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Development of a Framework for BIM Implementation in the Zambian AEC Industry

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Abstract. The Architecture, Engineering, and Construction (AEC) sector in Zambia is crucial for economic growth yet faces challenges like project delays and cost overruns. Building Information Modelling (BIM) has emerged as a solution. This research aims to develop a comprehensive framework to enhance BIM implementation in Zambia's AEC industry. Using mixed-methods research, including surveys and interviews with stakeholders, the study found that BIM is not widely practiced due to factors like limited awareness and high costs. However, there is willingness to adopt it. The proposed framework offers a roadmap for successful BIM adoption and implementation, emphasizing awareness programs, government partnerships with technology providers, and small-scale pilot projects. An evaluation system is recommended for monitoring progress. This approach aims to improve collaboration, effectiveness, and competitiveness in Zambia's AEC industry.

Keywords: Building Information Modelling, Implementation, Framework, Collaboration, AEC industry, Zambia

Introduction

The construction industry encompasses various activities related to building, repairing, and maintaining infrastructures, making significant contributions to a country's economic output (Mirawati et al., 2015). In Zambia, the construction sector constitutes a substantial portion of the GDP, experiencing notable growth over recent years (Zambia Statistics Agency, 2022). Technological advancements, particularly in Information Technology (IT), have revolutionized the industry, with Building Information Modelling (BIM) emerging as a leading innovation in the Architecture, Engineering, and Construction (AEC) sector (Fischer & Kunz, 2006). BIM can be described as a tool that enables the storage and reuse of information and domain knowledge throughout the lifecycle of the project (Vanlande et al., 2008).

BIM serves as a multi-functional solution in the AEC industry, providing shared digital representations of building assets and promoting efficient design, construction, and operational processes and form a reliable basis for decision-making (British Standards Institution, 2018). Despite variations in BIM definitions, there's a consensus that it's more than just software—it's a combination of software and processes aimed at enhancing project management and collaboration (Wong & Zhou, 2015). Moreover, BIM is a multiple-function method that integrates business processes, digital representation, organization, and control of the process. It can provide three-dimensional (3D) modelling of the project, manage the project schedule throughout the whole lifecycle, provide a communication platform for all stakeholders, estimate and calculate project costs, detect clashes, and allow stakeholders to inspect and manage buildings throughout their building lifecycle (Lu et al., 2017).

While BIM adoption is increasing in developed countries, its implementation in developing nations like Zambia remains limited. Despite the potential economic and environmental benefits, the adoption of BIM has been slow due to factors such as resistance to change (Bernstein & Pittman, 2005). However, organizations that embrace BIM stand to gain a competitive advantage (Froise, 2014). As global population growth necessitates smarter and more efficient construction practices (AUTODESK, n.d.), BIM emerges as a key enabler for achieving sustainable development goals.

BIM aligns with Africa's development agenda and UN Sustainable Development Goals, offering prospects for inclusive growth, sustainable infrastructure, and climate action. Traditional construction practices are associated with high rework costs and poor communication, highlighting the need for more efficient project management solutions like BIM (Davies et al., 1989; Yap et al., 2016). Effective BIM implementation promises improved project performance through enhanced collaboration and decision-making (Akintola et al., 2017).

Statement of the Problem

There is little evidence of BIM being used as a collaborative tool, and no structured approach to facilitate its implementation at National Level, as a result, this research investigates the necessary steps and key factors for successful BIM implementation in the Zambian AEC sector.

Research Aim and Objectives

This research aims to develop a framework for successful BIM implementation in Zambia's AEC industry. The study objectives include identifying implementation challenges, assessing the extent of BIM's collaborative use, and evaluating strategies and key success factors for BIM implementation.

Significance

Collaborative BIM utilization holds promise for improving construction project outcomes, yet its adoption in Zambia's AEC industry remains limited (Chipulu, 2015; Chiponde et al., 2017). This study aims to address this gap by providing stakeholders with guidance on implementing comprehensive BIM frameworks. Focusing on buildings under the Ministry of Infrastructure, Housing, and Urban Development.

Literature Review

International literature on Building Information Modelling (BIM) implementation provides valuable insights into strategies and challenges across various levels, including organizations, projects, and the industry. Succar (2009) pioneered a comprehensive framework emphasizing the collaborative efforts of stakeholders and the importance of policy, process, and technology in successful implementation. Khosrowshahi & Arayici (2012) identified education, organizational culture, and information management as crucial for BIM adoption in the UK construction industry. Sun et al. (2015) highlighted technology, cost, management, personnel, and legal considerations as key obstacles, while Sahil (2016) explored strategies for facilitating BIM adoption in developing countries. Kouch (2018) developed a framework for SMEs, and Georgiadou (2019) recommended the development of initiatives to support Small and Medium Enterprises (SMEs) in implementing BIM, as well as the introduction of educational programs in the built environment to educate students on collaborative BIM work practices. Vidalakis et al. (2020) emphasized effective leadership, industry initiatives, and peer education for SME adoption, and Brito et al. (2021) identified critical success factors for BIM adoption in public organizations in Brazil which were categorized according to the same BIM implementation fields initially identified by Succar (2009), encompassing technology, process, and policy aspects. These studies offered valuable insights applicable to BIM implementation in Zambia's AEC industry, informing strategies and addressing challenges at various levels.

The limited research on Building Information Modelling (BIM) adoption in Zambia has laid the groundwork for further investigation. Chipulu (2015) examined the necessity of full

BIM adoption in the Zambian Architecture, Engineering, and Construction (AEC) industry, highlighting architects' high usage and contractors' low usage of BIM. Chiponde et al. (2017) aimed to enhance collaboration in the Zambian Construction Industry (ZCI) through BIM implementation, identifying challenges such as delays in information exchange and poor project relationships. The study emphasized BIM's potential to improve communication and coordination among stakeholders, vital for complex construction projects. Wachata (2020) explored BIM collaboration in Zambia, revealing that while individual discipline-based BIM software was in use, full adoption faced barriers like high implementation costs and lack of government support. Architects showed greater awareness of BIM benefits compared to other stakeholders. These studies underscore the importance of BIM adoption in Zambia's construction industry, offering insights into challenges and strategies for effective implementation. They provide valuable guidance for industry stakeholders seeking to leverage BIM for improved project management and outcomes.

Chipulu (2015) identified three main obstacles hindering the widespread adoption of Building Information Modelling (BIM) in the Zambian Architecture, Engineering, and Construction (AEC) industry: a lack of BIM training, high costs associated with BIM software and training, and a perception that existing 2D Computer-Aided Design (CAD) systems suffice for industry needs. The study highlighted the challenge of training professionals in BIM due to limited availability of institutions teaching BIM software, leading to reliance on costly external hiring. Additionally, the expense of BIM implementation, including software and hardware upgrades, was noted, alongside a prevailing satisfaction with 2D CAD systems among respondents. Sujesh et al. (2016) corroborated the low level of digital technology usage in the Zambian AEC industry, emphasizing the urgent need for further research to address this gap. Both studies stressed the necessity of comprehensive BIM adoption to overcome the limitations of traditional 2D CAD approaches, citing issues such as limited visualization capabilities and coordination complexity. The findings underscore the imperative of addressing barriers to BIM adoption in Zambia's AEC industry to enhance digital technology utilization and improve industry practices.

The reviews show that no detailed study has been done on the effectual implementation of BIM in the AEC industry, and this research develops that implementation plan.

Methodology

The methodology employed in this study is the mixed-methods approach. Primary information was sourced from various credible sources, including written reports, publications, books by BIM specialists, and relevant articles from selected websites. Additionally, webinars, short courses, conference papers, and dissertations from the University of Zambia were utilized.

To select participants, a two-pronged approach was adopted. The first method involved probability sampling, specifically simple random sampling/stratified, while the second method utilized non-probability sampling, specifically convenience sampling. Project managers, architects, engineers, quantity surveyors, and contractors operating in Zambia's public AEC sector were included in the sample. Purposive sampling was used to select professionals for interviews based on specified criteria.

Data Collection

Data collection involved the simultaneous administration of semi-structured interviews and questionnaires to make the best use of available research participants and ensure independent responses. The ethics commission for the natural sciences provided ethical approval prior to discussions with industry professionals.

The use of concurrent mixed methods of data collection, as advocated by Creswell & Plano (2007), allowed for data validation, transformation, and addressing various research objectives. This approach also facilitated utilizing qualitative comments to enhance and clarify survey findings.

The sample size was determined using the formula under stratified random sampling, resulting in a sample size of 99 professionals from a total population of 131 at the Ministry of Infrastructure, Housing and Urban Development. Interviews were conducted with 10 professionals, while questionnaires were distributed to the remaining 89 professionals to collect qualitative and quantitative data, respectively.

Quantitative data from closed-ended questions in the questionnaire were analyzed using the Statistical Package for the Social Sciences (SPSS) program. Respondents' agreement with statements was scored on a five-point Likert scale, and the data were tabulated and presented using percentages for easy comprehension. Pie charts and bar charts were employed to visually compare relative values of nominal data. For qualitative data obtained from open-ended questions in the questionnaire and interviews, thematic content analysis was employed.

Findings

Participants in this study included individuals working in the public sector as well as architects, engineers, and quantity surveyors from Zambia's architecture, engineering, and construction (AEC) industry. 73 % of the 89 questionnaires that were issued were returned, with 65 of them having been completed. The findings from the questionnaire survey were complemented by semi-structured interviews conducted with five participants, out of the initially targeted ten participants.

Quantitative Data Analysis and Results

The educational background of the individuals showed that 69.2% had a bachelor's degree, 18.5% with a master's degree, 9.2% had a college paper, 3.1% completed their secondary or high school education.

Their level of expertise in using BIM indicated that; 3.1% had more than ten years' experience, 6.2% had five to ten years' experience, 40% had one to five years' experience, and 50.8% had no prior experience.

Perception of BIM

The largest proportion of participants (26.2%) possess a certain level of understanding of BIM, while 24.6% have basic knowledge. Approximately 21.5% demonstrate a general grasp of BIM, whereas about 13.8% of respondents lack awareness. A smaller segment (12.3%) claim to be "well versed" in BIM, indicating a deeper comprehension. Lastly, a mere 1.6% of participants self-identified as "expert users" of BIM, implying advanced proficiency in the subject.

The collaborative techniques used in the projects by the respondents indicated that; 41.5% used 'Level 0,' (most project data was sent through printed documents or digital files, such as PDFs). Both "Level 1" and "Level 2," had an equal representation of 15.4%. Level 2 enabled the interchange of design data via a standardized file format, whereas Level 1 normally included 2D drafting for statutory approval documents. 6.2% selected 'Level 3'also referred to as "the holy grail," represented total interoperability between various software platforms and data types. The percentage of respondents who selected the 'I am not sure' response option was 21.5%, suggesting a general lack of understanding or awareness regarding the precise amount of digital technology used in each project.

Benefits, Barriers, Readiness and Strategies of BIM

The data analysis regarding the benefits, barriers, readiness, and strategies of BIM implementation in Zambia revealed the following:

Benefits: The study identified various benefits of BIM adoption in Zambia's AEC industry across five thematic domains. Respondents generally agreed on the advantages of BIM, particularly in terms of time and quality, communication and collaboration, and cost-effectiveness. However, there were varying levels of agreement regarding design and planning benefits and the expansion of the construction sector. Additionally, respondents highlighted BIM's role in improving project efficiency, accuracy, cost reduction, and stakeholder collaboration. Nevertheless, low awareness and limited implementation were noted as challenges.

Barriers: Technological challenges, lack of knowledge, financial constraints, and resistance to change were identified as significant barriers to BIM adoption. Poor IT infrastructure, limited access to BIM tools, and a lack of knowledge about BIM benefits and functionalities hindered adoption. Financial concerns, including high software costs and inadequate client demand, also posed challenges. Resistance to change, skills gaps, and the absence of standardization further impeded progress.

Readiness: The study assessed Zambia's readiness for BIM implementation, indicating positive attitudes toward technology and knowledge factors. While respondents generally agreed on having access to suitable hardware and software technologies, affordability, and adequate IT infrastructure, concerns remained regarding knowledge gaps and implementation plans. Awareness, motivation, and knowledge readiness were generally high, but converting readiness into actionable plans posed challenges.

Strategies: Respondents proposed various strategies to overcome barriers and foster BIM implementation in Zambia. Suggestions included creating awareness through sensitization programs, integrating BIM education into curricula, offering financial incentives, and government support. Developing technology infrastructure, sharing information platforms, conducting pilot projects, and fostering collaboration were also recommended. Overall, these strategies aimed to address financial, technological, educational, and regulatory barriers and promote effective BIM integration.

Cross tabulation

Table 1 shows the analysis of respondents' familiarity with BIM based on their education. It reveals a clear positive correlation between higher education levels and BIM awareness and proficiency. In terms of familiarity, University Master's degree holders lead with 33.3%, followed by University Bachelor's degree holders at 13.3%. Proficiency-wise, 16.7% of University Master's degree holders claim to be well-versed, alongside 11.1% with a University Bachelor's degree. The data consistently indicates that higher education levels are associated with increased BIM awareness, familiarity, and proficiency, with master’s degree holders demonstrating the highest expertise.

Table 1: Cross-tabulation between familiarity with BIM and level of education

		What is the highest level of formal education you have achieved?				
		Secondary/ High School	**College**	**University Bachelor**	**University Masters**	**Total**
How acquainted are you with Building Information Technology (BIM)?	Not Aware	1	2	6	0	9
		50.0%	33.3%	13.3%	0.0%	13.8%
	Somewhat	0	0	14	2	16
		0.0%	0.0%	31.1%	16.7%	24.6%
	Familiar	1	3	6	4	14
		50.0%	50.0%	13.3%	33.3%	21.5%
		0	0	14	3	17

	Fairly Familiar	0.0%	0.0%	31.1%	25.0%	26.2%
	Well Versed in it	0	1	5	2	8
		0.0%	16.7%	11.1%	16.7%	12.3%
	An Expert User	0	0	0	1	1
		0.0%	0.0%	0.0%	8.3%	1.5%
Total		2	6	45	12	65
		100.0%	100.0%	69.2%	100.0%	100.0%

Table 2 shows the analysis of respondents' familiarity with BIM and their current job positions. It underscores the diversity in BIM awareness and proficiency across different job positions, emphasizing notable distinctions among various professional roles. This variability in familiarity levels suggests that the adoption and understanding of BIM practices are influenced by the specific requirements and responsibilities inherent to each role within the surveyed population.

Table 2: Cross-tabulation between familiarity with BIM and current job position

		How acquainted are you with Building Information Technology (BIM)?						
		Not Aware	**Somewhat**	**Familiar**	**Fairly Familiar**	**Well-versed in it**	**An Expert User**	**Total**
What role best represents your current position?	Client Representative	0	2	1	1	0	0	4
		0.0%	50.0%	25.0%	25.0%	0.0%	0.0%	100.0%
	Consultant	4	10	11	10	6	1	42
		9.5%	23.8%	26.2%	23.8%	14.3%	2.4%	100.0%
	Researcher	1	1	0	0	0	0	2
		50.0%	50.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	BIM Software Developer	0	1	0	0	0	0	1
		0.0%	100.0%	0.0%	0.0%	0.0%	0.0%	100.0%
	Contractor	2	0	0	3	0	0	5
		40.0%	0.0%	0.0%	60.0%	0.0%	0.0%	100.0%
	Others	2	2	2	3	2	0	11
		18.2%	18.2%	18.2%	27.3%	18.2%	0.0%	100.0%
Total		9	16	14	17	8	1	65
		13.8%	24.6%	21.5%	26.2%	12.3%	1.5%	100.0%

Table 3 shows the analysis of respondents' familiarity with BIM based on their years of experience working with the technology. It shows that for those with no prior experience with BIM, a significant 42.4% exhibit a basic level of awareness. In the 1 to 5 years of experience category, 30.58% report a substantial familiarity, including fair familiarity and expertise with BIM. Notably, in the 6 to 10 years of experience range, 75.0% of respondents are fairly familiar with BIM, indicating a heightened proficiency level. For individuals with 10+ years of experience with BIM, there is a notable prevalence of familiarity and expert users, constituting 50.0% for both categories.

Table 3: Cross-tabulation between familiarity with BIM and years of experience working with BIM

		How many years of experience do you have working with BIM?				
		Nil	**1 to 5 years**	**6 to 10 years**	**10 + years**	**Total**
How acquainted are you with Building Information Technology (BIM)?	Not Aware	7	2	0	0	9
		21.2%	7.7%	0.0%	0.0%	13.8%
	Somewhat	14	2	0	0	16
		42.4%	7.7%	0.0%	0.0%	24.6%
	Familiar	6	6	1	1	14
		18.2%	23.1%	25.0%	50%	21.5%
	Fairly Familiar	6	8	3	0	17
		18.2%	30.8%	75.0%	0.0%	26.2%
	Well Versed in it	0	8	0	0	8
		0.0%	30.8%	0.0%	0.0%	12.3%
	An Expert User	0	0	0	1	1
		0.0%	0.0%	0.0%	50%	100.0%
Total		33	26	4	2	65
		100.0%	100.0%	100.0%	100.0%	100.0%

Correlation Analysis

Table 4 shows the Correlation between Respondent Demographics and Familiarity with BIM.

Table 4: Correlation between Respondent Demographics and Familiarity with BIM.

Familiarity with BIM		
Question	**Correlation**	**Significance**
What is the highest level of formal education you have achieved?	0.211*	0.050
What role best represents your current position?	-0.038	0.722
How many years of work experience do you have specifically related to construction projects?	0.203	0.062
Which option best describes your organization?	0.000	1.000
How many years of experience do you have working with BIM?	0.463**	0.000

Note: * Correlation significant at the 0.05 level (2-tailed); ** Correlation significant at the 0.01 level (2-tailed).

The results indicate that level of education has a low but significant relationship with BIM familiarity. Job responsibility has a highly negative relationship with BIM familiarity. Organization description does not correlate with BIM familiarity. The number of years of work experience working with BIM has a medium and significant relationship with BIM familiarity.

Table 5 shows the Correlations between familiarity with BIM and Barriers to BIM Implementation.

Table 5: Correlations between Familiarity BIM and Technology Barriers

Familiarity with BIM			
Technology Barriers	**Question**	**Correlation**	**Significance**
	Limited IT infrastructure, including poor data connections and little capacity	0.202*	0.047
	BIM tools (software packages) aren't widely available in Zambia	0.171	0.092

Note: * Correlation significant at the 0.05 level (2-tailed).

The results show a weak but significant relationship between Limited IT infrastructure, including poor data connections and little capacity and how acquainted the responded are with BIM. On the other hand, there is a low and insignificant correlation between BIM familiarity and availability of BIM tools in Zambia.

Table 6 shows the Correlations between Familiarity with BIM and Knowledge/ Awareness Barriers.

Table 6: Correlations between Familiarity with BIM and Knowledge/ Awareness Barriers

Familiarity with BIM			
Knowledge/ Awareness Barriers	**Question**	**Correlation**	**Significance**
	Ignorance of the advantages of BIM	0.213*	0.038
	Lack of expertise, education, and training in BIM	0.132	0.198
	Difficulty understanding the functionalities of BIM software and a laborious learning process	0.069	0.501

Note: * Correlation significant at the 0.05 level (2-tailed).

The results indicate a low but significant correlation between BIM familiarity and Ignorance of the advantages of BIM. There is no significant relationship between lack of expertise, education, and training in BIM and BIM familiarity, the same is true for difficulty in understanding the functionalities of BIM software and a laborious learning process. The correlation coefficient for both variables is weak.

Table 7 shows the Correlations between familiarity with BIM and Financial Barriers.

Table 7: Correlations between familiarity with BIM and Financial Barriers

Familiarity with BIM			
Financial Barriers	**Question**	**Correlation**	**Significance**
	High cost of acquiring or engaging BIM specialists and the pricey nature of BIM software	0.402*	0.000
	Change resistance and a lack of commitment from clients in the public sector	0.078	0.444

	BIM software is not being requested by clients for engineering and architectural designs and analyses	0.134	0.189
	There is no (legal) practice guide to support the use of BIM in Zambia	0.144	0.157
	Zambia lacks a legal practice manual to enable the use of BIM, there are questions around model ownership and exchange among team members	0.203	0.049
	BIM isn't really needed or requested throughout project development by team members like architects and engineers	0.013	0.900
	BIM is difficult to learn	-0.113	0.270
	BIM requires more time to master than 2D CAD, which results in longer model development times	-0.099	0.330
	In Zambia, there is a lack of qualified personnel with experience using BIM software	0.05	0.608
	BIM is thought to not considerably improve organizations in Zambia's AEC industry	0.188	0.242

Note: * Correlation significant at the 0.05 level (2-tailed).

The results show that under financial barriers, only high cost of acquiring or engaging BIM specialists and the pricey nature of BIM software had a significant relationship with BIM familiarity. BIM being difficult to learn and BIM requiring more time to master than 2D CAD, had a negative but insignificant relationship with BIM familiarity. The rest of the financial barriers had a weak and insignificant relationship with BIM familiarity.

Table 8 shows the Correlations between familiarity BIM and BIM Implementation Readiness.

Table 8: Correlation between BIM Familiarity and Technology and Knowledge Factors

Familiarity with BIM			
	Question	**Correlation**	**Significance**
Technology and Knowledge Factor	Availability of suitable hardware and software technologies to be able to fully take advantage of BIM capabilities	0.235*	0.022
	Affordability of BIM tools in Zambia	0.191	0.062
	Existence of necessary BIM knowledge to aid development of BIM models and data management	0.095	0.358
	Adequacy of information technology infrastructure such as bandwidth and BIM servers to support Internet usage of the technology	0.068	0.509

Note: * Correlation significant at the 0.05 level (2-tailed).

The results indicated that the availability of suitable hardware and software technologies to be able to fully take advantage of BIM capabilities had a significantly low correlation with

BIM familiarity, the rest of the factors had very weak and insignificant correlation with BIM familiarity.

Table 9 shows the correlation between familiarity with BIM and BIM readiness of AEC stakeholders.

Table 9: Correlation between BIM Familiarity and BIM Readiness of AEC Stakeholders

Familiarity with BIM			
BIM Readiness AEC Stakeholders	**Question**	**Correlation**	**Significance**
	Awareness about BIM	0.180	0.358
	Awareness of the benefits of BIM	0.169	0.079
	Tools to measure the benefits of using BIM	0.232*	0.023
	Awareness about the challenges of using BIM	0.164	0.113
	Personal motivation to adopt BIM	0.088	0.395
	Companies' motivation to use BIM	-0.008	0.935
	Demand from clients for usage of BIM	-0.023	0.821
	Support and encouragement of other AEC stakeholders for the adoption of BIM	0.149	0.150
	Availability of university graduates with requisite BIM training knowledge	0.024	0.818
	Existence of strategic initiatives for BIM adoption	0.061	0.552
	Insistence of statutory approval which mandate the usage of BIM	0.011	0.912
	Promotion of BIM awareness through conferences and workshops	0.029	0.778
	Existence of standard BIM implementation documents or guidelines prepared by statutory or regulatory authorities	0.180	0.080
	Availability of higher education courses in BIM	0.129	0.203

Note: * Correlation significant at the 0.05 level (2-tailed).

The results indicate that tools to measure the benefits of using BIM had a weak but significant relationship with BIM familiarity. Companies' motivation to use BIM and demand from clients for usage of BIM both have very low negative and insignificant relationship with BIM familiarity. The results further indicate that the other factors have a very weak and insignificant relationship with BIM familiarity.

Qualitative Results and Analysis

Participants represented a mix of professionals from both public and private consulting firms, including architects and contractors. Face-to-face interviews were conducted with individuals who had worked closely with the ministry for at least ten years, ensuring a depth of insight into the industry's dynamics.

Thematic analysis of the interviews revealed several key findings:

Digital Transformation and Resistance to Change: Participants highlighted perceived complexity, lack of awareness, and resistance from traditional stakeholders as major obstacles to widespread adoption of digital tools like BIM. Education and change management were deemed essential to address this resistance effectively.

Impact of Regulatory Environment and Policies: The absence of legislative support and regulatory constraints were cited as significant barriers to digital advancement. Participants emphasized the need for supportive policies to drive change and align organizational practices with evolving technological landscapes.

Educational Institutions: Education emerged as a critical factor influencing industry readiness for digital transformation. Awareness and education gaps were identified as hindrances to digital tool implementation, highlighting the need for focused educational initiatives and curriculum enhancements.

Technological Infrastructure and Equipment: Adequate technology infrastructure was deemed essential for realizing the potential benefits of digital tools in construction projects. Investment in robust technological frameworks was emphasized to facilitate seamless integration and optimize tool functionality.

Challenges in BIM Implementation: Participants discussed challenges in efficiently managing the BIM process, organizing teams, and navigating the early stages of BIM adoption. Proactive problem-solving and anticipation of obstacles were deemed crucial for successful integration.

Role of Government and Professional Bodies: The importance of government support and intervention, along with the role of professional associations, in driving digital transformation was highlighted. Stakeholder collaboration was identified as key to fostering an ecosystem supportive of digital integration.

Discussion

Determining Challenges Associated with BIM Implementation

Qualitative Insights: The qualitative investigation unearthed various challenges impeding the adoption of BIM within Zambia's AEC sector. Notably, resistance to change, stemming from traditional stakeholder opposition, ignorance, and perceived complexity, emerged as a recurring obstacle. Additionally, the absence of legislative support and regulatory constraints posed significant hurdles. Challenges related to inadequate technology infrastructure and educational preparedness were also prominent.

Quantitative Insights: The quantitative analysis corroborated and quantified key qualitative findings. It revealed a modest yet significant correlation between BIM knowledge and factors such as limited IT infrastructure, highlighting the tangible impact of technological constraints. Financial challenges, notably the high costs associated with hiring BIM experts and software, were statistically linked to familiarity with BIM. Moreover, the study demonstrated a relationship between schooling levels and BIM knowledge, underlining the importance of educational preparedness.

Investigating BIM's Use as a Collaboration Strategy

Qualitative Insights: Qualitative exploration emphasized the critical role of collaborative dynamics, efficient communication, and strong teamwork in maximizing project outcomes. Highlighting coordination challenges, the study underscored the importance of fostering a collaborative culture, especially concerning cutting-edge technologies like BIM, where education and change management are crucial for overcoming resistance to change.

Quantitative Insights: The quantitative examination revealed distinctive collaboration patterns across various job roles, shedding light on varying levels of BIM awareness and skill. Measuring employee participation in BIM coaching or training sessions within companies, the study indicated differing levels of engagement across job types, emphasizing the need for tailored approaches.

Assessing Strategies and Key Success Factors for BIM Implementation

Qualitative Insights: The qualitative component illuminated how laws and regulatory frameworks shape the adoption of digital tools, emphasizing the need for a supportive legislative environment. Highlighting the importance of targeted educational initiatives and collaboration with academic institutions, the study underscored the necessity of closing knowledge gaps to enhance industry readiness.

Quantitative Insights: Examining relationships between BIM knowledge and elements such as IT infrastructure and cost constraints, the study identified weak but significant correlations between financial obstacles and BIM familiarity, underscoring the importance of addressing cost-related issues for effective implementation.

Framework

The findings of this study align with key research in the international literature, reflecting common challenges and strategies in BIM implementation. Sun et al. (2015) and Khosrowshahi and Arayici (2012) identified hindrances to BIM adoption, echoed in this research. Kouch (2018) and Georgiadou (2019) emphasized the varied nature of BIM implementation, a notion supported by this study's findings. Similarly, Wachata (2020) identified barriers to full BIM adoption in Zambia, corroborating the challenges uncovered here. Chipulu (2015) also outlined factors limiting BIM use, consistent with themes found in this investigation.

The synthesis of qualitative and quantitative data provides a comprehensive understanding of BIM implementation challenges and opportunities in Zambia's AEC sector. This synthesis forms the basis for developing a tailored framework for BIM deployment, addressing industry-specific challenges. Designed to overcome obstacles, promote collaboration, and leverage success factors, this framework emphasizes collaboration, education, and strategic planning. It represents a significant step towards the successful integration of BIM technologies in Zambia's AEC industry, fostering digital excellence in construction practices.

The findings contribute valuable insights towards the development of a BIM implementation framework for Zambia's AEC industry, covering three main domains: technology, process, and policy.

The technology aspect of the proposed BIM implementation framework for Zambia's AEC industry holds significant importance, encompassing software, hardware, equipment, and networking systems to enhance project efficiency. Technology plays a central role in facilitating the creation, management, and exchange of digital representations of buildings or infrastructure in BIM (Ghaffarianhoseini et al., 2017). Software tailored for BIM enables collaborative design, analysis, and project management. (Gu & London, 2010). Some of the key stakeholders that will drive BIM implementation are private training centres, software developers, educational institutions, industry associations (ZIA, EIZ, etc), government agencies (GRZ bodies shaping policies), and architects, engineers, and construction professionals.

Initiating the shift towards BIM implementation requires raising awareness and fostering BIM competency within the Zambian AEC industry. Private training centers specializing in BIM education serve as crucial facilitators, offering hands-on experience through workshops, seminars, and practical training sessions. Collaborative partnerships between these centers and educational institutions further enhance technology-driven education, integrating BIM into university and technical college curricula to produce graduates well-versed in BIM principles.

Continuous professional development is essential in a rapidly evolving technological landscape. Certifications in BIM and participation in industry events keep professionals updated on the latest advancements, enhancing individual skill sets and elevating industry standards.

The Process Field in Building Information Modelling (BIM) involves various stakeholders responsible for the entire life cycle of structures, including facility owners, architects, engineers, contractors, and facility managers (Succar B. , 2009). Successful BIM implementation as a process requires a robust change management strategy to enhance communication, foster collaboration, and define roles and responsibilities clearly among professionals. Adopting BIM necessitates a departure from traditional practices and the integration of interdisciplinary processes (Succar B. , 2009).

Effective BIM implementation demands seamless collaboration across all design and delivery phases, facilitating the exchange of reliable, structured information. This shift involves transforming existing workflows and incorporating 3D BIM models and process flows. Clarifying team roles and responsibilities is crucial for streamlining workflows and optimizing collaboration potential.

In summary, successful BIM implementation in Zambia's AEC industry within the Process Field requires a comprehensive change management strategy focusing on communication enhancement, collaboration fostering, and role definition. Embracing interdisciplinary processes and adjusting delivery methods are essential steps contributing to effective BIM utilization.

The Policy Field within the Architecture, Engineering, Construction, and Operations (AECO) industry involves key entities responsible for preparatory, regulatory, and contractual aspects of construction projects, including insurance companies, research centers, educational institutions, and regulatory bodies. In Zambia's AEC industry, the establishment of the Zambian BIM Council is crucial for comprehensive Building Information Modelling (BIM) implementation, addressing gaps in government initiatives and contractual frameworks.

As emphasized by Succar and Kassem (2015), national BIM policies, standards, guidelines, mandates, and regulatory bodies are essential for effective BIM implementation. The Zambian BIM Council, acting as a regulatory body, can develop and enforce tailored policies and standards aligned with international best practices while considering local industry dynamics.

The council can serve as a unifying platform, bringing together stakeholders from various backgrounds to create a shared vision for BIM implementation in Zambia. Through workshops and collaborative initiatives, it can facilitate knowledge exchange and capacity-building, addressing industry-wide awareness and support deficiencies.

Moreover, the Zambian BIM Council can engage top management in the AEC industry, advocating for BIM integration into organizational strategies and promoting a cultural shift towards embracing advanced construction technologies.

In essence, the establishment of the Zambian BIM Council is not only a regulatory necessity but also a strategic move to coordinate efforts in advancing BIM implementation. It acts as the linchpin in the policy framework, driving the formulation, implementation, and enforcement of BIM policies and standards while fostering collaboration and awareness crucial for Zambia's Construction Industry transformation.

Proposed Framework

The proposed BIM Implementation Framework for Zambia's AEC industry unfolds in five sequential stages, each meticulously crafted to facilitate the smooth integration of BIM practices.

At the forefront of this framework is the establishment of a BIM Council, acting as a crucial regulatory body. Comprising stakeholders from government bodies, industry practitioners, educational institutions, and research centers, the BIM Council serves to coordinate efforts and foster collaboration to advance BIM adoption in Zambia.

The second stage focuses on the development of BIM Standards, emphasizing alignment with international best practices while tailoring standards to Zambia's specific needs. The BIM Council, serving as a regulatory authority, plays a central role in formulating and enforcing these standards. Additionally, this stage involves BIM training, infrastructure investment, and engagement with software developers to discuss cost incentives for BIM software.

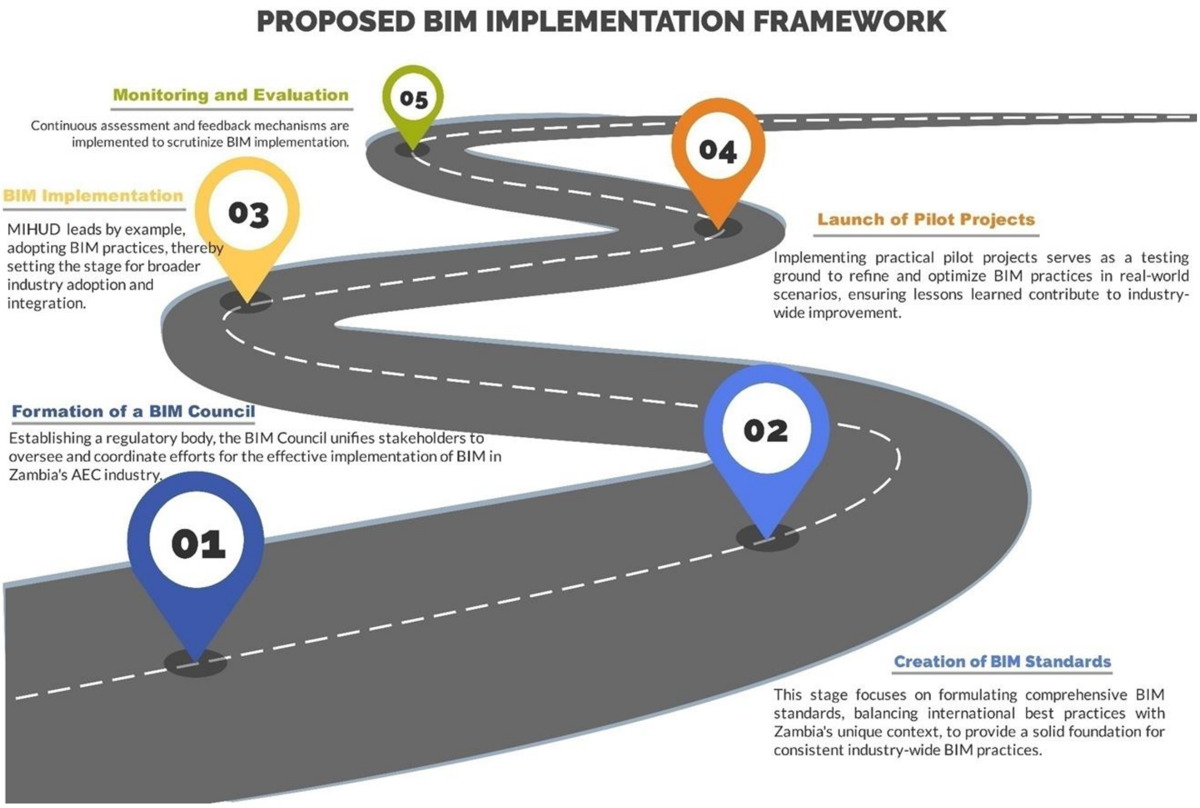
Once standards are established, the third stage involves implementing BIM within the Ministry of Infrastructure, Housing, and Urban Development. This strategic move ensures that a key governmental body leads by example, paving the way for comprehensive integration of BIM practices across various construction projects.

The fourth stage involves the Launch of Pilot Projects, enabling a practical and phased approach to BIM implementation. These pilot initiatives serve as testing grounds for refining and optimizing BIM practices in real-world scenarios, with lessons learned contributing to continuous improvement across the industry.

Finally, the fifth stage emphasizes Monitoring and Evaluation, highlighting the importance of continuous assessment and feedback mechanisms. Ongoing scrutiny ensures the effectiveness of BIM implementation, allowing for adjustments and improvements as needed. Regular evaluations also foster a culture of adaptability and innovation within the AEC industry.

These stages are designed to facilitate the seamless integration of BIM practices, starting with the establishment of regulatory oversight and culminating in continuous monitoring and improvement. By fostering collaboration, promoting skill development, and ensuring regulatory support, the framework aims to position Zambia's AEC industry for sustainable growth and competitiveness in the global arena.

In essence, the proposed BIM Implementation Framework unfolds as a strategic roadmap, guiding Zambia's AEC industry through a structured and collaborative journey towards the successful and sustainable integration of BIM practices.



Conclusion

Challenges Associated with BIM Implementation: The study identified several challenges hindering BIM implementation in Zambia's AEC industry. Poor IT infrastructure, limited access to BIM tools, and insufficient technological capabilities were major concerns. Knowledge gaps and awareness about BIM benefits also posed obstacles, alongside financial barriers and resistance to change within the industry. Overcoming these challenges requires targeted educational programs, financial incentives, effective change management, and government support.

Extent of BIM Usage as a Collaboration Strategy: While stakeholders in Zambia demonstrated a high level of readiness for BIM adoption, challenges in translating readiness into specific implementation plans were observed. Differences in viewpoints regarding statutory approval mandating BIM usage and strategic initiatives for adoption underscored the complexity of BIM implementation factors. Addressing these challenges necessitates further research and strategic planning to bridge the gap between readiness and implementation.

Strategies and Key Success Factors for BIM Implementation: The study revealed strong support for strategies such as task forces, government-led implementation plans, education, and awareness initiatives. However, challenges were identified in areas such as data and infrastructure, indicating the need for focused strategies to overcome potential obstacles. Lower agreement levels on strategies related to BIM libraries, data transfer, and interoperability improvements highlight the need for targeted research and planning efforts in these areas. Recommendations include creating awareness, integrating BIM education into academic curricula, and providing financial incentives to encourage BIM adoption.

Through a thorough examination of barriers to BIM integration, insights into maximising teamwork, and the identification of workable techniques, this study offers a trajectory for the development of BIM implementation strategies within Zambia's AEC industry. With a roadmap for overcoming obstacles and boosting cooperation, stakeholders may fully use BIM's potential to improve productivity, teamwork, and creativity in construction processes.

The study recognizes several limitations, notably its focus on a single public sector entity, the Ministry of Infrastructure, which excludes other ministries involved in infrastructure development, like local government agencies. Moreover, it acknowledges the absence of engagement with key stakeholders such as contractors and private sector developers. Additionally, discrepancies were noted in responses to specific questionnaire items, particularly regarding job positions that did not align with the organizational structure.

Recommendations

The government should prioritize the creation of dedicated BIM training centres to provide professionals with hands-on experience and practical training. The government can also explore partnerships with technology providers to access cost incentives that facilitate BIM adoption. Research efforts should focus on optimizing interdisciplinary collaboration in BIM projects, identifying key success factors, and addressing potential challenges. Establish the Zambian BIM Council that should be tasked with developing and enforcing national BIM policies, standards, and guidelines. The BIM Council should actively engage with key stakeholders in the AEC industry to garner support for BIM integration.

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