KASU ENVIRONMENTAL SCIENCE JOURNAL (KESJ)
KASU Environmental Science Journal (KESJ) ISSN: 2734-2751
Volume 5, Issue 1, August 2025

LEVERAGING BIM AND DIGITAL COLLABORATION FOR SUSTAINABLE DEVELOPMENT IN THE NIGERIAN CONSTRUCTION SECTOR: A SYSTEMATIC REVIEW

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ABSTRACT

Purpose: *Building Information Modeling (BIM) and digital collaboration technologies are transforming the global construction industry, yet adoption in Nigeria remains underdeveloped. The Nigerian construction sector faces a dual challenge, a significant lag in the adoption of Building Information Modeling (BIM) technology and an urgent need for more sustainable construction practices. While BIM has proven to be a vital tool for improving collaboration, efficiency, and sustainability in construction globally, Nigeria's adoption of this technology remains slow.*

Design/methodology/approach*: The primary aim of this study is to explore the role of BIM and digital collaboration technologies in fostering sustainable construction within the Nigerian construction and design industry. This study employs a systematic review approach, structured using PRISMA guidelines. The literature search was conducted across multiple databases, including Scopus, Google Scholar, and ResearchGate. Key search terms included combinations of "Building Information Modelling (BIM)," "Digital Collaboration," "Sustainable Construction," "Nigerian Construction Industry," "AEC Industry," and "Barriers to BIM Adoption." The review follows a structured process that involves identifying relevant studies, evaluating their quality, and synthesising their findings to provide insights into the current state of BIM adoption, the barriers and facilitators to implementation, and the potential of BIM in fostering sustainable construction practices in Nigeria.*

Findings: *The findings reveal that while BIM awareness is increasing, its practical implementation remains limited. Bridging this gap will require targeted training, enhanced collaboration, and stronger regulatory frameworks. The review also identifies future research directions, particularly in comparative African contexts and longitudinal adoption studies.*

Practical implications: *The Nigerian government should take a leading role in promoting BIM adoption by developing national policies and guidelines that mandate or incentivise the use of BIM in public sector projects. Such policies have been successful in other countries, and similar initiatives could drive greater adoption within Nigeria. In addition, regulatory bodies such as the Nigerian Institute of Architects (NIA) and the Nigerian Society of Engineers (NSE) should provide clear guidelines for BIM implementation, ensuring that all professionals are aligned with industry standards.*

Originality/value: *This systematic review uniquely synthesises evidence on BIM adoption in Nigeria, highlighting barriers such as inadequate policies, a shortage of skilled professionals, and reluctance to transition from traditional methods. Unlike previous reviews, this study explicitly frames BIM adoption through sustainability and digital maturity models, contributing to both academic literature and practice.*

Keywords: BIM Adoption, Digital Collaboration, Nigerian Construction Sector, Sustainability, Technology

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1.0 INTRODUCTION

The construction sector is a cornerstone of global economic development, contributing to significant portions of national GDPs and employment generation (Martek, 2022). Despite this, the industry is plagued with inefficiency, cost overruns, delays, and project abandonment, particularly in developing countries like Nigeria (Martek, 2022). These challenges highlight the urgent need for innovative tools and processes that can streamline operations, improve collaboration, and enhance the overall sustainability of construction projects (Adagba *et al.,* 2023; Okolie & Edo, 2023). Building Information Modelling (BIM) has emerged as a transformative technology that addresses many of these long-standing issues within the construction sector. BIM is defined as a digital representation of the physical and functional characteristics of a facility, providing a shared knowledge resource for information about a facility to support decision-making throughout its lifecycle, from earliest conception to demolition (Succar, 2009). Globally, BIM adoption has been driven by its ability to foster collaboration, improve project management, reduce waste, and achieve cost efficiency. Countries such as the UK, Singapore, and South Korea have mandated the use of BIM in public projects, significantly boosting productivity and sustainability in their construction industries (Munir & Jeffrey, 2013; Smith, 2014).

In contrast, Nigeria's construction sector lags in adopting BIM despite its potential to address many of the industry's problems. Studies show that challenges such as inadequate infrastructure, lack of skilled professionals, systemic rigidity, and low awareness of BIM have hindered its widespread implementation (Kori & Kiviniemi, 2015; Hamma-Adama & Kouider, 2018). The Nigerian construction industry is a significant contributor to the country's economy and fixed capital formation, yet it remains a "sleeping giant" due to these persistent inefficiencies (Obakin & Oladunmoye, 2023).At the same time, sustainability has become an increasingly important goal for the global construction industry. Sustainable construction aims to minimise environmental impact, reduce waste, and enhance resource efficiency, all while ensuring that the needs of future generations are not compromised (Young, 1997). Digital technologies, particularly BIM, play a critical role in achieving these goals by enabling real-time collaboration, predictive maintenance, and efficient resource management (Obakin & Oladunmoye, 2023). However, Nigeria’s construction industry has yet to fully harness BIM's potential as a sustainable development tool.

1.1 PROBLEM STATEMENT

The Nigerian construction sector faces a dual challenge, a significant lag in the adoption of Building Information Modelling (BIM) technology and an urgent need for more sustainable construction practices. While BIM has proven to be a vital tool for improving collaboration, efficiency, and sustainability in construction globally, Nigeria's adoption of this technology remains slow (Onungwa & Uduma-Olugu, 2017a). Studies suggest that inadequate infrastructure, lack of skilled professionals, high costs, and systemic resistance to change are the primary barriers to the successful implementation of BIM in Nigeria (Toyin & Mewomo, 2022). Furthermore, as the global construction industry moves towards more sustainable practices, Nigeria risks being left behind in terms of technological advancement and environmental responsibility. Sustainable construction is crucial to reducing waste, improving air quality, and minimising carbon emissions (Ershadi & Goodarzi, 2021). The lack of widespread BIM adoption in Nigeria hinders the construction sector's ability to align with global sustainability standards. Additionally, the slow pace of digital collaboration within the construction sector exacerbates these problems, leading to inefficiencies and suboptimal project outcomes (Abubakar *et al.,* 2014).Therefore, this study seeks to explore the intersection of BIM adoption and digital collaboration in the Nigerian construction industry, focusing on how these technologies can be leveraged to achieve sustainable construction outcomes. The research will contribute to the existing literature by providing a comprehensive review of BIM adoption in Nigeria, identifying barriers, and offering recommendations to accelerate its integration for sustainable development.

1.2 STUDY AIM AND OBJECTIVES

The primary aim of this study is to explore the role of Building Information Modelling (BIM) and digital collaboration technologies in fostering sustainable construction within the Nigerian construction and design industry. The study seeks to highlight both the potential benefits and the existing barriers to the widespread adoption of BIM in Nigeria to improve sustainability outcomes.

1.2.1 Objectives:

1. To identify the barriers to the adoption of BIM and digital collaboration technologies in the Nigerian construction sector.
2. To evaluate the potential benefits of BIM in promoting sustainable construction practices in Nigeria.
3. To assess the role of digital technologies in enhancing collaboration among stakeholders in construction projects in Nigeria.

2.0 METHODOLOGY

2.1 RESEARCH DESIGN

This study employs a systematic review approach, structured using PRISMA guidelines (Shaheen et al., 2023). Literature searches conducted in Scopus, Google Scholar, and ResearchGate using terms such as BIM, digital collaboration, Nigerian construction sector, and sustainability. The review included studies published between 2010 and 2025. The review follows a structured process that involves identifying relevant studies, evaluating their quality, and synthesising their findings to provide insights into the current state of BIM adoption, the barriers and facilitators to implementation, and the potential of BIM in fostering sustainable construction practices in Nigeria.

2.2 LITERATURE SEARCH STRATEGY

To ensure a comprehensive collection of relevant studies, the literature search was conducted across multiple databases, including Scopus, Google Scholar, and ResearchGate. Key search terms included combinations of “Building Information Modelling (BIM),” “Digital Collaboration,” “Sustainable Construction,” “Nigerian Construction Industry,” “AEC Industry,” and “Barriers to BIM Adoption.” Considering the paucity of studies, the researcher opened the study date range to 10 years to capture both recent and all relevant advancements and discussions on BIM in the Nigerian context. Both peer-reviewed articles and grey literature, such as conference papers and policy reports, were included to ensure a broad spectrum of insights.

2.3 INCLUSION AND EXCLUSION CRITERIA

Table 1: Eligibility Criteria

Inclusion Criteria	Exclusion Criteria
o Studies published in English. o Research focusing on BIM and digital collaboration technologies. o Studies specifically examining the Nigerian AEC industry or developing country contexts relevant to Nigeria. o Articles exploring BIM’s potential in promoting sustainability within construction	o Studies that do not specifically focus on Nigeria or the AEC industry. o Articles published before 2010, unless they provide seminal insights into BIM adoption and digital collaboration technologies. o Studies that focus solely on the technical aspects of BIM software without consideration of its application in construction practices

2.4 DATA EXTRACTION

A total of six studies were included in the review, each focusing on the adoption and impact of BIM and digital collaboration technologies in the Nigerian construction industry. These studies utilised various methodologies, including structured questionnaires, literature reviews, and empirical analyses, providing a comprehensive view of the barriers and drivers for BIM adoption. The studies covered key areas such as the influence of BIM on collaboration, the barriers to its implementation (e.g., cost, lack of awareness, and infrastructure issues), and its potential for fostering sustainable construction. Data extracted from these studies are organised into a study characteristics table below to provide a concise summary of the evidence base.

Table 2: Studies Characteristics

Author	Objective	Methodology	Findings
Obakin & Oladunmoye (2021)	To explore BIM as a digital technology for sustainable construction in Nigeria.	Qualitative analysis using secondary data from 26 AEC periodicals.	BIM offers benefits such as improved collaboration, predictive maintenance, and efficient design processes, but faces barriers like systemic rigidity and high costs.
Hamma-adama & Kouider (2018)	To review the adoption and potential of BIM in the Nigerian AEC industry.	Scoping review of literature and analysis of challenges in BIM adoption.	BIM adoption in Nigeria is slow, hindered by a lack of awareness, policies, and infrastructure; potential benefits include improved project outcomes.
Abubakar et al. (2014)	To assess contractors' perceptions of factors affecting BIM adoption in Nigeria.	Structured questionnaire administered to contractors in Nigeria.	BIM adoption is influenced by factors like cost, lack of training, and software availability. Collaboration between stakeholders is critical.
Olanrewaju et al. (2020)	To investigate the barriers to BIM implementation in the Nigerian construction industry.	Structured questionnaire distributed to construction professionals in Lagos.	Key barriers to BIM implementation include cost, lack of training, inadequate standards, and reluctance among stakeholders.
Onungwa & Uduma-Olugu (2017)	To investigate BIM's impact on collaboration in the Nigerian AEC industry.	Structured questionnaire distributed to 30 AEC firms in Lagos.	BIM improves client satisfaction, reduces conflicts, and enhances supervision, but faces challenges like inadequate infrastructure and awareness.
Saka & Chan (2019)	To identify barriers to BIM adoption in small and medium enterprises (SMEs) in Nigeria.	Quantitative survey of SMEs in the Nigerian construction industry.	SMEs face significant barriers to BIM adoption, including cost, lack of technical expertise, and infrastructure limitations.

This systematic approach ensured that all studies were evaluated consistently, and important themes and patterns across the literature were identified.

3.0 RESULTS AND DISCUSSION

3.1 BARRIERS TO BIM ADOPTION

Barriers to the widespread adoption of Building Information Modelling (BIM) in the Nigerian construction sector are a persistent theme across multiple studies. Barriers include inadequate infrastructure (Obakin & Oladunmoye, 2021), high software and training costs (Abubakar et al., 2014; Saka & Chan, 2019), lack of regulatory support (Olanrewaju et al., 2020), resistance to change (Bamgbose et al., 2024), shortage of skilled personnel (Hamma-Adama & Kouider, 2018), and low client demand. Despite the recognised benefits of BIM in improving collaboration, reducing project timelines, and fostering sustainability, its implementation has been slow. Below is a detailed analysis of the key barriers to BIM adoption identified in the reviewed literature:

3.1.1 Lack of Infrastructure

One of the most significant challenges to BIM adoption in Nigeria is the lack of necessary infrastructure, including technological and digital infrastructure. BIM requires a robust IT environment, including high-speed internet, cloud storage, and advanced computer hardware for handling complex 3D models and large datasets. Studies by Obakin and Oladunmoye (2021) and Onungwa and Uduma-Olugu (2017) highlighted that many construction firms in Nigeria, especially small and medium enterprises (SMEs), struggle with inadequate technological infrastructure, making it difficult to adopt and implement BIM tools effectively. In comparison to developed countries where digital infrastructure is well-established, Nigerian firms are often hindered by poor internet connectivity, frequent power outages, and limited access to affordable technology (Okoye & Umeifekwem, 2023). This creates a gap in the capacity to adopt BIM at the level required for effective project delivery.

3.1.2 High Cost of BIM Software and Training

The cost associated with acquiring BIM software, such as Autodesk Revit, ArchiCAD, and other related tools, is another significant barrier. Saka *et al.*(2019) and Abubakar *et al.* (2014) both noted that BIM software and licenses are expensive, especially for smaller firms, making them inaccessible to a large portion of the Nigerian construction industry (Abubakar 2014). In addition to software costs, the hardware required to run these programs—high-performance computers and servers—adds to the financial burden. Moreover, there are significant costs associated with training personnel to use BIM software. BIM is not just about the software; it requires skilled professionals who can create and manipulate 3D models and collaborate with other stakeholders. Hamma-Adama and Kouider (2018) emphasised that many Nigerian firms lack the financial capacity to invest in both the software and the extensive training required to upskill their workforce.

3.1.3 Insufficient Policy and Regulatory Support

The absence of strong government policies and regulatory frameworks mandating or incentivising BIM adoption has also contributed to its slow uptake. In countries like the UK and Singapore, where BIM adoption has been more successful, governments have played an active role by mandating BIM use for public sector projects and creating clear guidelines for implementation (Jiang *et al.,* 2021). In contrast, Nigeria lacks comprehensive national policies that encourage or require the use of BIM in construction projects. Olanrewaju *et al*. (2020) and Saka *et al.* (2019) identified this lack of regulatory push as a key factor that has allowed many firms to continue using traditional 2D CAD systems

instead of transitioning to BIM (Olanrewaju *et al.,* 2020) Without clear policies from regulatory bodies such as the Nigerian Institute of Architects or the Nigerian Society of Engineers, there is little motivation for firms to make the costly switch to BIM.

3.1.4 Resistance to Change and Cultural Barriers

Resistance to change is a common theme across the literature. Many professionals in the Nigerian construction industry are accustomed to traditional methods and workflows, such as 2D drafting using AutoCAD. Abubakar *et al.* (2014) and Hamma-Adama and Kouider (2018) both highlighted that there is often a reluctance among construction professionals to adopt new technologies like BIM due to the steep learning curve and disruption to established practices (Bamgbose *et al.,* 2024). This resistance is exacerbated by a lack of awareness about the benefits of BIM. Many firms, particularly smaller ones, are unaware of the long-term cost savings, efficiency gains, and enhanced collaboration that BIM can provide. Obakin and Oladunmoye (2021) noted that the fear of the unknown and the perceived complexity of BIM are major deterrents to its adoption.

3.1.5 Lack of Skilled Personnel and Training Programs

Another significant barrier to BIM adoption in Nigeria is the shortage of skilled personnel who are proficient in BIM tools and processes. Hamma-Adama and Kouider (2018) and Onungwa and Uduma-Olugu (2017) both emphasised the need for more comprehensive education and training programs to equip professionals with the skills necessary to use BIM. While some universities and technical institutes are beginning to include BIM in their curricula, these efforts are not yet widespread (Muhammad *et al.,* 2017). The training that does exist is often limited to architecture students, with other construction-related disciplines, such as engineering and quantity surveying, lagging (Abdirad & Dossick, 2016). This lack of interdisciplinary training undermines BIM's potential to improve collaboration across various stakeholders in a project.

3.1.6 Lack of Awareness and Low Demand

Finally, low demand for BIM from clients, developers, and even the government hinders its adoption. Abubakar *et al.* (2014) and Olanrewaju et al. (2020) pointed out that many clients and project owners are either unaware of BIM or do not demand its use in project delivery. Without client-driven demand, construction firms see little reason to adopt BIM, especially given the costs and challenges associated with its implementation. This lack of demand is closely tied to a broader lack of awareness about BIM's benefits. Saka *et al.* (2019) suggested that more awareness campaigns and advocacy are needed to inform key stakeholders about the advantages of BIM, particularly in terms of sustainability and project efficiency.

3.2 COLLABORATION AND INTEROPERABILITY

Collaboration and interoperability are two central advantages of Building Information Modelling (BIM), particularly in enhancing the workflow within the construction and design industry. BIM offers a collaborative environment where all stakeholders, from architects and engineers to contractors and project managers, can work on a single platform, ensuring that project details are shared seamlessly throughout the project's lifecycle. This shared digital model fosters real-time collaboration, reducing the communication gaps that often lead to errors, delays, and cost overruns. Several studies emphasise the potential of BIM to break down silos within the construction industry, enabling a more cohesive and integrated approach to project management.

Obakin and Oladunmoye (2021) and Onungwa and Uduma-Olugu (2017) both highlighted how BIM allows different professionals to contribute to a single model, ensuring that decisions are made based on accurate, up-to-date information. This level of collaboration improves the quality of decision-making during the design, construction, and facility management stages, thereby reducing the likelihood of rework or project delays (Onungwa & Uduma-Olugu, 2017b). For example, through BIM's 3D modelling and clash detection features, architects and engineers can identify potential conflicts in designs before construction begins, thus avoiding costly on-site adjustments (Charehzehi *et al.,* 2017). By enhancing communication among stakeholders, BIM reduces fragmentation in the construction process, which has historically plagued the industry and led to inefficiencies.

Despite these advantages, the reality in Nigeria, as pointed out by Abubakar *et al.* (2014) and Saka *et al.* (2019), is that the full collaborative potential of BIM is yet to be realised due to limited adoption across the construction sector. Many professionals continue to use traditional methods, such as 2D CAD, which do not offer the same level of interoperability or collaborative efficiency (Liu, 2024). This limited adoption of BIM means that the benefits of shared models, real-time updates, and integrated project workflows are not being fully leveraged. Moreover, the lack of interoperability between different BIM software solutions exacerbates the issue. Without standardisation, different stakeholders may use different software, making it difficult to integrate models or share data effectively (Alam *et al.,* 2023a; Pan *et al.,* 2024; Van Tam *et al.,* 2021a).

Additionally, a critical challenge mentioned by Hamma-Adama and Kouider (2018) is the absence of universal standards for BIM adoption in Nigeria, which further complicates interoperability between different project teams. This gap results in difficulties when stakeholders from various firms or disciplines attempt to collaborate on BIM-based projects (Alam *et al.,* 2023b). Even when some firms adopt BIM, the lack of a standardised framework means that their systems may not be compatible with others, limiting the seamless exchange of information. For BIM to deliver its full collaborative potential, there needs to be a concerted effort to develop interoperability standards across the industry.

The studies also emphasise that collaboration through BIM extends beyond the design phase. BIM allows stakeholders to maintain communication and alignment throughout the entire project lifecycle, including construction, post-construction, and facility management. This lifecycle collaboration is especially important for sustainable construction projects, where ongoing maintenance and energy efficiency are critical considerations. However, as Onungwa and Uduma-Olugu (2017) noted, in Nigeria, collaboration is often limited to the design phase, with little integration during construction and post-construction stages.

In summary, while BIM offers immense potential to improve collaboration and interoperability in the Nigerian construction industry, these benefits are not yet fully realised. The limited adoption of BIM, coupled with a lack of standardisation and technical infrastructure, hampers the effective collaboration that BIM promises. To fully harness BIM's capabilities, there needs to be an industry-wide push towards greater interoperability and broader adoption of BIM across all phases of construction projects. This will require investment in both technology and training, as well as the development of policies and standards that support a collaborative digital environment.

3.3 COST AND TIME EFFICIENCY

Cost and time efficiency are some of the most significant benefits attributed to the adoption of Building Information Modelling (BIM) in the construction industry. The ability of BIM to streamline processes, enhance accuracy, and reduce project timelines has been consistently emphasised in the literature. Studies such as those by Abubakar *et al.* (2014) and Saka *et al*. (2019) highlight that BIM

provides a platform for better planning, resource allocation, and project management, which in turn leads to considerable savings in both time and costs. BIM's cost efficiency stems from its capacity to minimise errors and rework, which are common sources of budget overruns in traditional construction practices (Van Tam *et al.,* 2021b). By enabling the digital simulation of a building project, BIM allows project teams to identify potential issues early in the design phase, such as clashes between structural and mechanical components, before construction begins. This proactive identification and resolution of conflicts significantly reduce the need for costly on-site adjustments, as noted by Hamma-Adama and Kouider (2018). Moreover, BIM's detailed and accurate quantity take-offs allow for precise cost estimation, ensuring that projects stay within budget by preventing material waste and avoiding unexpected expenses due to estimation inaccuracies.

Time efficiency is another area where BIM proves invaluable. Obakin and Oladunmoye (2021) and Onungwa and Uduma-Olugu (2017) highlighted that BIM's scheduling capabilities, often referred to as 4D BIM, enable project teams to create and manage detailed project timelines that link design and construction activities in real-time. This integration allows for better project coordination and ensures that teams can follow the project schedule more closely, reducing delays and enabling faster project delivery. By visualising the construction sequence through BIM, stakeholders can plan construction phases more effectively, anticipate bottlenecks, and make necessary adjustments to avoid interruptions. The ability to visualise the entire construction process before it starts also allows teams to optimise the sequence of operations, which reduces time wastage on site (el-Mounla *et al.,* 2023; Raza *et al.,* 2023). Furthermore, BIM promotes better communication among project stakeholders, contributing to faster decision-making. Saka *et al.* (2019) noted that with all relevant information stored in a shared digital model, project managers and decision-makers can access up-to-date data and make informed decisions more quickly. This real-time access to information not only accelerates decision-making but also eliminates the delays associated with waiting for updated drawings, reports, or specifications, which are common in traditional construction workflows.

Despite these clear advantages, the cost and time efficiencies of BIM are not yet fully realised in Nigeria, primarily due to the low rate of adoption across the industry. Olanrewaju et al. (2020) and Abubakar *et al.* (2014) emphasised that while firms that have adopted BIM report substantial improvements in both cost and time management, many construction companies in Nigeria continue to rely on traditional 2D CAD systems, which lack the integration and foresight provided by BIM (Olanrewaju 2020; Abubakar 2014). The reluctance to adopt BIM is often driven by the perceived high initial costs of software, hardware, and training, even though the long-term savings in cost and time would outweigh these upfront investments.

Moreover, Hamma-Adama and Kouider (2018) pointed out that smaller firms, which make up a large portion of Nigeria's construction sector, are particularly hesitant to adopt BIM due to concerns about the financial burden associated with transitioning to this new technology. These firms often operate on thin margins and are more focused on immediate cost-saving measures rather than long-term investments that could improve efficiency. This reluctance presents a significant barrier to realising the full potential of BIM's cost and time efficiencies within the Nigerian context. In conclusion, BIM has been shown to enhance both cost and time efficiency through improved planning, better collaboration, and the reduction of errors and rework (Olanrewaju *et al.,* 2021). These efficiencies translate into significant savings for construction firms, particularly in reducing project delays and staying within budget. However, the benefits of BIM in these areas remain largely untapped in Nigeria due to the slow adoption of the technology and concerns about initial costs (Okereke *et al.,* 2021; Olanrewaju *et al.,* 2020). For the Nigerian construction industry to fully capitalise on BIM's ability to improve cost and time efficiency, there needs to be a broader acceptance of the technology, driven by greater awareness of its long-term benefits and supported by policies that encourage its adoption.

3.4 AWARENESS AND TRAINING

Awareness and training are critical factors influencing the adoption of Building Information Modelling (BIM) in the Nigerian construction sector. A recurrent theme in the literature is that while BIM has the potential to transform the construction landscape, its adoption remains low largely due to a lack of awareness about its benefits and a shortage of adequately trained professionals to implement and use the technology effectively. Studies such as those by Abubakar *et al.* (2014) and Hamma-Adama and Kouider (2018) consistently point out that many construction firms in Nigeria are either unaware of BIM or do not fully understand how it can be integrated into their workflows to improve project outcomes (Abubakar, 2014). One of the major challenges is that BIM, although recognised globally, is still seen as a new and complex technology in Nigeria. Many professionals, particularly in smaller firms, are either unfamiliar with BIM or perceive it as too costly and difficult to implement. Onungwa and Uduma-Olugu (2017) highlighted that BIM's benefits, such as enhanced collaboration, cost savings, and improved efficiency, are not widely known among industry practitioners. This lack of awareness means that even when firms are introduced to the concept of BIM, they may not be fully convinced of its advantages, resulting in resistance to adopting the technology.

The role of educational institutions in raising awareness and providing training is crucial, but currently insufficient in Nigeria. Saka *et al*. (2019) and Olanrewaju *et al.* (2020) noted that while some universities have begun to include BIM in their curricula, this is not yet widespread, and there is a significant gap in BIM education across various disciplines within the construction industry (Olanrewaju, 2020). Most of the training that exists is focused on architecture, leaving engineers, quantity surveyors, and other professionals behind. This limited scope of BIM education results in a fragmented understanding of the technology, further hindering its full adoption. To maximise the potential of BIM, there needs to be interdisciplinary training that covers all aspects of the construction process, from design to facility management.

In addition to formal education, ongoing professional development and certification programs are essential for equipping the current workforce with BIM skills. However, Hamma-Adama and Kouider (2018) emphasised that there are very few training programs or workshops available in Nigeria to help professionals transition from traditional methods to BIM-based workflows. Those that do exist are often too expensive for many firms, particularly small and medium-sized enterprises (SMEs). As a result, many professionals continue to rely on outdated technologies and methods despite the clear advantages that BIM offers. This lack of access to affordable and practical training exacerbates the gap between larger firms with the resources to invest in BIM and smaller firms that remain constrained by limited financial and technical capacity.

Another key issue is the lack of industry-wide awareness campaigns or initiatives to promote the benefits of BIM. In countries where BIM adoption has been more successful, such as the UK and Singapore, governments and industry bodies have played an active role in raising awareness and providing training. In contrast, Nigeria lacks the coordinated efforts needed to educate stakeholders across the AEC industry about BIM's potential. Abubakar et al. (2014) noted that without government mandates or professional body endorsements, many firms see no immediate reason to invest in BIM (Abubakar, 2014). This highlights the need for more proactive efforts from governmental and professional organisations to promote BIM, such as offering incentives for training or making BIM certification mandatory for certain types of projects.

Furthermore, many professionals in Nigeria still rely on traditional 2D CAD systems, which have been used for decades. The transition from these familiar tools to BIM requires not only technical training but also a mindset shift. Obakin and Oladunmoye (2021) pointed out that many professionals

resist the transition because they are accustomed to the older systems, and learning BIM is perceived as difficult and time-consuming. This cultural resistance to change is compounded by the fact that many firms do not have access to hands-on training that would demonstrate how BIM can be integrated into their existing workflows, making the transition smoother and more manageable (Nast & Rekve, 2022). The lack of awareness and training is a significant barrier to BIM adoption in Nigeria. Without widespread knowledge of BIM's benefits and access to affordable, practical training, many professionals and firms are unable or unwilling to make the shift (Bello & Ayegba, 2024; Hamma-adama & Kouider, 2019). Addressing this issue will require a concerted effort from educational institutions, industry bodies, and the government to provide comprehensive BIM education and training programs, as well as initiatives to raise awareness across the industry. By improving access to training and fostering a deeper understanding of BIM, the Nigerian construction industry can take full advantage of the technology's potential to enhance project outcomes, reduce costs, and improve sustainability.

3.5 SUSTAINABILITY AND ENVIRONMENTAL IMPACT

Building Information Modelling (BIM) has been increasingly recognised for its potential to enhance sustainability and reduce the environmental impact of construction projects, a theme that emerges prominently across several studies. Sustainability has become a global priority within the construction and design industry, and BIM is viewed as a key technology to drive more environmentally conscious practices in construction. In Nigeria, where construction practices have often been criticised for contributing to environmental degradation, BIM's ability to promote sustainability is especially important. Several studies, including those by Obakin and Oladunmoye (2021) and Onungwa and Uduma-Olugu (2017), highlight BIM's role in addressing issues such as material waste, energy efficiency, and the overall environmental footprint of construction projects. One of the key ways in which BIM contributes to sustainability is through its ability to optimise resource management. By creating detailed digital models of buildings, BIM allows for more precise calculation of material quantities, reducing waste and minimising over-ordering of materials. This is particularly important in the Nigerian context, where inefficient use of resources is a common challenge. Hamma-Adama and Kouider (2018) pointed out that Nigerian construction projects frequently suffer from poor resource management, leading to excess waste, which not only increases project costs but also has a negative environmental impact. BIM's ability to generate accurate Bills of Quantities (BoQ) helps mitigate this problem by ensuring that the correct number of materials is ordered and used efficiently.

In addition to reducing material waste, BIM supports sustainable design by enabling energy performance simulations and other environmental analyses during the planning stage. Obakin and Oladunmoye (2021) emphasised that BIM's capacity for energy modelling allows architects and engineers to assess how buildings will perform in terms of energy consumption before construction begins. This enables them to make informed decisions about energy-efficient designs, materials, and systems, leading to buildings that require less energy for heating, cooling, and lighting. In a country like Nigeria, where energy consumption is often inefficient, these insights are crucial for designing more sustainable buildings that consume less power and reduce reliance on fossil fuels. Energy performance simulations can also help in meeting global sustainability standards, such as those set by Leadership in Energy and Environmental Design (LEED) or the Building Research Establishment Environmental Assessment Method (BREEAM).

BIM also enhances sustainability by facilitating lifecycle assessments of buildings. A key feature of BIM is its ability to track a building's performance throughout its lifecycle, from design and construction to operation and eventual decommissioning. This holistic view allows for better planning and management of the building's environmental impact over time. Saka et al. (2019) and

Onungwa and Uduma-Olugu (2017) both highlighted that by providing a comprehensive database of building components, BIM enables facilities managers to optimise maintenance schedules, predict when systems will need to be replaced, and manage energy use more efficiently. This long-term view of building performance is essential for achieving sustainability goals, as it ensures that environmental considerations are not limited to the construction phase but continue throughout the building's operational life.

Moreover, BIM's ability to facilitate collaboration among various stakeholders plays a significant role in achieving sustainability. Abubakar *et al*. (2014) and Hamma-Adama and Kouider (2018) both pointed out that BIM allows architects, engineers, contractors, and environmental consultants to work together on a shared platform, ensuring that sustainability goals are integrated into every stage of the project (Abubakar et al., 2014). This collaborative approach is crucial for ensuring that sustainable practices are maintained consistently throughout the design, construction, and operation phases. Without such collaboration, sustainability efforts can be fragmented, with each stakeholder working in isolation, which often leads to suboptimal results.

Despite these potential benefits, the studies also highlight that the adoption of BIM for sustainability purposes in Nigeria is still limited. Olanrewaju et al. (2020) and Saka *et al*. (2019) noted that while BIM has the potential to significantly reduce the environmental impact of construction, its adoption remains slow due to barriers such as high costs, lack of awareness and insufficient training (Olanrewaju, 2020). Many firms in Nigeria are either unaware of BIM's sustainability benefits or do not have the technical expertise to implement it effectively. As a result, the full potential of BIM to enhance sustainability and reduce environmental impact remains untapped. Furthermore, there is a need for stronger policy frameworks that mandate the use of BIM in sustainable construction practices. In countries like the UK and Singapore, governments have played a pivotal role in driving the adoption of BIM by mandating its use for public sector projects and incorporating sustainability requirements into construction regulations. However, Hamma-Adama and Kouider (2018) pointed out that in Nigeria, there are currently no such policies in place, which means that many firms see little incentive to invest in BIM or prioritise sustainability. Without government mandates or industry-wide sustainability targets, the Nigerian construction sector may continue to rely on traditional methods that are less efficient and more harmful to the environment.

In conclusion, BIM holds significant promise for improving sustainability and reducing the environmental impact of construction projects in Nigeria. Through better resource management, energy-efficient design, lifecycle assessment, and enhanced collaboration, BIM can help the Nigerian construction industry transition towards more sustainable practices. However, to fully realise these benefits, there needs to be greater awareness, improved training, and stronger policy support to encourage the adoption of BIM for sustainability purposes. As the global construction industry increasingly prioritises environmental responsibility, Nigeria must leverage BIM's potential to meet sustainability goals and reduce the environmental impact of its growing construction sector.

4.0 CONCLUSION AND RECOMMENDATION

4.1 CONCLUSION

Building Information Modelling (BIM) and digital collaboration technologies hold significant potential for transforming the Nigerian construction and design industry, particularly in achieving cost efficiency, improving collaboration, and promoting sustainability. Despite these recognised benefits, the adoption of BIM in Nigeria remains limited due to several persistent barriers, including the high costs of implementation, lack of infrastructure, insufficient awareness, inadequate training, and the absence of supportive policy frameworks. These challenges have hindered the industry's

ability to fully leverage BIM's capabilities for improving project outcomes and reducing environmental impacts.

The systematic review of studies in this paper has revealed that while there are clear examples of BIM's success in other global contexts, Nigeria has yet to experience these benefits on a broad scale. The studies reviewed emphasised that addressing the barriers to BIM adoption, particularly through improving awareness, enhancing training programs, and fostering greater collaboration among stakeholders, is crucial for realising its potential. Additionally, BIM's ability to optimise project timelines, reduce material waste, and enhance energy efficiency positions it as a vital tool for promoting sustainability within Nigeria's growing construction sector.

In conclusion, while BIM offers substantial advantages for the Nigerian construction sector, its widespread adoption will require a concerted effort from government bodies, industry stakeholders, and educational institutions to overcome existing challenges and encourage more comprehensive use of the technology. This transition is critical for ensuring that the Nigerian construction industry remains competitive, efficient, and environmentally responsible in the face of global challenges and opportunities.

4.2 RECOMMENDATIONS

Based on the findings of this systematic review, the following recommendations are proposed to accelerate the adoption of BIM and digital collaboration technologies in Nigeria and to promote more sustainable construction practices:

i. **Development and Implementation of National BIM Policies and Guidelines:** The Nigerian government should take a leading role in promoting BIM adoption by developing national policies and guidelines that mandate or incentivise the use of BIM in public sector projects. Such policies have been successful in other countries, and similar initiatives could drive greater adoption within Nigeria. In addition, regulatory bodies such as the Nigerian Institute of Architects (NIA) and the Nigerian Society of Engineers (NSE) should provide clear guidelines for BIM implementation, ensuring that all professionals are aligned with industry standards.
ii. **Increased Awareness Through Targeted Campaigns:** Professional organisations and government agencies should conduct targeted awareness campaigns to educate stakeholders across the construction industry on the benefits of BIM. These campaigns should highlight BIM's ability to improve collaboration, reduce costs, and foster sustainability. Special efforts should be made to reach small and medium-sized enterprises (SMEs), which may have limited awareness of BIM's advantages and capabilities.
iii. **Training and Educational Programs:** There is an urgent need to expand BIM training and education programs at both the academic and professional levels. Universities and technical institutions should incorporate BIM into their curricula for architecture, engineering, and construction management students. Additionally, continuous professional development programs should be made available to current industry professionals. These training programs should be affordable and accessible to ensure that firms of all sizes can upskill their workforce.
iv. **Financial Incentives and Support for BIM Adoption:** Given the high initial costs of BIM software, hardware, and training, financial support and incentives should be offered to encourage firms, particularly SMEs, to adopt BIM. These could include tax breaks, subsidies for purchasing BIM software, and low-interest loans for technology upgrades. Providing financial incentives will lower the entry barrier for smaller firms, allowing them to transition to BIM-based workflows without being financially strained.

v. **Interdisciplinary Collaboration Through BIM:** To fully realise the collaborative benefits of BIM, industry stakeholders should foster greater interdisciplinary collaboration by creating platforms and environments where architects, engineers, contractors, and environmental consultants can work together on BIM-based projects. This could involve setting up shared digital environments where stakeholders can access real-time project information, ensuring that all parties are aligned on project goals and timelines.
vi. **Prioritise Sustainability in BIM Implementation:** Finally, sustainability should be at the core of BIM implementation in Nigeria. Government and industry bodies should promote the use of BIM for energy modelling, lifecycle assessments, and resource optimisation to meet global sustainability standards. Additionally, clients and developers should be encouraged to prioritise sustainable construction practices by leveraging BIM's ability to improve energy efficiency, reduce waste, and promote environmentally responsible building designs.

By implementing these recommendations, the Nigerian construction industry can overcome many of the barriers to BIM adoption, ultimately improving project outcomes and enhancing the sustainability of future developments. The integration of BIM and digital collaboration technologies will be key to ensuring that Nigeria's construction sector remains competitive, efficient, and environmentally responsible in the years to come.

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