International Journal of Engineering, Management and Humanities (IJEMH)
Volume 6, Issue 1, Jan.-Feb, 2025 pp: 93-117 ISSN: 2584-2145 www.ijemh.com

Key Factors for BIM Implementation in Small and Medium Sized Construction Enterprises in Hainan Province, China: Based On the Improved Toe Framework

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Date of Submission: 07-01-2025 Date of Acceptance: 19-01-2025

ABSTRACT: Despite the large number of small and medium sized construction enterprises (SMEs) in China, their digital transformation process remains slow. Building Information Modeling (BIM) technology, as a key driver of digital transformation, is still underutilized in these enterprises. Although the government and industry have promoted BIM technology through policies, the effect has been limited, with BIM applications mainly concentrated in large enterprises and complex projects. This paper conducts a systematic literature review combined with expert interviews, based on an improved TOE (Technology, Organization, Environment) framework, to identify 22 key factors affecting BIM implementation and categorizes them into five dimensions: technology, organization, environment, personnel, and economy. The study finds that among these factors, eight key elements have the most significant impact on driving BIM implementation. Based on these key factors, this paper proposes a series of strategies, including strengthening technical training and knowledge transfer, optimizing organizational structure to enhance BIM adaptability, promoting policy support and market guidance, and improving enterprises' understanding of the economic benefits of BIM technology. Implementing these strategies can effectively overcome the main obstacles encountered by small and medium sized construction enterprises in Hainan province during BIM implementation, thereby advancing their digital transformation. Furthermore, this study provides valuable decision making references for government departments, investors, and related stakeholders, helping governments to formulate more comprehensive BIM policies and supporting investors in making informed decisions. Overall, this paper provides theoretical support and practical guidance for the promotion of BIM technology in small and medium sized construction enterprises in Hainan.

Keywords: *SMEs, BIM, BIM Implementation, Influencing Factors, TOE*

I. INTRODUCTION

The construction industry in China is dominated by Small and Medium-sized Enterprises (SMEs), accounting for more than 95% of all firms in the sector, with over 85% of the industry's workforce engaged in these enterprises. Despite their significant contribution to the industry, with nearly 75% of construction projects completed by SMEs (Fan & Li, 2022), their adoption of Building Information Modeling (BIM) technology has been lagging compared to large enterprises. Although BIM has been widely adopted in the construction industry globally, with demonstrated benefits such as reduced project time and costs, enhanced collaboration, and improved project outcomes, SMEs in China continue to face substantial challenges in its implementation (Sarvari et al., 2024). BIM, as a key tool for digital transformation in the construction industry, promises to significantly improve project management efficiency and resource allocation, yet its adoption remains limited within SMEs, particularly in regions like Hainan Province. The challenges are compounded by the region's underdeveloped economic base, insufficient policy enforcement, and a lack of resource allocation, which make it difficult for SMEs to fully benefit from BIM technology.

While BIM adoption has grown significantly among large enterprises and large-scale projects, SMEs have yet to embrace its full potential due to limitations in technical expertise, financial resources, and insufficient policy support (Lin et al., 2023). The Hainan Province government has introduced several policies to promote BIM technology, such as the "BIM Technology Application Guidelines" published in December 2022 and the modifications to bidding procedures in May 2023 to prioritize BIM adoption. Despite these efforts, SMEs continue to struggle due to weak technical capacity, financial constraints, and limited access to necessary resources (Wang & Sun, 2020). Furthermore, external factors such as local government support and industry ecosystem dynamics have also played a crucial role in hindering the adoption of BIM by SMEs in the region.

BIM technology is a disruptive digital tool that offers substantial value to the construction industry. Research indicates that the core factors influencing BIM implementation include technical, organizational, and environmental dimensions. In the technical dimension, the interoperability of software platforms, high costs, and the compatibility of technical standards are the major barriers for SMEs (Hall, 2023). Organizational barriers such as insufficient management support, weak internal technical capabilities, and a lack of understanding of BIM further limit its effective implementation (Awwad et al., 2020). In the environmental dimension, factors such as government policies, market demand, and the industry ecosystem significantly influence BIM adoption. The absence of mandatory policies and incentives in some regions has slowed BIM adoption (Makabate et al., 2022). For example, in the UK, the mandatory requirements for public projects have significantly accelerated BIM adoption, while regions with weaker policy support face slower progress.

For SMEs, the primary barriers include insufficient technical resources, rigid management structures, resistance to change from stakeholders, and lack of external support (Sarvari et al., 2024). Moreover, the absence of a clear return on investment (ROI) for BIM technology also undermines SMEs' confidence in its long-term benefits (Sompolgrunk et al., 2023). Environmental factors play a significant role, as market demand fluctuations and local government support directly impact the willingness and sustainability of BIM adoption among SMEs.

This study's innovation lies in two main aspects. First, it adopts a regional perspective by focusing on Hainan Province, exploring how local environmental factors—such as policy support and industry dynamics—impact BIM adoption in SMEs. Second, it extends the traditional Technology-Organization-Environment (TOE) framework by adding "Personnel" and "Economic" dimensions. The Personnel dimension addresses the shortage of skilled professionals, while the Economic dimension considers the survival pressures of SMEs in resource-scarce environments. These modifications make the TOE framework more comprehensive in addressing the multifaceted challenges faced by SMEs in BIM adoption.

Through a systematic literature review and semi-structured expert interviews, this study identifies and refines 22 key factors influencing BIM adoption, covering areas such as technical capabilities, organizational management, policy environment, market demand, talent availability, and financial support, thereby forming a comprehensive analytical framework.

The practical and policy implications of this research are significant. It provides theoretical support for BIM implementation in SMEs in Hainan Province and offers specific recommendations for policymakers. At the policy level, governments should reduce financial pressures on SMEs through fiscal support, tax incentives, and low-interest loans, while also strengthening the development and promotion of BIM-related technical standards. At the environmental level, it is necessary to create an open industry ecosystem that fosters market demand for BIM and encourages collaboration and innovation among enterprises. At the enterprise level, SMEs need to improve their internal management systems, enhance BIM training, and actively seek policy and industry support.

II. LITERATURE REVIEW

2.1 Challenges and Trends in BIM Implementation for SMEs

The application of Building Information Modeling (BIM) technology in the construction industry has become increasingly widespread, providing strong support to improve project efficiency, reduce costs, and enhance quality. However, Small and Medium sized Enterprises (SMEs) face numerous challenges when implementing BIM technology. This section reviews recent research on BIM implementation in SMEs, exploring the main challenges and future trends, with the aim of providing guidance and reference for SMEs in adopting BIM technology.

2.1.1 Challenges in BIM Implementation for SMEs

(1) Uncertainty of Return on Investment (ROI)

Key stakeholders in SMEs often perceive the return on BIM investment as uncertain, which is one of the major barriers. Hosseini et al. (2016) noted that while the lack of knowledge is a challenge, the real primary obstacle is the perceived risk related to the uncertainty of BIM ROI. Vidalakis et al. (2020) also found that limited financial capabilities are a primary barrier to BIM adoption in SMEs. Many SMEs are

concerned about the implementation costs of BIM and the uncertainty of achieving the expected return after significant investment. This uncertainty makes SMEs more cautious in their decision making, thus delaying the widespread adoption of BIM technology.
(2) Technological and Knowledge Barriers
Insufficient Technical Understanding: SMEs often have doubts about BIM's technical features, implementation processes, and cost benefit considerations, which hinders its application and promotion in the construction industry. Saka et al. (2020) pointed out that many SMEs have limited knowledge of BIM and lack an understanding of its implementation framework and key factors. Although many countries have launched training programs, the cultivation of various skills and knowledge required in the construction industry remains inadequate, especially in SMEs. Bamgbose et al. (2024) suggested providing training opportunities for construction professionals, promoting government support through incentives, protecting intellectual property related to BIM projects, and enhancing cooperation among construction industry stakeholders.
(3) Lack of Resources and Support
Internal Resource Constraints: SMEs typically face internal resource limitations, such as insufficient funding, technology, and talent, which make BIM implementation more challenging. Wang Ziming and Yuan Chunyan (2020) highlighted that small and medium sized construction enterprises encounter multiple difficulties in applying BIM technology, including internal resource constraints and outdated management models.
(4) Insufficient External Support: The lack of external support, such as government policy backing and industry standards, is also a significant barrier to BIM implementation in SMEs. Liu et al. (2022) noted that for small and medium sized fire protection enterprises in China, the lack of external support and the absence of applicable BIM regulations in the fire protection industry are critical issues.
(5) Cultural and Management Barriers
Cultural Resistance: There may be cultural resistance within SMEs toward BIM technology, with low acceptance from employees and management toward new technologies. Zhen et al. (2020) indicated that, at the micro level, the main challenge in adopting BIM technology is cultural resistance and organizational change.
(6)Lack of Management Support: The absence of top down management support makes BIM implementation difficult to advance. YingHong et al. (2019) noted that Australian companies tend to use BIM to address organizational collaboration issues and optimize workflow efficiency, whereas Chinese companies focus more on improving technical capabilities and are more cautious to reduce uncertainty.

2.1.2 Trends in BIM Implementation for SMEs

(1) Technological Integration and Innovation
Intelligence and Automation: BIM technology will integrate with emerging technologies such as artificial intelligence, the Internet of Things, and big data, forming more intelligent and efficient building information models. The future development trend of BIM will continue to move towards greater intelligence, collaboration, and efficiency.
(2) Digital Transformation
Digital Transformation: With the pressing demand for digital transformation in the construction industry, BIM technology will become an important driving force for industry innovation. Waldir Lazaro Aleman et al. (2020) pointed out that adopting BIM methods to implement digital transformation in medium sized construction companies can effectively reduce document approval times and operating costs.
(3) Policy Support and Standards
Government Initiatives: Governments in various countries and regions have introduced policies and standards to promote the widespread adoption and application of BIM technology. The Ministry of Housing and Urban Rural Development's "14th Five Year Plan for the Development of Information Technology in the Construction Industry" emphasizes accelerating the application of new technologies, such as BIM and web based collaborative work, in engineering projects.
(4) Standard System Improvement: The BIM standard system continues to improve, laying a foundation for BIM application. Between 2016 and 2021, the national government released seven BIM national standards, initially establishing a BIM standard system.
(5) Training and Education
Professional Training: Providing training opportunities for construction professionals to enhance their application of BIM technology. BIM Training Network offers integrated solutions, including BIM laboratories, curriculum systems, and teaching resources, to support the development of educational institutions.
(6) Industry Collaboration
Strengthening Collaboration: Strengthening collaboration among construction industry stakeholders to improve clients' understanding of modern technologies and promote knowledge sharing.

Bamgbose et al. (2024) suggested that promoting BIM adoption through professional training, government incentives, and intellectual property protection is essential.
(7) Market and Competition
Enhancing Competitiveness: The widespread use of BIM technology will enhance the competitiveness of SMEs, helping them survive in future industry developments. Koucha et al. (2018) noted that BIM is a transitional technology, moving from the traditional single sequence form to a modern multi parallel data integration form, supporting the management of multi dimensional tasks and activities throughout the building lifecycle.
SMEs face many challenges in BIM implementation, including uncertain return on investment, technological and knowledge barriers, lack of resources and support, as well as cultural and management obstacles. However, with the integration of technology, policy support, training and education, and market competition, the application prospects for BIM technology remain broad. SMEs should actively address these challenges, seize opportunities, and achieve digital transformation and enhanced competitiveness. Future research should further explore how to help SMEs overcome BIM implementation barriers through policy support, technological innovation, and educational training, promoting the widespread application of BIM technology in the construction industry.

2.2 Concept and Improvement of the TOE Framework

2.2.1 Concept of the TOE Framework

The TOE (Technology Organization Environment) framework was proposed by Tornatzky and Fleischer in their book The Process of Technological Innovation as a theoretical model to analyze the influences on organizations when adopting new technologies [Tornatzky & Fleischer, 1990]. Based on the theory of innovation diffusion, the TOE framework provides a systematic tool for analyzing the technological innovation process from three dimensions: technology, organization, and environment [Oliveira & Martins, 2011]. As an analytical tool, the TOE framework is widely applicable and has been successfully used in studies on technology adoption in fields such as information technology, e commerce, and ERP systems [Zhao Kaili, 2023].

2.2.2 Improvement of the TOE Framework: Addition of "Personnel" and "Economic" Dimensions

In recent years, scholars have extended the TOE framework to meet the specific needs of certain industries. In the construction industry, researchers have proposed adding the "personnel" and "economic" dimensions to more comprehensively analyze the factors influencing construction companies' adoption of BIM technology [Zhao Kaili, 2023] [Liu Yuxin, 2023].

Personnel Dimension:Research by Zhao Kaili (2023) suggests that the skill level, innovative capabilities, and attitude toward new technologies of employees are key influencing factors. The promotion of BIM technology requires the support of skilled professionals, but a lack of technical skills or resistance to change can pose obstacles [Khosrowshahi & Arayici, 2012]. In construction companies, training employees to improve their ability to adapt to BIM technology is fundamental to advancing technology adoption.

Economic Dimension:Liu Yuxin (2023) noted that economic factors are an important aspect influencing technology adoption, including initial investment, operating and maintenance costs, and expected return on investment. For small and medium sized construction companies, cost issues often become a major barrier to technology adoption [Low et al., 2011] [Succar, 2009]. The economic pressure faced by enterprises makes their decisions on BIM technology implementation more cautious, and clear return expectations are needed to support technology adoption.

2.2.3 Applicability of the Improved Framework

By adding the "personnel" and "economic" dimensions, the improved framework can more comprehensively analyze the barriers and decision making processes related to BIM technology adoption in the construction industry. The personnel dimension emphasizes the importance of technical personnel within the company. The economic dimension focuses on resource constrained SMEs, highlighting the significant impact of implementation costs and expected return on investment on their decision making. The improved framework not only applies to analyzing the barriers faced by small and medium sized construction companies but also provides precise theoretical guidance for the promotion of BIM technology [Zhao Kaili, 2023] [Liu Yuxin, 2023].

2.3 The Impact of Hainan Province's Specificities on BIM Technology Application and Research Directions

In the study of BIM (Building Information Modeling) technology, considering regional context is of vital importance, especially for specific regions such as Hainan Province. As an economic special zone in China, Hainan Province has unique geographical, cultural, policy, and developmental characteristics, which directly or indirectly influence the application and promotion of BIM technology. Therefore, this section will explore the impact of Hainan's specificities on BIM implementation, analyze the shortcomings of existing literature, and introduce the research content and improvements proposed in this study.

2.3.1 The Importance of Regional Context in BIM Research

The promotion and application of BIM technology are influenced by factors at multiple levels, with regional context being particularly prominent. Hainan Province, as a unique tropical island province, has distinctive social, economic, and policy environments. Firstly, Hainan faces issues such as the urban rural gap and insufficient infrastructure development in its rapid growth within the construction industry, making BIM technology highly potential for improving construction efficiency, quality, and management. Secondly, Hainan's government policies, such as promoting green development and digital transformation in the construction sector, have actively supported the application of BIM technology. Additionally, Hainan’s unique climate, environment, and natural conditions require more sustainable and energy efficient design and construction solutions, and BIM technology can provide strong support for these needs.

However, despite initial progress in promoting BIM technology in Hainan, the application of BIM in small and medium sized enterprises (SMEs) is still in its early stages due to limitations in economic development, industry awareness, and technical training. Therefore, studying the specific challenges and opportunities in BIM promotion within Hainan Province can provide theoretical support and practical guidance for optimizing BIM strategies in regional applications.

2.3.2 Limitations of Existing Literature

Although there is a wealth of international research on BIM technology application, studies focused on specific regions, particularly those with unique backgrounds like Hainan Province, are relatively scarce. Most existing literature concentrates on large economic zones or mature markets with fast urbanization processes, neglecting in depth analysis of local economic, policy, and cultural contexts. For instance, literature on Hainan's construction industry mainly focuses on the building market, infrastructure development, and green building, with a lack of systematic research on BIM technology applications locally. Many studies also fail to delve into the challenges faced by SMEs in BIM implementation, particularly how to overcome local resource shortages, technical deficiencies, and insufficient policy support.

Moreover, most existing studies focus on technological aspects, such as the development and optimization of BIM tools, while there is relatively little discussion on BIM technology management, cultural adaptation, and personnel training. These limitations have led to the neglect of regional background, restricting the generalizability and practical application of research outcomes. Therefore, to fill the research gap in BIM application within Hainan Province, the following areas need to be addressed: the specific challenges of BIM technology implementation in Hainan, the role of local government policies, the actual needs and issues of local construction enterprises, especially SMEs, and how to formulate more effective BIM implementation strategies based on the regional context of Hainan.

2.3.3 Research Content and Improvement Methods of This Study

Based on the limitations of existing literature, this study will focus on the specificities and challenges of BIM technology application in Hainan, particularly on how to promote BIM technology in small and medium sized construction enterprises. The main research content includes:

1.Analysis of BIM Implementation Status: Through a systematic literature review and semi structured expert interviews, analyze the key barriers to BIM implementation in Hainan’s small and medium sized construction industry.

2. Dimension Classification of Key Factors in BIM Implementation Based on the Improved TOE Framework: By adding the "personnel" and "economic" dimensions to the TOE framework, this study will help Hainan’s small and medium sized

construction enterprises better identify and understand the key factors in BIM implementation.

3. Proposing Improvement Measures: Based on the specific context of Hainan, this study will propose corresponding improvement measures, such as training and support policies for SMEs, the development of local BIM standards, and how to leverage Hainan's policy advantages to promote BIM technology application.

III. METHODOLOGY

3.1 Systematic Literature Review (SLR)

In recent years, research on BIM implementation in small and medium sized construction enterprises has attracted extensive attention from scholars both domestically and internationally. This paper uses the Systematic Literature Review (SLR) method to identify the key factors influencing BIM implementation in small and medium sized construction enterprises, aiming to build a comprehensive framework of BIM implementation factors. SLR is a scientific method for organizing and summarizing literature, which effectively avoids biases in literature selection and subjective interference【Kitchenham, B., & Charters, S., 2007】. The following is a research plan table (Table 1) for the key factors of BIM implementation in small and medium sized construction enterprises using the systematic literature review method, designed to clarify the research process and standardize the steps for data collection and analysis.

Table 1: Systematic Literature Review Research Plan for Key Factors of BIM Implementation

Main Part	Sub Part
3.1.1 Research Tools:	3.1.1.1 Systematic Review and Meta Analysis
	3.1.1.2 Meta Analysis in Systematic Review
	3.1.1.3 Adherence to PRISMA Guidelines
3.1.2 Database Search Strategy:	3.1.2.1 Database Selection
	3.1.2.2 Search Terms and Keywords
	3.1.2.3 Inclusion and Exclusion Criteria
3.1.3 Eligibility Criteria	————————
3.1.4 Risk of Bias	————————
3.1.5 Data Extraction and Study Quality Assessment	————————

***3
.1.1 Research Tools:***

3.1.1.1 Systematic Review and Meta Analysis: To assess the key factors for BIM implementation in small and medium sized construction enterprises, systematic review and meta analysis methods will be used. These methods will help evaluate the factors influencing BIM implementation from multiple perspectives and summarize its application effects in the industry. By synthesizing multiple existing studies, the advantages and challenges of BIM implementation will be evaluated, and potential key obstacles in the implementation process will be explored.

3.1.1.2 Meta Analysis in Systematic Review: In the systematic review, meta analysis will be combined to quantitatively assess the common trends and influencing factors across different research results. Through meta analysis, a quantitative basis for understanding the application of BIM technology in small and medium sized construction enterprises will be provided, helping to identify the most significant key factors in the implementation process.

3.1.1.3 Adherence to PRISMA Guidelines: This study strictly follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) guidelines to ensure that all steps in the systematic review and meta analysis process comply with international standards, enhancing the transparency and credibility of the research.

3.1.2 Database Search Strategy

3.1.2.1 Selection of Databases

Based on the following references, this study selects SCOPUS, Web of Science (WoS), and CNKI as the primary data sources for the following reasons:

1. Coverage and Authority of BIM Research : SCOPUS is considered the largest abstract and citation database of peer reviewed literature and high quality web sources globally. It offers innovative tracking, analysis, and visualization features, making it an ideal choice for literature retrieval in the BIM

field (Schotten et al., 2017; Martin Martin et al., 2021). SCOPUS has a broader literature coverage than PubMed, Web of Science, and Google Scholar (Martin Martin et al., 2021), which is why SCOPUS has been chosen as the primary literature database for this study.

2.Specificity of the Research Background : This study focuses on small and medium sized construction enterprises (SMEs) in Hainan, China. Given the specific nature of the research subject, CNKI, as the largest Chinese database, provides rich Chinese language resources, especially in the fields of construction and BIM applications, which have incomparable advantages (Shahruddin & Zairul, 2020). CNKI's literature coverage of domestic construction enterprises and their related technologies is particularly helpful in providing more localized and industry specific research data, thus filling the gaps left by international databases.

3.Ensuring the Rigorousness of the Research : Although SCOPUS offers greater coverage than PubMed, Web of Science, and Google Scholar, to ensure the comprehensiveness and rigor of the study, Web of Science (WoS) was also selected as a supplementary source, further extending the coverage of literature resources (Schotten et al., 2017). WoS is highly authoritative in both the quality and quantity of literature in the fields of construction and engineering, and its international academic influence makes it an ideal supplement for this research, ensuring both breadth and quality of the literature.

4.Limitations of the IEEE Xplore Database : After searching keywords in the IEEE Xplore database, no suitable reference materials were found. While IEEE Xplore has a strong coverage in the fields of electrical engineering, computer science, and technology, there is limited research on BIM applications and risk management in SMEs (Reza Samadzadeh et al., 2013). Therefore, IEEE Xplore was not selected as a database for this study.

5. Reason for Excluding ScienceDirect : Although ScienceDirect, as Elsevier's electronic platform, provides a large number of publications in the fields of science, technology, and medicine, and holds high academic influence in these areas, the core focus of this study is on small and medium sized construction enterprises, especially in BIM technology application and risk management. While ScienceDirect offers extensive coverage in technology and medical fields, its coverage in the construction sector, particularly in BIM applications and SMEs, is weaker, thus it was not selected as a database for this research.

In summary, SCOPUS, Web of Science, and CNKI were chosen as the primary data sources for this study to ensure comprehensive coverage of literature related to SMEs and BIM applications, while also considering the specific research background in Hainan, China. These databases will provide authoritative and extensive literature support for the study.

3.1.2.2 Search Strings and Keywords

The data collection process began with a comprehensive evaluation of BIM barriers in existing literature. The primary goal was to identify the key BIM barriers affecting small-scale construction projects. Moreover, the overall strategy was designed to identify the BIM barriers most commonly agreed upon by previous researchers, as critically assessing the current research is essential to draw any conclusions. Information was gathered from six different sources, including Springer, Web of Science (WOS), China National Knowledge Infrastructure (CNKI), Science Direct, Google Scholar, and Scopus, with the research timeframe kept between 2011 and 2024. We used various combinations of keywords for article searches and adjusted the flexibility of these keywords based on the overall theme of the study. We specifically looked for BIM barriers mentioned in prior publications, focusing on small-scale projects. Using all possible keyword combinations, we searched existing papers from the perspective of BIM barriers. The number of studies collected and the research findings from the aforementioned databases are summarized in Table 2.

Table 2 Summary of Database Keyword Search

Database	Search Keywords	Number of Publications	Total
SCOPUS	BIM or Building Information Modeling and SMEs or Small and Medium Enterprises	110	1793
WEB OF SCIENCE		103	
Science Direct		468	
Google scholar		846	
CNKI		20	
Springer		246	

3.1.2.3 Inclusion and Exclusion Criteria

To ensure the high relevance of the research topic and the scientific rigor of the included publications, this study developed a set of inclusion and exclusion criteria based on the PRISMA 2020 guidelines, as detailed in Table 3. The primary criterion is "Relevance to the Topic," which requires that the research focus on the key factors for the implementation of Building Information Modeling (BIM) in small and medium sized construction enterprises (SMEs), the challenges faced, and the barriers encountered. Given the relative scarcity of research in this field, especially with limited coverage in some databases, this criterion is further refined into the following three points:

(1) Analysis of the key factors for BIM implementation in small and medium sized construction enterprises;

(2) Specific applications of BIM in small and medium sized construction enterprises;

(3) Main challenges and barriers to implementing BIM in small and medium sized construction enterprises.

The second criterion is "Publication Type." According to this criterion, selected studies must be peer reviewed journal articles, and other types of publications will be excluded. Additionally, the languages of the included studies are Chinese and English, in order to accommodate the research background of Hainan, China, and cover a broader range of relevant literature.

To ensure the timeliness and alignment with the policy context of the research, the publication date range for selected articles is set from 2011 to 2024. This is because the "2011 2015 Development Plan for the Informatization of the Construction Industry," issued by the Chinese government on May 20, 2011, marked the gradual introduction of BIM technology into national policy, significantly influencing the development of the industry. Also, the literature available in the database began to increase significantly from 2010 onwards, providing abundant resources for this study.

Table 3. Inclusion and Exclusion Criteria

Criterion	**Inclusion**	**Exclusion**
Relevance to Topic	Key factors, challenges, and barriers in BIM implementation in SMEs	Irrelevant content
Publication Type	Peer reviewed journal articles	Non peer reviewed sources, conference papers, review papers, and academic reports
Language	English/Chinese	Non English/Non Chinese
Time Range	Between 2011 and 2024	Before 2011
Research Type	Quantitative and qualitative research	Irrelevant research types
Geographical Range	From any region	No relevant geographical limitation
Theses and issertations	No restrictions (published only)	Unpublished papers, theses, and dissertations
Non accessibility	Accessible through selected databases	Inaccessible literature
Open Access	Published in open access journals, or open access versions of articles in subscription based journals	Non open access literature

3.1.3 Eligibility Criteria

After importing an Excel spreadsheet containing 1,793 articles into Mendeley, the first step was to clean up duplicates and irrelevant articles. Subsequently, each article's content was initially assessed to determine its relevance to the research topics of BIM and small- and medium-sized construction enterprises. Upon further application of inclusion and exclusion criteria during the eligibility review, 66 articles were found to meet the study requirements. After a thorough full-text evaluation of the remaining articles, a total of 32 papers were finally deemed suitable for analysis, as detailed in Table 4.

Table 4: Literature Screening Results for BIM Implementation in Small and Medium Sized Construction Enterprises

Screening Stage	Description	Remaining Quantity
Duplicate Screening; Based on Inclusion and Exclusion Criteria	Removed duplicates found in different databases, such as articles included in both SCOPUS and Web of Science. See Table 2 for the inclusion and exclusion criteria.	66
Full Text Screening	After reading the full text, further removed articles whose content did not align with BIM implementation indicators.	32
Final Retention	Articles that met the research requirements.	32

3.1.4 Risk of Bias

To ensure the applicability of the studies selected for this review and to minimize any form of bias, this study used the ROBINS I (Risk of Bias in Non Randomized Studies of Interventions) tool. This tool is a rigorous quality assessment method specifically designed to evaluate the risk of bias in non randomized studies. In this study, bias assessment covered several areas, including confounding factors, selection bias, classification of interventions, deviations from intended interventions, missing data, measurement bias in outcomes, and bias in the selection of reported results. The specific content and process for these assessment areas are outlined in the steps listed in Table 5. The implementation of the ROBINS I tool is considered a key method to ensure the accuracy and reliability of the findings in this review, particularly when including non randomized studies (Stem et al., 2016).

Table 5: ROBINS-I Tool for Assessing Risk of Bias in Studies

ROBINS-I Domain	Assessment Content
Bias due to Confounding Factors	Does the study explicitly address the key factors and barriers in SMEs' BIM implementation, while considering potential confounding factors?
Selection Bias	Were the cases or participants from SMEs reasonably chosen to avoid selection bias?
Bias in Classification of Interventions	Is the study design appropriate for answering the research question about BIM implementation, thus avoiding potential bias in intervention classification?
Bias Due to Deviations from Intended Interventions	Were transparent and rigorous data collection and analysis methods adopted to minimize bias arising from deviations in intended BIM strategies?
Bias Due to Missing Data	Does the study provide sufficient details about BIM implementation to avoid bias due to missing data?
Bias in Measurement of Outcomes	Does the study adequately explain the level of BIM integration and implementation to reduce outcome measurement bias?
Bias in Selection of Reported Results	Were the key outcomes of BIM implementation reasonably selected and reported to avoid selective reporting bias?
Overall Risk of Bias	Were key factors across multiple domains that influence BIM implementation explicitly identified, and was the risk of bias comprehensively assessed?
Bias Due to Data Source	Are the data sources reliable enough to ensure the credibility of the study and reduce related bias?
Bias Due to Measurement Tools	Were effective indicators used to evaluate BIM implementation outcomes, minimizing bias related to measurement tools?
Bias Due to Sample Representativeness	Does the study sample represent SMEs adequately, reflecting the real situation of BIM implementation in SMEs and avoiding participant or case selection bias?
Bias Due to Statistical Methods	Were appropriate statistical methods used, considering the complexity of the study data and minimizing bias in statistical analysis?

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 6, Issue 1, Jan.-Feb, 2025 pp: 93-117 ISSN: 2584-2145 www.ijemh.com

3.1.5 Data Extraction and Research Quality Evaluation

To analyze the remaining articles listed in Table 6, this study adopted the thematic analysis method. Thematic analysis is a systematic procedure used to identify and analyze patterns or trends within a dataset. The process involves several stages.

First, researchers thoroughly read the literature multiple times to become familiar with the content and gradually develop an in-depth understanding of the data. Next, they generated initial codes to identify and classify significant features within the dataset. These initial codes were subsequently grouped into prospective themes, which represent broad patterns in the data. These themes were meticulously reviewed and refined to ensure logical consistency and alignment with the research questions.

In the final stage, each theme was accurately described and given a name that encapsulated its core essence. Researchers then composed a coherent report, organizing the research findings within a theoretical framework and supporting them with relevant examples extracted from the data. Throughout the process, potential biases were identified and addressed to ensure the credibility of the research.

Thematic analysis provides researchers with flexibility, allowing adjustments to the analytical approach according to different stages of the study and the characteristics of the data, thereby enhancing the quality and depth of the research (Dawadi, 2020; Weeras, 2022; Clarke, Braun, & Hayfield, 2015).

Through this analysis, the study defined primary and sub-themes related to the implementation, management, and risk mitigation of BIM in small and medium-sized construction enterprises, aimed at achieving higher sustainability goals. These themes include: key factors for BIM implementation, challenges faced, barriers in the implementation process, and how BIM technology enhances enterprise sustainability.

Table 6 Selected Studies Meeting the Inclusion Criteria

Authors	Date	Journal	Country
Hosseini, M.R., et al.	2016	Construction Economics and Building	Australia
Bamgbose, O.A., et al.	2024	Buildings	Nigeria
Murphy, B., et al.	2022	Proceedings of International Structural Engineering and Construction	Australia
Makarfi, U., & Udeaja, C.	2019	ARCOM 2019 Proceedings of the 35th Annual Conference	United Kingdom
Kouch, A.M., Illikainen, K., & Perälä, S.	2018	ISARC 2018 35th International Symposium on Automation and Robotics in Construction	Germany
Hong, Y., et al.	2020	Journal of Construction Engineering and Management	Australia
Lazaro Aleman, W., et al.	2020	ICITM 2020 29th International Conference on Industrial Technology and Management	Australia/ China
Rodgers, C., et al.	2015	ARCOM 2015	Australia
Saka, A.B., et al.	2020	Sustainability	Nigeria
Kouch, A.M.	2018	IFIP Advances in Information and Communication Technology	EU
Makabate, C.T., et al.	2022	Engineering, Construction and Architectural Management	United Kingdom
Saka, A.B., & Chan, D.W.M.	2020	Construction Innovation	Nigeria
Nguyen, M., et al.	2021	AIP Conference Proceedings	Vietnam
Vidalakis, C., Abanda, F.H., & Oti, A.H.	2020	Construction Innovation	United Kingdom
Hall, A.T., et al.	2023	Engineering, Construction and Architectural Management	New Zealand
Bakhary, N.A.	2023	Proceedings of the European Conference on Research Methods in Business and Management Studies	Malaysia
Thanh Pham, T.N., et al.	2020	Proceedings of the International Conference of Architectural Science Association	New Zealand

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 6, Issue 1, Jan.-Feb, 2025 pp: 93-117 ISSN: 2584-2145 www.ijemh.com

Authors	Date	Journal	Country
Mahmoud, B.B., et al.	2022	Buildings	Canada
Sarvari, H., et al.	2024	Architectural Engineering and Design Management	Iran
Awwad, K.A., et al.	2022	International Journal of Construction Management	United Kingdom
Pakinathan, M.S., et al.	2024	Lecture Notes in Civil Engineering	Malaysia
Li, P., et al.	2019	Advances in Civil Engineering	China
Saka, A.B., et al.	2024	Engineering, Construction and Architectural Management	Nigeria
Saka, A.B., & Chan, D.W.M.	2021	Engineering, Construction and Architectural Management	Review
Hong, Y., et al.	2020	Journal of Construction Engineering and Management	Australia
Yilmaz, G., et al.	2023	Computers in Industry	United Kingdom
Waqar, A., et al.	2023	Sustainability	Malaysia
Liu, H., et al.	2022	Journal of Environmental and Public Health	Hong Kong
Niu, Jiangrui, & Yang, Xiaonan	2023	Jiangxi Building Materials	China
Wang, Min, & Sun, Chengshuang	2020	Shanxi Architecture	China
Wang, Ziming, & Yuan, Chunyan	2020	Juyue (Housing Industry)	China
Fan, Yuncui, & Li, Xinhao	2022	Urban Building Space	China

3.2 Expert Interviews Design and Implementation

3.2.1 Expert Interview Design

Expert interviews are an important method for obtaining in depth qualitative information to support judgments and decisions by soliciting the opinions and experiences of experts in relevant fields. This study focuses on small and medium sized construction enterprises in Hainan Province, using semi structured interviews to identify the key influencing factors of BIM implementation and verify the dimensions of the improved TOE framework.

The core elements of the interview design include the following:

Research Objective : Based on the preliminary influencing factors selected from the literature review, these factors will be revised and improved, considering the specific characteristics of construction enterprises in Hainan, and the rationality of the dimension classification will be verified.

Interview Content : The interview outline is designed around five main categories of obstacles to BIM implementation (personnel, technology, organization, environment, and economics). The outline includes understanding of key BIM implementation barriers, the main issues faced in practice, solutions, and their impact on the BIM transformation of enterprises.

Interview Tool : A semi structured interview questionnaire based on the improved TOE framework (technology, organization, environment) will be developed. The questionnaire is divided into two parts: the first part focuses on the specific content of key barriers, and the second part addresses the classification of TOE dimensions and their applicability.

3.2.2 Expert Selection and Sample Size Determination

The expert sample selection is based on the principles of diversity and professionalism, ensuring that the interview results are representative and of reference value:

Expert Background : BIM practitioners from multiple departments in design consulting firms and construction enterprises will be invited, including technical leaders, department managers, and other senior management personnel.

Sample Size : Based on the sample size range suggested by Dworkin (2012) (5 to 50 people) and the minimum sample size recommended by Hesse Biber (2010) (10 people), and considering the

resources and objectives of this study, the interview subjects will consist of 12 industry experts.
Expert Distribution : The interviewees will be distributed across small and medium sized construction enterprises in Hainan Province, representing typical local BIM practices.

3.2.3 Expert Interview Implementation Steps

The interview process includes the following key steps:
(1) Preparation before the Interview :
1. Based on the literature review, select preliminary influencing factors, initially classify the TOE dimensions, and design a semi structured interview outline.
2. Determine the list of interview experts, contact relevant experts through industry associations and enterprises, send invitations, and clarify the research objectives and interview arrangements.
3. Develop an interview plan, arrange the interview format (teleconference or face to face communication) and timing, ensuring the smooth progress of the interviews.
(2) Interview Implementation :
1. Introduce the research background, objectives, and interview content to the experts, ensuring they understand the purpose of the interview.
2. Use the semi structured interview outline to guide experts in discussing key BIM implementation factors and the dimension classification of the TOE framework.
3. In response to expert feedback, further probe specific cases and experiences to obtain practice information with local characteristics of Hainan.
(3) Post Interview Processing :
1. Organize interview records and conduct preliminary analysis, extracting experts' specific descriptions of key BIM implementation factors and their opinions on dimension classification.
2. Compare and analyze with the results of the literature review, identify similarities and differences, and revise and improve the key factors list and framework dimension classification.
(4) Verification of Framework Improvement and Research Hypothesis with Literature Review
The literature review provides preliminary research findings on the key factors of BIM implementation, while expert interviews further revise and validate these results:
Verification and Improvement of Preliminary Factors : Expert interviews will specifically revise the BIM implementation barriers selected in the literature review, ensuring their applicability to the actual situation of small and medium sized construction enterprises in Hainan.
Verification of Framework Dimension Classification : Based on the improved TOE framework, verify whether the initially classified dimensions are comprehensive and reasonable, and adjust or refine the framework structure.
By combining the literature review with expert interviews in the research design, the study not only lays the theoretical foundation but also supplements and validates the framework and hypotheses from a practical perspective, improving the scientific and applicable value of the research results.

IV. RESULTS

4.1 Factor Frequency Statistics of BIM Implementation in Small and Medium-Sized Construction Enterprises

After the screening steps, a total of 32 relevant articles on the factors influencing BIM implementation in small and medium-sized construction enterprises were selected. Based on these 32 articles, factors related to the adoption or implementation of BIM in small and medium-sized construction enterprises were extracted. In indicator systems containing both primary and secondary indicators, the secondary indicators were mainly extracted; in indicator systems containing only primary indicators, only the primary indicators were extracted. A total of 84 influencing factors were ultimately extracted, forming the factor pool for BIM implementation in this study.

Through categorizing similar influencing factors, for example, "market demand for BIM (customers are not interested in using BIM)," "insufficient customer demand," and "small project scale with low demand for BIM technology" were categorized as "insufficient market demand for BIM"; "legal disputes and policy uncertainty," "unclear contractual responsibilities for inaccuracies in BIM models," and "lack of specific laws to resolve BIM-related disputes and legal issues" were categorized as "underdeveloped BIM legal system"; "lack of government support," "lack of local government funding," and "disadvantage in securing government funding" were categorized as "insufficient government support"; "high BIM training costs," "lack of funding support for proper BIM training," and "lack of investment in BIM experts" were categorized as "high BIM training costs"; "high BIM implementation costs," "expensive software and licenses," and "high facility investment with high costs for hardware upgrades" were categorized as "high initial investment costs for BIM implementation"; "interoperability risks between BIM-related software," "insufficient platform interoperability," "software incompatibility," and "software mismatch" were categorized as "poor compatibility of BIM-related software"; "lack of senior management support," "lack of leadership support," "insufficient cooperation among senior teams," and "indecisiveness of senior management" were categorized as "lack of senior management support."

In total, 70 factors that hinder BIM implementation in small and medium-sized construction enterprises were identified, and the number of citations for each factor was counted. Among these factors, 23 BIM implementation key factors were cited three times or more, as shown in Table 7 below.

Table 7: Statistical Table of Key Barriers Affecting BIM Implementation in Small and Medium Sized Construction Enterprises

Serial No.	Impact Factor	References	Frequency
1	Poor Compatibility of BIM Related Software	Bamgbose et al. (2024), Zhen et al. (2020), Hall et al. (2023), Basma Ben Mahmoud et al. (2022), Li Pengfei et al. (2019), Saka, A. B., & Chan, D. W. M. (2021), Koucha et al. (2018), Wang Ziming & Yuan Chunyan (2020)	8
2	Complexity and Difficulty of BIM Technology	Bamgbose et al. (2024), Ahsan Waqar et al. (2024), Niu Jiangrui & Yang Xiaonan (2023), Wang Ziming & Yuan Chunyan (2020), Saka et al. (2020)	5
3	Lack of Domestic BIM Software	Koucha et al. (2018), Basma Ben Mahmoud et al. (2022), Liu et al. (2022), Niu Jiangrui & Yang Xiaonan (2023), Wang Ziming & Yuan Chunyan (2020)	5
4	Poor Hardware Facilities	Bamgbose et al. (2024), Koucha et al. (2018), Wang Ziming & Yuan Chunyan (2020)	3
5	Reluctance or Resistance to Adopt BIM Technology	Bamgbose et al. (2024), Hosseini et al. (2016), Zhen et al. (2020), Basma Ben Mahmoud et al. (2022), Saka, A. B., & Chan, D. W. M. (2021), Niu Jiangrui & Yang Xiaonan (2023), Wang Min & Sun Chengshuang (2020), Liu et al. (2022)	8
6	Unreasonable Organizational Structure	Bamgbose et al. (2024), Zhen et al. (2020), Liu et al. (2022), Wang Min & Sun Chengshuang (2020), Li Pengfei et al. (2019), Niu Jiangrui & Yang Xiaonan (2023)	6
7	Lack of Support from Senior Management	Saka et al. (2020), Awwad et al. (2020), Saka, A. B., & Chan, D. W. M. (2021), Liu et al. (2022), Wang Ziming & Yuan Chunyan (2020), Sarvari et al. (2024)	6
8	Lack of BIM Workflow	Basma Ben Mahmoud et al. (2022), Ahsan Waqar et al. (2024), Wang Min & Sun Chengshuang (2020), Koucha et al. (2018)	4
9	Insufficient Awareness of BIM Benefits	Bamgbose et al. (2024), Awwad et al. (2020), Ahsan Waqar et al. (2024), Liu et al. (2022), Wang Ziming & Yuan Chunyan (2020)	4

Serial No.	Impact Factor	References	Frequency
10	High Initial Investment Cost for BIM Implementation	Hosseini et al. (2016), Bamgbose et al. (2024), Koucha et al. (2018), Hall et al. (2023), Hayat El Asri & Laila Benhlima (2023), Li Pengfei et al. (2019), Saka, A. B., & Chan, D. W. M. (2021), Hong et al. (2020), Ahsan Waqar et al. (2024), Liu et al. (2022), Niu Jiangrui & Yang Xiaonan (2023), Wang Ziming & Yuan Chunyan (2020)	12
11	High BIM Training Costs	Hosseini et al. (2016), Bamgbose et al. (2024), Koucha et al. (2018), Hayat El Asri & Laila Benhlima (2023), Li Pengfei et al. (2019), Liu et al. (2022)	6
12	Unclear Benefits of BIM Implementation	Hosseini et al. (2016), Bamgbose et al. (2024), Niu Jiangrui & Yang Xiaonan (2023)	3
13	Insufficient Market Demand for BIM	Hosseini et al. (2016), Bamgbose et al. (2024), Andrew Hall et al. (2023), Awwad et al. (2020), Li Pengfei et al. (2019), Saka, A. B., & Chan, D. W. M. (2021), Ahsan Waqar et al. (2024), Liu et al. (2022), Wang Min & Sun Chengshuang (2020)	8
14	Lack of BIM Implementation Standards	Hosseini et al. (2016), Bamgbose et al. (2024), Niu Jiangrui & Yang Xiaonan (2023), Wang Ziming & Yuan Chunyan (2020), Saka, A. B., & Chan, D. W. M. (2021), Wang Min & Sun Chengshuang (2020)	6
15	Insufficient Government Support	Bamgbose et al. (2024), Hall et al. (2023), Pakinathan et al. (2024), Liu et al. (2022), Niu Jiangrui & Yang Xiaonan (2023), Wang Min & Sun Chengshuang (2020)	6
16	Inadequate BIM Legal Framework	Bamgbose et al. (2024), Awwad et al. (2020), Li Pengfei et al. (2019), Saka, A. B., & Chan, D. W. M. (2021), Hong et al. (2020), Ahsan Waqar et al. (2024), Liu et al. (2022), Wang Ziming & Yuan Chunyan (2020)	7
17	Imbalanced BIM Technology Levels Among Stakeholders	Bamgbose et al. (2024), Zhen et al. (2020), Hayat El Asri & Laila Benhlima (2023), Ahsan Waqar et al. (2024), Wang Min & Sun Chengshuang (2020)	5
18	Lack of BIM Contract Standards	Basma Ben Mahmoud et al. (2022), Li Pengfei et al. (2019), Liu et al. (2022)	3
19	Insufficient Protection of BIM Intellectual Property	Bamgbose et al. (2024), Basma Ben Mahmoud et al. (2022), Li Pengfei et al. (2019)	3
20	Shortage of BIM Professional Technicians	Bamgbose et al. (2024), Hosseini et al. (2016), Pakinathan et al. (2024), Saka, A. B., & Chan, D. W. M. (2021), Ahsan Waqar et al. (2024), Liu et al. (2022), Wang Ziming & Yuan Chunyan (2020)	7
21	Lack of Interest in BIM Learning	Bamgbose et al. (2024), Niu Jiangrui & Yang Xiaonan (2023), Wang Min & Sun Chengshuang (2020), Liu et al. (2022)	4

Serial No.	Impact Factor	References	Frequency
22	Lack of BIM Expert Talent	Zhen et al. (2020), Hayat El Asri & Laila Benhlima (2023), Niu Jiangrui & Yang Xiaonan (2023), Pakinathan et al. (2024)	4
23	Lack of Systematic BIM Education and Training	Bamgbose et al. (2024), Ahsan Waqar et al. (2024), Koucha et al. (2018), Hayat El Asri & Laila Benhlima (2023), Awwad et al. (2020), Hong et al. (2020), Niu Jiangrui & Yang Xiaonan (2023)	6

4.2 Dimensional Classification of BIM Implementation Factors Based on the Improved TOE Framework

This study adopts the widely applied Technology-Organization-Environment (TOE) framework from the field of information technology, and further improves this framework by adding two new dimensions: Personnel and Economic. This enhancement makes the framework more suitable for analyzing the factors influencing BIM implementation in small and medium-sized construction enterprises (SMEs), which typically face challenges such as weak economic strength, relatively underdeveloped technical foundations, and limited resource allocation. Using this improved TOE framework, the factors influencing BIM implementation are classified into five dimensions: Technology, Organization, Economy, Personnel, and Environment.

The Technology Dimension reflects the technical infrastructure and support capabilities required for BIM application, including investments in infrastructure, hardware and software provisioning, and data management capabilities. Key factors in this dimension include BIM software and hardware compatibility, technological complexity, and imbalances in the technical capabilities of stakeholders. For SMEs, these challenges are particularly significant due to resource limitations and insufficient technological reserves. For example, many SMEs cannot afford expensive BIM software, and their existing hardware infrastructure is often inadequate to support BIM operations. Additionally, the technological complexity of BIM and issues related to cross-platform collaboration significantly increase the difficulty of implementation for these enterprises.

The Organization Dimension refers to a company's ability to adjust and optimize its attributes, structure, and culture to accommodate the needs of BIM applications. This includes reengineering workflows, rationalizing organizational structures, senior management support, and employee awareness and willingness to adopt BIM. SMEs face challenges in this dimension mainly due to the lack of specialized BIM implementation teams, weak organizational coordination, and a low willingness to accept new technologies. Given the limited resources of SMEs, management typically focuses more on short-term economic benefits, which leads to a lack of long-term planning and strong internal support for BIM adoption.

The Economic Dimension refers to the financial capabilities and constraints associated with BIM implementation, covering aspects such as initial investments, training costs, and expected economic benefits. For SMEs, high upfront costs (such as BIM software purchases, hardware upgrades, and employee training) often become the largest constraint. Furthermore, due to the limited short-term benefits of BIM implementation, SMEs find it difficult to attract external investment or obtain policy subsidies, further exacerbating their financial pressures.

The Personnel Dimension emphasizes the company's ability to attract, train, and manage talent for BIM application, including the supply of BIM professionals, systematic education and training, and the establishment of expert teams. SMEs are particularly disadvantaged in this dimension due to factors such as insufficient salary attractiveness, lack of a talent development system, and employees' lack of interest and initiative in learning. This limitation makes it difficult for SMEs to achieve the expected level of BIM implementation and management, further affecting the effectiveness of BIM promotion.

The Environment Dimension involves external environmental factors that affect the BIM implementation process, including industry standards, legal systems, government support, market demand, and intellectual property protection. SMEs are in a weak position in the external environment, particularly when facing an incomplete legal system, ambiguous industry standards, and insufficient government support, which significantly decreases their confidence and motivation to implement BIM. In addition, customer lack of awareness of BIM technology and limited market demand further weaken SMEs' competitiveness and willingness to adopt technological transformation.

The improved TOE framework provides a systematic analytical perspective for BIM implementation in SMEs, summarizing and integrating the key influencing factors from the five dimensions of technology, organization, economy, personnel, and environment (see Table 8). This framework not only helps comprehensively identify the main obstacles SMEs face in BIM implementation but also provides a scientific basis for developing targeted optimization strategies in the future.

Table 8: Key Barriers and Dimensions of BIM Implementation Based on the Expanded TOE Framework

Dimension	Specific Factors	Code
Technology Dimension	BIM software compatibility issues	TE01
	Complexity of BIM technology	TE02
	Lack of domestic BIM software	TE03
	Poor hardware facilities	TE04
	Imbalance in the BIM technical level among stakeholders	TE05
Economic Dimension	High upfront investment costs for BIM implementation	EC01
	High BIM training costs	EC02
	Unclear benefits of BIM implementation	EC03
Environmental Dimension	Insufficient market demand for BIM	EN01
	Lack of BIM implementation standards	EN02
	Insufficient government support	EN03
	Incomplete legal framework for BIM	EN04
	Lack of BIM contract standard documents	EN05
	Lack of intellectual property protection for BIM	EN06
Personnel Dimension	Lack of professional BIM technical personnel	PE01
	Lack of interest in learning BIM	PE02
	Shortage of BIM experts	PE03
	Insufficient systematic BIM education and training	PE04
Organizational Dimension	Unreasonable organizational structure	OR01
	Lack of top level support in the enterprise	OR02
	Lack of BIM workflow	OR03
	Insufficient awareness of the benefits of BIM	OR04
	Reluctance or resistance to adopt BIM technology	OR05

4.3 BIM Implementation Barriers Analysis and Improvement Based on Expert Interviews

In the semi-structured interviews conducted regarding BIM implementation barriers in small and medium-sized construction enterprises (SMEs) in Hainan Province, the research team designed a qualitative questionnaire covering five major categories of BIM implementation barriers: personnel, technology, organization, environment, and economy. The following data were obtained through the analysis:

1.Change "Lack of BIM Implementation Standards (EN02)" to "Lack of BIM Technical Implementation Cases"

The "BIM Technology Application Guidelines for Hainan Province" issued by the Hainan Provincial Department of Housing and Urban-Rural Development in 2022 clearly outlines the application points of BIM technology during the design, construction, and operation phases, as well as model delivery requirements. However, the document does not include specific implementation cases. For SMEs with weak technical foundations and limited time, typical cases are more intuitive and easier to understand than complex norms or standards. These cases can effectively lower the threshold for learning and applying BIM technology, thus helping to promote and popularize BIM technology.

2.Delete "Lack of BIM Intellectual Property Protection (EN06)", Retain "Incomplete BIM Legal System (EN04)"

Intellectual property protection, as an essential part of the legal system, is a specific manifestation of the "Incomplete BIM Legal System (EN04)." Deleting "Lack of BIM Intellectual Property Protection (EN06)" can avoid redundant expressions and instead incorporate this issue within the broader legal system improvement framework. This helps systematically address the legal barriers in BIM promotion, clarifies the rights and interests of all parties, reduces disputes caused by legal gaps, and creates a fairer and more transparent legal environment for the promotion of BIM technology.

3.Delete "Lack of BIM Expert-level Talent (PE03)", Retain "Lack of BIM Professional Technical Talent (PE01)"

SMEs typically undertake small or simple projects and their BIM needs are more focused on practical operational capabilities rather than expert-level guidance. Therefore, instead of emphasizing the scarcity of expert-level talent, it is more appropriate to focus on the development of professional technical talent to meet the actual needs of projects. This adjustment is more in line with the practical requirements of SMEs and helps promote the application of BIM technology in these enterprises, while improving their technical application capabilities.

4.Add "Lack of BIM Strategy in Enterprises" under the Organization Dimension

Although SMEs are smaller in scale and have limited technical resources, the lack of a clear BIM strategy will severely hinder the application and promotion of BIM technology. Formulating a clear BIM strategic plan can provide directional support for enterprises to learn and implement BIM technology, and offer long-term guarantees for enhancing their core competitiveness. This not only helps enterprises seize opportunities in industry transformation but also promotes sustainable development and enhances long-term competitiveness.

Based on the interview results, the BIM implementation barrier factors were further analyzed and improved, ultimately leading to the identification of 22 key influencing factors (see Table 9). The modified factors are more aligned with the actual needs of SMEs in Hainan Province and other regions, providing more targeted solutions and practical guidance for their implementation of BIM technology.

Table 9 Influencing Factors and Dimensions of BIM Implementation Based on the Improved TOE Framework

Dimension	Specific Influencing Factors	Code
Technical Dimension (TE)	BIM software compatibility issues	TE01
	Complexity of BIM technology	TE02
	Lack of domestic BIM software	TE03
	Poor hardware infrastructure	TE04
	Imbalanced BIM technology levels among stakeholders	TE05
Economic Dimension (EC)	High initial investment cost of BIM implementation	EC01
	High cost of BIM training	EC02
	Unclear benefits of BIM implementation	EC03
Environmental Dimension (EN)	Insufficient market demand for BIM	EN01
	Lack of BIM implementation cases	EN02
	Insufficient government support for BIM	EN03
	Underdeveloped BIM related legal framework	EN04
	Lack of standard BIM contract documents	EN05
Personnel Dimension (PE)	Lack of professional BIM technical personnel	PE01
	Low interest in learning BIM	PE02
	Lack of systematic BIM education and training	PE03

Dimension	Specific Influencing Factors	Code
Organizational Dimension (OR)	Unreasonable organizational structure	OR01
	Lack of support from senior management	OR02
	Absence of BIM workflows	OR03
	Insufficient awareness of BIM benefits	OR04
	Resistance or reluctance to adopt BIM	OR05
	Lack of corporate BIM strategy	OR06

To facilitate a clearer and more concise understanding of the key factors in BIM implementation, we have converted the 22 BIM implementation barriers in Table 5 into neutral terms and used them to create a framework diagram for BIM implementation in small and medium sized construction enterprises, as shown in Figure 1. The core aim of this adjustment is to replace "barrier" terms with "neutral" expressions. For example, "lack of enterprise BIM strategy" is changed to "enterprise BIM strategy," and "lack of support from enterprise leadership" is changed to "leadership support." This approach helps to view these factors from a positive perspective, making it easier to propose subsequent analysis and improvement measures.

V. DISCUSSION

As can be clearly seen from Table 7, the citation frequency of the 23 key factors ranges from 3 to 12 times. Based on the frequency of citations, these factors can be categorized into three levels of influence:

Level 1 Influence Factors:Cited 7 times or more, including 7 factors, representing the most influential and challenging core issues in the current literature.

Level 2 Influence Factors:Cited 5-6 times, including 8 factors, with a broad impact, but relatively limited depth.

Level 3 Influence Factors:Cited 3-4 times, including 8 factors, whose influence is limited to specific project phases.

Considering the results of the expert interviews and the importance of the enterprise's BIM strategy for the sustainable development of BIM implementation, it was placed as a Level 1 influence factor. Therefore, Table 10 is as follows.

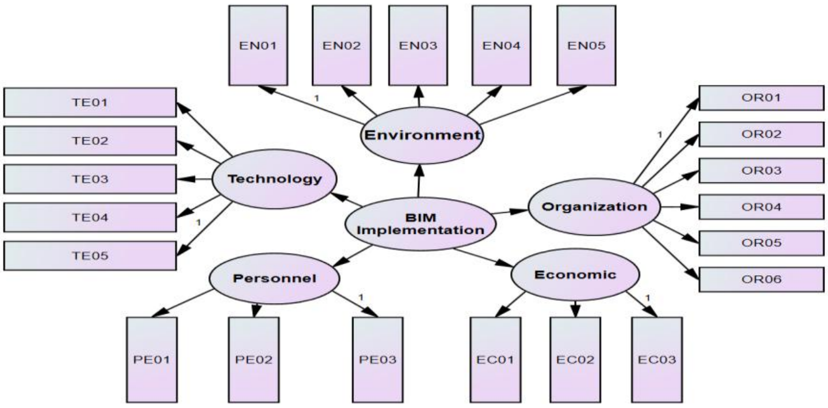

Figure 1: Key Factors Framework Influencing BIM Implementation Based on the improved TOE Framework

Table 10: Classification and Citation Frequency Statistics of BIM Implementation Influencing Factors

Influence Factor Level	Citation Frequency Range	Number of Factors	Specific Influence Factors
Level1 Influence Factors	7 times or more	8	High initial BIM implementation costs
			Insufficient market demand for BIM
			Poor compatibility of BIM-related software

Influence Factor Level	Citation Frequency Range	Number of Factors	Specific Influence Factors
			Reluctance to adopt or resistance to BIM technology
			Insufficient government support
			Incomplete BIM legal system
			Lack of BIM professional technical personnel
			Lack of enterprise BIM strategy (interview modification result)
Level2 Influence Factors	5-6 times	8	Complex and difficult BIM technology
			Lack of domestic BIM software
			Irregular organizational structure
			Lack of senior management support
			High BIM training costs
			Lack of BIM implementation cases (interview modification result)
			Imbalance in BIM technical levels among stakeholders
			Lack of systematic BIM education and training
Level3 Influence Factors	3-4 times	6	Lack of BIM workflows
			Insufficient awareness of BIM benefits
			Lack of interest in learning BIM
			Lack of BIM contract standard documents
			Unclear benefits of BIM implementation
			Poor hardware facilities

5.1 Discussion of Level 1 Influence Factors

The level 1 influence factors reveal the core challenges commonly faced by small and medium-sized construction enterprises (SMEs) in the process of BIM technology promotion. Considering the limited resources and weak risk resistance of SMEs, this article focuses on the following eight level 1 influence factors. Based on the improved TOE framework theory, these factors are discussed across five dimensions: technology, organization, economy, personnel, and environment. For detailed classification of the core level 1 influence factors for BIM implementation in SMEs, please refer to Table 11.

Table 11 Core Level 1 Influence Factors for BIM Implementation in Small and Medium-Sized Construction Enterprises

Dimension	Level1 Influence Factor	Description
Technology	Poor compatibility of BIM software	The diversity of enterprise software and hardware infrastructure leads to insufficient software compatibility, directly affecting the efficiency and scope of BIM implementation.
Organization	Reluctance to adopt or resistance to BIM technology	Low acceptance of new technology among management or employees due to concerns over cost, complexity, or transformation risks.
	Lack of a clear BIM strategy	The enterprise lacks clear BIM implementation goals and development plans, making resource allocation and action plans difficult to implement.

Dimension	Level1 Influence Factor	Description
Economy	High initial investment cost for BIM implementation	High initial costs (e.g., hardware, software purchases, employee training) exceed the economic capacity of small and medium-sized enterprises.
Personnel	Lack of BIM technical professionals	The enterprise lacks professionals with BIM skills, and the talent training mechanism is lagging, further limiting the spread of BIM.
Environment	Insufficient market demand for BIM	The market environment has not fully recognized the potential value of BIM, leading to weak demand and a lack of market-driven motivation for enterprises.
	Insufficient government support	Insufficient government policy guidance and subsidy support result in enterprises lacking necessary external support during the transformation process.
	Incomplete BIM legal system	The lack of clear regulations, standards, and legal support increases the complexity and risk of BIM implementation.

1. Technical Dimension: Poor BIM Software Compatibility

The application of BIM technology significantly enhances enterprise productivity, quality control, project schedule management, cost reduction, and risk mitigation. However, software compatibility issues are a critical barrier to its widespread adoption, especially in small and medium-sized enterprises (SMEs). These businesses often face limitations in technical resources, exacerbating compatibility issues. Specifically, the lack of compatibility between BIM software and traditional software (such as CAD) increases the complexity of data exchange. This not only reduces collaboration efficiency among project teams but also significantly raises collaboration costs, which diminishes the willingness of enterprises to adopt BIM technology. Therefore, solving the software compatibility problem is crucial for promoting BIM technology in SMEs.

Strategies: (1)Choose Highly Compatible Software:Prefer mainstream BIM software that supports multiple data formats to ensure smooth data exchange.(2)Develop Data Standards:Standardize the use of international formats (e.g., IFC) to reduce data conflicts.(3)Enhance Technical Training:Improve employees' ability to resolve compatibility issues and optimize operational efficiency.(4)Introduce Conversion Tools:Use data conversion plugins to reduce the complexity of format conversions.(6)Optimize Collaboration Processes:At the start of a project, unify the software plan and clarify the collaboration process.

2.Organizational Dimension: Reluctance to Adopt or Resist BIM Technology, Lack of BIM Strategy

Reluctance to Adopt or Resist BIM Technology:The acceptance of new technologies directly impacts the success of BIM technology implementation. SMEs, especially those with limited resources and insufficient technical reserves, are more likely to resist BIM. BIM implementation requires a long period and may not deliver immediate financial benefits, leading enterprise leaders and employees to question its efficacy. In local markets such as Hainan, the acceptance of technological innovation is low, and enterprises are often stuck in the inertia of traditional construction methods, exacerbating this issue.

Strategies:(1)Enhance BIM Technology Popularization Education and Training:Organize training courses and invite experts to increase employees' understanding of BIM technology and help them recognize the long-term benefits, gradually reducing resistance.(2)Short-term Incentives and Case Demonstrations:The government can provide financial subsidies or tax reductions to support early-stage BIM adoption and use successful case studies for demonstration. This can help dispel doubts and build trust in BIM technology.

Lack of BIM Strategy：Many SMEs lack a clear BIM strategy, without a comprehensive plan for the application and systematization of BIM technology. Especially in Hainan, where technical resources and management capabilities are relatively weak, enterprises often fail to establish long-term BIM strategies, leaving BIM adoption in a trial phase with limited depth and sustainability.

Strategies:Develop BIM Implementation Plans:Encourage enterprises to develop clear BIM strategies tailored to their business needs, covering

International Journal of Engineering, Management and Humanities (IJEMH)
Volume 6, Issue 1, Jan.-Feb, 2025 pp: 93-117 ISSN: 2584-2145 www.ijemh.com

aspects such as technology introduction, employee training, equipment investment, and specific goals for BIM application.

Integrate Resources and Policy Support : The Hainan government should provide policy support, such as tax incentives and financial subsidies, and offer technical and management guidance to help enterprises formulate effective BIM strategies.

3.Economic Dimension: High Initial Investment Costs for BIM Implementation

Implementing BIM technology requires significant upfront investments, including software procurement, hardware upgrades, and employee training. However, SMEs often struggle to bear these costs due to limited financial resources. Additionally, smaller project scales and longer return cycles further reduce their willingness to invest in BIM, creating a vicious cycle of "high investment - low returns - low adoption intent."

Strategies:The key to solving this issue is to reduce the initial cost burden, shorten the return cycle, and optimize the benefit distribution mechanism through policy support and industry collaboration, allowing enterprises to feel the benefits of BIM technology more quickly.

4.Personnel Dimension: Lack of BIM Professional Talent

Skilled personnel are the core drivers of BIM implementation. However, SMEs, due to salary and resource constraints, find it difficult to attract and cultivate high-level technical talent. Additionally, existing employees lack systematic training, limiting the effective implementation of BIM technology.

In Hainan, BIM talent is in short supply, and existing training mainly focuses on modeling skills, neglecting the integration of BIM with actual projects. This leads employees to perceive limited efficiency improvements from BIM technology. To address this, the following suggestions are made:

(1)University Training: Since there are few construction-related universities in Hainan, it is essential to offer BIM application courses, optimize course content, and establish training bases through "teaching + enterprise" partnerships, allowing students to enhance their BIM skills through practical experience. Moreover, building a team of BIM instructors with practical experience will improve teaching quality.

(2)Enterprise Training:Enterprises should popularize basic BIM knowledge and provide customized training for different positions. Frontline employees should focus on operational skills, while middle and senior management should emphasize project management training. Additionally, enterprises should conduct BIM skills assessments and hire experienced composite talent to enhance the BIM talent pool.

By fostering composite BIM talent through collaboration between universities and enterprises, the application of BIM technology in Hainan's construction industry can be effectively promoted.

5.Environmental Dimension: Insufficient Market Demand for BIM, Lack of Government Support, and Inadequate BIM Legal System

Market Demand Insufficient for BIM:SMEs heavily rely on the external market environment, and insufficient market demand directly affects their technological transformation motivation. Particularly in small projects, there are few mandatory BIM requirements, and clients lack awareness of BIM's benefits, making it difficult for enterprises to see direct returns from BIM applications, further suppressing their willingness to adopt it.

Strategies: Develop relevant policies, such as requiring government investment projects to mandate BIM technology usage, to promote its application in the local construction industry.

Evaluate enterprises implementing BIM technology and offer tax breaks or compensation based on the evaluation results, increasing their motivation for technological transformation.

Encourage enterprises to set up BIM engineer positions to further enhance professional capabilities and promote the widespread adoption of BIM technology.

Lack of Government Support: Government support plays a crucial role in technological transformation, but current government support for BIM promotion is mostly limited to advocacy, lacking substantial financial incentives (e.g., subsidies, tax reductions). This presents a significant constraint for SMEs with limited financial resources in Hainan, hindering the widespread application of BIM technology.

Strategies:Policies should be tailored to local realities, especially for SMEs in Hainan, which are relatively weak in terms of resources and technology. These policies should emphasize specific execution, encouraging enterprises to increase investment in digital technologies.

The government should increase financial subsidies, create tax incentives related to digital transformation, and promote investment in digital technologies to support industry upgrades.

Inadequate BIM Legal System :The lack of legal safeguards increases the uncertainty of BIM promotion, especially for SMEs in Hainan, which

face high collaboration risks due to the absence of standardized contracts and clear responsibility allocation. Additionally, intellectual property protection and data security laws are underdeveloped, making enterprises hesitant to adopt BIM. Although BIM application standards were issued in 2016, they fail to meet the actual project needs, necessitating the improvement of unified implementation standards.
Strategies:The government should collaborate with local enterprises, refer to experiences from developed countries, and establish BIM development plans tailored to Hainan. They should work on improving contract models and dispute resolution mechanisms to provide legal safeguards for BIM promotion.

5.2 Exploration of Secondary and Tertiary Influencing Factors

Secondary influencing factors primarily focus on technical complexity and organizational coordination issues. High technical complexity, the lack of domestic BIM software, unreasonable organizational structures, and uneven technical proficiency among stakeholders are significant barriers to the adoption of BIM by small and medium-sized enterprises (SMEs). While these factors have a broad impact, their depth of influence is not as substantial as that of primary factors.
Tertiary influencing factors mainly affect specific project stages on a localized level. Issues such as unclear implementation benefits, poor hardware infrastructure, and the absence of standardized contract documents do not significantly hinder overall adoption but still warrant attention in certain contexts.
The analysis above highlights that the main obstacles to BIM adoption among SMEs in Hainan Province lie in primary factors such as cost, market demand, technical adaptability, policy support, talent, and strategic planning. Addressing these primary factors as a priority will significantly enhance BIM adoption. Meanwhile, targeted optimization of secondary and tertiary factors will contribute to a more comprehensive improvement in the implementation capacity of enterprises.

VI. CONCLUSION

This study identifies and emphasizes the key factors influencing the sustainable adoption of BIM technology in small and medium-sized construction enterprises (SMEs) in Hainan, China. Through a structured literature review, 23 initial barriers were identified and systematically categorized into five dimensions using the improved TOE framework: technology, economics, organization, environment, and personnel.

The research further refined these barriers through expert interviews and NVIVO-based analysis, resulting in a final framework of 22 key factors tailored to SMEs. This framework bridges theoretical insights with practical challenges, offering a model specifically designed to address the unique needs of SMEs in Hainan’s construction industry.

The findings contribute to existing literature by highlighting region-specific barriers and providing actionable insights for overcoming them. For stakeholders, including SMEs and policymakers, the study offers evidence-based guidance for developing targeted solutions such as enhancing training, improving government support, and promoting BIM workflows. These efforts can lower adoption barriers and facilitate the effective integration of BIM technology in the region.

While this research focuses on Hainan, the insights gained have broader applicability. The framework can serve as a reference for SMEs in other regions facing similar challenges, offering a pathway for achieving digital transformation and enhancing project efficiency in the construction sector. Addressing these barriers will be critical to advancing BIM adoption and driving innovation across the industry.

VII. STUDY LIMITATIONS AND FUTURE DIRECTIONS

This study systematically reviewed, screened, and analyzed the influencing factors of BIM implementation through a literature review, categorizing them into dimensions based on the improved TOE framework and refining them through expert interviews. However, the study has several limitations:
1.Lack of Empirical Validation:
The identified factors and framework have not been empirically tested in real-world settings. Surveys, case studies, or quantitative analysis could provide empirical data to validate the importance and applicability of each factor.
2.Regional Context:
The study focuses on SMEs in Hainan Province, which may limit the generalizability of the findings to SMEs in other regions or countries with different technological, organizational, or environmental contexts.
3.Small Sample Size for Expert Interviews:
The expert interviews involved 12 participants, which, while sufficient for exploratory research, may not fully capture the diversity of challenges faced by

SMEs in the construction industry.

4.Reliance on Secondary Data:

The literature review was limited to English and Chinese publications from specific databases. This reliance may introduce biases or exclude relevant but unpublished or non-indexed studies.

5.Practical Applicability:

The framework provides theoretical insights but lacks immediate applicability due to the absence of real-world examples or implementation trials. Future studies could focus on testing the framework in SMEs through pilot programs or longitudinal studies.

Despite these limitations, the study provides a valuable foundation for understanding BIM implementation barriers in SMEs and offers a framework that can be refined and validated through future research.

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