of application of BIM for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State. As indicated, the extent of application of BIM for quantity take–off of building construction projects by building construction practitioners in Akwa Ibom State is low. The corresponding hypothesis as presented in Table 3 further revealed that the extent to which building construction practitioners do apply BIM for quantity take – off of building construction projects in Akwa Ibom State is not significant. This is as a result that of the fact that constructors often lack consistent quality model that would allow them to extract data that would facilitate an appropriate quantity take-off and estimate. This could be reason for having uncompleted buildings that looks abandoned by the owners. The finding is in collaboration with the findings of Firat *et al*. (2010) and Balah and Akut, (2015) who reported the application of BIM in quantity take – off of building construction projects among building construction practitioners to be very low. As discussed in the study, the application of BIM determines the cost and workload of building construction from start to the finish. This blueprint is believed to determine accurate measurements of materials to be used in construction and also productivity of the constructors. BIM model serves to reduce time as estimators are able to extract measurements and material quantities straight from models. The finding is also consistent with the findings of Latiffi *et al.* (2015) who stated that BIM was applied at various stages of building project in scheduling, 3D visualization, quantity take – off. However, this serves to be cost effective and efficient when constructors of building adopt the use of BIM as shown in the study. Thus, conclusion is made that the application of BIM in building helps the constructors in understanding the project needs and thereby execute the job on time without running cost.

Extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State.

The result in Table 2 showed the extent to which BIM is applied for visualization of building construction projects by building construction practitioners in Akwa Ibom State. It was found that the extent of application of BIM for visualization of building construction projects by building construction practitioners in Akwa Ibom State is low, while the corresponding hypothesis as presented in Table 4 revealed that the extent to which building construction practitioners do apply BIM for visualization of building construction projects in Akwa Ibom State is not significant. The result is attributed to the fact that the constructors are not consistent in the use of BIM while constructing buildings as they are still adopting the traditional method. The finding of the study is in harmony with the findings of Ntegwung and Usoro (2023) who

noted that BIM has not been fully maximized by building construction practitioners in visualization of building construction projects due to dearth of skilled personnel and the cost implications. Also, the findings agree with that of Nasila and Cloete (2018) who revealed low level of application of BIM in design and visualization, clash detection among building constructors in the construction industry in Kenya. However, the importance of BIM is discussed to have include the enhanced performance when the constructors are consistent in its application. This is in collaboration with the findings of Soliman (2017) who presented that the application of BIM is economical and easy leading to improvement, enhanced technical and general management of construction projects which can lead to total control of cost estimates, prompt delivery of projects and quality are the most important key performance indicators in construction.

Conclusion

Based on findings, the present study maintains that the extent of application of Building Information Modelling (BIM) for quantity take-off and visualization of building construction projects in Akwa Ibom State is low. The implication is that building constructors in Akwa Ibom State are not consistent in the use of BIM. There is therefore the need for more sensitization on the application and adoption of BIM models in building construction projects in the area, considering its varied benefits.

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