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Barriers to the Integration of Building Information Modeling (BIM) in Modular Construction in Sub-Saharan Africa

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Abstract: The construction industry is constantly evolving through government policies, technologies, and innovative processes. BIM and modular construction are innovative concepts aimed at achieving sustainable smart cities by enhancing cost performance, efficiency, and sustainability. Despite growing global interest in their integration, there is a notable knowledge gap in sub-Saharan Africa. As a result, this research aims to explore the barriers to integrating BIM into modular construction in sub-Saharan Africa. The study adopted a non-experimental design, using a four-stage methodological framework. Initially, a literature review was carried out to conceptualize the study. Stage two involves a pilot survey to create an adequate data collection instrument. In the third stage, 81 registered companies were purposely selected, and data was collected through an online survey. Finally, the fourth stage uses descriptive and inferential techniques to make logical and informed conclusions. The top-ranked barriers are high initial costs, insufficient cross-field expertise, stakeholder collaboration problems, limited software interoperability, and skills shortages. Recommendations include early stakeholder collaboration, BIM execution plan development by modular companies, improved staff training, and increasing financial support from the government. Future research should explore country-specific barriers and case studies to aid the integration of the two innovative solutions in the region.

Keywords: building information modeling (BIM); modular/offsite construction; sub-Saharan Africa; BIM barriers; construction innovation; prefabricated construction

Citation: Saliu, L.O.; Monko, R.; Zulu, S.; Maro, G. Barriers to the Integration of Building Information Modeling (BIM) in Modular Construction in Sub-Saharan Africa. *Buildings* **2024**, *14*, 2448. https://doi.org/10.3390/buildings14082448

Academic Editor: Chang-Su Shim

Received: 11 July 2024
Revised: 31 July 2024
Accepted: 6 August 2024
Published: 8 August 2024

1. Introduction

The traditional construction industry can effectively address its current challenges by leveraging two innovative approaches: building information modeling (BIM) and modular (offsite) construction [1,2]. The two technologies are highly interconnected and can be applied together to ensure the maximization of profits in the construction industry [2,3].

Modular construction refers to prefabricated building units manufactured to perfection in a manufacturing facility off-site, then transported and assembled on-site [4]. This technique, in comparison with traditional on-site construction methods, offers benefits of higher quality, robust safety and health, safer and more conducive working conditions, tolerance improvement, cost reduction, minimized reworks, construction waste reduction, streamlined construction processes, factory-tested products, reliable sustainability performance, and improved control and quality assurance [5–11].

Despite these benefits, the adoption of modular construction in sub-Saharan Africa remains limited. Wuni and Shen [12] point to poor market conditions, minimal industrialization, and inadequate infrastructure as significant barriers. Idris and Adamu [9] note that traditional construction methods still dominate in Nigeria, largely due to a lack of awareness of modular techniques. Furthermore, Bello et al. [10] and Awodele et al. [13] highlight the high costs, lack of local expertise, and poor financing as additional obstacles.

Arowoiya and Oyefusi [6] further emphasize the unavailability of modular companies and necessary technology as critical issues.

In addition to these barriers, the optimal use of modular construction faces challenges such as the need for extensive pre-project planning and coordination among interdisciplinary professionals. These challenges can potentially affect the efficiency and effectiveness of modular construction projects [14–17] and could be addressed through the BIM platform [14]. In fact, Goulding et al. [18] argued that the largest improvement in construction productivity will be driven by the automation of off-site processes through the implementation of BIM.

Building Information Modelling (BIM) has revolutionized construction projects with enhanced collaboration and value delivery [19]. It integrates policies, processes, and technologies that revolutionize how project information is created, managed, and utilized across a structure's entire lifecycle [20]. It improves planning, collaboration, and modular construction efficiency by providing the needed information in the appropriate format at the correct time and location. BIM contains life-cycle data that can enhance design reviews, construction feasibility reviews, and process and construction cost simulations through the digital visualization of target buildings based on 3D modeling [21]. This is useful for the stakeholders to make logical and up-to-date decisions about changes in design and prefabricated module production over the project life cycle [22].

Consequently, there have been an increasing number of studies on this subject in recent years. These include research on the benefits and barriers of BIM in modular construction [23–28] and frameworks for implementing BIM in modular construction [29–31]. However, these studies extensively conducted in regions like Hong Kong, the UK, China, Malaysia, and Australia fail to address the unique socio-economic and technological context of sub-Saharan Africa.

According to Succar [32], the benefits and obstacles of BIM in any project depend on the level at which it is implemented, which varies across the globe. Lepkova et al. [33] further explained that countries are at different stages of BIM implementation, leading to diverse challenges and opportunities across the architecture, engineering, and construction (AEC) industries. In many sub-Saharan African countries, the adoption of building information modeling (BIM) is still in its early stages. According to Oyesode et al. [34], BIM practices have not been widely embraced by most construction entities in these countries. This low adoption of BIM is due to high initial costs, a lack of awareness and skilled personnel, resistance to change, inadequate governmental support, and low technology maturity [19,35]. Consequently, sub-Saharan African countries are expected to face diverse barriers to BIM implementation compared to developed countries and other developing countries like China and Malaysia, which have made significant progress in BIM adoption.

Similarly, the available studies on the barriers to implementing BIM in sub-Saharan African countries, such as [36–38], predominantly focus on conventional construction methods, overlooking the distinct processes involved in modular construction. To address this gap, there is a pressing need for a dedicated study that focuses on identifying barriers to BIM implementation in modular construction projects, considering the unique context and challenges of sub-Saharan Africa. Such research is pivotal in developing strategies and policies to facilitate the adoption of BIM in the region's modular construction industry, contributing to the effective adoption of BIM-enhanced modular construction practices in the region.

This study fills this gap by investigating the barriers to BIM integration in modular construction in sub-Saharan Africa. The study aims to inform stakeholders, policymakers, and researchers, facilitating the effective adoption of these technologies in the region. To achieve this aim, the following research questions were set: What are the barriers hindering the implementation of BIM in modular construction worldwide? What are the most significant barriers to integrating BIM into modular construction in sub-Saharan Africa? What is the correlation between significant barriers to the integration of BIM in modular construction in sub-Saharan Africa?

To answer these questions, a detailed review of the literature was conducted to identify the barriers hindering the implementation of BIM in modular construction worldwide and in the construction industry in general. This was important considering the limited literature focusing on BIM implementation in modular construction in the sub-Saharan African region. Secondly, a pilot survey of modular construction experts was conducted to reveal barriers specific to BIM implementation in the sub-Saharan African modular construction industry. Finally, an online survey targeting sub-Saharan African modular firms identified the most significant barriers to integrating BIM in modular construction within the region. Based on the research findings and discussions, a set of recommendations is proposed and examined to support the implementation of BIM in modular construction. This research provides a valuable foundation for further studies aimed at facilitating the implementation of BIM in the sub-Saharan African modular construction industry.

2. Literature Review

The construction industry is a complex sector encompassing a wide range of activities, including but not limited to new construction, maintenance, refurbishment, rehabilitation, conversion, extension, and renovation [39]. Its importance for socioeconomic growth and its contribution to the growth of many other major economies make it one of the most important industries in the development of a nation [40]. This was further reinforced by Olanrewaju and Junior [39], who noted that the contributions of the industry to the gross domestic product of most countries range from 3% to 10%. Moreover, the construction sector is a multifaceted industry involving numerous stakeholders, such as clients, design professionals, construction professionals, and operational teams, and a wide range of activities [41,42].

This complexity, coupled with its multidimensional nature, has resulted in inefficiency compared to other sectors like manufacturing [42]. Moreover, the sector faces challenges like significant safety risks and subpar environmental performance [20]. As noted by Isaac et al. [43], these challenges are associated with the relatively slow implementation of advanced digital technologies and industrialization concepts, such as robotics, mechanization, standardization, automation, modularization, and information-based construction. Consequently, promoting a more integrated industry has been recommended as a way to boost productivity [20].

As a result, in the last three decades, there has been a growing interest in modular construction worldwide [44]. This approach provides a better alternative to traditional construction methods, offering enhanced productivity, efficiency, quality, safety, and sustainability, among other benefits [44,45]. The primary objective of modular construction is to transfer some construction activities to more controlled environments and manufacturing facilities [40]. The ease of installation reduces construction time, and its safety features have driven its rapid growth worldwide in recent years [22]. In support of this, Wang et al. [17] considered that a major advantage of modular construction was its potential to reduce construction time by 30–50% compared to conventional methods, as the construction modules can be prefabricated in a factory while site preparation takes place simultaneously [17,46].

Goodier and Gibb [47] identified the biggest advantages of modular construction over traditional methods in the UK as reduced construction time, improved quality, consistency in products, reduced defects, and increased value. This was reinforced by Samarasinghe et al. [30], who noted that in modular construction, construction time is 50%–60% less than in conventional construction. The key advantages of modular construction, according to Goulding et al. [18], are reduced construction times, superior quality control due to factory-based production, improved economies of scale, enhanced health and safety measures, and lower labor costs. Furthermore, to address the need for more affordable housing, modular construction has been suggested as the most viable solution, capable of increasing the supply of new housing stocks significantly [44]. Thus, modular housing has transformed the construction sector by incorporating industrialization principles throughout the entire lifecycle of construction projects, encompassing various stages including design, manufacturing, transportation, on-site assembly, maintenance, and deconstruction [48].

Despite these advantages, developing countries tend to lag in the adoption of modular construction compared to developed countries [49]. NPerera et al. [40], however, noted that there has been some significant progress in modular construction research in some developing countries. For instance, Malaysia has been advancing industrialized building systems (IBSs), while China has been focusing on the study and development of precast concrete elements.

Regardless of the immense benefit of modular construction in solving most of the challenges of conventional constructional methods, it is facing a lot of challenges in its adoption and optimal utilization. Information fragmentation and a disjointed working environment have been noted as major obstacles to the efficient supply of prefabricated housing projects in Hong Kong [48,50]. Several studies have shown that the disruption caused by information fragmentation leads to communication breakdown and coordination challenges, while a lack of collaboration among stakeholders results in inefficiencies and undermines overall project quality. This is supported by Goulding et al. [18], who identified poor stakeholder collaboration as a significant factor contributing to miscommunication in the adoption of modular construction in the UK. Additionally, some researchers have noted that the total time from design to on-site assembly can sometimes exceed that of conventional construction methods [14–16].

Similarly, a study conducted in the US revealed that almost 50% of modular projects saved less than 5% of total labor hours [17]. Other similar studies have found that modular buildings can be between 26.3% and 72.1% more expensive than traditional buildings [51–53]. Despite incorporating BIM in some modular projects, these barriers remain [23]. These results show that to fully realize the full potential of BIM in optimizing modular construction projects, a focused study on how to optimize the integration of BIM is essential [16,34]. Consequently, Goulding et al. [18] argue that significant improvements in construction productivity will primarily come from automating off-site activities through BIM.

Building information modelling (BIM) is a comprehensive approach that integrates policies, processes, and technologies to digitally manage buildings from inception to demolition [54]. The BIM concept employs 3D, 4D, and 5D models, revolutionizing how project information is created, managed, and utilized across a structure's entire lifecycle [48]. BIM enables various tasks, such as design reviews, feasibility assessments, and cost simulations, by providing digital visualizations of target buildings through 3D modeling [54].

Furthermore, the integration of BIM has been identified as a potential solution for enhancing collaboration and efficiency in modular construction by providing the required information in the appropriate format at the correct time and place, and there have been a growing number of studies on this topic in recent years [29,55–57]. BIM is essential in modular construction by allowing an accurate digital replica of a building's physical components, facilitating accurate fabrication and assembly in a factory setting before assembly on-site. In addition, computer-aided BIM, as highlighted by Wasim et al. [22], can automatically generate architectural drawings and detailed sections for all components of prefabricated structures by creating a visual model using standard component creation and design for manufacture and assembly (DfMA). This assists stakeholders in making informed decisions regarding design changes and prefabricated construction production throughout the project life cycle. In addition to supporting the design and manufacturing of building elements, BIM is also valuable in the construction and operational phases of a building [30].

Moreover, the integration of BIMs object-oriented features with the production-focused aspects of modular construction enhances stakeholder collaboration, thus improving its efficiency and decision-making [58]. This, in turn, leads to enhanced marketing, reduced lead time, and a reduction in design errors [58]. BIM can also revolutionize the supply chain process within the building component fabricating industry through improved 3D visual models, data accuracy, information management, and 5D automated cost estimating, thus enabling leaner construction methods if well harnessed within an organization's department [58]. Similarly, with the help of the BIM platform, fabricators can easily manage information and improve internal processes by supporting parametric relationships and importing product model information from designers' BIM platforms [24].

Despite the potential benefits, the real-world deployment of BIM in modular construction remains limited [24], and the extent of BIM implementation in the sub-Saharan African construction industry is generally lower compared to developed countries [36]. The advantages of BIM can only be realized by effectively addressing critical barriers, prompting various studies to investigate the obstacles to its implementation. As a result, numerous studies have delved into barriers to BIM implementation in conventional construction across various sub-Saharan African countries [36–38]. Additionally, several studies have provided valuable insights into the hindrances faced in implementing BIM in modular construction worldwide, as highlighted in Table 1 below.

Table 1. Barriers to the integration of BIM in modular construction.

S/N	Barriers	Interpretation	Reference
1	Lack of support and resistance to change from management	Inadequate backing from top management and organizational resistance to changing traditional practices to adopt BIM.	[25–27,36,59–66]
2	Poor Stakeholder Collaboration	Insufficient collaboration among project stakeholders in modular construction projects	[25–27,59–61,63,65]
3	Unclear BIM roles	When roles and responsibilities related to BIM in modular construction projects are undefined, confusion can arise, impeding progress	[25,27,64,66]
4	Limited client demand	Clients' lack of interest in BIM usage.	[60–62,64]
5	Lack of action plan and workflow	Lack of a well-established action plan and workflow for BIM and modular construction integration.	[24,25,27,60,64,67]
6	Extended planning and risk assessment difficulties	BIM adoption extends planning efforts and poses challenges in risk allocation for modular construction	[25,27,59,60,68]
7	Project strategies and policies	Lack of incentive-oriented strategies and policies	[27,60,61,66]
8	Ambiguous economic benefits	When stakeholders do not perceive the economic benefits of adopting BIM in modular construction projects.	[24,25,60,62,64,66,67]
9	Increased design costs	BIM adoption may lead to increased design expenses	[24,27]
10	Shortage of BIM skills	Insufficient number of professionals with BIM-related skills	[27,61–67]
11	BIM learning and training problem	BIM technology learning difficulties and insufficient BIM training programs	[24,59–62,64,66]
12	Insufficient cross-field expertise	Shortage of specialists who have expertise in both BIM and modular construction	[24,59–61]
13	Limited research in industry and academia	Inadequate research on BIM implementation in modular construction in the region	[24,60]
14	Misunderstanding of the BIM process	poor understanding of modular construction and BIM benefits and process	[24,25,61,65]
15	Absence of domestic BIM tools	Lack of BIM software developed for local needs.	[24,64,65]
16	Poor user experience	Challenges with the usability and user-friendliness of BIM software	[60,64,65]
17	Complex BIM software	The complexity of BIM software developed abroad can be a barrier	[62,64,65]
18	Limited software interoperability	Incompatibility between different BIM software Packages.	[25,59,60,62,64–66]
19	High costs of BIM software, tools, and training	The significant financial investment required for BIM software, tools, and training can hinder its widespread use.	[24–27,59–67]
20	Intellectual Property and data security concerns	Concerns about intellectual property and data security.	[24,25,28,59,60,63,65]

However, previous studies focusing on BIM implementation barriers in sub-Saharan African countries have primarily focused on conventional construction, overlooking the distinct processes involved in modular construction. Secondly, research on BIM barriers in modular construction worldwide has not specifically investigated the unique challenges faced in the sub-Saharan African context, which is characterized by a vast and diverse market. Thus, there is a pressing need for a study dedicated to identifying barriers to BIM integration in modular construction, considering the unique context and challenges of the sub-Saharan African region. Such a study could be pivotal in guiding the development of effective strategies and policies to support BIM adoption within the modular construction industry in the region.

3. Methodology

This study employed a comprehensive four-stage methodological framework to investigate the barriers to integrating building information modeling (BIM) in modular construction in sub-Saharan Africa. In Stage 1, a thorough literature review was conducted to pinpoint the existing research gap and develop a theoretical list of potential barriers to BIM integration. In Stage 2, pilot interviews were conducted with experts in modular construction to validate the identified barriers and create a precise data collection instrument. For Stage 3, relevant respondents were identified, and data on the barriers to integrating BIM in modular construction in sub-Saharan Africa were systematically collected. Finally, in Stage 4, advanced statistical techniques were applied to analyze the dataset, providing valuable insights to draw informed conclusions. The following subsections detail the methodological framework employed throughout the study.

3.1. Identifying and Validating Potential Barriers to the Integration of BIM in Modular Construction in sub-Saharan Africa

This study commenced with a thorough review of relevant articles published in reputable research publications to discern potential barriers to the integration of building information modeling (BIM) in modular construction in sub-Saharan Africa. This review culminated in the creation of a comprehensive checklist comprising twenty significant barriers to the integration of BIM in modular construction in the region, as presented in Table 1.

To validate the identified barriers, one of the authors reached out to five modular construction experts in sub-Saharan Africa, each with extensive expertise in BIM and modular construction. This approach is consistent with Wuni and Shen [69], who recommend using an odd number of experts in construction surveys to ensure the selection of the most popular opinion when experts disagree on management practices. These experts were chosen based on their expertise and their countries' significant contributions to the field, with their economies hosting 17, 16, and 10 of the 81 identified modular construction firms across the region, respectively. Of the five experts contacted, three responses were received. The feedback from these experts was considered sufficient as it is consistent with the standards of similar published studies [70–72].

The initial questionnaire was tested with these experts to identify any potential issues with the questions, format, or overall structure. The experts were specifically asked to indicate whether each question was relevant to the study or not. Their feedback highlighted areas for improvement, ensuring that the questions were clear, relevant, and effective.

They suggested the removal or merger of certain barriers, which are detailed in Table 2 below, to streamline the questionnaire and enhance its relevance.

Table 2. Eliminated barriers during the validation process.

S/N	Barriers	Reasons
1	Unclear BIM role	Two of the respondents suggested merging this to B3 (lack of action plan and workflow) since the BIM role is linked to the action plan and workflow.
2	limited client demand	The three experts agreed that this is not a barrier in modular construction, where clients focus on the end product rather than the process, leaving BIM usage to the discretion of modular companies.
3	Increased design cost	Two of the experts suggested merging this into B14 (high costs of BIM software, tools, and training). They believed the additional cost of design is a result of the cost of acquiring BIM tools and design software.
4	Misunderstanding of the BIM process	Two of the experts believed that this is not a barrier. They believed misunderstanding is a result of lack of skills and poor education/training which are already covered in B7 and B8.
5	Complex BIM software	Two of the experts believed the complexity of BIM software and user-friendliness are similar. As a result, they suggested merging with B12.

As a result, a summary of the 15 validated barriers is provided in Table 3 below. These fifteen shortlisted barriers were then identified as candidates for the subsequent questionnaire survey.

Table 3. Summary of the validated barriers to the integration of BIM in modular construction.

Code	Barriers
B1	Lack of support and resistance to change from management
B2	Poor stakeholder collaboration
B3	Lack of action plan and workflow
B4	Extended planning and risk assessment difficulties
B5	Project strategies and policies
B6	Ambiguous economic benefits
B7	Shortage of BIM skills
B8	BIM learning and training problem
B9	Insufficient cross-field expertise
B10	Limited research in industry and academia
B11	Absence of domestic BIM tools
B12	Software complexity and poor user experience
B13	Limited software interoperability
B14	High costs of BIM software, tools, and training
B15	Intellectual property and data security concerns

3.2. Recruitment of Relevant Respondents

This study employed an online survey to examine the barriers to implementing building information modeling (BIM) in modular construction in sub-Saharan Africa, specifically focusing on the practices of modular companies in the region. The survey targeted construction professionals and BIM experts within these companies, employing a meticulous recruitment process.

Given the absence of a central database encompassing all modular construction companies in sub-Saharan Africa, this study employed a purposive sampling approach. This method enables the researcher to focus on knowledgeable experts within a specific cultural domain. Companies were deliberately selected based on specific criteria, including registration status, geographical location, online presence, and project portfolio. Using these criteria, the contact details of 81 relevant modular construction companies in sub-Saharan Africa were identified. These details were sourced from published articles, workshop reports, conferences, and the official websites of modular companies across various countries in the region. This recruitment strategy is consistent with established practices in prior studies, such as the work of Osei-Kyei et al. [73], which successfully engaged experts within specific geographic contexts.

While recognizing the contextual sensitivity of BIM barriers in modular construction across different countries in sub-Saharan Africa, this study opted to use a regional approach to identify barriers to the successful integration of BIM in modular construction. The importance of this benchmarking outcome lies in the fact that modular construction projects in the region often require cross-border collaboration to source materials, expertise, and prefabricated, prefinished volumetric modules. Consequently, leveraging a regional expert knowledge base to evaluate and prioritize the barriers is considered crucial. The 81 companies identified through this process constituted the sample frame for this study.

3.3. Data Collection Survey Design and Data Collection

While previous studies have commonly utilized questionnaires and interviews to explore barriers to building information modeling (BIM) [44], this study opted to use questionnaires as the primary data collection method. This choice was driven by the need for quantitative insights from regional domain experts to assess and prioritize BIM integration barriers in modular construction within sub-Saharan Africa.

The structured questionnaire consisted of two sections. The first section gathered background information from respondents, while the second section asked domain experts to assess the relative significance of BIM barriers in modular construction using a five-point Likert scale: 1 (not a barrier), 2 (minor barrier), 3 (moderate barrier), 4 (significant barrier), and 5 (critical barrier). The questionnaire underwent a pilot phase with three experts who reviewed the barrier list, ensuring the instrument's reliability and validity, as explained in Section 3.1 above. All experts found the questionnaire appropriate and straightforward.

Personalized invitation emails were sent to the 81 identified modular companies to complete the questionnaire survey. After multiple weekly reminders, a total of 31 valid responses were received in five weeks, representing a response rate of 38.3%. The 31 responses were from 14 countries, as presented in Table 4 below:

Table 4. Response Rate.

Country	Frequency	Percentage
Nigeria	6	19.4
Ghana	5	16.1
South-Africa	4	12.9
Kenya	3	9.7
Cameroon	2	6.5
Ethiopia	2	6.5
Uganda	2	6.5
Benin	1	3.2
Botswana	1	3.2
Cote d'Ivoire	1	3.2
DR Congo	1	3.2
Rwanda	1	3.2
Tanzania	1	3.2
Zimbabwe	1	3.2
Total	31	100.0

The response rate appears low; however, the 31 responses were deemed sufficient for statistical analysis for several reasons. First, there is no universally accepted standard for what constitutes a sufficient response rate for online surveys [74]. Additionally, the number of responses exceeded the minimum of 30 valid responses needed according to the central limit theorem for reliable conclusions [69]. Moreover, similar international online survey studies have reported smaller sample sizes, such as 27 [75], 47 [73], 33 [76], 15 [77], and 31 [78]. In addition, considering the percentage of responses received, Fellow and

Liu (2003), as cited in Musyimi [74], suggested an acceptable response rate of 25% and 35% for online questionnaires in construction studies.

Demographic Information of Respondents

Table 5 shows the background and profile information of respondents, as well as the demographics of the modular companies represented.

Table 5. Demographic information of respondents.

Characteristics	Frequency	Percentage
Company Role		
Managing Director	2	6.5
Project Manager	2	6.5
BIM Manager	1	3.2
Architect/Engineer/Designer/Quantity Surveyor	18	58.1
Contractor/Sub-Contractor	3	9.7
Others	5	16.1
Total	31	100.0
Company Size		
Less than 10	1	3.2
10–49	9	29.0
50–99	9	29.0
100–249	3	9.7
250–499	3	9.7
500 and above	6	19.4
Total	31	100.0
Modular Construction Experience		
Less than 1 year	2	6.5
1–5 years	14	45.2
6–10 years	9	29.0
11–20 years	6	19.4
More than 20 years	0	0
Total	31	100.0
BIM Experience		
None	2	6.5
1–5 years	10	32.3
6–10 years	17	54.8
11–20 years	2	19.4
More than 20 years	0	0
Total	31	100.0

The data from Table 5 reveal a predominant presence (58.1%) of architects, engineers, designers, and quantity surveyors, emphasizing the importance of adequate pre-project planning in modular construction since these professionals are involved in the early stages of project planning. The distribution of company sizes reveals a notable emphasis on small- and medium-sized companies, with both 10 to 49 employees and 50 to 99 employees each accounting for 29.0%. Companies with 100 to 499 employees and those with over 500 employees each account for 19.4%. The data on modular construction experience among respondents indicates a significant presence (45.2%) of professionals with 1 to 5 years of modular construction experience, which is reflective of the emerging nature of this field in sub-Saharan Africa [71]. Moreover, BIM experience among respondents varies widely; 54.8% have 6 to 10 years of experience, complemented by 32.3% with 1 to 5 years. This diversity indicates a strong adaptation to BIM technologies, supporting innovative applications in modular construction. Such varied expertise suggests well-informed opinions based on accumulated knowledge and experience.

3.4. Data Analysis

The gathered data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25. In the first stage, Cronbach's alpha was employed to assess the internal consistency and reliability of the questionnaire responses. The interpretation of Cronbach's alpha results varies, but a widely accepted standard considers a value of 0.70 as the minimum acceptable threshold [79]. The reliability analysis of the dataset yielded a Cronbach's alpha of 0.887, indicating excellent internal consistency among the responses.

Additionally, parametric and nonparametric statistical tests were applied to explore statistically significant differences among responses. Parametric tests assume a normal distribution of the data, unlike nonparametric tests, which do not impose such assumptions [80]. Therefore, employing a normality test becomes imperative to guide the selection between parametric and nonparametric statistical tests for scrutinizing the survey-based dataset. The widely recognized Shapiro–Wilk test was employed to assess the normal distribution of the dataset [62]. A key criterion for normal distribution is met when the probability (p) values of the success factors are less than the predetermined level of significance, commonly set at 0.05 for a 95% confidence interval.

In the second stage of analysis, various statistical indicators were computed to prioritize the building information modeling (BIM) barriers within modular construction in sub-Saharan Africa. The mean score (μi) and standard deviation (σi) for each barrier were determined. Mean score analysis is widely used to assess the aggregate average rating of variables on Likert scale data [81]. The mean scores were used to rank the barriers in descending order. Higher mean scores signify higher rankings, while lower scores indicate lower rankings. The mean scores were complemented by standard deviations to account for the limitations of the mean [62], which can be influenced by outliers and may not accurately reflect the critical threshold on a Likert scale (Ott and Longnecker, 2016, as cited in Wuni and Shen [69]).

In addition, the correlation coefficient was used to compute the extent to which two barriers align in the integration of BIM in modular construction. The coefficient describes both the strength and direction of the relationship or association. The Pearson product-moment correlation and the Spearman rank-order correlation are the two conventional techniques for linear correlation analysis. The Spearman rank-order correlation was chosen for this study because it is appropriate for ordinal data and data that do not follow a normal distribution, assuming a monotonic relationship where barriers may covary but not necessarily at a consistent rate.

4. Results and Findings

4.1. Frequency Distribution of the Barriers to the Integration of BIM in Modular Construction in Sub-Saharan Africa

Before carrying out the descriptive and inferential evaluation of the study, it was necessary to determine whether to use parametric or nonparametric statistical methods. The Shapiro-Wilk tests produced p values below 0.05 for all 15 barriers at a 95% confidence level (Table 6), indicating that the dataset does not follow a normal distribution.

Table 6. Test of normality.

Code	Barriers	Shapiro-Wilk		
		Statistic	**Df**	**Sig.**
B1	Lack of management support and resistance to change	0.867	31	0.001
B2	Poor stakeholder collaboration	0.842	31	0.000
B3	Lack of action plan and workflow	0.864	31	0.001
B4	Extended planning and risk assessment difficulties	0.894	31	0.005
B5	Lack of incentive-oriented strategies and policies	0.886	31	0.003

Table 6. *Cont.*

Code	Barriers	Shapiro-Wilk		
		Statistic	Df	Sig.
B6	Ambiguous economic benefits	0.903	31	0.009
B7	Shortage of BIM skills	0.881	31	0.003
B8	BIM learning and training problem	0.921	31	0.025
B9	Insufficient cross-field expertise	0.786	31	0.000
B10	Limited research in industry and academia	0.887	31	0.003
B11	Absence of domestic BIM tools	0.891	31	0.004
B12	Poor user experience	0.910	31	0.013
B13	Limited software interoperability	0.865	31	0.001
B14	High costs of BIM software, tools, and training	0.707	31	0.000
B15	Intellectual property and data security concerns	0.909	31	0.012

Note(s): The test was significant at the 0.05 significance level. This result necessitated the use of nonparametric techniques to evaluate correlations between different barriers.

4.2. Mean, Standard Deviation, and Ranking of the Barriers to the Integration of BIM in Modular Construction

Table 7 provides a comprehensive overview of the perceived barriers to the successful integration of building information modeling (BIM) in modular construction in sub-Saharan Africa. Notably, the most critical barrier is the high cost associated with BIM software, tools, and training, with a prominent mean score of 4.2258. This underscores the financial challenges that practitioners commonly face in adopting BIM methodologies. Close behind are the lack of cross-field expertise and difficulties in achieving effective stakeholder collaboration, both of which have mean scores above 3.5 (3.9677 and 3.6774, respectively). Challenges related to limited software interoperability (3.6452) and a shortage of BIM skills (3.5806) complete the significant barriers.

Table 7. Barriers to BIM Integration in modular construction in sub-Saharan Africa.

Code	Barriers	Mean	Std. Deviation	Rank	Significance
B14	High costs of BIM software, tools, and training	4.2258	1.08657	1	Yes
B9	Insufficient cross-field expertise	3.9677	1.13970	2	Yes
B2	Poor Stakeholder collaboration	3.6774	1.01282	3	Yes
B13	Limited software interoperability	3.6452	0.79785	4	Yes
B7	Shortage of BIM skills	3.5806	1.08855	5	Yes
B5	Lack of incentive-oriented strategies and policies	3.4516	1.02758	6	No
B3	Lack of action plan and workflow	3.2903	0.93785	7	No
B10	Limited research in industry and academia	3.2581	1.18231	8	No
B15	Intellectual property and data security concerns	3.2581	1.09446	9	No
B8	BIM learning and training problem	3.0968	1.19317	10	No
B11	Absence of domestic BIM tools	3.0000	1.31656	11	No
B1	Lack of management support and resistance to change	3.0000	1.52753	12	No
B12	Poor user experience	2.9677	1.27760	13	No
B6	Ambiguous economic benefits	2.9032	1.07563	14	No
B4	Extended planning and risk assessment difficulties	2.6774	1.01282	15	No

Source: Field data, 2024.

Conversely, barriers such as the lack of incentive-oriented strategies and policies (3.4516), the absence of an action plan and workflow (3.2903), and limited research in industry and academia (3.2581) are considered of lesser significance, each scoring below the mid-value of 3.5. While these barriers are recognized, they may warrant less immediate attention compared to the more impactful challenges identified.

It is worth noting that barriers with the lowest mean scores, including poor user experience (mean score: 2.9677), ambiguous economic benefits (mean score: 2.9032), and extended planning and risk assessment difficulties (mean score: 2.6774), are considered less important. While not negligible, these barriers may be addressed with a different emphasis, allowing practitioners to focus their efforts based on the significance of each barrier.

4.3. Correlation Matrix of the Barriers to the Integration of BIM in Modular Construction in Sub-Saharan Africa

A correlation coefficient quantifies the degree of linear relationship between two variables. For this study, it was used to compute the extent to which two barriers align in the integration of BIM in modular construction. Table 8 presents the correlation matrix of the 15 barriers to the integration of BIM in modular construction.

Table 8. Correlation matrix of BIM barriers in modular construction.

Code		B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12	B13	B14	B15
B1	r	1.000														
B2	r	0.359 *	1.000													
B3	r	0.308	0.684 **	1.000												
B4	r	0.331	0.527 **	0.452 *	1.000											
B5	r	0.229	0.489 **	0.641 **	0.543 **	1.000										
B6	r	0.461 **	0.465 **	0.286	0.559 **	0.431 *	1.000									
B7	r	0.332	0.379 *	0.395 *	0.140	0.564 **	0.299	1.000								
B8	r	0.435 *	0.345	0.319	0.317	0.552 **	0.592 **	0.559 **	1.000							
B9	r	0.124	0.358 *	0.285	−0.122	0.278	0.114	0.581 **	0.134	1.000						
B10	r	0.673 **	0.088	0.173	0.196	0.341	0.350	0.516 **	0.412 *	0.243	1.000					
B11	r	0.252	0.144	0.160	−0.007	0.292	0.353	0.415 *	0.611 **	0.183	0.349	1.000				
B12	r	0.141	0.295	0.032	0.137	0.147	0.409 *	0.334	0.445 *	0.170	0.235	0.551 **	1.000			
B13	r	0.281	0.668 **	0.487 **	0.304	0.521 **	0.606 **	0.624 **	0.574 **	0.621 **	0.179	0.315	0.349	1.000		
B14	r	0.080	0.453 *	0.362 *	−0.018	0.330	0.123	0.360 *	0.100	0.806 **	0.013	0.190	0.165	0.568 **	1.000	
B15	r	0.337	0.295	0.368 *	0.314	0.486 **	0.388 *	0.431 *	0.418 *	0.256	0.461 **	0.418 *	0.206	0.404 *	0.3542	1.000

* Correlation is significant at the 0.05 level (2–tailed). ** Correlation is significant at the 0.01 level (2–tailed).

The Spearman rank-order correlation coefficient (r) ranges from −1 to +1. A coefficient of +1 indicates that an improvement in one barrier corresponds to an improvement in the associated barrier, while −1 signifies that an improvement in one barrier is linked to a deterioration in the related barrier. This analysis helps identify correlated barriers for factor analysis and contributes to developing a conceptual framework.

The results of the correlation matrix (Table 8) imply that most of the barriers are complementary and should be carefully considered in the integration of BIM in modular construction.

5. Discussion of Findings

The five significant barriers to the integration of BIM in modular construction in sub-Saharan Africa are discussed (in ranked order) in this section with references to the statistics in Tables 7 and 8 above.

5.1. High Costs of BIM Software, Tools, and Training (B14)

Based on Table 7, the highest-ranked barrier is the high costs associated with BIM software, tools, and training, with a prominent mean score of 4.2258 and a standard deviation of 1.08657. It has significant positive correlations with B2, B3, B7, B9, and B13, indicating that its successful mitigation could enhance the mitigation of five other barriers.

This is consistent with previous, similar studies. Gharaibeh et al. [62] and Vernikos et al. [63] identified the high initial costs as one of the most important barriers requiring utmost attention for the successful implementation of BIM in modular construction projects. In support of this, Mahmoud et al. [25] considered that the high initial cost was due to the need for developing software libraries and the ongoing effort required to master and effectively utilize these tools. This was supported by Ang et al. [28], who explained that replacing CAD technologies with BIM requires high investment in BIM software, hardware, and training. As a result, Wu et al. [64] and Evans and Farrell [60] also identified the high cost of BIM software as one of the major barriers to BIM implementation in China’s industrialized building structure. Similarly, Ang et al. [28] and Ghalenoei et al. [61] identified BIM training costs, BIM experts, and tool expenditure as the most critical barriers to the successful integration of BIM in Malaysian industrialized building system (IBS) construction projects.

As a result, Chan et al. [48] proposed adequate financial support to set up BIM systems and BIM training programs as one of the critical success factors for BIM implementation.

5.2. Insufficient Cross-Field Expertise (B9)

Having sufficient expertise in building information modeling and modular construction is paramount to successfully integrating these two innovative solutions. This is particularly true in sub-Saharan Africa, where modular construction is still evolving and where there are very few modular construction projects across the region. Therefore, it is not unexpected that B9 was identified as a highly critical barrier to the integration of BIM in modular construction. B9 was ranked 2nd among the 15 barriers with a mean index of 3.9677 and a standard deviation of 1.1397 (Table 7). It has significant positive correlations with B2, B7, B13, and B14, indicating that its successful mitigation could enhance the mitigation of four other barriers.

This is consistent with Wu et al. [64], who identified a lack of talent with relevant skills and knowledge as one of the most critical barriers to BIM implementation for industrialized building construction. Having sufficient expertise in building information modeling and modular construction is paramount for the successful integration of these two innovative solutions. Also, Chan et al. [59], Evans and Farrell [60], Ghalenoei et al. [61], and Xu et al. [27] identified a lack of expertise as one of the barriers to BIM implementation in modular construction.

As a result, Chan et al. [48] and Olawumi and Chan [82,83] proposed having the necessary experience and technical expertise as a critical success factor for BIM implementation.

5.3. Poor Stakeholder Collaboration (B2)

This barrier was ranked 3rd among the 15 barriers with a mean index of 3.6774 and a standard deviation of 1.01282 (Table 7). It has significant positive correlations with B1, B3, B4, B5, B6, B7, B9, B13, and B14, indicating that the effective mitigation of the problem of poor stakeholder collaboration could enhance the mitigation of nine other barriers.

Poor collaboration among project stakeholders in modular construction projects has been identified as one of the barriers to the integration of BIM in modular construction in several studies [25–27,59–61,63]. However, none of those studies ranked it as a critical barrier. The results obtained in the present study differ from previous studies in this regard. This could be attributed to the geographical differences between this study and other studies. Since modular construction is still evolving in sub-Saharan Africa, the problem of collaboration among professionals is still prevalent when compared to those in developed nations.

As a result, seamless cooperation and coordination among all stakeholders involved in modular construction projects is essential for the successful integration of BIM in modular construction [28,68,72,83–86].

5.4. Limited Software Interoperability (B13)

Limited software interoperability was ranked 4th out of the 15 barriers, with a mean index of 3.6452 and a standard deviation of 0.79785 (Table 7). It has significant positive correlations with B2, B3, B5, B6, B7, B8, B9, B14, and B15, indicating that the successful mitigation of software interoperability issues could help to mitigate these other barriers.

Limited software interoperability has also been identified in previous studies as one of the most critical barriers to the successful implementation of BIM in modular construction. Gharaibeh et al. [62] identified the interoperability issue as one of the most critical barriers to be addressed in the implementation of BIM in Swedish prefabricated wood construction projects. Similarly, Chan et al. [59] considered that the insufficient interoperability of computer software was a major barrier to the implementation of BIM in the Hong Kong construction industry.

It is not surprising then that Gosling [85] and Olawumi and Chan [83] advocate for the seamless integration of different BIM tools to facilitate data exchange among modular construction stakeholders and, in return, enhance the integration of BIM in modular construction.

5.5. Shortage of BIM Skills (B7)

A shortage of BIM skills was ranked 5th out of the 15 barriers, with a mean index of 3.5806 and a standard deviation of 1.08855 (Table 7). It has significant positive correlations with B2, B3, B5, B8, B9, B10, B11, B13, B14, and B15, indicating that the successful management of BIM skill shortages could enhance the mitigation of those other barriers.

Having an adequate number of people trained in the skills needed for building information modeling is paramount for the successful integration of innovative solutions. Many previous studies have identified this barrier as one of the most critical factors hindering BIM adoption. According to Wu et al. [64], one of the major barriers to BIM implementation in China's industrialized building construction is the lack of talent and relevant BIM skills and knowledge. Similarly, Gharaibeh et al. [62] and Vernikos et al. [63] concluded that a lack of knowledge is a critical barrier that must be mitigated for optimal use of BIM in modular construction projects. In the sub-Saharan African region, authors Olanrewajuetal [37] and Toyin and Mewomo [36] in Nigeria and Senkondo [38] in Tanzania identified a lack of knowledge as a barrier to BIM implementation.

Therefore, to successfully integrate BIM into modular construction, many studies have advocated for the establishment of policies that promote continuous education and training in BIM within companies [48,67,68,84].

6. Conclusions and Recommendations

The construction industry is continuously evolving through the adoption and implementation of innovative policies, technologies, and processes. BIM and modular construction are two leading concepts in the industry that were developed due to stakeholders' quest for an eco-friendly, smarter city. While modular construction is still an emerging concept in sub-Saharan Africa, integrating BIM has been recognized worldwide as a means to enhance its implementation. However, there is a shortage of research focusing on BIM-enhanced modular construction in the region, thus the need for studies that consider the region's technological maturity and socio-cultural characteristics.

This study addresses this gap by investigating the barriers to the integration of BIM in modular construction in sub-Saharan Africa. Drawing from a review of past empirical studies, the study compiles a list of 20 barriers to the use of building information modeling (BIM) in modular construction projects. This study, informed by the perspectives of modular construction industry experts from sub-Saharan Africa, identifies the critical barriers to BIM integration in modular construction in the region. These include high costs associated with BIM software, tools, and training; insufficient cross-field expertise; difficulties in achieving effective stakeholder collaboration; challenges related to limited software interoperability; and a shortage of BIM skills. The findings underscore the necessity of addressing these barriers to facilitate the successful adoption of BIM in modular construction projects across the region. This study also provides a valuable foundation for further studies aimed at facilitating and enhancing the implementation of BIM in the sub-Saharan African modular construction industry.

The findings of this study highlight the need for targeted policy interventions to address the identified barriers to BIM integration in modular construction in the region. Policymakers should consider subsidizing BIM software and training programs to reduce high costs while also establishing national standards for BIM to improve software interoperability. For industry practitioners, the study recommends that key stakeholders in the modular construction industry should prioritize collaboration and coordination from the early stages of modular project development. This could be achieved by establishing a joint planning session involving all stakeholders to align project goals and strategies. Also, modular construction companies are advised to create BIM execution plans for their projects and to adopt BIM initiatives early in the planning phase of modular project development. This BIM execution plan should contain detailed information about BIM tools and processes and their implementation strategies throughout the modular project lifecycle. Moreover, it calls on professional associations and modular construction companies to intensify their efforts to educate their members and employees about BIM through training workshops and knowledge seminars. These recommendations are seen as pivotal for pushing forward construction technology and promoting the growth of the industry.

However, the uneven distribution of modular construction firms and the differences in BIM maturity among different sub-Saharan countries present limitations. Most medium- and large-scale modular firms are concentrated in a few countries, with many countries within the region lacking the presence of modular firms entirely. This resulted in a relatively small sample size and response rates for the region.

Future research could extend the findings of the current study by exploring barriers on a country-specific level, thereby gaining a deeper insight into the unique challenges encountered across different sub-Saharan African nations. Furthermore, subsequent studies should aim to analyze specific case studies of modular construction projects, which would likely uncover a broader spectrum of barriers beyond those identified in this survey research. It is also recommended that future research conduct a quantitative cost–benefit analysis of the gains of implementing BIM–modular construction in sub-Saharan Africa to provide a sound basis for project comparison and benchmarking. Future studies can also explore the implementation of other smart technologies in modular construction projects across the region.

The results of this study have contributed to and reinforced the existing body of knowledge regarding BIM and modular construction research across different fields. By identifying the key barriers hindering the adoption of BIM in modular construction within the sub-Saharan African region, the study provides valuable insights for stakeholders in the construction industry. These insights are crucial in aiding the development of more targeted and effective strategies to address and mitigate these barriers in the future.

Author Contributions: Conceptualization: L.O.S.; literature review: L.O.S., R.M. and G.M.; methodology: L.O.S., R.M., S.Z. and G.M.; findings and discussion: L.O.S. and R.M.; general review: L.O.S., R.M. and S.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The study was funded by the Africa Sustainable Infrastructure Mobility (ASIM) Scholarship.

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflict of interest.

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