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Assessment of building information modeling adoption in building material scheduling in Tanzania's construction industry

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Abstract

The building construction industry continues to face challenges that affect project delivery, one of which is the traditional practices used for building material scheduling (BMS). Studies indicate that these practices are often inefficient and prone to errors, leading to delays, cost overruns, and low-quality work, affecting the project objectives. Building Information Modeling (BIM) presents a promising solution for addressing these challenges, proven through existing integrations. However, its adoption in BMS practices in construction is still relatively low. Therefore, this study aimed to assess BIM use in BMS in Tanzania's building construction industry. The study adopted a quantitative research approach, and the study population of 153 registered quantity surveying firms was purposively selected. The study data was collected using online questionnaires and analyzed with the Statistical Package for Social Sciences (SPSS). The study findings indicate that traditional practices are still favored over BIM when scheduling building materials in Tanzania, with the most predominant practices being spreadsheets and paper-based methods. Additionally, findings suggest that BIM is not a new concept in Tanzania. However, its adoption in the current practices is relatively low, mainly due to insufficient expertise, training resources, and limited access to BIM software/tools. Moreover, findings indicate a significant belief that BIM can improve BMS practices. These insights can inform policymakers, industry stakeholders, and educational institutions on the necessary steps to promote BIM integration. Therefore, it is recommended that BIM adoption be prioritized by addressing these barriers to enhance project outcomes. Shifting from traditional methods to BIM will lead to more efficient and effective construction processes, making BIM's broader adoption essential for the industry's future success.

Keywords: Building materials, BIM, Building construction, Material scheduling

1. Introduction

The construction industry has witnessed significant technological advancements over the years, and one such innovation that has gained widespread recognition is building information modeling (BIM). Building Information Modeling (BIM) is a digital representation of a building's physical and functional properties, which has emerged as a crucial tool in the construction industry worldwide [1]. BIM has gained significant attention worldwide due to its potential to improve project efficiency, reduce costs, and enhance collaboration among

project participants [2], [3]. Additionally, BIM enables various stakeholders, including quantity surveyors, architects, engineers, contractors, and owners to collaborate, visualize, and analyze the building project in a virtual environment, leading to improved decision-making and better project outcomes [4].
The construction industry is critical in developing countries, contributing significantly to their Gross Domestic Product (GDP) and creating employment opportunities. It generates economic activity by providing infrastructure, housing, and commercial buildings that support other sectors, such as manufacturing, transportation, and trade [5], [6]. Despite its contribution, the sector faces challenges, including the low adoption of technology in the practices [5], [7]–[9]. In Tanzania, the building construction industry faces significant project delivery challenges, including delays, cost overruns, and quality issues [10], [11], which are attributed to traditional practices and the slow adoption of technology [12].

Similarly, Building Materials Scheduling (BMS) is a critical aspect of construction project management. It impacts the planning, procurement, and tracking of construction materials to ensure timely delivery and installation on the construction site [13]. Effective BMS is crucial for project success as it provides the timely availability of materials, minimizes delays, reduces waste, and optimizes costs [14]. Likewise, poor materials scheduling can result in delays, rework, and cost overruns, which are common challenges in the building construction industry in Tanzania [10], [11], [15], [16].

Although BIM presents a promising solution for addressing the earlier stated project delivery challenges [2], its adoption is still hindered by several barriers including a lack of knowledge about BIM processes, lack of awareness about the benefits of BIM, organizational management, the organization's culture, and interoperability issues [12], [17]–[20]. This is also the case in Tanzania's building construction industry as it is still associated with relatively low BIM adoption [12], [17]. Additionally, there is a limited understanding of the practices used for BMS and the application of BIM in the used practices to improve building construction project outcomes effectively [2]. Therefore, this study presents BIM usage in the current BMS practices in the building construction industry in Tanzania.

2. Research method

This establishes the step-by-step procedures taken in conducting the study, which are designed in three major steps, as shown in Figure 2.1. The methodology starts by reviewing the literature to establish the problem statement, knowledge gap, and barriers to BIM adoption in the construction industry. Step 2 involves data collection to identify the currently used building material scheduling practices, and the final step is analyzing the collected data to determine BIM usage in these practices.

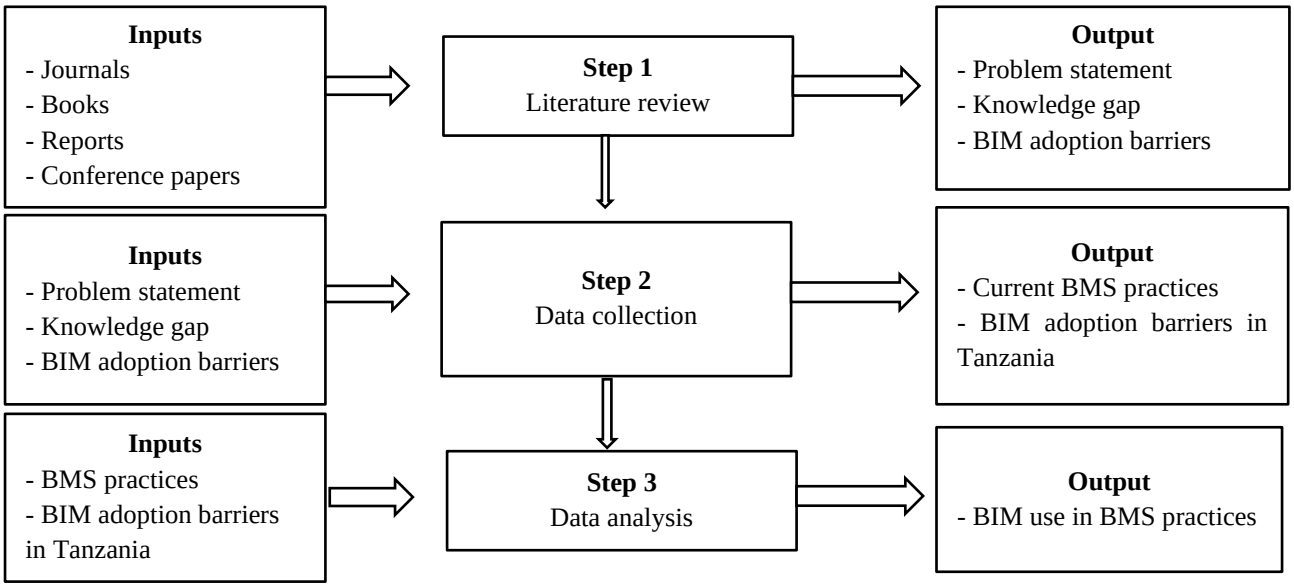

Figure 1. Methodology for determining BIM use in BMS

The study focused on registered quantity surveying firms due to their specialized knowledge in this study area, the potential to collaborate with different stakeholders, and access to valuable data on material quantities and specifications [21], [22]. According to [23] Tanzania has 153 registered firms, all of which were involved in data collection for this study.

The data for the study was obtained from both secondary and primary sources. Where, secondary data was obtained from journal articles, books, conference papers, reports, and books through a literature review on the subject matter to get documented information on the barriers to BIM adoption in the building construction industry. Primary data was obtained through close-ended questions in a questionnaire survey to obtain statistical data. Before the main data collection survey, a pilot study was conducted to fine-tune the questions and data collection tools. Twelve (12) close-ended questions were shared with 4 senior quantity surveyors in an online Google form to test the questions. Following feedback from the pilot survey, minor adjustments were made. These adjustments included rephrasing the questions that appeared confusing to the respondents and removing two (2) redundant questions. This was followed by the main study where, questionnaire surveys were conducted online using Google Forms due to the ease of use, accessibility, flexibility, and immediate feedback [24]–[26]. The link to the survey was sent to the registered quantity surveying firms via emails and direct contact to obtain insight into the respondents' demographic information, current BMS practices, and the state of BIM in the building construction industry in Tanzania.

The collected survey data was sorted using MS Excel and then imported into Statistical Package for the Social Sciences (SPSS) version 25 for analysis. The survey data was analyzed using descriptive statistics, which were used to calculate frequencies, percentages, and means. The mean results were computed from the 5-point Likert scale from 1 for low to 5 for high extent. Mean was interpreted in intervals of 1.0-1.5 for low, 1.51-2.5 for somewhat, 2.51 -3.5 for moderate, 3.51-4.5 for substantial, and 4.5-5.0 for high [27].

To ensure the reliability of the findings, the internal consistency method, specifically the coefficient alpha (or Cronbach's alpha), was employed to establish the consistency of the data [28] and calculated using the formula shown in Equation (1). The study yielded an α-value of 0.826, surpassing the minimum threshold of 0.70 [29]. This indicates that the data was reliable and internally consistent, making it suitable for further statistical analysis.

$$\alpha = \frac{N*\bar{c}}{\bar{v}+(N-1)*\bar{c}} \quad (1)$$

Where, α = coefficient alpha, N = number of items, $\bar{c}$ = mean covariance between items, and $\bar{v}$ = mean item variance.

3. Findings and discussions

3.1. Responses from questionnaires

The online questionnaire was shared with the target population as discussed in the methodology. Of the targeted 153 responses, 109 were received, amounting to a 71.24% response rate. This response rate has been considered sufficient and can be used to make reliable recommendations and conclusions as it comprises more than 50% of the population. Moreover, [30] found that a minimum % response rate of 48% is needed to maintain acceptable precision in online evaluations.

3.2. Demographic information of the respondents

Table 1 shows the demographic information of the respondents. The results indicate that all of the 109 respondents (100%) work in the building construction industry, with 46 (42.2%) having 6-10 years of experience and only 3 (2.8%) having less than one year of experience. Additionally, 73 (67%) respondents have experience working on large-scale projects, and 47 (43.1%) work for large firms.

Table 1. Demographic information of the respondents

Characteristics	Frequency	Percent	Rank
Experience			
Less than 1 year	3	2.8	4
1-5 years	45	41.3	2
6-10 years	46	42.2	1
More than 10 years	15	13.8	3
Scale of Construction Projects			
Small (e.g., Residential buildings)	36	33.0	2
Large (e.g. Commercial buildings)	73	67.0	1
Size of the Firm			
Small (1-10 employees)	29	26.6	3
Medium (11-50 employees)	33	30.3	2
Large (51+ employees)	47	43.1	1

These findings suggest that the data was collected from the target industry, the respondents have significant experience and work in reputable firms, and therefore, their responses depict the industry practices based on expert opinions, making the study's results reliable.

3.3. Current building materials scheduling practices in Tanzania's building construction industry

The study aimed to evaluate the building material scheduling practices used in the Tanzania building construction industry. For this purpose, three practices were selected from the existing literature and used as the basis of the study, as outlined in Table 2. The results show that the most commonly used practice is customized spreadsheets, with 86 responses (51.5%) out of 109. Manual practices (e.g., use of pen and paper) are the second most common, with 69 responses (41.3%), and only 12 responses (7.2%) reported the use of the software. No new practice emerged from the study responses.

Table 2. Current building material scheduling practices

Practice	Frequency	Percent
Spreadsheet-based	86	51.5
Manual (e.g. Paper-based)	69	41.3
Software-based	12	7.2
Total	167	100.0

The analysis results in Table 2 suggest that the current building material scheduling practices used in the Tanzanian building construction industry are still traditional and that BIM technology has not been widely adopted, which justifies the challenges identified by the studies done by [10], [11], [31].

Furthermore, the high adoption of spreadsheet-based templates could be attributed to the fact that MS Excel is readily available and can integrate different aspects depending on the user's requirements, with the ability to handle data logically. This is true because studies by [32]–[34] have explored the effectiveness of customized Excel spreadsheets in various aspects including algorithms to schedule repetitive construction projects and cost-effective time scheduling to enhance construction projects' outcomes. These demonstrate that using spreadsheets is common in the construction industry, which is also true for Tanzania's building material scheduling practices, as evidenced in the study results presented in Table 2. The study also shows manual-based practices to be more than software-related tools for building material scheduling. This is true due to the low level of BIM adoption, and the challenges hindering its adoption which are justified by the study findings in Tables 4 and 6 respectively.

Additionally, participants evaluated the efficiency of current building material scheduling practices using a 5-point Likert scale. The results, which are shown in Table 3, indicate that out of 109 responses, 55 (50.5%) rated the practices as 3; 35 (32.1%) rated them as 4; 9 (8.3%) rated them as 2; 7 (6.4%) rated them as 5, and only 3 (2.8%) rated them as 1.

Table 3. Efficiency of current building material scheduling practices

Scale	Frequency	Percent	Mean
1	3	2.8	
2	9	8.3	
3	55	50.5	3.31
4	35	32.1	
5	7	6.4	
Total	109	100.0	

These results indicate that the average rating for the efficiency of the current practices was 3.31, implying that the current building material scheduling practices are moderately but not highly efficient, a shortcoming associated with traditional practices as highlighted in a study by [31], which could be a contributor to the project delivery challenges identified by [10], [11]. This justifies the need to improve the current BMS practices used in the Tanzania building construction industry to enhance their efficiency leading to improved project outcomes.

3.4. BIM in building material scheduling

To better understand the respondents' knowledge of BIM, data was collected on their awareness and experience with BIM in material scheduling practices. Additionally, their perspective was obtained on how BIM technology can enhance Building Material Scheduling, as well as the main challenges that have hindered its adoption in the current practices in the Tanzanian construction industry.

The study found that out of 109 respondents, 74 (67.9%) were familiar with or aware of BIM, while 35 (32.1%) were not, as shown in Table 4. It also indicates that of the total respondents, 34 (31.2%) have low experience, 24 (22%) have experienced below the moderate level, and 28 (25.7%) have no experience at all working with BIM-related software.

Table 4. BIM awareness and experience of respondents

Details	Frequency	Percent	Mean
BIM Familiarity/Awareness			
Yes	74	67.9	
No	35	32.1	
Total	109	100.0	
BIM Experience (Scale)			
0	28	25.7	
1	34	31.2	
2	24	22.0	1.52
3	13	11.9	
4	5	4.6	
5	5	4.6	
Total	109	100.0	

The study indicates that there has been an increase in awareness of BIM in Tanzania's construction industry between 2018 and 2023. In 2018, [12] revealed that only 24% of respondents were aware of BIM, while the remaining 76% had no idea about it. However, at the time of the study, results indicate that there has been a noticeable improvement, with 67.9% of respondents being aware of BIM and only 32.1% being unaware. This

suggests that more than 50% of quantity surveying firms in Tanzania are already aware/familiar with BIM which could be attributed to the availability of various studies such as studies by [12], [17] on the subject matter in Tanzania. Despite the increase/significant level of awareness, there is still a shallow level of experience in using BIM in Tanzania's building material scheduling practices, with a mean value of 1.52 on a 5-point Likert scale which is below the moderate level, as indicated in Table 4. This indicates that there is still a need to enhance BIM utilization in current practices and more efforts to overcome the barriers to its adoption and ensure that firms are not only aware of it but also implement it and make it part of the practices in the day-to-day operation to provide collaborative and integrated work environments. Also setting up regulations by the government or responsible regulatory authorities such as the Architects and Quantity Surveyors Registration Board (AQRB) to ensure BIM adoption could also be a potential driver, as this has been proven effective in Indonesia [35].

Moreover, respondents believe BIM can significantly enhance building material scheduling practices in the building construction industry in Tanzania based on the results in Table 5. The analysis results indicate the majority of respondents, 40 (36.7%), 37 (33.9%), and 23 (21.1%) out of 109, believed that BIM can improve the current practices to a high, substantial, and moderate extent, respectively with a mean score of 3.94 on a 5-point Likert scale. This indicated that respondents believe BIM can substantially improve the current BMS practices if utilized.

Table 5. Respondents' belief in BIM's capacity to improve building material scheduling practices

Scale	Frequency	Percent	Mean
1	3	2.8	
2	6	5.5	
3	23	21.1	3.94
4	40	36.7	
5	37	33.9	
Total	109	100.0	

However much the respondents' significant belief in BIM’s ability to improve BMS practices, its adoption in these practices is mostly hindered by the lack of BIM expertise, insufficient training resources, and limited access to BIM software/tools, which account for 96 (29.2%), 80 (24.3%), and 58 (17.6%), respectively as shown in Table 6. Other hindrances include integration issues with existing workflows, high implementation costs, resistance from industry stakeholders, and data security concerns, which account for the remaining 28.9% of the total responses.

Table 6. Challenges hindering BIM adoption in the building material scheduling practices

Challenges	Frequency	Percent
Lack of BIM expertise	96	29.2
Insufficient training resources	80	24.3
Limited access to BIM software/tools	58	17.6
Integration issues with existing workflows	34	10.3
High implementation costs	33	10.0
Resistance from industry stakeholders	17	5.2
Data security concerns	11	3.3
Total	329	100.0

These findings are consistent with the existing literature, which indicates that the most significant obstacles to the utilization of BIM include a "lack of awareness of BIM by stakeholders, lack of knowledge about BIM software, lack of awareness of BIM benefits, lack of engineers' skills in BIM, lack of education, training on the use of BIM and the cost and time required to complete BIM models” [36], [37], which also aligns with studies by [12], [17]–[19], [38]. These findings along with existing literature indicate that BIM adoption is not only a

challenge in the building construction industry in Tanzania, but also in other such as the USA, Canada, the UK, Ghana, South Africa, China, India, and Australia, and the rest of the world. It is, therefore, essential to address these challenges in BIM adoption in the industry by improving BIM experience through training, providing more access to BIM software/tools, integrating BIM with existing workflows, and reducing implementation costs. This will enable the building construction industry in Tanzania and other countries with similar characteristics and challenges such as Kenya and Uganda, particularly in BMS practices, to benefit from BIM technology.

4. Conclusions

The research shows that traditional methods are still preferred over technology-based practices in Tanzania for scheduling building materials, accounting for 92.8% of the responses. The study found that the most common practices are spreadsheets and paper-based methods, which account for 51.5% and 41.3% of the total responses, respectively. While the study reveals that most respondents (67.9%) know BIM, its practical use is relatively low, with only 7.2% reporting the use of software-based practices in BMS. This is mainly due to a lack of expertise, training resources, and limited access to BIM software/tools, as shown in the study's results in Table 6. The study concludes that BIM use in BMS practices is limited, despite the respondents' belief in its potential to enhance these practices in the building construction industry significantly. Therefore, it is recommended that BIM adoption be prioritized through regular training and increased accessibility to BIM-based practical solutions to improve expertise, incorporating topics related to BIM technology in the academic curriculum to equip learners with this knowledge at the early stages of their professional journey, and formulating policies promoting BIM integrated tools/models to enhance project outcomes. This shift from traditional methods to BIM will lead to more efficient and effective construction processes, making BIM's broader adoption essential for the industry's future success.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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