Assessment of BIM-Based Maintenance Management Practices in Lagos State Higher Education Institutions

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Tertiary institutions, with their extensive building portfolios, face unique challenges in managing maintenance operations effectively. BIM technology serves as a central repository of building information, consolidating data on design, construction, and operation, thereby revolutionizing traditional maintenance practices. This study assessed the state of Building Information Modelling (BIM)-based maintenance management practices of higher education institution buildings in Lagos State focusing on maintenance staff perspectives in public universities. The research evaluates the level of usage of BIM-based maintenance practices and recommend strategies to enhance BIM integration in maintenance. Targeting federal and state-owned universities in Lagos State, the study employs a quantitative approach, gathering data through structured questionnaires distributed via purposive sampling. Responses from two hundred and ninety-six (296) maintenance technical staff were analysed using descriptive statistics. Findings reveal that preparation of maintenance codes that regulate minimum safety requirements for facility maintenance (RUI – 0.52; RK -1), basic sketches and notes for maintenance works of building elements (RUI – 0.51; RK – 2), produce basic digital drawings of building elements not generated from 3d dimensions (RUI -0.50; RK -3) were ranked high in the level of usage of BIM. The study concludes that many of the institutions have high awareness of BIM, its implementation in maintenance is limited, underscoring the need for policy advancements to strengthen maintenance management quality and optimize facility maintenance management system. It is recommended that the management of the university should invest on training of maintenance staff in BIM software tools for improved and efficient facility and maintenance management of institution buildings.

Keywords: BIM Implementation, building maintenance, building systems and services, maintenance technical staff, higher education Institutions

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Introduction

In the rapidly evolving field of facility management, building maintenance plays a crucial role in ensuring the longevity and optimal performance of structures (Ogungbemi *et al.*, 2020). Tertiary institutions, with their extensive building portfolios, face unique challenges in managing maintenance operations effectively. BIM technology serves as a central repository of building information, consolidating data on design, construction, and operation, thereby revolutionizing traditional maintenance practices (Aghabayli, 2021).

Building Information Modelling (BIM) is a digital representation of the physical and functional characteristics of a facility, which provides a shared knowledge resource for information about a facility (Motawa & Almarshad, 2013). BIM is instrumental in the architecture, engineering, and construction (AEC) industry, facilitating improved design, construction, and management of buildings (Deniz & Esin, 2015). Its application in Facility Management (FM) has gained significant attention, particularly within higher education institutions.

BIM has revolutionized the construction industry, reducing planning time and costs, and improving project outcomes (Latiffi *et al.*, 2014). However, its adoption and implementation remain low among construction companies in developing countries. Effective building maintenance is crucial for preserving the condition and functionality of structures. BIM has the potential to enhance maintenance practices by providing accurate data and automating processes (Gledson & Greenwood, 2017). However, challenges such as inadequate documentation and lack of coordination among maintenance teams hinder effective maintenance in tertiary institutions in Lagos State. Studies show that BIM can significantly reduce design and construction costs and enhance project efficiency (Motawa & Almarshad, 2013).

Despite its benefits, the adoption of BIM in developing countries remains low. This study aims to investigate BIM-based maintenance management practices and their impact on buildings in selected tertiary institutions

in Lagos State. By conducting a comprehensive review of the state of structures and proposing suggestions for improving maintenance practices, this study hopes to contribute to the body of knowledge on BIM and maintenance practices in tertiary institutions. The findings will help stakeholders understand the benefits and challenges of implementing BIM-based maintenance systems, ultimately enhancing the efficiency, safety, and sustainability of buildings.

Building Information Modelling (BIM) offers significant potential for improving facilities management (FM) in universities (Takim *et al.,* 2013). However, the adoption and implementation of BIM in universities in Lagos State face several challenges. The main issues hindering the implementation of BIM in Nigeria include a lack of published standards and protocols, high initial costs and financial constraints, insufficient understanding of BIM's practical applications, and limited availability of learning resources (Takim *et al.,* 2013; Takim *et al.,* 2016; Anifowose *et al.* 2018; Koseoglu & Nurtan-Gunes, 2018). These challenges contribute to the slow adoption of BIM across the Architecture, Engineering, and Construction (AEC) industry in Nigeria.

The adoption of Building Information Modelling (BIM) in the construction industry has been slow, particularly in developing countries like Nigeria. Despite its benefits, including improved maintenance and facility management, many professionals in the industry are unclear about its importance and practical applications. Studies have shown that the lack of understanding, limited training, and inadequate infrastructure are major barriers to the adoption of BIM (Azhar *et al.*, 2012; Julius *et al.*, 2012). Effective maintenance of building services equipment in tertiary institutions is crucial, but current practices are often inadequate. The adoption of BIM and other technologies can improve maintenance management, but there is a need for a structured approach to implementation (Koseoglu & Nurtan-Gunes, 2018). The study assessed BIM-based maintenance management practices of higher education buildings in Lagos State with the goal of improving level of usage in public universities buildings. This was done by determining the level of usage of BIM-Based maintenance practices in tertiary institution buildings and identify measures for improving BIM-Based maintenance practices in the study area.

Literature Review

Overview

Building Information Modelling (BIM) is a digital representation of a building's physical and functional characteristics, enabling collaboration and coordination throughout the development lifecycle (Motawa & Almarshad, 2013). The concept of BIM has its roots in computer-aided design (CAD) and computer-aided engineering (CAE), and its evolution can be traced back to the 1960s. However, the term "BIM" was coined in the early 2000s, and its adoption and implementation have been gaining momentum in the architecture, engineering, and construction (AEC) industry since then (Migilinskas *et al.,* 2013).

The BIM system consists of three primary components: object-based modelling, model-based collaboration, and network-based integration. Object-based modelling creates a virtual representation of a building using digital objects, while model-based collaboration enables real-time sharing and coordination of information among project stakeholders. Network-based integration facilitates the exchange and integration of data and information across different platforms and systems. BIM tools, such as Revit Architecture, Revit Structural, and Navisworks, are used to implement BIM in construction projects (Anifowose *et al.,* 2018; Koseoglu & Nurtan-Gunes, 2018).

The benefits of BIM include improved project visualization, enhanced coordination, reduced rework, increased productivity, better cost control, and improved facility management. BIM also enables the integration of different disciplines and trades, allowing for better coordination and communication (Julius *et al.,* 2012). The 6D, 7D, and 8D applications of BIM enhance its value proposition, making it a comprehensive tool for stakeholders throughout the entire building lifecycle. These dimensions include sustainability and environmental analysis, facility management and operations, and cost estimation and project decision-making (Azhar *et al.*, 2012).

Table 1: BIM Software and Tools Analysis

S/N	Software	Use	Professionals	Service Available
1.	Tekla Structures	Steel and Concrete Detailing, structural models	Structural, Steel and Civil Engineers	**Structural Designer, Tedds, BIMSight**
2.	Archicad	Architectural BIM CAD	Architects	**Parametric Modelling and Design, Data Interchange, Remote Access and Collaboration**
3.	ArchiFM	Asset planning, Maintenance, Reporting Services	Facility Managers, Estate Surveyors	**BIM Computer Aided Facility Management Software**
4.	Green Building Studio	Analysis of Green Building requirement, Energy Analysis, Interoperability	Green Building Experts, Designers, Contractors and Planners	**BIM-Green Building Standards Integration Module**
5.	Masterbill	Integrated CAD and BIM enabled measurement Module	Quantity Surveyors, Estate Surveyors, Project Schedulers	**BIM Enabled estimating and Scheduling (4D BIM)**
6.	Revit Architecture	Architectural Designs, Structural and MEP modelling	Architects, Services and Civil Engineers	**4D BIM modelling and Parametric Design**
7.	Skecthup	Architectural and Mechanical Design and Models, Interior design,	Architects, Mechanical and Interior Designers.	**3D modelling**
8.	PowerCivil	Integrated site, building and aerial planning	Design Team	**Site Development**
9.	Digital Project	Information Sharing and Interoperability of various CAD software.	Architects, Modelers, Schedulers	**Architectural computer aided design**
10.	Navisworks Manage	Complement 3D Design Packages, 4D Time simulation	Architects, Quantity Surveyors, Scheduler, Project Managers.	**Roamer, Publisher, Clash Detective, Autodesk Renderer, Quantification, Timeliner, Animator, Scripter**
11.	Autodesk Quantity take-off	Quantity Take-offs	Quantity Surveyors, Scheduler	**3D and CAD enabled quantity taking of**
12.	VICO Software	Virtual Construction, Quantity Take-offs, Project Scheduling, Cost Estimation, Production Control.	Contractors, Quantity Surveyors, Scheduler,	**5D BIM Virtual Construction**
13.	Bentley BIM Suite	Architectural Designs, Structural and MEP modelling,	Architects, Services and Civil Engineers	**Architectural, engineering and Construction, 3D Modelling**

Source: Succar & Kassem, 2015; Anifowose *et al.*, 2018; Olanrewaju *et al.*, 2020

Maintenance management practices

Maintenance management is crucial in educational buildings to ensure a conducive learning environment. Studies have shown that there is a significant relationship between educational building performance and student quality (Ferreira & Souza, 2021; Milad & Mastaneh, 2021; Chinda & Wokekoro, 2022; Innocent & Babajide, 2023). However, maintaining buildings in tertiary institutions has been a challenge due to poor maintenance culture and inadequate funding. To address this, a well-planned maintenance management framework is necessary.

According to Chidi and Ogunoh (2020), building maintenance involves various activities, including

servicing, rectification, replacement, and protection. Servicing includes routine cleaning and maintenance schedules, rectification involves correcting defects and faults, replacement involves substituting worn-out parts, and protection involves controlling functions to prevent damage. Maintenance can be classified into planned and unplanned maintenance, with planned maintenance being scheduled and unplanned maintenance requiring immediate attention (Chinda & Wokekoro, 2022).

Effective maintenance management can help prevent building defects, reduce costs, and improve the overall quality of educational buildings (Faremi *et al.*, 2017). A maintenance management plan should be developed to align with the institution's goals and objectives, including regular inspections, maintenance schedules, and a budget for maintenance activities (Chinda & Wokekoro, 2022)**.** Training and awareness programs can also be implemented to educate staff and students on the importance of maintenance and their roles in maintaining the buildings (Ferreira & Souza, 2021)**.**

BIM and maintenance management practices

Building Information Modelling (BIM) plays a significant role in enhancing maintenance management in facilities (Akcamete *et al.,* 2010; Deniz & Esin, 2015; Mario, *et al.,* 2019). BIM provides a 3D digital environment for visualizing, tracking, and managing maintenance-related information, improving efficiency and effectiveness. The integration of BIM models with related information enables facility maintainers to improve maintenance and management work. BIM facilitates 3D visualization and mapping of facility assets, maintenance information, and related documents, enhancing understanding and tracking of maintenance needs (Akcamete *et al.,* 2010).

The qualities of maintenance management practices enhanced by BIM include efficiency, integration of maintenance information, visualization and mapping, web-based access, document management integration, transparency and information sharing, 4D BIM for maintenance planning, data-driven decision-making, improved maintenance monitoring, and enhanced collaboration (Deniz & Esin, 2015).

To improve BIM-based maintenance management, measures can be taken, such as capturing and integrating accurate and complete information, standardizing data formats and exchange protocols, implementing automated data transfer, developing visualization and analysis tools, training and educating facility managers, fostering collaboration and communication, considering legal and contractual considerations, and establishing feedback loops (Mario *et al.*, 2019)

Implementing these measures can improve the effectiveness and efficiency of BIM-based maintenance management, leading to better maintenance planning, reduced costs, and improved facility performance. Effective maintenance management can help organizations optimize maintenance operations, reduce downtime, extend asset lifecycles, and ensure the overall safety and efficiency of the facility (Deniz & Esin, 2015).

Benefits of BIM in facility management

1. **Enhanced Information Tracking and Sharing**: BIM integrates building information with FM processes, allowing facility managers to access and track facility-related data in a 3D environment. This includes information on facility locations, maintenance work, schedules, and results. It enhances the efficiency of facility information tracking and sharing, leading to better decision-making and maintenance (Olanrewaju *et al.,* 2020).
2. **Visualization and Spatial Analysis**: BIM provides 3D spatial information, which is invaluable for visualizing and analysing maintenance activities. Facility managers can use this information to identify patterns and trends in breakdowns and repairs, prioritize maintenance tasks, and improve the overall management of maintenance activities (Su *et al.*, 2010).
3. **Maintenance Management**: The integration of BIM with FM systems supports the tracking, coordination, and access to building maintenance information. This integration helps in monitoring maintenance operations, planning maintenance activities, and conducting quality inspections more efficiently (Volk *et al.,* 2014).
4. **4D BIM Models**: The use of 4D BIM models, which integrate time-based information with 3D models, allows facility managers to visualize the schedule of maintenance tasks, track progress, and manage maintenance activities more effectively. This capability enhances maintenance planning and execution (Takim *et al.,* 2016).

Research Methodology

The study adopted quantitative surveys and inferential statistics with maintenance technical staff in selected four public higher education institutions (1 Federal University and 3 State Universities) in Lagos State. Data on the usage of BIM and measures for improving on the adoption of BIM-Based maintenance are collected and analysed.

The study adopted descriptive research, with a quantitative strategy that focuses on exploratory data. The study used purposive sampling technique in selecting two hundred and ninety-six (296) respondents from various Maintenance Technical staff in the

universities. Data were collected through questionnaires and analysed using descriptive statistics. The research area is significant, as it has the potential to revolutionise maintenance practices in educational facilities, enhancing the quality of education, safety, and sustainability.

Results and Discussion

Demographic information of respondents

To understand the background of the respondents as shown in Table 2, questions were asked to ascertain the gender, profession, level of education, and experience of the respondents. This also helps to reveal and assess the level of understanding of the respondents on the subject matter in the selected tertiary institutions in Lagos State. Collectively, the total number of male respondents (270) vastly overshadows the number of female respondents (26), resulting in an overall gender ratio of approximately 91.5% male to 8.5% female. Such an imbalance may reflect broader societal trends in educational access, choices of fields of study, or cultural factors influencing enrolment.

The Federal University exhibits a more varied range of qualifications among respondents compared to State Universities. The data reveals that State Universities have a high percentage of HND holders (65%), indicating a strong vocational focus, while Federal University shows more varied qualifications but still lack respondents pursuing advanced degrees, as none of the institutions have PhD candidates. This suggests a need for increased support for advanced education and a balance between vocational training and academic qualifications. The data shows that the majority of faculty members in both Federal and State Universities have between 11 to 15 years of experience, with State Universities having a higher percentage in this category (57.7%). Federal University has a significant portion of faculty with over 15 years of experience (47.37%), while State Universities have 38.80% in this bracket. Notably, State Universities lack faculty with less than 5 years of experience, unlike the Federal University, which has a small representation in that category.

Table 2: Demographic Information of the Respondents

University	Demographic	Frequency	Percentage
Federal	Male	81	85%
	Female	14	15%
State	Male	189	94%
	Female	12	6%
Academic qualification			
Federal	NABTEB	4	4%
	ND/NCE	15	16%
	HND	34	36%
	BSc/BSc-Edu	29	31%
	MSc/MSc-Edu	13	14%
	PhD	0	0%
State	NABTEB	0	0%
	ND/NCE	9	5%
	HND	128	65%
	BSc/BSc-Edu	52	24%
	MSc/MSc-Edu	12	6%
	PhD	0	0%
Years of experience			
Federal	Less than 5years	1	1.05%
	Between 6-10years	8	8.42%
	Between 11-15years	41	43.16%
	Above 15years	45	47.37%
State	Less than 5years	0	0.00%
	Between 6-10years	7	3.50%
	Between 11-15years	116	57.7%
	Above 15years	78	38.80%

Level of usage of BIM-Based maintenance practices

The calculated relative usage index (RUI) of use was interpreted using the scale $0.37 \leq RUI \leq 0.42$ to represent sometimes used (SU), scale $0.43 \leq RUI \leq 0.48$ to represent often used (OU), scale $0.49 \leq RUI \leq 0.55$ to represent always used (AU). RK means Rank and RM means Remark.

The result in Table 3 shows the level of usage of BIM-Based maintenance practices in tertiary institutions in Lagos State by the Maintenance technical staff. At Federal University (Unilag), the maintenance staff rated the level of usage at 20% often used and 80% always used. According to the perception of respondents that are maintenance technical staff in the state-owned universities: In Lasustech, the level of usage is 100% always used. In LASU, the level of usage is 13% often used and 87% always used. In Lasued, the level of usage is 40% sometimes used and 60% often used respectively.

Some of the usage of BIM-based maintenance practices in each institution is taken as a priority by the maintenance technical staff confirm it because according to Li *et al.* (2019), the technological perspective of developments in building operation and maintenance, BIM is one of the key technologies expected to impact the sector. The maintenance staff concludes on the factors influencing the level of usage of BIM-Based maintenance practices in tertiary institutions in Lagos State which are the ability to perform tasks with BIM among maintenance personnel, the attitude of maintenance personnel towards innovations and technology, experience of BIM Users with Maintenance Departments, issues relating to the accuracy and consistency of maintenance data with computer system.

Table 3: Level of implementation of BIM-Based maintenance practices

S/N	Level of usage	FEDERAL UNIVERSITY				STATE UNIVERSITIES				TOTAL			
		N	RUI	RK	RM	N	RUI	RK	RM	N	RUI	RK	RM
1	Basic Sketches and Notes for Maintenance Works of Building Elements	95	0.52	2	AU	201	0.51	2	AU	296	0.51	2	AU
2	Produce Basic Digital Drawings of Building Elements not Generated from 3D Dimensions	95	0.51	4	AU	201	0.50	3	AU	296	0.50	3	AU
3	Produce a Graphical Representation of Building Element Generated with a Graphical Representation of 3D Dimension	95	0.5	6	AU	201	0.49	7	OU	296	0.49	6	OU
4	Use Structured Information that is Linked to 3D Digital Drawings	95	0.5	7	AU	201	0.49	7	OU	296	0.49	6	OU
5	Produce 4D Planning for an Action Plan for Facility Maintenance	95	0.49	12	AU	201	0.47	12	OU	296	0.48	12	OU
6	Collaborate with Other Maintenance Teams Through a Common Enabling Environment	95	0.49	8	AU	201	0.48	9	OU	296	0.48	9	OU
7	The Approach of Maintenance Works with Relevant Information of the BIM Model	95	0.47	15	OU	201	0.45	15	OU	296	0.46	15	OU
8	Use BIM to Review Details of Building Elements and Maintenance Performance of Assets	95	0.49	11	AU	201	0.48	10	OU	296	0.48	10	OU
9	Use of a Computerized System between Different Dimensions of BIM	95	0.49	8	AU	201	0.48	10	OU	296	0.48	10	OU
10	Budget Preparation of Detailed Cost of Maintenance of Building Element	95	0.51	5	AU	201	0.49	4	OU	296	0.50	4	AU
11	Specification Writing for Maintenance Works Before Execution	95	0.49	8	AU	201	0.49	6	OU	296	0.49	6	OU
12	Preparation of Maintenance Codes that Regulate Minimum Safety Requirements for Facility Maintenance	95	0.53	1	AU	201	0.52	1	AU	296	0.52	1	AU
13	Use BIM Models in Facilities and Operations Maintenance Management	95	0.48	14	OU	201	0.47	14	OU	296	0.47	14	OU
14	Documentation of all Maintenance Activities of Building Elements with BIM Software	95	0.51	3	OU	201	0.49	4	OU	296	0.50	4	AU
15	Integration of BIM for Reporting of Maintenance Challenges of Building Elements	95	0.49	12	AU	201	0.47	12	OU	296	0.48	12	OU

Determining the measures for improving the use of BIM-Based maintenance practices

The calculated relative importance index (RII) was interpreted using the scale $0.31 \leq RII \leq 0.42$ to represent less significant (LS), scale $0.43 \leq RII \leq 0.48$ to represent significant (S), scale $0.49 \leq RII \leq 0.55$ to represent most significant (MS). RK means Rank and RM means Remark.

The result in Table 4 shows measures for improving the use of BIM-Based maintenance practices in tertiary

institutions in Lagos State by the Maintenance Staff. In federal university, the maintenance staff rated measures for improving the use of BIM-Based maintenance practices at 33% significant and 67% most significant. According to the perception of respondents from the state universities, in Lasustech, measures for improving the use of BIM-based maintenance practices are 100% most significant. In Lasu, measures for improving the use of BIM-Based maintenance practices are 25% significant and 75% most significant. In Lasued, measures for improving the use of BIM-based maintenance practices are 92% less significant and 8% significant respectively. The most significant measures for improving the use of BIM-based maintenance practices are; the creation of the awareness of BIM for facilities/building maintenance, increased desire of university management to invest in information technology, the need to establish a computerized maintenance unit, government policy decisions on the adoption of software for maintenance. The less significant measures for improving the use of bim-based maintenance practices are; the need to improve communication between the maintenance unit and users, proper planning and scheduling of maintenance works in achieving desired results, adoption of a computer-aided facilities management system, scheduled online channel for users report and maintenance**.**

To boost the efficiency of the maintenance staff on quality strategies, corrective maintenance should be avoided at all times. The physical appearance of maintenance equipment and tools, the professional appearance of the maintenance personnel, the condition and aesthetics of the facilities, technical expertise, and knowledge are very crucial for the quality of the maintenance management service of buildings. There are various ways on the measures to improve the use of BIM-based maintenance practices.

Table 4: Measures for the Level of BIM Implementation

S/N	VARIABLES	FEDERAL UNIVERSITY				STATE UNIVERSITIES				TOTAL			
		N	RII	RK	RM	N	RII	RK	RM	N	RII	RK	RM
1	Increased Desire of University Management to Invest in Information Technology	95	0.5	1	MS	201	0.48	2	S	296	0.49	2	MS
2	Needs to Establish a Computerized Maintenance Unit	95	0.5	1	MS	201	0.48	2	S	296	0.49	2	MS
3	Needs to Increase Funding System for Maintenance Works	95	0.49	6	MS	201	0.47	6	S	296	0.48	6	S
4	Needs to Improve Communication Between the Maintenance Unit and Users	95	0.48	10	S	201	0.46	9	S	296	0.47	9	S
5	Adequate Planned and Routine Maintenance System of Building Elements	95	0.49	6	MS	201	0.47	7	S	296	0.47	7	S
6	Proper Planning and Scheduling of Maintenance Works in Achieving Desired Results	95	0.48	10	S	201	0.46	9	S	296	0.47	9	S
7	Adoption of a Computer-Aided Facilities Management System	95	0.48	9	S	201	0.46	9	S	296	0.47	9	S
8	Improved Financial Resources Management System for Building Elements	95	0.49	5	MS	201	0.47	7	S	296	0.47	7	S
9	Scheduled Online Channel for Users Report and Maintenance	95	0.47	12	S	201	0.45	12	S	296	0.46	12	S
10	Government Policy Decisions on the Adoption of Software for Maintenance	95	0.49	4	MS	201	0.47	4	S	296	0.48	4	S
11	Creation of the Awareness of BIM for Facilities/Building Maintenance	95	0.5	1	MS	201	0.49	1	MS	296	0.49	1	MS
12	Employment of Information Technology Expert as Maintenance Personnel	95	0.49	6	MS	201	0.47	4	S	296	0.48	4	S

Conclusion

This study showed that BIM is an effective tool for managing building maintenance at tertiary institutions; nevertheless, in the chosen study area, higher education institutions have not yet fully adopted BIM-based maintenance practices. To facilitate the acceptance and application of BIM maintenance management, there is need for increased awareness, training, and resources. Using BIM lowers expenses, boosts building conditions overall, and facilitates better facility management. Enhancing facility management, cutting expenses, and increasing maintenance efficiency are all possible using BIM. The use of BIM is greatly influenced by technological elements, such as hardware and software

capacities. Successful implementation requires organisational elements including resource allocation and leadership support. Efficient utilization depends heavily on human variables like user acceptability and training.

Based on the findings and conclusion, the following recommendations are itemized:

i. Using BIM analysis to update, replace building components and elements to maximize building upkeep for an efficient built environment
ii. The management of the university should invest on training of maintenance staff in BIM software tools for improved and efficient facility and maintenance management of institution buildings.
iii. Advocating for policies with government organisations and agencies is necessary to create frameworks for legislation and incentives that support the usage of BIM in maintenance management in higher education institutions.
iv. A larger portion of the maintenance budget should be designated for BIM projects for building systems and conditions maintenance management procedures.
v. To effectively promote the potential advantages of BIM for facilities management, cooperation between academic departments, information, communication, technology, and works and physical planning staff is required.

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