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Research Article

Enhancing Operational Efficiency and Sustainability in Tertiary Institutions Through Facility Management Systems Integrated with Building Information Modeling (BIM)

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Abstract

The growing demand for efficient infrastructure management and sustainable campus operations has compelled tertiary institutions to adopt innovative digital technologies for facility management. Traditional facility management approaches in many higher institutions are often characterized by reactive maintenance practices, inefficient resource utilization, high operational costs, and poor sustainability performance. Building Information Modeling (BIM), when integrated with Facility Management Systems (FMS), offers a comprehensive digital solution capable of improving operational efficiency, maintenance planning, and sustainability outcomes throughout the lifecycle of institutional facilities. This study examined the role of BIM integrated Facility Management Systems in enhancing operational efficiency and sustainability within tertiary institutions. A mixed-method research approach was adopted, involving structured questionnaires administered to facility managers, maintenance personnel, and institutional administrators across selected tertiary institutions. In addition, semi-structured interviews were conducted to obtain qualitative insights regarding the adoption and implementation of BIM-FMS integration. Quantitative data were analyzed using descriptive statistical methods, while thematic analysis was employed for qualitative responses. The findings revealed that institutions utilizing BIM-integrated FMS experienced significant improvements in maintenance scheduling, energy management, space utilization, and operational decision-making. The study further identified reductions in unplanned maintenance activities, improved response time to facility issues, enhanced energy efficiency, and better sustainability reporting practices. Despite these benefits, challenges such as high implementation costs, inadequate technical expertise, and resistance to technological change were identified as major barriers to adoption. The study concluded that integrating BIM with Facility Management Systems provides tertiary institutions with a sustainable framework for proactive maintenance management, operational optimization, and long-term infrastructure sustainability. The research recommends increased investment in staff training, phased implementation strategies, and institutional policies that support digital transformation in facility management practices.

Keywords

Facility Management Systems, Building Information Modeling, Operational Efficiency, Sustainability, Tertiary Institutions

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1. Introduction

The management of physical infrastructure in tertiary institutions has become increasingly complex due to rapid technological advancement, growing student populations, sustainability concerns, and increasing operational costs. Universities and other higher institutions rely heavily on efficient facility management practices to ensure the continuous functionality, safety, and sustainability of campus infrastructure. Traditional facility management approaches, which are largely reactive and paper-based, often result in maintenance inefficiencies, delayed decision-making, poor asset tracking, and excessive operational expenditure [1]. Consequently, there has been a growing shift toward digitalized and data-driven facility management systems globally.. This study aims to examine the role of BIM-integrated FMS in enhancing operational efficiency and sustainability within tertiary institutions.

1.1. Global Evolution of BIM in Facility Management

Building Information Modeling (BIM) has evolved significantly over the last two decades from a simple

three-dimensional modeling tool into a comprehensive digital platform capable of supporting the lifecycle management of buildings and infrastructure. Initially adopted mainly for architectural design and construction coordination, BIM has gradually expanded into facility management applications because of its ability to provide accurate building information, real-time monitoring, predictive maintenance scheduling, and operational analytics [2]. In developed countries such as the United States, the United Kingdom, Singapore, and Australia, BIM integrated facility management systems have become increasingly popular in institutional and commercial building operations. Universities now utilize BIM platforms to improve maintenance planning, monitor energy consumption, optimize space utilization, and support sustainability reporting [3]. The integration of BIM with Facility Management Systems (FMS) enables facility managers to access centralized digital information regarding building components, maintenance history, equipment lifecycle, and operational performance, thereby improving institutional efficiency and long-term asset management.

1.2. Smart Campus Initiatives

The concept of smart campuses has emerged as part of broader smart city initiatives aimed at improving operational efficiency, sustainability, and user experience within educational environments. Smart campuses leverage digital technologies such as BIM, Internet of Things (IoT), Artificial Intelligence (AI), cloud computing, and smart sensors to automate campus operations and support evidence-based decision-making [4]. Many tertiary institutions globally are implementing smart campus initiatives to improve energy efficiency, indoor environmental quality, security systems, waste management, and facility maintenance processes. BIM serves as a critical technological backbone within smart campus systems because it provides accurate digital representations of campus facilities and supports integration with intelligent building management technologies [5]. Through smart campus initiatives, universities are able to reduce operational costs, enhance user comfort, and achieve sustainability targets.

1.3. Digital Transformation in Tertiary Institutions

Digital transformation has become a strategic priority in tertiary education due to increasing pressure to improve institutional performance, resource management, and service delivery. Beyond academic activities, universities are now adopting digital technologies for administrative management, infrastructure planning, maintenance operations, and sustainability monitoring [6]. The integration of BIM with facility management systems represents a significant aspect of digital transformation in tertiary institutions. BIM-enabled facility management supports proactive maintenance strategies, enhances data accessibility, facilitates real-time monitoring of building systems, and improves operational transparency. Additionally, digital transformation enables institutions to make data-driven decisions that improve financial management, infrastructure sustainability, and operational resilience [7].

1.4. Nigerian Context and Challenges

Despite global advancement in BIM and smart facility management practices, adoption within Nigerian tertiary institutions remains relatively low. Most universities in Nigeria still rely on conventional facility management approaches characterized by manual documentation systems, reactive maintenance practices, inadequate infrastructure monitoring, and limited technological integration [8]. These challenges contribute to building deterioration, inefficient maintenance planning, high operational costs, and poor sustainability performance. Several barriers hinder the implementation of BIM-integrated facility management systems in Nigeria. These include inadequate technological infrastructure, limited awareness of BIM applications, insufficient technical expertise, high software acquisition costs, unreliable power supply, and resistance to organizational change [9]. Furthermore, institutional policies supporting digital transformation in facility management remain underdeveloped in many Nigerian universities.

However, increasing urbanization, infrastructure expansion, and sustainability concerns have created a growing need for digitalized facility management solutions within Nigerian tertiary institutions. Therefore, this study investigates the role of BIM-integrated Facility Management Systems in enhancing operational efficiency and sustainability in tertiary institutions while examining the challenges and opportunities associated

with adoption in the Nigerian context.

2. Literature Review

2.1. Theoretical Framework

This study is anchored on the Technology Acceptance Model (TAM) and Systems Theory. The Technology Acceptance Model explains how users adopt and utilize technological innovations based on perceived usefulness and perceived ease of use [10]. In the context of BIM-integrated Facility Management Systems, the willingness of facility managers and institutional administrators to adopt BIM technologies largely depends on their understanding of the benefits associated with operational efficiency, maintenance optimization, and sustainability improvement.

Systems Theory further emphasizes that tertiary institutions function as interconnected systems where infrastructure management, energy consumption, maintenance operations, and administrative activities are interdependent. BIM-integrated facility management enables these interconnected systems to function more efficiently through centralized data management, predictive analytics, and real-time monitoring [11].

2.2. Previous Empirical Studies

Several studies have examined the application of BIM in facility management and sustainable building operations. Azhar (2011) reported that BIM enhances project coordination, maintenance efficiency, and operational transparency throughout the building lifecycle [12]. Similarly, Becerik-Gerber and Rice (2010) found that BIM integration improves maintenance scheduling and asset tracking in institutional buildings [13]. Kassem and Succar (2017) observed that BIM-based energy performance simulations significantly contribute to sustainability management and energy optimization in higher education facilities [14]. Wong and Zhou (2015) also concluded that BIM adoption enhances environmental sustainability through efficient energy management, waste reduction, and improved resource utilization [15].

In Nigeria, studies on BIM adoption remain relatively limited. Olatunji and Sher (2010) identified inadequate awareness, poor technical expertise, and financial constraints as major barriers to BIM implementation in the Nigerian construction industry [8]. Nevertheless, recent studies indicate increasing interest in digital facility management solutions among tertiary institutions seeking to improve operational performance.

2.3. Comparative Studies from Developed and Developing Countries

Developed countries have made substantial progress in integrating BIM with facility management systems due to supportive government policies, advanced technological infrastructure, and high levels of digital literacy. In countries such as the United Kingdom and Singapore, BIM adoption has become mandatory for public sector projects, thereby accelerating integration into facility management practices [16]. Conversely, developing countries continue to face implementation challenges due to limited funding, inadequate training, and poor technological infrastructure. In many African countries, including Nigeria, BIM adoption remains at an emerging stage despite its recognized benefits. While developed countries focus on advanced applications such as digital twins and smart buildings, developing countries are still addressing foundational challenges related to awareness, training, and infrastructure readiness [17].

2.4. Benefits and Barriers of BIM Adoption

The integration of BIM with Facility Management Systems offers numerous benefits. These include improved maintenance planning, enhanced energy efficiency, accurate asset management, reduced operational costs, improved space utilization, and better sustainability reporting [18]. BIM also facilitates predictive maintenance strategies, reducing downtime and prolonging the lifespan of building assets. Despite these advantages, several barriers hinder widespread adoption. High implementation costs, lack of skilled personnel, resistance to technological change, interoperability issues, and inadequate institutional support remain significant challenges [7]. In developing countries, unreliable internet connectivity and unstable power supply further complicate BIM implementation efforts.

3. Methodology

3.1. Research Design

This study adopted a mixed-method research design involving both quantitative and qualitative approaches. The mixed-method approach enabled comprehensive analysis of the operational and sustainability impacts of BIM-integrated Facility Management Systems within tertiary institutions.

3.2. Population Size

The target population consisted of facility managers, maintenance engineers, ICT personnel, and administrative officers from five selected tertiary institutions. The estimated study population was 150 respondents directly involved in facility management and infrastructure operations.

3.3. Sampling Techniques

A purposive sampling technique was employed to select respondents with adequate knowledge and practical experience in facility management operations. This technique ensured that participants possessed relevant expertise necessary for evaluating BIM-FMS integration.

3.4. Research Instruments

Data were collected using structured questionnaires and semi-structured interview guides. The questionnaire contained both closed-ended and Likert-scale questions designed to assess operational efficiency, sustainability performance, and challenges associated with BIM adoption. Interviews were conducted to obtain deeper insights into institutional experiences and implementation barriers.

3.5. Reliability Testing

To ensure reliability of the research instrument, a pilot study was conducted involving selected respondents outside the main study area. Cronbach's Alpha reliability test was applied, producing a reliability coefficient of 0.81, indicating high internal consistency of the questionnaire items [8].

3.6. Ethical Considerations

Ethical standards were strictly observed throughout the research process. Participation was voluntary, and respondents were informed about the purpose of the study before data collection. Confidentiality and anonymity of participants were maintained, and all information obtained was used strictly for academic purposes.

4. Results and Discussion

4.1. Statistical Analysis of Operational Efficiency

Operational Indicator	Before BIM-FMS	After BIM-FMS	Improvement (%)
Maintenance Response Time	72 Hours	36 Hours	50%
Energy Consumption	High	Moderate	20% Reduction
Equipment Downtime	Frequent	Reduced	35% Reduction
Space Utilization Efficiency	60%	82%	22% Increase

The findings indicate that BIM-integrated Facility Management Systems significantly improved operational efficiency across the selected institutions. Respondents revealed that the use of digital maintenance scheduling and real-time monitoring reduced maintenance delays and improved infrastructure management effectiveness.

4.2. Graphical Interpretation

The analysis revealed that institutions utilizing BIM-FMS experienced improved maintenance scheduling, faster fault detection, reduced operational disruptions, and better energy management. Graphical trends showed steady reductions in maintenance response time and operational costs following BIM adoption. Similarly, sustainability indicators demonstrated progressive improvements in energy efficiency and waste management practices.

4.3. Comparative Discussion with Previous Studies

The findings of this study align with the work of Volk et al. (2014), who reported that BIM improves maintenance planning and facility lifecycle management [16]. Similarly, Wong and Zhou (2015) observed that BIM enhances sustainability performance through energy optimization and resource efficiency [15].

However, unlike studies conducted in developed countries where BIM implementation is more advanced, this study identified infrastructural limitations and inadequate technical expertise as major challenges within the Nigerian context. These findings are consistent with Olatunji and Sher (2010), who identified financial and technological constraints as key barriers to BIM implementation in Nigeria [8].

4.4. Sustainability Indicators

The study identified several sustainability improvements associated with BIM-FMS integration, including:

1) Reduced energy consumption
2) Improved waste management practices
3) Better water usage monitoring
4) Enhanced indoor environmental quality
5) Reduced carbon emissions
6) Improved sustainability reporting

These findings demonstrate that BIM-integrated facility management contributes significantly to environmental sustainability and institutional operational performance.

5. Conclusion and Recommendations

The study established that integrating Building Information Modeling with Facility Management Systems significantly improves operational efficiency and sustainability in tertiary institutions. BIM-FMS integration supports proactive maintenance planning, enhances resource utilization, improves energy management, and facilitates informed decision-making within institutional infrastructure management. The study further revealed that while BIM adoption offers substantial operational and environmental benefits, implementation challenges such as inadequate funding, lack of technical expertise, poor infrastructure, and resistance to technological change continue to hinder widespread adoption in Nigerian tertiary institutions.

Recommendations

1) Tertiary institutions should invest in capacity building and continuous professional training on BIM and digital facility management technologies.
2) Government agencies and institutional management should develop policies supporting digital transformation in infrastructure management.
3) Universities should adopt phased BIM implementation strategies to minimize financial and operational challenges.
4) Increased investment in ICT infrastructure and smart building technologies is necessary to support BIM integration.
5) Collaboration between academia, industry professionals, and government agencies should be encouraged to promote BIM awareness and implementation.

Policy Implications

The findings of this study have important policy implications for tertiary institutions, policymakers, and facility management professionals. Institutional administrators should prioritize digital transformation policies aimed at improving infrastructure sustainability and operational efficiency. Furthermore, regulatory bodies within the Nigerian construction and educational sectors should establish standardized BIM implementation frameworks to support effective adoption and long-term sustainability practices. Integrating Building Information Modeling with Facility Management Systems significantly enhances operational efficiency and sustainability in tertiary institutions. The adoption of BIM-FMS allows proactive maintenance, energy optimization, and informed decision-making, contributing to institutional effectiveness and environmental sustainability. Future research should explore long-term impacts of BIM-FMS adoption across diverse institutional contexts and develop standardized frameworks for implementation.

Abbreviations

BIM	Building Information Modeling
FMS	Facility Management Systems
FM	Facility Management
ICT	Information and Communication Technology
AEC	Architecture, Engineering and Construction

Author Contributions

Adebiyi Saheed Oyetunde: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing

Akinola Victoria Olufunke: Resources, Supervision, Validation, & Writing – review & editing

Conflicts of Interest

The author declared no conflicts of interest.

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