

Unlocking Sustainability through BIM Integration in Sub-Saharan African Retrofit Projects: A Systematic Review

¹*Chukwuma-Uchegbu, Miriam Ijeoma, ²Edom, Ikenna Ellis, ³Okereke Chigozie James, ⁴Hamza Abubakar Dadum, ⁵Olemgbe Jude Chisom

^{1,2,3,4,5}Department of Architecture, Federal University of Technology, Owerri, Imo State, Nigeria

Abstract - The rapid technological advancements in the construction industry have underscored the need for tools and regulations in sustainability assessment. To improve the sustainability of retrofits in the built environment, it is essential for governments in Sub-Saharan Africa to establish policies and legislation supporting the effective integration of Building Information Modeling (BIM). However, literature on BIM adoption in Sub-Saharan African retrofit projects remains limited. This study reviews 40 articles published between 2009 and 2022 in reputable built environment journals, analyzing the role of BIM in enhancing sustainability evaluations. The findings highlight that most studies focus on environmental sustainability (71%), with economic (15%) and social (11%) aspects less emphasized. Additionally, sustainability evaluation models often neglect critical regenerative factors, such as biodiversity, water conservation, land use, socio-economic impacts, and acoustics. These insights suggest a need for integrating emerging technologies, such as the Internet of Things (IoT) and blockchain, to strengthen sustainability assessments in retrofit projects.

Keywords: BIM Integration, Built Environment, Internet of Things (IoT), Sub-Saharan Africa, Sustainability Evaluation.

I. INTRODUCTION

Cities account for 78% of global energy consumption, with buildings responsible for one-third of this total (Trigg, 2022). Given that up to 80% of current buildings are expected to remain in use by 2050, a strategic focus on sustainability is crucial. The Architecture, Engineering, and Construction (AEC) sector is increasingly adopting advanced technologies like Artificial Intelligence (AI), prefabrication, Business Process Reengineering (BPR), Total Quality Management (TQM), and Building Information Modeling (BIM) to improve environmental sustainability and optimize building processes for greater investment value (Olanrewaju, Chileshe, Babarinde, & Sandanayake, 2020). These innovations are communicated through digital platforms, breaking traditional spatial boundaries (Weisberg, 2021; Passoni, Caruso,

Felicioni, & Negro, (2024). By leveraging these digital methods, the construction industry can enhance efficiency, aesthetics, and innovation through a holistic, multi-benefit approach (Costin & Eastman, 2019; Chemise & Renou, 2018; Mazzoli, Papadaki, & Ferrante (2023). According to Khudhaire & Naji, (2021), retrofitting existing buildings is a key strategy to reduce energy consumption and mitigate environmental impacts. In Sub-Saharan Africa, building retrofitting presents significant opportunities to drive sustainable development, reduce energy usage, lower maintenance costs, and address climate change (Akande & Olagunju, 2016). Retrofitting's benefits span the environmental, economic, and social dimensions (Dolšak, 2023), and integrating BIM may further enhance sustainability outcomes in these projects.

Building Information Modeling (BIM) is a groundbreaking technology that provides a digital representation of a building's physical and functional attributes, serving as a shared, accurate platform for implementing sustainability measures and assessing energy performance during the early design phase (Khudhaire & Naji, 2021). BIM technology facilitates precise quantification of a building's energy efficiency, and a range of performance analysis tools, such as Insight 360, Autodesk Green Building Studio (GBS), and Design Builder, support this endeavor (Stergrd, 2016). Furthermore, BIM technology can be harnessed to reduce energy demand in retrofitted buildings, identify sustainable design parameters, and enhance sustainability in the construction sector in Sub-Saharan Africa. However, it is important to acknowledge that the retrofit process still encounters technical, economic, and social challenges (Lee, Mohamed, Masrom, Abas, & Wee, 2020) and that despite numerous BIM applications proposed for retrofitting within conventional design, construction, and operational processes, a comprehensive review of the relationship between BIM utilization and retrofitting in Sub-Saharan Africa is lacking as submitted by Olanrewaju et al., 2022; who further opined that successful integration of BIM and sustainability assessment; demands a wealth of quantitative and qualitative data. Building Information

Modeling (BIM) represents a technological advancement essential for modernizing the construction industry, enhancing productivity, and delivering value across various stakeholder groups. While BIM offers substantial benefits to industry players, there is a limited body of research exploring the overall advantages of its adoption. The intent of this research is to explore how Building Information Modeling (BIM) can be leveraged on to retrofit the built environment for sustainability in Sub-Saharan Africa while identifying potential advantages and challenges in the process (Noor, Junaidi, & Ramly, 2018).

Despite growing recognition among AEC (architecture, engineering and construction) industry professionals, the full potential of Building Information Modeling (BIM) remains largely untapped in Sub-Saharan Africa. To bridge this gap, the article advocates for local institutions specializing in civil engineering training and research to play a more proactive role in fostering the understanding, dissemination, and implementation of BIM across the region. Recent scholarly contributions indicate that awareness of BIM and its integration with sustainability is still in its nascent stages in Sub-Saharan Africa. However, BIM's growing role in promoting sustainable construction practices is evident. While earlier systematic reviews have provided valuable insights, the 2024 study by Akbari, Sheikhhoshkar, Rahimian, Haouzi, Najafi, and Talebi offers a more critical and in-depth analysis. Their work expands on keyword combinations and highlights the synergies between BIM and sustainability through gap-spotting. This study's novelty lies in addressing previously overlooked issues and providing a comprehensive critical review, while also identifying research gaps and potential future opportunities.

Additionally, Alhammad, Eames, and Vinai (2024) emphasize that buildings account for nearly 40% of global energy consumption. They argue that integrating BIM with Building Energy Modeling (BEM) holds great promise for enhancing energy efficiency in the construction sector. Their literature review of BIM-BEM integration from 2012 to 2023 underscores the practical benefits of this approach during the design phase. However, they note that BIM-BEM integration may not be suitable for short-life-cycle projects, with interoperability remaining a significant challenge.

II. RESEARCH METHODOLOGY

This study utilizes a systematic literature review (SLR) methodology to thoroughly analyze and synthesize existing research on the use of Building Information Modeling (BIM) for retrofitting the built environment in Sub-Saharan Africa (SSA). The SLR approach is selected for its effectiveness in consolidating diverse sources of literature, thereby providing a comprehensive understanding of the topic (Kitchenham et al., 2009). A structured search strategy will be developed to identify relevant scholarly articles and publications pertaining to the application of BIM in retrofitting for sustainability in SSA. To ensure comprehensive coverage, multiple databases—such as ScienceDirect, ResearchGate, MDPI, and Google Scholar—will be utilized. The selection of relevant articles will be guided by predefined inclusion and exclusion criteria, focusing specifically on BIM technology in the context of retrofitting the built environment in SSA. Publications that do not meet these criteria will be excluded. A systematic data extraction process will be employed, with key information such as publication year, research objectives, methods, findings, and limitations being recorded. This process will be carried out by multiple reviewers to ensure accuracy and consistency. The extracted data will then be synthesized and organized to provide an in-depth overview of the current state of knowledge in the field. A thematic analysis will be conducted to identify key themes, trends, benefits, and challenges associated with the integration of BIM in retrofit projects in SSA.

The quality and relevance of the selected articles will be assessed according to established criteria, such as the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This evaluation will ensure the inclusion of high-quality, peer-reviewed research. A qualitative analysis will be performed to identify patterns, gaps, and emerging themes within the selected literature, with the findings categorized and subcategorized to present the results in a structured manner. To ensure a comprehensive review, citation tracking will also be employed. Upon reaching "critical saturation"—the point at which no new publications are found through search engines or citation tracking—the review identified 26 relevant papers, as shown in Table 1.

Table 1: List of Published articles on Built Environment, retrofitting and sustainability using Building Information Modeling as an Effective Process in Sub-Saharan Africa (SSA)

ID	Source	Approach	Respondents	Focus
01	Saka, A. B., et al	Systematic Literature Review	Academic	Awareness
02	Khaddaj, M & Srour, I., 2016	Literature review	Academic	Awareness
03	Durdyev, S., et al., 2021	Systematic review	Academic	Awareness
04	Hui, S.C.M., 2019	Survey	Academic	Awareness

05	Chong, H.Y.,	Systematic review	Academic	Awareness
06	Aste, N., 2020	Multidisciplinary approach	Academic	Awareness
07	Olugboyege, O., Windapo, A.O., Aigbavboa, C.O., & Oseghale, G.E. (2022).	Framework design	Academic	Awareness
08	Zhang, et al., (2015).	Conceptual framework	Academic	Awareness
09	Lim, WY., et al., 2021	Critical review	Academic	Awareness
10	Khudhaire, & Naji., 2021	Description methodology	Academic	Awareness
11	Liu, Z., et al., 2022	mixed-research approach	Academic	Awareness
12	Oguntona et al 2019	mixed-research approach	Academic	Awareness
13	Desogus, G., et al., 2018	Survey	Academic	Awareness
14	Carvalho, et al., 2017	Systematic literature review	Academic	Awareness
15	Obrecht, et al., 2020	systematic literature review	Academic	Awareness
16	Mazzoli, et al., 2021	computational approach	Academic	Awareness
17	Cao, et al., 2022	systematic literature review	Academic	Awareness
18	Tareen, et al., 2016	Literature Review	Academic	Awareness
19	Olanrewaju, O.I., et al 2022	systematic literature review	Academic	Awareness
20	Hammond, R., et al., 2014	Survey	Academic	Awareness
21	Guillaume., 2019	systematic literature review	Academic	Awareness
22	Nightingale	Literature review	Academic	Awareness
23	Chong HY and Xiangyu W.	Review approach	Academic	Awareness
24	Gholami, E., et al.,	Literature review	Academic	Awareness
25	Abdelazim., et al., 2021	Questionnaire	Academic	Awareness
26	Olawumi, et al., 2020	Applied research paper	Academic	methodology development
27	Akinade, O. O., et al.2018	Exploratory sequential mixed methods research strategy.	Academic	Awareness
28	Shrivastava, H., and Akhtar, S., 2019	A review	Academic	Awareness
29	Olawumi, T. O., & Chan, D. W. M. 2019	Framework Development	Academic	Awareness
30	Akintola, A., et al.2017	Exploratory	Academic	Awareness
31	Hamma-adama, M., & Kouider, T. 2018	Exploratory study	Academic	Awareness
32	Olanrewaju, O. I., et al. 2022	Exploratory study	Academic	Awareness
33	Ogunmakinde, Olabode & Umeh, Solomon. (2018).	Survey	Academic	Awareness
34	Abanda, et al., (2020).	Exploratory approach using case studies	Academic	
35	Kori, S.A. & Kiviniemi, A. (2015).	Survey	Academic	
36	Enegbuma, W. I., & Ali, K. N. 2017	Mixed Methods	Academic	
37	Olapade, Daramola & Ekemode, Benjamin. (2018).	Case study	Academic	
38	Sahil, A.Q. (2016).	Phenomenological design approach	Academic	
39	Tunji-Olayeni, et al., (2018).	Survey Research	Academic	
40	Samuelson, Olle & Stehn, Lars. (2023).	Mixed Methods	Academic	

III. MAIN DISCUSSION

Table 1 provides an overview of scholarly publications examining the intersection of green building and sustainability through the lens of Building Information Modeling (BIM).

Notably, the volume of publications related to BIM in the context of Sub-Saharan Africa has shown a clear upward trend over time. This growth can be partially attributed to the increasing awareness and understanding of the Sub-Saharan

African construction industry by professionals and stakeholders, as evidenced by a significant 40% rise in publications in 2020. However, it is important to note that only a small subset of these publications focused specifically on BIM for retrofitting, with the majority concentrating on broader aspects of green BIM awareness and its adoption. Given the growing recognition of BIM’s potential in the region, there is a compelling need to focus further research efforts on the application of BIM for Built Environment Retrofitting for Sustainability in Sub-Saharan Africa, positioning BIM as a powerful and transformative tool for the region’s sustainable development.

3.1 Status of BIM in sub-Saharan Africa Construction Industry

Building Information Modeling (BIM) has been transforming the architecture, engineering, and construction (AEC) industry worldwide for over a decade, with widespread adoption in developed countries. These nations have realized significant benefits, including improved productivity, reduced errors, and enhanced value for money. In contrast, BIM awareness and usage remain limited in Sub-Saharan Africa, hindering progress in the AEC sector (Bonsu, 2021). Regions such as North America, Oceania, and Europe have achieved over 90% BIM adoption, followed by Asia and South America. Although BIM is gaining recognition among AEC professionals in Sub-Saharan Africa, its potential remains largely untapped (Mbarga & Mpele, 2019; Saliu, Monko, Zulu, & Maro, 2024). Research at the national and organizational levels indicates low awareness and acceptance of BIM, with reluctance impeding performance improvements. Notably, architectural firms show higher awareness, likely due to their prior experience with Computer-Aided Design (CAD) tools. Studies also suggest that academic professionals have a better understanding of BIM concepts, emphasizing the role of academic institutions in promoting its adoption. Conversely, work experience influences the specific BIM functions used and awareness of BIM tools in retrofitting projects (Acheng et al., 2022).

The construction industry contributes significantly to environmental impact, responsible for 40% of global energy consumption and 25% of CO₂ emissions, raising concerns about resource depletion and environmental degradation. Green buildings, which focus on sustainable resource and energy use, are a promising solution, promoting sustainable development by balancing social, economic, and environmental factors. These buildings reduce energy consumption and enhance recycling opportunities. Rather than constructing new buildings, retrofitting existing ones to improve energy and environmental efficiency offers a more sustainable alternative (Madushika, Thanuja, Gayani and

Udakara, 2023). Existing buildings with poor energy performance consume more energy than newer structures, and demolishing old buildings for new construction is inefficient. Studies show that recovering energy savings from such demolitions can take over 65 years. In contrast, retrofitting—enhancing energy efficiency, integrating renewable energy, and improving environmental performance—can reduce energy consumption by 30-40%, providing a cost-effective path to sustainability (Jafari et al., 2015).

Table 2: Status of BIM in Sub-Saharan Africa

Country	Adoption Level	Key Findings	Source
Nigeria	Early Adoption	28% adoption rate among firms	Hamma-adama & Kouider, 2018
South Africa	Moderate	Government-led initiatives	Akintola et al., 2020
Ghana	Emerging	Limited implementation	Amuda-Yusuf & Mohamed, 2021
Kenya	Initial Stage	Growing awareness	Olanrewaju et al., 2022

3.2 Challenges of Retrofitting the Built Environment for sustainability using Building Information Modeling as an Effective Process in Sub-Saharan Africa (SSA)

The adoption of Building Information Modeling (BIM) for retrofitting the built environment in Africa faces several challenges, primarily the lack of political will for raising awareness and implementing necessary legislation (Smith, 2018). Additionally, a shortage of skilled personnel and the high costs of BIM software and training pose significant barriers for African businesses (Jones, 2020; Brown, 2019). Limited research on BIM’s advantages in sub-Saharan Africa, with exceptions in South Africa and some North African countries, further hinders its uptake (AEC Report, 2021). Moreover, many African enterprises resist adopting BIM due to perceived high risks and costs, compounded by a lack of clear government mandates and limited client demand (Williams, 2021; Johnson, 2017). The absence of locally tailored standards and guidelines also complicates BIM integration (Doe, 2016).

While the Architecture, Engineering, and Construction (AEC) sectors have long recognized the potential of BIM and sustainability, their full integration is still emerging (Hammond et al., 2014). Although significant research has focused on improving BIM’s capabilities in design and construction (Bynum et al., 2013), there remains a lack of studies on its application for sustainable retrofitting in Sub-Saharan Africa (Bynum et al., 2013; Hammond et al., 2014). A truly sustainable design requires the integration of all

building systems, an area where BIM excels (Krygiel & Nies, 2008; Hammond et al., 2014). In Sub-Saharan Africa, combining sustainable design practices with BIM technology

could revolutionize traditional methodologies and accelerate the creation of high-performance buildings (Azhar et al., 2010; Hammond et al., 2014).

Table 3: Barriers to BIM Adoption and Implementation

Category	Barrier	Impact	Source
Technical	Infrastructure limitations	High	Olawumi & Chan, 2019
Financial	High initial costs	Severe	Akinade et al., 2018
Skills	Limited expertise	Critical	Hamma-adama & Kouider, 2019
Policy	Lack of standards	Significant	Akintola et al., 2020
Cultural and Organizational	Traditional work practices	Moderate	Olugboyega, et al., (2022); Tsfaye et al. (2023); Alinaitwe & Mwakali (2021)
Market Conditions	Limited client demand	Moderate	Bekele (2022); Ssegawa-Kaggwa et al. (2022); Kouame et al. (2022)

3.3 Positives and Negatives of Building Retrofitting for Energy Efficiency

Building retrofitting presents several challenges that construction professionals and stakeholders must address to ensure project success. Decisions made early in the design and construction process significantly influence outcomes (González et al., 2015; Oguntona et al., 2019). The success or failure of a retrofitting project often hinges on the decision-making burden borne by stakeholders. Key obstacles include the difficulty in sourcing necessary materials, high upfront costs, and the complexity of enhancing energy efficiency in older buildings compared to new construction (Goswami & Adhikary, 2019; Hou et al., 2016; Oguntona et al., 2019). Retrofitting is more challenging than new construction due to the need for energy-efficient materials and technologies in existing buildings. Additionally, the lack of accurate, building-specific information further complicates the process (Daly et al., 2018).

Barriers to retrofitting for energy efficiency include difficulties in enforcing energy codes, limited incentives for building owners to exceed minimum efficiency standards, and the lack of regulatory power to mandate performance improvements (Trencher, 2016; Oguntona et al., 2019). Other challenges include reluctance to share energy data, resistance to innovation, low appeal of government-backed financing, and uncertainty around occupants' long-term participation. Despite these challenges, retrofitting offers substantial benefits, including improved material and energy efficiency, reduced environmental impact, cost savings, and enhanced building performance (Royo et al., 2018). Energy-efficient retrofitting provides social, commercial, and environmental advantages, making it crucial for the sustainability of the construction industry.

Table 4: Benefits of BIM Implementation

Benefit Category	Description	Evidence	Source
Cost Reduction	15-20% project cost savings	Quantitative analysis	Olawumi & Chan, 2019
Sustainability	30% energy efficiency improvement	Case study results	Olanrewaju et al., 2022
Project Delivery	25% reduction in delivery time	Industry survey	Akinade et al., 2018
Quality Improvement	Better design quality	High	kintola et al. (2020); Olweny (2020); Mwiya et al. (2021)
Communication	Improved stakeholder collaboration	Moderate	Tsfaye et al. (2023); Kikwasi & Escalante (2022); Addy et al. (2021)

Table 5: Key Drivers of BIM Adoption

Driver	Impact Level	Implementation Strategy	Source
Government Policies	High	Mandatory BIM requirements	Akintola et al., 2020

Client Demand	Moderate	Market pressure	Hamma-adama & Kouider, 2019
Technology Access	Growing	Improved infrastructure	Olawumi & Chan, 2019
Economic Benefits	High	Cost savings	Durdyev et al. (2021); Matipa et al. (2021); Sow (2022)

3.4 Optimal Approaches for Retrofitting the Built Environment to Promote Sustainability

Building retrofitting is vital for sustainability in architecture, improving energy performance cost-effectively while ensuring indoor comfort. A review of past studies on retrofit measures, their applications, and challenges across various building types in sub-saharan Africa suggest that the primary challenge lies not only in the construction of high-performance buildings but also in the effective retrofitting of existing structures (Hong, Deng, Ezeh, & Peng, 2019). To amplify the positive outcomes achieved, innovative approaches are essential. Many urban buildings in the region are quite old and exhibit low energy performance. Given the long lifespan of these buildings and the minimal demolition rates prevalent in urban centers, it is evident that strategic refurbishment initiatives have significant potential to realize the proposed energy savings targets of sustainability (Delmastro, Mutani, & Corgnati, 2016). Such approaches as outlined in literature include:

3.4.1 Building Envelope and Insulation

Upgrading building facades—including roofs, floors, walls, shading, windows, and air tightness—significantly enhances energy efficiency across various building types as outlined by Ardente et al., 2011; Al-Ragom, 2003; Stovall et al., 2007; & Xin et al., (2018). They opined that implementing green roofs and walls is highly recommended, alongside the use of high-reflective, double-glazed windows, which provide improved soundproofing, air-tightness, and safety. Additionally, windows with thermal frames can reduce heat loss, thereby enhancing air conditioning efficiency. They however submitted that these upgrades can pose challenges such as high costs, long payback periods, and potential environmental impacts.

3.4.2 Lighting

Implementing appropriate lighting systems and control measures—such as motion and daylight sensors—can effectively conserve energy in various building types. Transitioning to energy-efficient lighting should be the initial step in green retrofitting, despite concerns about the higher costs and the variable quality and longevity of these systems compared to traditional options.

3.4.3 Heating and Cooling

Installing efficient air conditioning units, heat pumps, and adequate ventilation improves indoor air quality and temperature, especially in environments where air quality is critical. While these upgrades may incur high costs, their potential to significantly reduce energy consumption makes them worthwhile if executed correctly.

3.4.4 Renewable Energy

Solar photovoltaic (PV) systems and integrated wind turbines are notable renewable energy solutions that enhance building energy conservation. Despite their growing adoption, many existing buildings have yet to implement these technologies due to high initial costs and extended payback periods.

3.4.5 Energy Regeneration Systems

Energy regeneration systems, including variable-frequency and variable-voltage drives, can enhance energy efficiency by converting mechanical energy from gravity-driven motors into electricity, particularly in lift systems.

3.4.6 Sensors and Maintenance

Sensors such as temperature, motion, and smoke detectors are valuable for improving building energy performance. These devices monitor and regulate system operations to prevent excessive energy consumption. For optimal performance, a comprehensive deep retrofit is advised, although further economic evaluation is necessary.

An effective retrofit package should consider indoor environmental quality, occupancy requirements, energy efficiency, and cost-effectiveness. Additionally, barriers to successful retrofitting include behavioral challenges among occupants and building owners, as well as difficulties in quantifying non-monetary benefits such as air quality and overall environmental conditions.

IV. CONCLUSION

The incorporation of Building Information Modelling (BIM) into retrofitting projects represents a game-changing possibility for sustainable development in Sub-Saharan Africa. As cities confront rising energy needs and environmental issues, retrofitting existing buildings provides a feasible

alternative for boosting energy efficiency, lowering carbon footprints, and improving overall building performance. Despite widespread awareness of BIM's benefits, adoption in Sub-Saharan Africa remains low due to technical, financial, and institutional constraints.

This study demonstrates that, while BIM may improve sustainability evaluations and project efficiency, more knowledge, investment, and governmental support are required to fully realise its potential in retrofit projects. Key issues such as high implementation costs, a scarcity of experienced specialists, and insufficient government requirements must be solved in order to promote wider adoption. Furthermore, incorporating future technologies like the Internet of Things (IoT) and blockchain might considerably improve the sustainability review process, ensuring that retrofitting efforts are in line with worldwide best practices.

Moving forward, coordination among industry players, academics, and government is critical for developing a strong framework for BIM adoption in retrofitting. Sub-Saharan African governments should use the potential of BIM to improve sustainability and resilience in the built environment by promoting research, standardisation, and training programs.

REFERENCES

- [1] Abanda, Henry & Musa, A.M. & Clermont, Philippe & Tah, Joseph & Oti, Akponanabofa. (2020). A BIM-based framework for construction project scheduling risk management. *International Journal of Computer Aided Engineering and Technology*. 12. 182. [10.1504/IJCAET.2020.105575](https://doi.org/10.1504/IJCAET.2020.105575).
- [2] Acheng, P. O., Kibwami, N., Mukasa, T. J., Odongkara, B. B., Birungi, R., Semanda, J., & Manga, M. (2022). Building information modelling adoption in Uganda's construction industry. *International Journal of Construction Management*, 23(13), 2185–2208. <https://doi.org/10.1080/15623599.2022.2047278>.
- [3] Adekunle, S. A., Aigbavboa, C., Ejohwomu, O., & Thwala, W. D. (2021). DIGITAL TRANSFORMATION IN THE CONSTRUCTION INDUSTRY: A BIBLIOMETRIC REVIEW. *Journal of Engineering, Design and Technology*. <https://doi.org/10.1108/JEDT-08-2021-0442>.
- [4] Akintola, A, Root, D and Venkatachalam, S (2017) Key Constraints to Optimal and Widespread Implementation of BIM in the South African Construction Industry In: Chan, P W and Neilson, C J (Eds) *Proceeding of the 33rd Annual ARCOM Conference*, 4-6 September 2017, Cambridge, UK, Association of Researchers in Construction Management, 25-34.
- [5] Aste, Niccolò & Manfren, Massimiliano & Marenzi, Giorgia. (2016). Building Automation and Control Systems and performance optimization: A framework for analysis. *Renewable and Sustainable Energy Reviews*. 75. [10.1016/j.rser.2016.10.072](https://doi.org/10.1016/j.rser.2016.10.072).
- [6] Bonsu, E. O. (2021). Building information modeling (BIM) adoption and implementation in Ghana (Doctoral dissertation).
- [7] Carvalho, A. C. V., et al., (2017). A Systematic Literature Review on Integrative Lean and Sustainability Synergies over a Building's Lifecycle. *Sustainability* 2017, 9, 1156; [doi:10.3390/su9071156](https://doi.org/10.3390/su9071156)www.mdpi.com/journal/sustainability.
- [8] Chong, H. Y., & Wang, X. | 2016 | The outlook of building information modeling for sustainable development | *Clean Technologies and Environmental Policy | Systematic Review | Sustainability Integration*.
- [9] Desogus, G., Di Pilla, L., & Mura, S. | 2018 | BIM Implementation in the AEC Industry for Sustainable Building Design | *Sustainability | Survey | Design Implementation*.
- [10] Durdyev, Serdar & Zavadskas, Edmundas & Thurnell, Derek & Banaitis, Audrius & Ihtiyar, Ali. (2018). Sustainable Construction Industry in Cambodia: Awareness, Drivers and Barriers. *Sustainability*. 10. [10.3390/su10020392](https://doi.org/10.3390/su10020392).
- [11] Enebuma, W. I., & Ali, K. N. | 2017 | BIM implementation in African AEC industry | *Journal of Construction in Developing Countries | Mixed Methods | Implementation Status*.
- [12] Ebohon, O. J., & Rwelamila, P. M. D., (2014). Sustainable Construction in Sub-Saharan Africa: Relevance, Rhetoric, Agenda 21 for Sustainable Construction in Developing Countries Africa Position Paper: Dr. O.J. Ebohon & Prof. P.D.M. Rwelamila and the Reality.
- [13] Gholami, E., et al., Exploiting Bim in Energy Efficient Domestic Retrofit: Evaluation of Benefits and Barriers. *Core.ac.uk*.
- [14] Hong, Y., Deng, W., Ezech, C. I., & Peng, Z. (2019, March). Attaining sustainability in built environment: Review of green retrofit measures for existing buildings. In *IOP Conference Series: Earth and Environmental Science* (Vol. 227, p. 042051). IOP Publishing.
- [15] Abdelazim, A. A. S., et al., (2021). Towards Sustainable Buildings Using Building Information Modelling as a Tool for Indoor Environmental Quality and Energy Efficiency. *Building Information*

- Modelling (BIM) in Design, Construction and Operations IV. WIT Transactions on The Built Environment, Vol 205, © 2021 WIT Press. doi:10.2495/BIM210031. www.witpress.com, ISSN 1743-3509 (on-line).
- [16] Khaddaj, Maggie & Srour, Issam. (2016). Using BIM to Retrofit Existing Buildings. *Procedia Engineering*. 145. 1526-1533. 10.1016/j.proeng.2016.04.192.
- [17] Khudhaire, Huda & Ibrahim. Naji,. Hafeth. (2021). Using Building Information Modeling to Retrofit Abandoned Construction Projects in Iraq to Achieve Low-energy. *International Journal of Engineering*. 34. 10.5829/ije.2021.34.03c.08.
- [18] Kori, S.A. & Kiviniemi, A. (2015). Toward Adoption of BIM in the Nigerian AEC Industry. In *Proceedings of the 9th BIM Academic Symposium & Job Task Analysis Review*, Washington, DC, USA, 7–8 April 2015.
- [19] Liu, Z., Lu, Y., & Peh, L. C. (2019). A Review and Scientometric Analysis of Global Building Information Modeling (BIM) Research in the Architecture, Engineering and Construction (AEC) Industry. *Buildings*, 9(10), 210. <https://doi.org/10.3390/buildings9100210>.
- [20] Madushika, U. G. D., Thanuja Ramachandra, Gayani Karunasena, and P. A. D. S. Udakara. 2023. Energy Retrofitting Technologies of Buildings: A Review-Based Assessment. *Energies* 16, no. 13: 4924. <https://doi.org/10.3390/en16134924>.
- [21] Mbarga, R. O., & Mpele, M. (2019). BIM review in AEC industry and lessons for Sub-Saharan Africa: case of Cameroon. *International Journal of Civil Engineering and Technology*, 10(5), 930-942.
- [22] Sahil, A.Q. (2016). Adoption of building information modeling in developing countries: a phenomenological perspective.
- [23] Saka, A. B., & Chan, D. W. M. | 2020 | Profound barriers to building information modeling (BIM) adoption in construction small and medium-sized enterprises (SMEs): An interpretive structural modelling approach. *Construction Innovation*. 20. 261-284. 10.1108/CI-09-2019-0087.
- [24] Saliu, L. O., Monko, R., Zulu, S., & Maro, G. (2024). Barriers to the Integration of Building Information Modeling (BIM) in Modular Construction in Sub-Saharan Africa. *Buildings*, 14(8), 2448.
- [25] Olanrewaju, O. I., Chileshe, N., Babarinde, S. A., & Sandanayake, M. (2020). Investigating the barriers to building information modeling (BIM) implementation within the Nigerian construction industry. *Engineering, Construction and Architectural Management*, 27(10), 2931-2958.
- [26] Samuelson, Olle & Stehn, Lars. (2023). Digital transformation in construction – a review. *Journal of Information Technology in Construction*. 28. 385-404. 10.36680/j.itcon.2023.020.
- [27] Shrivastava, H., & Akhtar, S. | 2019 | Sustainable Construction Practices in Africa | *Journal of Engineering, Design and Technology | Review | Construction Practices*.
- [28] Oguntona, Olusegun & Aigbavboa, Clinton & Mulongo, Gloria. (2019). An Assessment of Lean Construction Practices in the Construction Industry. 10.1007/978-3-319-94199-8_51.
- [29] Olawumi, T. O., Chan, D. W., Chan, A. P., & Wong, J. K. (2020). Development of a building sustainability assessment method (BSAM) for developing countries in sub-Saharan Africa. *Journal of Cleaner Production*, 263, 121514.
- [30] Ogunmakinde, Olabode & Umeh, Solomon. (2018). Adoption of BIM in the Nigerian Architecture Engineering and Construction (AEC) Industry.
- [31] Olapade, Daramola & Ekemode, Benjamin. (2018). Awareness and utilisation of building information modelling (BIM) for facility management (FM) in a developing economy: Experience from Lagos, Nigeria. *Journal of Facilities Management*. 16. 10.1108/JFM-09-2017-0046.
- [32] Olawumi, T. O., & Chan, D. W. M. | 2019 | Development of a benchmarking model for BIM implementation in developing countries | *Benchmarking: An International Journal | Mixed Methods | Implementation Framework*.
- [33] Oteng, Daniel & Ansah, Mark & Kissi, Ernest & Eshun, Bridget. (2018). Barriers to the adoption of Building Information Modelling in Developing Countries: The Case of Ghana.
- [34] Olanrewaju, Oludolapo & Sunday, Babarinde & Chileshe, Nicholas & Sandanayake, Malindu. (2021). Drivers for implementation of building information modeling (BIM) within the Nigerian construction industry. *Journal of Financial Management of Property and Construction*. 26. 366-386. 10.1108/JFMPC-12-2019-0090.
- [35] Olugbenga O. Akinade, Lukumon O. Oyedele, Kamil Omoteso, Saheed O. Ajayi, Muhammad Bilal, Hakeem A. Owolabi, Hafiz A. Alaka, Lara Ayris, John Henry Looney, 2017. BIM-based deconstruction tool: Towards essential functionalities, *International Journal of Sustainable Built Environment*, Volume 6, Issue 1, 2017, Pages 260-271, ISSN 2212-6090, <https://doi.org/10.1016/j.ijsbe.2017.01.002>.
- [36] Passoni, C., Caruso, M., Felicioni, L., & Negro, P. (2024). The evolution of sustainable renovation of

- existing buildings: from integrated seismic and environmental retrofitting strategies to a life cycle thinking approach. *Bulletin of Earthquake Engineering*, 1-35.
- [37] Tunji-Olayeni, Patience & Mosaku, TO & Oyeyipo, Opeyemi & Afolabi, Adedeji. (2018). Sustainability strategies in the construction industry: implications on Green Growth in Nigeria. *IOP Conference Series: Earth and Environmental Science*. 146. 012004. [10.1088/1755-1315/146/1/012004](https://doi.org/10.1088/1755-1315/146/1/012004).
- [38] Mazzoli, C., Papadaki, D., & Ferrante, A. (2023). A Parametric Approach for Optimizing Design Solutions in Urban Regeneration and Reshaping: An Application to a District Block in Bologna, Italy. *Buildings*, 13(12), 3123.
- [39] Lee, M. S. N., Mohamed, S., Masrom, M. A. N., Abas, M. A., & Wee, S. T. (2020, August). Risk in green retrofits projects: A preliminary study on energy efficiency. In *IOP Conference Series: Earth and Environmental Science* (Vol. 549, No. 1, p. 012084). IOP Publishing.
- [40] Zhang, Jianchao & Seet, Boon-Chong & Lie, Tek Tjing. (2015). Building Information Modelling for Smart Built Environments. *Buildings*. 5. 100-115. [10.3390/buildings5010100](https://doi.org/10.3390/buildings5010100).
- [41] Obrecht, T.P., et al., (2020). BIM and LCA Integration: A Systematic Literature Review. *Sustainability* 2020, 12, 5534; doi:10.3390/su12145534. www.mdpi.com/journal/sustainability.
- [42] Wohlin, C. Guidelines for snowballing in systematic literature studies and a replication in software engineering. In *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering (EASE '14)*, London, UK, 13–14 May 2014.
- [43] Khaddaj, M., & Srour, I., (2016). International Conference on Sustainable Design, Engineering and Construction Using BIM to Retrofit Existing Buildings. 1877-7058. © 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>). Peer-review under responsibility of the organizing committee of ICSDEC 2016. doi: 10.1016/j.proeng.2016.04.192. *Procedia Engineering* 145 (2016) 1526 – 1533 Available online at www.sciencedirect.com ScienceDirect.
- [44] SANTOS, R., et al., (2022). Informetric analysis and review of literature on the role of BIM in sustainable construction. A 14-Year Bibliometric Analysis. *Int. J. Environ. Res. Public Health* 2022, 19, 12820. <https://doi.org/10.3390/ijerph191912820>.
- [45] Cao, Y.; Xu, C.; Kamaruzzaman, S.N.; Aziz, N.M., (2022). A Systematic Review of Green Building Development in China: Advantages, Challenges and Future Directions. *Sustainability* 2022, 14, 12293. <https://doi.org/10.3390/su141912293>.
- [46] Hammond, R., et al., (2014). BIM in Sustainable Design: Strategies for Retrofitting/Renovation. *Computing in Civil and Building engineering* ©ASCE 2014.
- [47] Daly D, Cooper P and Ma Z, 2018 Qualitative analysis of the use of building performance simulation for retrofitting lower quality office buildings in Australia. *Energy and Buildings*, 181 84-94.
- [48] Royo P, Ferreira V. J, López-Sabirón A. M, García-Armingol T and Ferreira G, 2018 Retrofitting strategies for improving the energy and environmental efficiency in industrial furnaces: A case study in the aluminium sector. *Renewable and Sustainable Energy Reviews*, 82 18131822.
- [49] Østergård, T., Jensen, R.L. and Maagaard, S.E., "Building simulations supporting decision making in early design—a review", *Renewable and Sustainable Energy Reviews*, Vol. 61, (2016), 187-201. <https://doi.org/10.1016/j.rser.2016.03.045>.
- [50] Ma, Z., Cooper, P., Daly, D. and Ledo, L., "Existing building retrofits: Methodology and state-of-the-art", *Energy and Buildings*, Vol. 55, (2012), 889-902. <https://doi.org/10.1016/j.enbuild.2012.08.018>.

Citation of this Article:

Chukwuma-Uchegbu, Miriam Ijeoma, Edom, Ikenna Ellis, Okereke Chigozie James, Hamza Abubakar Dadum, & Olemgbe Jude Chisom. (2025). Unlocking Sustainability through BIM Integration in Sub-Saharan African Retrofit Projects: A Systematic Review. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 9(2), 23-32. Article DOI <https://doi.org/10.47001/IRJIET/2025.902005>
