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Decision Analysis of Institutional and Technical BIM Implementation for SMEs

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ABSTRACT

Notwithstanding BIM's established reputation for enhancing project coordination, reducing errors, and augmenting long-term efficiency, its adoption in small and medium-sized enterprises (SMEs) remains inconsistent and fragmented. Statistical techniques, including exploratory factor analysis (EFA) and Spearman's correlation analysis, were used with a questionnaire survey that yielded 59 valid responses to underpin the study. The primary obstacles identified by the study include elevated software and training costs, insufficient governmental guidance, restricted technical expertise, and an ambiguous return on investment. Conversely, SMEs are inclined to adopt BIM when provided with appropriate incentives, including financial subsidies, practical training, and clearer regulations. The research indicated the hesitance of SMEs to use BIM software stems more from intrinsic constraints and an aversion to risk than from a dismissal of innovation. This study establishes the need for a dual strategy—first, reducing tangible obstacles and second, enhancing perceived value—to facilitate SMEs' adoption of BIM. In the construction industry's most resource-limited areas, it offers academic and practical perspectives for promoting digital transformation.

1. Introduction

The global construction industry has rapidly adopted Building Information Modelling (BIM) since the onset of the 21st century. Software companies popularised the term BIM among the industry [1]; BIM has evolved from a mere 3D modelling tool to a comprehensive platform for data integration throughout the whole project lifecycle. According to Wang [2], during the construction lifecycle, it is essential to produce and manage digital, object-oriented project data; this is the core principle of BIM. It has the capacity to address the construction industry's most urgent challenges, including its fragmented structure and inadequate productivity. Cheng *et al.*, [3] assert that it facilitates the integration of previously disparate processes in the construction supply chain and eliminates the silo effect.

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Notwithstanding the many benefits of BIM, its adoption has exacerbated the “digital divide” between major enterprises and small to medium-sized enterprises [4]. Large companies are considered “BIM compliant”, while small and medium-sized companies are considered “non-compliant” [5,6]. Compared with large companies, small and medium-sized companies often face more challenges in financing software costs, upgrading technology, and training employees. This is due to SMEs’ deficiency in resources, technological proficiency, and organisational structures compared to big firms [7].

In the third quarter of 2016, the United Kingdom had more over 300,000 construction-related enterprises, of which only 147 employed 300 or more individuals [8]. Furthermore, in the global construction sector, small and medium-sized enterprises have the greatest influence [9]. To promote the digital upgrade of the entire industry, it is crucial for SMEs to widely adopt BIM [10]. Harris *et al.,* [11] assert that SMEs within the ASEAN Economic Community (AEC) may lose market share if they fail to comply with BIM standards; hence, compliance is not just necessary but imperative for their survival and competitiveness.

Ghaffarianhoseini *et al.*, [12] reviewed the research using these methods and provided a comprehensive overview of BIM research trends. This study may shed light on the significant technological advancements that BIM has achieved in the architecture, engineering, and construction (AEC) industry.Research indicates that the proficiency in technology adoption and the flexibility of organisational structure are the two primary factors influencing BIM adoption by SMEs.

Abdirad [13] asserts that the ability to effectively install and use BIM systems is closely linked to an individual’s technology adoption competence, defined as their familiarity with and mastery of BIM-related processes, procedures, and concepts. Many SMEs have challenges with complex BIM platforms and processes owing to insufficient technical staff with BIM expertise, inadequate training resources, and limited investment capabilities. The second key issue in implementing BIM is the characteristics of the enterprise. Nonetheless, most current literature assessments about BIM inadequately address the specific challenges and needs of SMEs in the implementation of BIM [14]. Consequently, SMEs are inadequately represented in policy and research, diminishing the effectiveness of their practical implementation [10].

This research aims to investigate the interaction among cognition, resources, management, and policy support, along with other facilitating and obstructive factors, to identify the critical elements for SMEs in the adoption of BIM technology. Specific objectives include:

i. Identifying the main problems faced by SMEs in the use of BIM.
ii. Examining the primary motivational factors for SMEs to adopt BIM.
iii. Examining the interrelation between factors that facilitate and those that hinder.
iv. Employing factor analysis to derive structural dimensions.

1.1 SMEs Adoption of BIM

Lembangan and Nurdiah [15] assert that BIM is essential for the digital transformation of the construction sector as it enhances information management, mitigates project complexity and risk, and increases collaborative efficiency throughout the supply chain. SMEs significantly lag behind major corporations in the adoption and implementation of BIM. Notwithstanding the active promotion of BIM by governments, shown by the UK’s persistent advocacy for BIM Level 2 industry integration from the issuance of its Construction Strategy in 2011 [16] and a succession of recommendations and compliance rules [17].

Conversely, SMEs often encounter challenges due to insufficient devoted workers, unstable finance, limited technical expertise, and a lack of a structured strategy for digital advancement [18]. Despite the potential for SMEs to effectively use BIM in certain real-world contexts, they are often deterred by substantial costs and technical challenges, as noted by Dainty *et al.,* [1]. Although SMEs have problems in using BIM, research conducted by Eadie *et al.,* [19] in the UK indicates that cost is not the primary impediment.

In project practice, SMEs often assume the role of subcontractors, relying on bigger contractors or partners for BIM [7]. Nonetheless, in smaller projects, SMEs may also lead the BIM implementation. Business process modelling (BPM) is often seen unfavourably by SMEs, despite their inherent structural flexibility and low cost of modification. Some assert that BIM advantages large firms to the detriment of SMEs, a situation termed "technology discrimination" [20]. The promotion of novel management concepts such as lean construction has shown similar trends [7].

2.2 Core Barriers to BIM Adoption in SMEs

While many researchers have explored the real-world applications of BIM in building projects from diverse perspectives, most studies have concentrated on limited domains or the perspectives of large corporations, resulting in insufficient analysis of the systemic challenges faced by SMEs as implementation entities. Numerous studies neglect to include the distinctive attributes and intricacies of SMEs by use the word "project" instead than "organisation" as their unit of analysis [21].

Studies indicate that SMEs may either choose a passive role in BIM activities, such as outsourcing and receiving models for large projects, or actively lead BIM adoption in specific smaller projects. This diversity provides a more comprehensive framework for examining the dissemination of BIM [1]. The absence of external resources significantly impacts SMEs, while insufficient digital awareness and structured training procedures further hinder their technical preparedness and strategic orientation for BIM [13].

Although some systematic BIM review studies have emerged recently, such as Yalcinkaya and Singh [22] who used latent semantic analysis (LSA) to describe the main areas of BIM research and Zhao [23] who developed a BIM knowledge base from citation records in the Web of Science database, most of these studies focused on the visualization of literature structure and the development of topics, with little attention paid to the specific role of SMEs in BIM applications.

SMEs are particularly vulnerable in utilizing new technologies, especially in information exchange and IT project collaboration [24]. Pihkala *et al.,* [25] proposed the concept of SME alliance, which is to establish a virtual network organization to achieve resource sharing and work customization by creating a more flexible collaborative work model. In practice, these strategies often prove ineffective without ongoing financial support from governmental or corporate entities [26]. Consequently, some scholars argue that SMEs have to be seen not just as beneficiaries of digital transformation but as proactive contributors in formulating regulations and guiding their particular sectors [24-27].

Moreover, the significance of SMEs in advancing the digital transformation of the construction industry cannot be overlooked, given their substantial representation in this sector [28]. To develop support strategies tailored to the needs of SMEs, it is essential to possess a comprehensive understanding of their organisational processes, information flow, and technical collaboration aspects related to the BIM adoption process. This research addresses a gap in the literature by using structured questionnaires and quantitative analytical methods to identify the specific challenges and potential incentives encountered by SMEs in the implementation of BIM.

Currently, research on BIM mainly consists of surveys, interviews, or case studies aimed at evaluating the current status of its application [29]. However, there is little research on the specific challenges faced by SMEs in promoting BIM. Love and Irani [21] assert that several research neglect to consider the substantial influence of organisational size on technology adoption behaviour, since they use “projects” or “large enterprises” as their unit of analysis. Compared to large enterprises, SMEs often have unique BIM implementation strategies, staff training methods, and collaborative process development approaches. This is especially true for SMEs with flat organizational structures, limited resource allocation, and streamlined decision-making processes.

2. Methodology

2.1 Questionnaire Design

Validated baseline questionnaires, in particular the one by Hosseini *et al.,* [30], have demonstrated strong psychometric properties and are effective in identifying important issues in BIM. The use of validated instruments in this study ensured the scientific rigor of the study, comparability with previous studies, and reduced the risk of arbitrary fabrication of the questionnaire. The researcher meticulously revised the existing questionnaire in accordance with Warren’s [31] guidelines for questionnaire design. Warren [31] asserts that researchers should only contemplate altering or developing new surveys when existing ones do not meet certain study objectives or contexts. This technique ensured methodological rigor and contextual applicability, as the existing questionnaire was widely used and thoroughly validated. Targeted contextual modifications and terminology simplification were implemented in the original questionnaire to enhance comprehension among SMEs and increase response rates. While the original measurement parameters were maintained, several terms were modified to enhance accessibility for construction industry professionals in Ghana, considering their linguistic preferences and cognitive capacities. To enhance alignment with respondents’ everyday experiences, we reworded “strategic BIM implementation” to “long-term planning for BIM utilisation in projects.” To prevent ambiguities arising from academic jargon, we articulated “collaborative workflow” as “team collaboration in the context of BIM.” The phrase “interoperability barriers” was reworded as “incompatibility among various BIM software.” The use of BIM throughout the design, construction, and operational phases, together with the reluctance of personnel to adopt BIM, are more colloquial and specific interpretations of “lifecycle integration” and “resistance to innovation,” respectively. The modifications in language and semantics facilitated respondents’ ability to answer the questions, enhanced the dependability of the findings, and reduced their cognitive burden.

The questionnaire included a five-point Likert scale ranging from “strongly disagree” to “strongly agree” for the statements, to assess the previously listed multidimensional issues. Organisational behaviour and construction management extensively use the Likert scale owing to its ease of use and statistical practicality [32]. We have identified several dimensions of the issues, including restrictions on capital expenditures, a deficient technological foundation, insufficient training and skill development for personnel, challenges in collaboration and communication, and ambiguous requirements from owners or clients.

2.2 Data Collection and Data Analysis

This survey primarily utilized online questionnaire distribution, leveraging the researcher's established industry networks, architectural social media, and professional online forums. Survey links were distributed via QR codes and email, ensuring a sample size encompassing individuals from diverse backgrounds and professional levels. While convenience sampling was employed, this study strived to strike a balance between sample diversity and coverage, carefully designing and distributing questionnaires to obtain representative responses. To obtain objective feedback on BIM technology, all surveys were conducted anonymously through an online survey platform. Respondents used two statistical analysis software programs: R Studio and STATA 18. STATA 18 applications include descriptive statistics, normality tests (Shapiro-Wilk), and nonparametric analysis (Spearman's rho).

2.3 Data Validation

Figure 1 illustrates the flow chart of this research. Doloi *et al.,* [33] assert that descriptive statistics are crucial for comprehending the demographics of respondents, together with their attitudes and sentiments towards BIM technology. The study used inferential statistics for comprehensive analysis to explore the relationship between variables. The normality test assesses whether the data satisfy the criteria for parametric testing, conducted prior to selecting appropriate correlation coefficients. This research used the non-parametric Spearman's rank correlation coefficient (Spearman's rho) to evaluate the relationship between characteristics that facilitate BIM and obstacles to its advancement. A two-tailed test is used since the presence of correlation is expected, although the direction of the association cannot be predicted in advance [34].

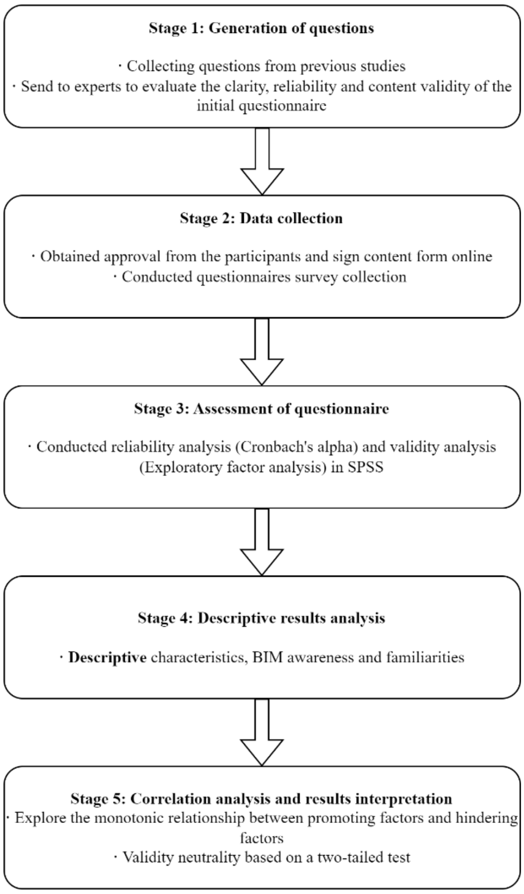

Fig. 1. Flowchart analysis of this research

This study uses exploratory factor analysis (EFA) to elucidate the features that facilitate or hinder BIM deployment. Data must be suitable for factor analysis prior to its execution. This is often achieved by evaluating the sample size, correlation matrix, Kaiser-Meyer-Olkin (KMO) sampling adequacy index, and Bartlett's test of sphericity. Jung [35] indicate that a suitable sample size for exploratory factor analysis (EFA) is between fifty and one hundred. This study's effective sample size was 59 to meet the requirements for EFA. This study assessed reliability using Cronbach's alpha coefficient. This study used Stata to analyse the Cronbach's alpha coefficient for many measurement variables in the questionnaire, a well-recognised metric for assessing whether a set of questions collectively reflects a latent construct. The study used a scale of 22 factors to facilitate the promotion of BIM in SMEs, addressing different hurdles and supportive conditions. To ensure consistency in scoring direction, the Cronbach's alpha coefficient was computed after the reverse coding of some items that seemed to contradict the overall conceptualisation.

3. Results

3.1 Implementation of BIM in the industry

Figure 2 illustrates that a significant segment of the survey sample originated from non-traditional construction entities, including design consulting businesses, architecture students, and IT service providers. This is despite the study's main objective of examining the principal problems faced by SMEs in the use of BIM technology.

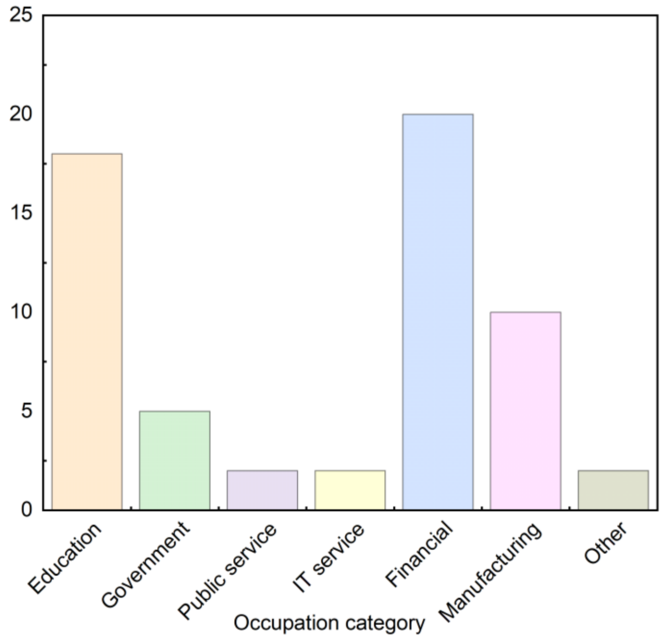

Fig. 2. Occupational category

Figure 3 illustrates the respondents' proficiency and expertise about BIM software. Among respondents familiar with BIM, the majority have a solid understanding of one software application. While most respondents have a basic understanding of BIM and its capabilities, only a minority are proficient in using a specific software application. The research shows that Revit and ArchiCAD have significantly higher recognition and usage than other software applications, reflecting their widespread recognition and popularity within the industry.

Figure 4 shows that despite having previous experience using the software, most of the respondents were still at a beginner level when using the BIM software.

The lack of professional training and practical opportunities continues to restrict users' capacity to improve their skills, despite the increasing use of BIM software. First-time users may find it challenging to comprehend the software's extensive features and functionalities, perhaps hindering their ability to effectively use BIM technology. Facilitating the effective adoption and dissemination of BIM necessitates comprehensive training and ongoing technical support for SMEs, especially for beginners.

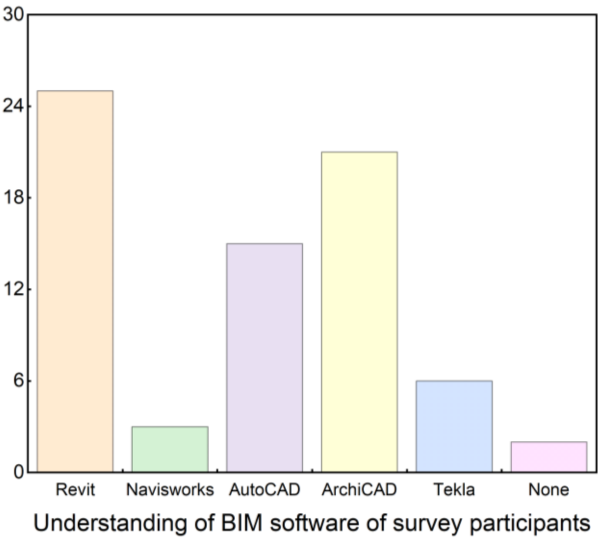

Fig. 3. Understanding of BIM software of survey participants

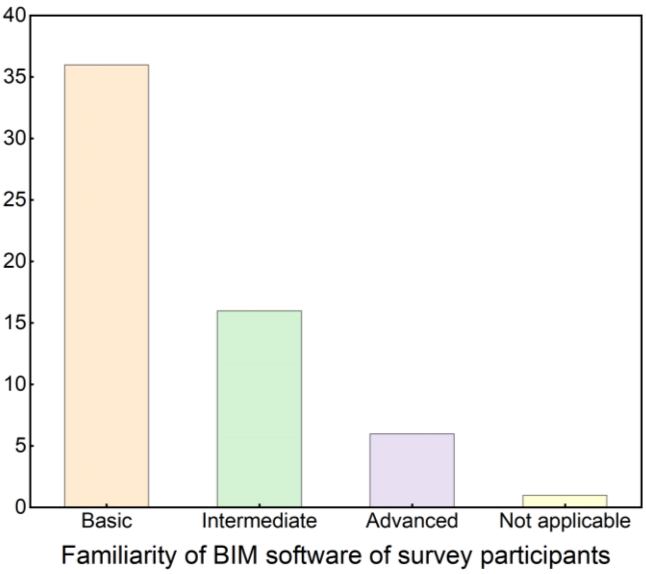

Fig. 4. Familiarity of BIM software of survey participants

3.2 BIM implementation analysis

Figure 5 illustrates the primary factors that promote or hinder the adoption and sustained implementation of BIM. The predominant answer indicated that “Excessive cost of BIM software,” with a score of 4.37. The majority of respondents agreed that the initial investment burden significantly influences SMEs’ adoption of BIM. Significant financial resources are often required for software procurement, license maintenance, hardware enhancements, and human training after comprehensive BIM installation. SMEs with limited financial resources find one-time expenditures particularly problematic [19,36]. Azhar [29] asserts that a primary obstacle to the widespread adoption of BIM in the construction industry is its substantial initial costs. The score of “ambiguous BIM responsibilities” was 4.19, indicating that respondents often encountered confusion in task division and vague job descriptions in the workplace.

The score of “financial subsidies needed” was 4.12, indicating that people are generally skeptical about the return mechanism of BIM. Many respondents found it difficult to determine the exact relationship between costs and benefits in their current work environment, which may be because most successful BIM implementation cases have occurred in large organizations. This uncertainty has led to a decline in people's confidence in BIM, which indirectly affects the effectiveness of its market promotion. According to the survey responses [37], companies are reluctant to invest in technologies that do not provide clear returns.

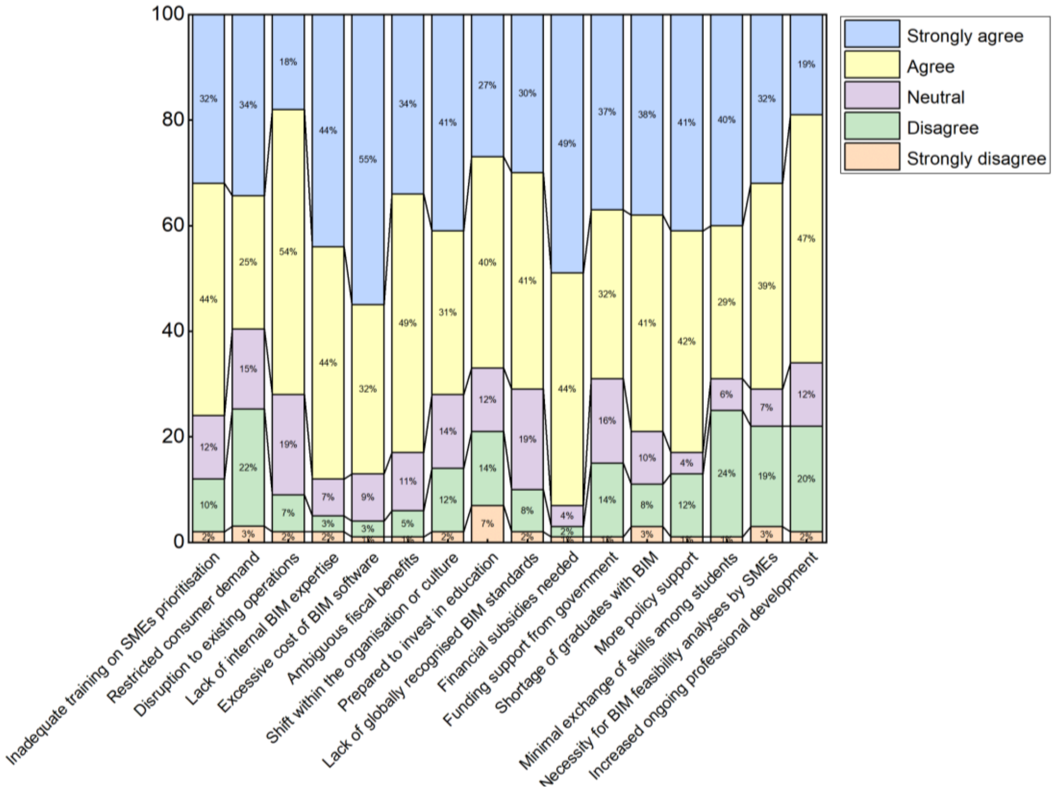

Fig. 5. Proportion of factors affecting BIM implementation

The findings indicated that participants were the second most inclined to evaluate "Inadequate training on SMEs prioritisation" with an average score of 4.34. This indicates that most respondents believe that personnel abilities are the paramount aspect in guaranteeing the proper deployment of BIM. Luthra and Mangla [38] assert that an absence of requisite skills is a primary factor contributing to the failure of BIM projects. The respondents' perspectives indicate a consensus on the significance of training expenditures for the adoption of new technology. While this may not accurately represent corporate spending strategies, it indicates that respondents see training as significant.

The score of 4.26 indicates that the accessibility of prevalent BIM standards facilitates adoption. Respondents believe that technological specifications and execution standards significantly impact SMEs. Challenges such as ambiguous roles and responsibilities, along with fragmented processes, may occur in practical BIM projects owing to the collaborative nature of the multidisciplinary cooperation involved [36]. Standardisation across sectors may assist SMEs in comprehending the usefulness of BIM, reducing the costs associated with technical experimentation, and enhancing interoperability across tools and platforms.

3.3 Influencing factors Analysis

This study used Bartlett's sphericity test and the KMO index to evaluate the adequacy of the data. Watkins [39] assert that exploratory factor analysis (EFA) is deemed acceptable when the Kaiser-Meyer-Olkin (KMO) value exceeds 0.60 and the p-value of Bartlett's test is below 0.05. This inquiry used principal component analysis (PCA) throughout the factor extraction phase. We retained only those factors for further analysis with eigenvalues over 1.0, in accordance with the eigenvalue criterion. Yong and Pearce [40] indicate that eigenvalues quantify the extent of variance elucidated by each factor.

The last phase was quantitatively assessing the factor loadings by Rotation Component Analysis. Watkins [39] said that this study used the Varimax orthogonal rotation method to exclude items with factor loadings under 0.5.

Table 1
Reliability and validity analysis

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.791
Bartlett's Test of Sphericity	Approx. Chi-Square	454.134
	df	75
	Sig.	<0.001

The study's KMO value of 0.791 is well within the acceptable range for the 0.6 criteria, as seen in Table 1. The sample size renders it relatively acceptable [41]. A significant connection exists among the variables, as shown by the statistical significance of Bartlett's sphericity test results ($p < 0.001$). We may proceed with exploratory factor analysis (EFA) on this dataset, but we must use caution in interpreting the results.

Table 2 lists the Cronbach's α coefficient for each extracted component, which helps to assess the internal consistency of the questionnaire construct. According to the data, Factor 1 (Policy and Cultural Factors) exhibited an α value of 0.568, Factor 2 (External Resources and Support) shown an α value of 0.645, and Factor 3 (Technical and Capability Barriers) presented an α value of 0.575. The three factors accounted for 60.13 percent of the total variance, indicating their structural stability, high representativeness, and effectiveness as a summary of the original variables' information.

Table 2
Loadings of the extracted factors

Factor	α	Variance	Proportion
Policy and Cultural (F1)	0.568	2.03	21.47%
External Resources and Support (F2)	0.645	1.87	19.80%
Technical and Capability Barriers (F3)	0.575	1.78	18.86%
Total			60.13%

Table 3
Cross-loadings of the factors

Variable	Factor1	Factor2	Factor3
Concerns about compatibility	0.149	0.152	0.650
Absence of formal directions	0.165	0.353	0.456
Ambiguous BIM responsibilities	0.168	0.252	0.388
Insufficient client understanding	0.242	0.597	0.026
Abundance of incompatible BIM software	0.074	0.600	-0.001
Intellectual Property and Legal Concerns	0.580	0.001	0.195
Inadequate training on SMEs prioritisation	0.184	-0.094	0.300
Restricted consumer demand	0.033	-0.078	0.682
Disruption to existing operations	0.045	0.385	0.473
Lack of internal BIM expertise	0.219	0.645	0.051

Table 3
Continued

Variable	Factor1	Factor2	Factor3
Excessive cost of BIM software	0.373	0.300	0.025
Ambiguous fiscal benefits	0.309	0.245	0.121
Shift within the organisation or culture	0.274	-0.154	0.308
Prepared to invest in education	0.177	0.151	0.082
Lack of globally recognised BIM standards	0.182	-0.209	0.470
Financial subsidies needed	0.052	0.517	0.008
Funding support from government	0.403	0.517	0.437
Shortage of graduates with BIM	0.722	0.070	-0.068
More policy support	0.322	0.495	-0.033
Minimal exchange of skills among students	0.561	0.081	-0.233
Necessity for BIM feasibility analyses by SMEs	0.442	-0.301	0.299
Increased ongoing professional development	0.668	-0.127	0.034

Factor 1 (Table 3) encompasses high-load variables such as intellectual property and legal concerns, shortage of graduates with BIM, and increased ongoing professional development. Collectively, these elements demonstrate the cultural adaptability and institutional guidance that SMEs rely on amid BIM advocacies. The “lack of globally recognised BIM standards” and “shift within the organisation or culture” indicate that the willingness to implement BIM is significantly linked to the clarity of an organisation’s regulations and the extent to which its staff may actively embrace innovative concepts. Simultaneously, “financial subsidies needed” is seen as a crucial indicator for enterprises to assess ROI. A decline in corporate inclination to use BIM is anticipated if the benefits are not readily apparent. Another way that cultural context influences technology adoption is through the factor of “training willingness,” which signals both individual motivations to learn and organizational receptivity to change.

Factor 2 (Table 3) includes several elements: the abundance incompatible BIM software, insufficient client understanding, insufficient internal BIM expertise, and the need for financial subsidies, government funding support, and additional policy support. These issues reflect the prevalent “external barriers” that enterprises encounter while attempting to advance BIM, including inadequate resources, guidelines, and communication channels. If the government’s guiding processes are inadequate, the market is neglected, and there is ambiguity on BIM responsibilities, then there exists an institutional issue with interdepartmental coordination.

This component might be seen as ‘external resources and assistance’. These instances demonstrate that SMEs are not resistant to adopting BIM; instead, they are engaging passively in the implementation process due to challenges such as insufficient resources, ambiguous processes, and undefined roles and responsibilities. According to Ilvonen *et al.,* [42] ‘institutional maturity model,’ institutional support and resource safeguards are fundamental elements for corporate digital transformation. This event aligns with that framework. It would be easier for businesses to deploy these systems if governments or industry organizations provided stronger financial support, platform and regulatory frameworks, and more comprehensive role-division standards and methods.

Factor 3 (Table 3) highlights concern about compatibility, absence of formal directions, restricted consumer demand, disruption to existing operation, lack of globally recognised BIM standards, and funding support from government. This factor, interpreted as a "knowledge base and skills gap," emphasizes the need for a solid professional foundation for effective BIM deployment. BIM guidance and training are crucial, as is understanding the environmental impact of building design. Architects may lack the proficiency to effectively use BIM without appropriate training and instruction [43].

Ghaffarianhoseini *et al.,* [12] assert that enterprises struggle to recognise the advantages of investing in BIM due to architects' uncertainty about the environmental impact of their projects. Moreover, a significant barrier for SMEs is the substantial cost associated with acquiring and implementing BIM. Mahamadu *et al.,* [44] indicate a deficiency in the provision of BIM capabilities. Because of the long-term nature of these issues, basic incentives or procurement of new technologies will not address them in the foreseeable future. Instead, they will need to rely on training programs, industry certifications, and educational institutions to address them. To close the skills gap, university curricula must be revised, continuing education opportunities increased, and corporate training programs overhauled to make BIM instruction more accessible. These initiatives will particularly benefit small and medium-sized enterprises (SMEs) by providing affordable and accessible training.

4. Conclusion

This study, through a structured questionnaire survey and empirical testing of 59 samples, identified several significant barriers to BIM adoption faced by SMEs. Key issues included high software and training costs, a lack of formal regulations, unclear return on investment expectations, and unclear roles and responsibilities within the BIM process. Budgetary constraints and organizational management issues also served as major barriers to BIM adoption for SMEs. A significant number of respondents expressed concerns about a lack of policy guidance, the challenges of changing work practices, and uncertainty about implementation outcomes, suggesting a more conservative outlook and limited internal resources.

However, the survey revealed that SMEs are not completely opposed to BIM. In fact, most SMEs are willing to invest in BIM training if the benefits are clear. Incentives, subsidies, and industry standards also promote BIM adoption. Current hesitation may be attributed to structural constraints rather than ideological opposition, as some respondents recognize the long-term benefits of BIM.

This study explored the relationship between these drivers and barriers through exploratory factor and correlation analyses. Faced with increased expenses, enterprises are more likely to seek external assistance. This suggests that targeted measures, such as subsidies and regulatory frameworks, may address the underlying issues. Factor analysis revealed three key themes: policy and cultural issues, external resource support, and internal technical capabilities.

This study makes important contributions both theoretically and practically. It provides systematic empirical data and conceptually addresses the underrepresentation of SMEs in BIM adoption, thus addressing research needs. Methodologically, through a systematic questionnaire design and meticulous data collection, this study lays a solid foundation for future comparative or longitudinal studies. The findings have practical implications for industry practitioners, legislators, and technology providers. They can enhance the digital competitiveness and innovation capabilities of SMEs through specialized training programs, enhanced collaborative processes, customized software solutions, and cost-control strategies.

However, these findings come with some caveats. While this study strived to obtain a diverse sample through both online and offline methods, most respondents reside in urban areas and work in the construction industry, potentially leading to potential for regional or industry biases. The survey included students, novices, and experienced professionals, providing a diverse perspective on BIM perceptions; however, this also increases the potential for inconsistencies in expertise and the accuracy of the findings.

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Conflicts of Interest
The authors declare no conflicts of interest.

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