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Key Elements And Improvement Strategies For BIM Implementation Capability In Small And Medium-Sized Construction Enterprises: A Case Study Of Hainan Province, China

Zhao Xiaochun[1,2]， Aidi Hizami Alias[3]

Faculty Of Engineering And Technology Infrastructure, Infrastructure University Kuala Lumpur
School Of Urban Construction, Hainan Vocational University Of Science And Technology,
Department Of Civil Engineering, Faculty Of Engineering, University Putra Malaysia

***Abstract*：**
Small and medium-sized construction enterprises play a crucial role in China's construction market, undertaking a significant number of projects. However, as the digital transformation of the construction industry accelerates, particularly with the widespread adoption of Building Information Modeling (BIM) technology, the potential competitive advantages of this key technology have yet to be fully explored and utilized by small and medium-sized construction enterprises. BIM technology spans the entire lifecycle of construction projects, including design, construction, operation, and maintenance. Despite significant progress in various fields, the global Architecture, Engineering, and Construction (AEC) industry still faces numerous challenges in BIM application due to insufficient BIM implementation capability at the enterprise level. Therefore, enhancing BIM implementation capability has become essential for AEC enterprises to achieve digital transformation and improve industry competitiveness.
Although the Chinese government and the Hainan provincial government have introduced multiple policies to promote the adoption and application of BIM technology, small and medium-sized construction enterprises still face various constraints in actual implementation. These include weak technical capabilities, a shortage of skilled professionals, outdated infrastructure, and insufficient financial investment, all of which significantly hinder the promotion and implementation of BIM technology. Based on this, this study focuses on the BIM implementation capability of small and medium-sized construction enterprises, aiming to identify key influencing factors and propose targeted enhancement strategies. Through a systematic review of 36 relevant studies and semi-structured interviews with 12 BIM managers, this research identifies 13 key BIM implementation capability factors. It further focuses on seven core factors, including BIM infrastructure development, clarity of BIM vision and objectives, completeness of BIM implementation standards and guidelines, soundness of the BIM training system, adaptability of organizational structure, execution capability of BIM personnel, and leadership of BIM technical directors, proposing optimization paths and practical strategies.
This study provides theoretical support and practical guidance for small and medium-sized construction enterprises to enhance their BIM implementation capability. Enterprises can leverage the BIM implementation capability enhancement framework proposed in this research, aligning it with their resource endowments to

formulate more precise and efficient development strategies, prioritizing key development goals under limited resource conditions. The research findings not only help small and medium-sized enterprises in Hainan, China, to fully understand the key components and optimization paths of BIM implementation capability, providing a scientific basis for their sustainable development, but also further promote the digital transformation process of the construction industry in Hainan and China as a whole.

Keywords: *BIM, BIM Capability, BIM Implementation, SMEs*

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I. Introduction

In recent years, the digital transformation of the global construction industry has been accelerating, with Building Information Modeling (BIM) emerging as a core technology driving industry transformation. BIM spans multiple stages, from design and construction to facility management, and has become a key tool for enhancing competitiveness due to its significant advantages in improving efficiency, optimizing resource allocation, and enhancing project quality. Yilmaz, Akcamete, and Demirors (2023) highlighted that although BIM adoption is expanding worldwide, there are significant differences in BIM capability levels and maturity across companies, particularly between enterprises of varying sizes and development stages. For instance, Abdallah et al. (2023) found that in public construction projects in Tanzania, BIM technology effectively addressed approximately 68% of major issues in the early project stages, underscoring its practical value in construction engineering.

In China, the digital transformation of the construction industry is at a critical juncture. However, from a broader perspective, approximately 46% of construction companies have yet to achieve process digitization, while around 50% of small and medium-sized enterprises (SMEs) still operate under traditional models, with only a small fraction proactively advancing digital transformation (Gong & Duan, 2022). Given the increasingly competitive market environment, BIM has become a crucial tool for improving management efficiency and economic benefits. However, compared to large construction firms with substantial financial and resource advantages, SMEs face numerous challenges in BIM implementation, such as limited awareness, a shortage of skilled professionals, and uncertainty regarding returns on BIM investment (Du, 2024). These factors significantly hinder SMEs from effectively adopting BIM, further widening the digital transformation gap between enterprises of different sizes. Jin et al. (2024) pointed out that under resource constraints, SME BIM adoption is influenced by a complex set of factors, highlighting the urgency and necessity of enhancing SMEs' BIM implementation capabilities.

It is worth noting that SMEs dominate China's construction industry, accounting for over 90% of enterprises and undertaking approximately 75% of construction projects (Fan & Li, 2022). Their digital transformation is not only crucial for their own sustainable development but also directly impacts the industry's overall technological advancement and market competitiveness. However, research indicates that SMEs significantly lag behind large firms in BIM adoption (Sun & Xu, 2022). Although SMEs possess certain advantages in flexibility and market adaptability, they face substantial shortcomings in technology adoption, talent development, and organizational capacity building, resulting in slow BIM implementation progress. Araujo and Alves (2024) further emphasized that simply introducing BIM technology is insufficient to ensure project success, particularly when companies lack a well-structured organization, adequate technical support, or a prepared design team. In such cases, BIM implementation may even be counterproductive. From a business perspective, enhancing SMEs' organizational BIM capabilities is not only crucial for strengthening their competitiveness but also for optimizing project management processes and driving high-quality industry development.

Given this background, this study focuses on identifying the key components of SMEs' BIM implementation capabilities, systematically analyzing their capability gaps, and exploring feasible enhancement strategies. This research aims to fill existing gaps in the literature and provide theoretical support and practical guidance for SMEs undergoing digital transformation.

To explore these issues in depth, this study will employ a systematic literature review and semi-structured interviews to address the following core research questions:

1. What are the key elements of SMEs' BIM implementation capabilities?
2. How can SMEs effectively enhance their BIM implementation capabilities?

The findings of this study will provide valuable insights for SMEs looking to optimize their BIM implementation capabilities while also serving as empirical evidence for policymakers and industry stakeholders in developing supportive policies for SMEs. Furthermore, the research outcomes will contribute to the digital transformation of China's construction industry, accelerate BIM adoption across the sector, and offer new perspectives and approaches for achieving high-quality industry development.

II. Literature Review

Classification and Definition of Enterprise BIM Implementation Capability

Enterprise BIM implementation capability refers to the comprehensive set of competencies an enterprise possesses in the application of Building Information Modeling (BIM) to achieve strategic objectives and enhance transformation value. The study by Rajabi et al. (2022) explored key criteria for evaluating organizational BIM capability, comparing cases in Malaysia and Iran. Their findings suggest that, despite slight variations across countries, these capabilities can be broadly categorized into two main dimensions: organizational BIM capability and organizational capability. Similarly, Munianday et al. (2022), through exploratory factor analysis, identified these same two dimensions and further demonstrated that organizational culture has a significant positive impact on both, while organizational competitiveness plays a crucial role in enhancing organizational capability.

Additionally, Rajabi et al. (2022) employed a Partial Least Squares Structural Equation Model (PLS-SEM) to analyze key factors influencing organizational BIM capability and related strategies. Their research examined the roles of BIM Capability Requirements (BIMCR) and Organizational Culture (OCU) in strengthening BIM implementation, providing theoretical support for the industry and facilitating more precise strategies for capability enhancement.

According to the *Enterprise BIM Implementation Capability Maturity Evaluation Standard*, issued by the China Engineering Construction Standardization Association in 2024, the key evaluation elements of enterprise BIM implementation capability include BIM strategy, organizational implementation capability, BIM personnel capability, and BIM resources. These elements can be further classified into two primary dimensions:

(1) Organizational BIM capability – encompassing BIM strategy, BIM personnel capability, and BIM resources.
(2) Organizational capability – focusing on enterprise-level resource integration and coordination.

Therefore, based on existing literature and Chinese standards, this study categorizes enterprise BIM implementation capability into these two dimensions:

(1) Organizational BIM capability, which emphasizes the professional application of BIM technology.
(2) Organizational capability, which focuses on internal resource integration and coordination.

By exploring these two dimensions, this study aims to comprehensively reveal the capability-building pathways and enhancement strategies for enterprises in BIM applications.

Organizational BIM Capability

Succar (2009) introduced the BIM Framework Theory, which defines BIM capability across strategic, managerial, and technical levels and advocates for a project-based BIM capability system to enhance the efficient application of BIM technology. Mahamadu et al. (2019) found that enterprise BIM implementation capability directly influences project delivery outcomes and emphasized the need to integrate both internal and external resources to achieve synergistic effects. Similarly, Mirhosseini et al. (2020) analyzed the relationship between leadership and team capabilities, further underscoring the role of organizational BIM capability in improving implementation efficiency.

Based on the aforementioned studies, organizational BIM capability is defined as an enterprise's specialized competency in deploying BIM technology, fostering team collaboration, and integrating resources for its application and promotion. Therefore, this study conceptualizes organizational BIM capability as an enterprise's dedicated ability to apply and promote BIM technology, covering key aspects such as:(1)BIM strategic planning,(2)BIM technology resource allocation, and (3)BIM team capability development.

Organizational Capability

Barney (1991) introduced the Resource-Based View (RBV), positing that organizational capability is a fundamental factor in transforming scarce resources into competitive advantages. Teece et al. (1997) later proposed the Dynamic Capability Theory, which highlights an organization's ability to adapt to technological, market, and environmental changes by dynamically restructuring resources. Furthermore, Lattuch & Hickey (2019) emphasized that in BIM transformation, organizational learning capability and cross-departmental collaboration play critical roles in driving technology adoption and innovation.

From these perspectives, organizational capability focuses on an enterprise's overall management proficiency and environmental adaptability, serving as a fundamental pillar of BIM implementation capability. Based on the theoretical and empirical literature, this study defines organizational capability as an enterprise's ability to achieve strategic objectives by effectively allocating and coordinating internal and external resources in a dynamic environment.

Summary

Organizational BIM capability and organizational capability complement each other and together form the core framework of enterprise BIM implementation capability, as illustrated in Figure 1. While organizational BIM capability focuses on the technical dimension and its deep application, organizational capability provides the necessary support mechanisms for effective integration of technology and environmental adaptation.

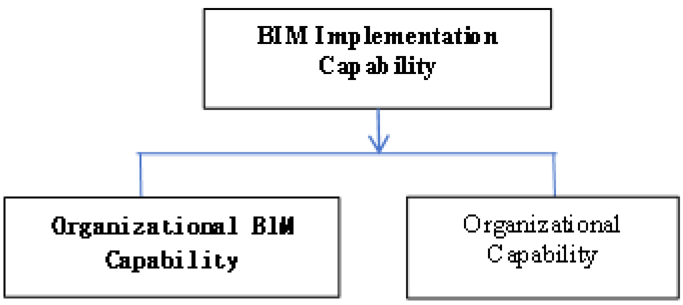

Figure 1. Dual-Dimensional Framework of Enterprise BIM Implementation Capability

Key Factors of BIM Implementation Capability in Small and Medium-Sized Construction Enterprises

In recent years, the application of Building Information Modeling (BIM) has rapidly expanded within the global construction industry. While numerous studies have explored BIM adoption in construction enterprises from the perspectives of organizational capability, technical capability, management mechanisms, and external environmental factors, research specifically focusing on BIM implementation capability in small and medium-sized enterprises (SMEs) remains relatively scarce. SMEs face unique challenges in adopting and implementing BIM, and the key factors influencing their BIM implementation capability have not been fully elucidated, necessitating further theoretical and practical research.

1. Organizational Capability and BIM Implementation

Organizational capability is one of the core factors influencing BIM implementation in small and medium-sized construction enterprises. Tong and Phung (2021), through 12 semi-structured interviews with Vietnamese design firms, BIM consultants, and design-build contractors, developed a framework comprising six key elements: strategy, organizational structure, processes, human resources, technology, and information management. These elements form the foundation of an organization's BIM implementation capability. Rajabi et al. (2022) conducted a systematic literature review and semi-structured interviews to identify 18 evaluation criteria. Their survey of BIM professionals in Malaysia and Iran revealed that corporate infrastructure, acceptance of new technologies, and a clear understanding of specialized fields are critical criteria. Additionally, Poirier et al. (2024) found that factors such as the enterprise's field of activity, BIM experience, organizational size, financial capacity, and geographic location are significantly associated with the level of BIM capability development.

2. Technical Capability and BIM Maturity

Technical capability is a crucial factor for successful BIM implementation. Wang and Feng (2022) found a positive correlation between the refinement of BIM technology, BIM processes, and BIM policies with BIM capability maturity. Similarly, Wang et al. (2020) constructed an evaluation index system covering technical, organizational management, and personnel dimensions, employing the interval entropy weight method to determine the weights, thereby identifying different levels of BIM application capability across enterprises. This study provided valuable support for improving BIM implementation strategies in construction enterprises. Furthermore, Mahamadu et al. (2017) pointed out that while the availability of software and hardware is a fundamental prerequisite for BIM implementation, its contribution to successful project delivery is less significant than that of BIM-related experience.

3. Organizational Culture and Competitiveness

Organizational culture and competitiveness have a significant impact on BIM implementation capability. Munianday et al. (2022) found that organizational culture positively influences BIM capability, while organizational competitiveness contributes to overall BIM capability enhancement. Additionally, Yusuf et al. (2022) examined the measures for enhancing BIM implementation capability in public-sector construction projects. Their findings indicated that establishing team-based structures, hiring adequate personnel, obtaining government support, adopting innovative processes, and investing in equipment and technology are essential measures for improving BIM capability. The study also emphasized the positive impact of performance incentive systems, employee training, and clear job descriptions on increasing BIM implementation efficiency.

4. Management Mechanisms and BIM Implementation

Effective management mechanisms are crucial for the successful implementation of BIM in small and medium-sized construction enterprises. Vigneshwar et al. (2022) analyzed BIM adoption in Indian construction projects and identified management support, technical capability, and personnel quality as the most critical factors in BIM implementation. Saghatforoush et al. (2021), through a systematic literature review and robust exploratory factor analysis, categorized 36 facilitating factors into four major groups: human skills, environmental factors, technical factors, and organizational factors. Their research indicated that government officials' support in verifying BIM adoption processes is a key organizational enabler. Additionally, Al-Mohammad et al. (2023) examined key factors influencing BIM implementation in Saudi Arabia’s construction industry, summarizing 14 critical factors across environmental, governmental, legal, and organizational domains.

5. The Role of Owner Organizations

Owner organizations play a pivotal role in ensuring the realization of BIM’s value. Pan et al. (2024) constructed a six-dimensional structural equation model, revealing the multidimensional nature of owner BIM capability. Their research found that process capability plays a central role in enhancing owner BIM capability, whereas technical capability is relatively less important. Therefore, project owners should focus more on organizational capability during BIM implementation rather than relying solely on technical capability.

6. Evaluation Systems and Key Criteria

Evaluation systems for BIM capability help enterprises identify their strengths and weaknesses, enabling them to develop targeted improvement strategies. According to the study *Key Criteria for Assessing Organizational BIM Capability* (2023), BIM capability evaluation primarily focuses on technical, economic, and managerial dimensions, emphasizing their critical role in enhancing construction project management efficiency. Ting Wang and Jingchun Feng (2022) reaffirmed that improvements in BIM technology, BIM processes, and BIM policies have a significant positive impact on BIM capability maturity.

Based on the above research, the BIM implementation capability of small and medium-sized construction enterprises is influenced by multiple factors, including organizational capability, technical competence, management mechanisms, external environment, and the role of owner organizations. Existing studies suggest that improving BIM implementation capability requires not only technical and infrastructure support but also the backing of a sound management system, organizational culture, and competitiveness. Additionally, the role of owner organizations should not be overlooked, as they play a crucial role in driving the realization of BIM value.

Strategies for Enhancing BIM Implementation Capability in Small and Medium-Sized Construction Enterprises

In the Architecture, Engineering, and Construction (AEC) sector, small and medium-sized construction enterprises (SMEs) often face multiple constraints in adopting Building Information Modeling (BIM) technology, including limited resources, talent, technology, and funding. To ensure the effective implementation of BIM throughout a project's lifecycle, existing research has proposed several key strategies from technological, organizational, managerial, and external environmental perspectives. Based on the findings of Ma et al. (2020), Munianday et al. (2022), Hasan et al. (2021), Nguyen et al. (2021), Li et al. (2019), and Gong & Duan (2022), the strategies for enhancing BIM implementation capability in SMEs can be summarized as follows.

Establishing Clear Implementation Plans and Goals to Strengthen the Technical Foundation

Ma et al. (2020) emphasized that formulating clear BIM implementation plans and goals is the primary prerequisite for ensuring successful BIM adoption. SMEs should focus on the following aspects:

Enhancing Technical Competence and Skill Development

SMEs should increase investment in BIM technology and continuously improve the professional capabilities of BIM modelers through systematic internal training and collaboration with external professional institutions (or by fully outsourcing BIM services). Hasan et al. (2021) highlighted that improving BIM modelers' capabilities not only enhances project design quality but also shortens design cycles and reduces costs, thereby positively impacting overall project efficiency.

Managing Engineering Information and Data

Effective BIM application requires high availability and interoperability of project data at all stages. SMEs should establish comprehensive data management systems to ensure efficient information sharing among project participants throughout the project lifecycle.

Securing Financial Support and Resource Integration

Adequate financial investment and cross-departmental resource integration are crucial for the successful implementation of BIM technology. SMEs should ensure sufficient funding allocation and collaborate across departments to overcome technical and financial constraints, thereby achieving synergy among multiple stakeholders (Ma et al., 2020).

Developing a Differentiation Strategy Focused on Core Competitiveness

Nguyen et al. (2021) suggested that while SMEs have limited resources, their flexibility and specialization often surpass those of large enterprises. SMEs can leverage BIM technology to enhance their core competencies through the following strategies:

Building High-Skilled BIM Human Resources and Technical Expertise

SMEs should cultivate an internal team with strong BIM expertise, continuously accumulating specialized technical know-how to establish proprietary technological advantages.

Enhancing Corporate Reputation and Industry Collaboration Networks

By engaging in BIM research projects and technical collaborations, SMEs can build stable industry networks, strengthening their brand reputation and market recognition in niche sectors.

Implementing Differentiation and Focus Strategies

SMEs can adopt differentiation and focus strategies in BIM strategic services, BIM application services, and specialized BIM market segments. This approach enables precise market positioning and enhances bargaining power in niche areas. Although economies of scale may limit cost-leadership strategies, SMEs can achieve diversified development and competitive advantage by integrating BIM services with other architectural consulting services.

Optimizing Organizational Governance and Strengthening Managerial Decision-Making

Organizational support is essential for successful BIM implementation. Munianday et al. (2022) highlighted that improving organizational BIM capability requires not only technical investment but also enhancements in governance structures, corporate culture, and managerial decision-making:

Institutional Governance and Adaptability to Change

SMEs should establish well-structured institutional frameworks to align BIM implementation goals with project objectives while optimizing internal management processes to accommodate technological transformation.

Fostering an Innovation-Driven Organizational Culture

Creating a positive corporate culture that encourages new technology adoption and dissemination can significantly enhance SMEs' overall competitiveness.

Managerial Decision-Making and Psychological Support

Managers play a critical role in BIM adoption decisions. Li et al. (2024) suggested that high perceived resource availability and expected performance benefits can enhance managers' willingness to adopt BIM, whereas risk concerns and limited awareness of commercial value may hinder adoption. Regular internal discussions, information sharing, positive incentive mechanisms, and well-structured risk management frameworks can enhance managerial confidence and facilitate BIM implementation.

Leveraging Policy Support, Industry Collaboration, and Digital Transformation

External environmental factors and policy frameworks also play a crucial role in BIM implementation for SMEs. Ma et al. (2020), Li et al. (2019), and Gong & Duan (2022) proposed the following strategies:

Government Policy Incentives and Regulatory Improvements

Governments should introduce favorable policies, provide special funding support, and establish unified BIM standards and legal frameworks to lower the adoption barriers for SMEs. Li et al. (2019) argued that optimizing the legal and regulatory environment can facilitate the promotion of integrated project delivery (IPD) models, thereby advancing BIM adoption.

Industry Collaboration and Resource Sharing

Large construction enterprises with experience in digital transformation can provide SMEs with reference models and collaboration platforms. Cross-enterprise and cross-regional cooperation can enable SMEs to share technical expertise and resources, helping them overcome resource constraints. Gong & Duan (2022) noted that when large enterprises and SMEs undergo digital transformation together, the former’s technological resources can drive the latter, creating strong synergy effects that accelerate SMEs' digitalization processes.

Cross-Industry Collaboration and Cloud-Based Solutions

Beyond traditional technology and resource sharing, researchers have emphasized the need for SMEs to enhance their understanding of BIM, promote integrated project delivery models, and adopt cloud-based solutions. Cloud platforms enable efficient data storage and sharing, providing SMEs with flexible, cost-effective technical support, thereby further facilitating their digital transformation and BIM application.

Research Gap and Positioning

As mentioned above, there is a lack of systematic research on the key factors affecting the BIM implementation capability of small and medium-sized construction enterprises (SMEs), and the strategies for effectively enhancing BIM implementation capabilities have not been fully explored. This is especially true for the Hainan region of China, where related research is even scarcer, and the specific challenges faced by SMEs in BIM application in this region have not been adequately considered. Therefore, this study aims to fill this research gap by systematically identifying the key factors influencing the BIM implementation capabilities of SMEs and exploring effective pathways to enhance BIM capabilities to accelerate digital transformation.

This study focuses on small and medium-sized construction enterprises in Hainan, deeply analyzing the core components of their BIM implementation capabilities and constructing a systematic framework for capacity enhancement strategies. The research results not only provide theoretical support for the in-depth application of BIM technology in the construction industry but also offer practical guidance for the digital transformation and sustainable development of SMEs. This can help them optimize BIM technology application under limited resources, improve market competitiveness, and address deficiencies in technological and managerial capabilities.

III. Methodology

Systematic Literature Review (SLR) Method

This study adopts the Systematic Literature Review (SLR) method to comprehensively review existing literature and generate a potential list of BIM implementation capability elements. First, comprehensive searches were conducted on existing construction management-related publications using the title/abstract/keywords search functions in databases such as Scopus, Web of Science, Google Scholar, and China National Knowledge Infrastructure (CNKI). The search keywords included “BIM capability,” “BIM maturity,” “BIM application capability,” and “BIM qualification,” with the search period set from 2010 to 2025. The language of the publications was limited to Chinese and English. Only articles that met the above criteria were included in the final search results.

Since the search results may include some literature that does not directly address BIM implementation capabilities (for example, some papers may mention "BIM capability" in the abstract but do not thoroughly discuss the relevant indicators), further screening was conducted to ensure the relevance and quality of the literature. The specific process is as follows:

(1) Duplicate Screening: Some articles may be included in multiple databases (such as WOS and Scopus). Therefore, duplicate entries were removed to ensure that the final results did not contain repeated literature.

(2) Abstract Screening: Some articles may include search keywords in the title or abstract but may not focus on BIM implementation capabilities, application capabilities, maturity, or qualification indicators. To address this, the abstracts were analyzed to identify the research objects, goals, and conclusions, selecting only those that truly fit the research topic.

(3) Full-Text Screening: The full text of the selected articles was read to further ensure the availability and relevance of the content.

(4) Reference Supplementary Screening: In the selected articles, their reference lists were reviewed to supplement any missing high-relevance literature, ensuring the comprehensiveness of the search as much as possible.

Through these steps, a high-quality and representative BIM implementation capability-related literature database was established, laying a solid foundation for subsequent analysis.

Semi-structured Expert Interview Method

Based on the literature review, the initial BIM implementation capability factors were identified, but many factors were still numerous, and some of them had unclear primary and secondary relationships or overlapping content, making them unsuitable for direct adoption. Therefore, to further optimize the BIM implementation capability factors for small and medium-sized construction enterprises, this study conducted a round of interviews using expert questionnaires, focusing on the following aspects: whether the expression of BIM implementation capability factors is reasonable, whether they need to be added, deleted, or adjusted, and how to optimize the classification and integration of each indicator.

Expert Interview Design

Expert interviews are an important qualitative research method aimed at soliciting the opinions and experiences of domain experts to gain in-depth information that supports judgments and decision-making. This study focuses on small and medium-sized construction enterprises in Hainan Province, adopting a semi-structured interview format to explore and verify the key elements of BIM implementation capability.

The core elements of the interview design include:
(1) Research Objective: Based on the preliminary BIM implementation capability factors identified in the literature review, and in consideration of the industry characteristics of construction enterprises in Hainan, revise, improve, and verify the rationality of their dimensional divisions.
(2) Interview Content: Focused on the core aspects of BIM implementation capability, with a particular emphasis on organizational BIM capability and organizational capacity, designing the interview outline accordingly.

Expert Selection and Sample Size Determination

To ensure the representativeness and reference value of the interview results, this study followed the principles of diversity and professionalism in selecting experts with extensive BIM practical experience.
(1) Expert Background: The interviewees came from different departments of design consulting and construction companies, including technical directors, department managers, and other senior management, ensuring a range of professional perspectives.
(2) Sample Size: Referring to the interview sample size recommendations by Dworkin (2012) (5 to 50 people) and the minimum sample size suggested by Hesse-Biber (2010) (10 people), and considering the research objectives and available resources, a total of 12 industry experts were selected as interviewees.
(3) Expert Distribution: All interviewed experts were from small and medium-sized construction enterprises in Hainan Province, providing a comprehensive reflection of the typical BIM practices in the region.

Implementation Steps of Expert Interviews

The interview process is divided into the following key steps:
(1) Preparation before the Interview
1)Based on the literature review, preliminarily select BIM implementation capability influencing factors and develop a semi-structured interview outline.
2)Contact experts through industry associations and enterprises, finalize interviewees, send formal invitations, and clarify the research objectives and interview arrangements.
3)Design the interview plan, including interview format (telephone or face-to-face) and schedule to ensure smooth execution.

(2) Conducting the Interview

1)Before starting the interview, introduce the research background, objectives, and interview content to the interviewee, ensuring they fully understand the purpose of the interview.

2)Using the semi-structured interview outline, guide the experts to discuss the BIM implementation capability factors and their classifications in depth.

3)Based on the expert feedback, ask follow-up questions regarding specific cases and practical experiences to ensure the research content is both theoretically valuable and practically applicable

(3) Post-interview Processing

1) Organize the interview records and conduct preliminary analysis, extracting specific suggestions from the experts regarding the key BIM implementation capability factors and optimization of the classification framework.

2) Compare the interview results with the literature review content to identify similarities and differences, and adjust and refine the key factors and framework dimensions accordingly.

(4) Verification of Interview Results and Adjustment of Research Hypotheses

This study combines the dual verification mechanism of literature review and expert interviews to ensure the scientific and practical applicability of the research framework:

1)Verification and Optimization of Key Factors: Through expert interviews, optimize the BIM implementation capability factors selected in the literature review to ensure they align with the actual situation of small and medium-sized construction enterprises in Hainan Province.

2)Adjustment of Framework and Research Hypotheses: Evaluate the feedback from interviews and adjust the research hypotheses to better meet the practical needs of BIM transformation in enterprises.

By combining the literature review and expert interviews, this study not only consolidates the theoretical framework of BIM implementation capability but also supplements and verifies it from a practical perspective, thereby enhancing the scientific and practical value of the research findings.

IV. Results

BIM Implementation Capability Elements Based on Systematic Literature Review

This study conducted a rigorous selection of the retrieved literature and ultimately selected 36 articles related to BIM implementation capability indicators. Based on these 36 articles, the study extracted content related to BIM capability, application capability, technical capability, maturity, and qualification indicators. For indicator systems containing both primary and secondary indicators, the secondary indicators were primarily extracted; for systems with only primary indicators, the primary indicators were directly extracted. In total, over 305 BIM implementation capability elements were extracted, forming the BIM implementation capability element database, which was summarized in an Excel table for word frequency analysis.

The word frequency analysis of BIM implementation capability elements was mainly based on the relevant indicators mentioned in the literature. To enhance the scientific rigor and accuracy of the categorization, three professors in the field of construction management were invited to merge the initial list of indicators, integrating variables with the same or similar meanings, and ensuring the professionalism of all terms to eliminate ambiguous expressions. This helped improve the rigor and consistency of the indicator system. For example, "BIM software coverage of specialties," "software support," and "software capability" were merged into "the number of specialties covered by BIM software"; "completeness of the BIM training system," "BIM training education," and "education and training of practitioners" were merged into "the completeness of the

BIM training system within the enterprise"; "rationality of organizational structure" and "fit between organizational structure and enterprise" were merged into "the adaptability of the organizational structure." After statistical organization, 18 key BIM implementation capability elements were selected, each appearing in at least three references (see Table 1).

Table 1: Frequency Statistics of BIM Implementation Capability Elements

Serial No.	Element	References	Frequency
1	Number of specialties covered by BIM software	Qiu Qi (2022), Yu Xiaoming (2017), Mahamadu et al. (2019), Succar et al. (2012), Wang et al. (2019), Mahamadu et al. (2019), Wang Yufang (2022), Chen Yonghong (2019), Wang Tianwei, Li Xiangdong (2018), Han Haikun (2020), Wang (2021), Zhang Jiarui (2023), Messner, J., & Kreider, R. (2013)	13
2	Completeness of hardware configuration	Qiu Qi (2022), Yu Xiaoming (2017), Mahamadu et al. (2019), Succar et al. (2012), Wang et al. (2019), Mahamadu et al. (2019), Wang Yufang (2022), Chen Yonghong (2019), Wang Tianwei, Li Xiangdong (2018), Han Haikun (2020), Wang (2021), Zhang Jiarui (2023), Messner, J., & Kreider, R. (2013)	13
3	Richness and reliability of BIM data	Qiu Qi (2022), Han Haikun (2020), Ailing Wang (2021), Zhang Jiarui (2023), Li Hao (2022)	5
4	Completeness of work processes	Qiu Qi (2022), Wang Tianwei, Li Xiangdong (2018), Messner, J., & Kreider, R. (2013)	3
5	Completeness of BIM training system	Qiu Qi (2022), Yu Xiaoming (2017), Chen Yonghong (2019), Wang Tianwei, Li Xiangdong (2018), Han Haikun (2020), Ailing Wang (2021), Messner, J., & Kreider, R. (2013)	7
6	Richness of employees' BIM experience	Qiu Qi (2022), Interviews, Succar et al. (2013), Mahamadu et al. (2019), Mahamadu et al. (2017), Wang Yufang (2022), Ailing Wang (2021)	7
7	Adaptability of organizational structure	Qiu Qi (2022), Zou Huining (2022), Wang Tianwei, Li Xiangdong (2018), Han Haikun (2020), Li Hao (2022), Messner, J., & Kreider, R. (2013)	7
8	Appropriateness of BIM talent allocation	Qiu Qi (2022), Yu Xiaoming (2017), Wang Tianwei, Li Xiangdong (2018), Han Haikun (2020), Giel, B., & Issa, R. R. A. (2014)	5
9	Research capability	Qiu Qi (2022), Yu Xiaoming (2017), Succar et al. (2013), Chen Yonghong (2019), Han Haikun (2020), Zhang Jiarui (2023)	5
10	Completeness of BIM implementation standards and guidelines	Qiu Qi (2022), Yu Xiaoming (2017), Mahamadu et al. (2019), Mahamadu et al. (2017), McCuen et al. (2012), Wang (2021), Li Hao (2022), Messner, J., & Kreider, R. (2013)	9
11	BIM vision and goals	Qiu Qi (2022), Yu Xiaoming (2017), Succar et al. (2013), Zou Huining (2022), Chen Yonghong (2019), Han Haikun (2020), Wang (2021), Zhang Jiarui (2023), Messner, J., & Kreider, R. (2013), Giel, B., & Issa, R. R. A. (2014)	10
1	Member support	Qiu Qi (2022), Interviews, Succar et al. (2013), Mirhosseini et	4

Serial No.	Element	References	Frequency
2		al. (2020), Succar et al. (2012)	
13	Secondary development capability of BIM software	Wang Tianwei, Li Xiangdong (2018), Ailing Wang (2021)	3
14	Sufficient resources for BIM implementation	Succar et al. (2013), Mahamadu et al. (2019), Succar et al. (2012), Mahamadu et al. (2017), Mahamadu et al. (2019), Ahuja et al. (2018), Giel, B., & Issa, R. R. A. (2014)	7
15	Good historical performance in BIM implementation	Mahamadu et al. (2019), Mahamadu et al. (2017), Mahamadu et al. (2019)	3
16	Specific roles for employees in the company	McCuen et al. (2012), Chen Yonghong (2019), Wang (2021), Messner, J., & Kreider, R. (2013)	4
17	Standard performance benchmarks in the company	Succar et al. (2013), Succar et al. (2012), Mahamadu et al. (2017)	3
18	Positive attitude towards new technologies in the company	Ahuja et al. (2020), Lattuch and Hickey (2019), Wang (2021)	3

Key Elements of BIM Implementation Capability Based on Semi-Structured Expert Interviews

In the semi-structured interviews conducted on the key elements of BIM implementation capability for small and medium-sized construction enterprises in Hainan Province, the research team designed a qualitative questionnaire covering two major categories of BIM implementation capability dimensions: organizational BIM capabilities and organizational capabilities. Based on feedback from expert interviews, experts provided suggestions for merging, adjusting, and supplementing some elements to further optimize the BIM implementation capabilities of small and medium-sized construction enterprises, improving the scientificity and applicability of element classification. The specific optimizations are as follows:

Merging "Number of Software Specialties Covered" and "Completeness of Hardware Configuration" into "Infrastructure Required for BIM Implementation"

Expert Reasoning: The infrastructure required for BIM implementation covers various aspects, including the public data environment built by the enterprise, BIM software purchased or self-developed, computers and related hardware configurations, network resources, and supporting tools. Due to financial and business scale limitations, small and medium-sized construction enterprises generally do not fully equip all high-end devices but instead make refined configurations based on business needs. Therefore, merging these elements into "Infrastructure Required for BIM Implementation" better reflects the actual situation of small and medium-sized enterprises and highlights the critical role of infrastructure in the BIM implementation process.

Merging "Employee BIM Experience Richness" and "Suitability of BIM Talent Allocation" into "BIM Personnel Execution Capability"

Expert Reasoning: The practical execution capability of BIM personnel is an important indicator of an enterprise's BIM implementation ability. In addition to holding corresponding BIM certification, BIM talent must have practical project experience and be able to execute BIM strategies efficiently on the job. For small and medium-sized construction enterprises, due to resource and staff scale limitations, it is often not possible to build a large BIM team, so existing personnel are required to have higher execution capabilities in BIM applications and match the business needs of the enterprise. After merging, "BIM Personnel Execution Capability" can more comprehensively reflect the rationality of personnel allocation and their practical capabilities.

Adding "Leadership of BIM Technology Leader"

Expert Reasoning: In small and medium-sized construction enterprises, the promotion of BIM technology often depends on the core management personnel. The BIM technology leader plays a key role in formulating the enterprise's BIM strategy, team collaboration, and resource allocation. Their leadership directly affects the depth and breadth of BIM application within the enterprise, including team execution capability, cross-departmental collaboration, and the implementation of BIM projects. Therefore, adding this indicator can more accurately assess the organizational capabilities of BIM implementation within the enterprise.

Removing "BIM-related Responsibilities and Roles" and "Company Assigning Specific Roles to Employees"

Expert Reasoning: BIM-related responsibilities and roles are already included in the enterprise's organizational structure, and during BIM implementation, enterprises usually adjust job responsibilities flexibly based on their own situations. Particularly for small and medium-sized construction enterprises, the BIM team is often cross-functional, with members performing multiple roles. Therefore, listing these indicators separately is unnecessary. Removing them reduces redundancy and improves the simplicity and operability of the element system.

Merging "Research Capabilities" and "BIM Software Secondary Development Capability" into "Organizational Innovation and R&D Strength"

Expert Reasoning: In small and medium-sized construction enterprises, the core goal of research and technological innovation is to enhance the enterprise's market competitiveness and project execution efficiency. However, compared to large construction enterprises with independent R&D departments, small and medium-sized enterprises' R&D activities are typically more targeted and focused on technical optimization and innovation based on business needs. BIM software secondary development capability is part of the enterprise's technological innovation, while research capabilities encompass the enterprise's ability to learn, digest, and apply new technologies. Given the limited resources in small enterprises, their innovation often relies on external technology introduction and internal optimization rather than independent development of a new BIM system. Therefore, merging "Research Capabilities" and "BIM Software Secondary Development Capability" into "Organizational Innovation and R&D Strength" better aligns with the practical situation of small and medium-sized construction enterprises and more comprehensively measures the enterprise's comprehensive capabilities in BIM technology application and innovation.

Merging "Company's Positive Attitude Towards New Technologies" and "Member Support" into "Company-wide Member Support"

Expert Reasoning: In small and medium-sized construction enterprises, the success of BIM technology promotion and application depends not only on the management's attitude but also on the actual execution by employees. The company's attitude toward new technologies is often reflected in management's decision-making support, financial investment, and training arrangements, while member support reflects the employees' acceptance of BIM technology, willingness to learn, and practical ability. However, in small construction enterprises, the management's attitude toward technology and the employees' execution ability are not independent but are interrelated. If the management recognizes and promotes BIM applications, employees are more likely to accept and actively participate. Conversely, if management support is insufficient, employees will find it difficult to form the motivation to apply the technology. Therefore, merging them into "Company-wide Member Support" better reflects the overall recognition and execution of BIM from top to bottom within the enterprise, avoiding the separation of management and employee support, and aligning with the characteristics of small and medium-sized enterprises' BIM implementation, where "top-down linkage and collaborative promotion" is crucial.

In addition, the promotion and application of BIM not only depend on software development but also on optimization and innovation based on existing technologies, such as customizing BIM parameters, developing plugins to suit specific business processes, and integrating other management systems. Therefore, "Organizational Innovation and R&D Strength" can more accurately reflect the overall ability of small and medium-sized construction enterprises in BIM application innovation, rather than being limited to software development or research capabilities alone.

Based on the definitions and understandings of organizational BIM capabilities and organizational capabilities, experts have revised the 13 key BIM implementation elements, classifying them into dimensions as shown in Figure 1. Elements such as the infrastructure required for BIM implementation, the completeness of the enterprise's BIM training system, the completeness of BIM implementation standards and guidelines, BIM vision and goals, BIM personnel execution capability, BIM data richness and reliability, and the leadership of the BIM technology leader fall under the category of organizational BIM capabilities. Elements like the applicability of organizational structure, the completeness of work processes, company-wide member support, the existence of a standard performance benchmark, the company's good history in BIM implementation, and organizational innovation and R&D strength fall under the category of organizational capabilities. The detailed explanations of each key element are presented in Table 2.

This revision based on the interview further integrates the actual situation of small and medium-sized construction enterprises, optimizing the original element classification and supplementing the core influencing factors of BIM implementation in enterprises, making the BIM implementation capability system clearer and more reasonable.

Table 2: Key BIM Implementation Capabilities Based on Semi-Structured Expert Interviews

Serial No.	Dimension	Key Element	Explanation	Frequency
1	Organizational BIM Ability	Company possesses necessary infrastructure for BIM	Includes public data environment, BIM software (purchased or developed by the company), hardware (computers and related	13

Serial No.	Dimension	Key Element	Explanation	Frequency
		implementation	equipment), network resources, and tools.	
2		Company has a comprehensive BIM training system	Promotes capability improvement centered on BIM technology innovation, scientifically trains BIM talents based on demand, and establishes a scientific talent evaluation mechanism.	7
3		Completeness of BIM implementation standards and guidelines	Self-developed BIM standards, specifications, and guidelines that comply with national regulations and meet BIM strategic and management needs.	9
4		BIM vision and goals	Develop clear, executable, and flexible BIM strategic development plans as an important part of the company's strategy.	10
5		BIM personnel execution capability	Possess relevant BIM certificates and experience, with the ability to execute BIM strategies; the proportion of staff holding professional certificates meets the job requirements.	7
6		BIM data richness and reliability	Emphasizes the comprehensiveness and accuracy of BIM data, ensuring that project management and decisions are based on reliable data.	5
7		Leadership of BIM technology leader	The person in charge has BIM qualifications and relevant experience, plays a core role in decision-making and management, and has the leadership ability to implement BIM strategies.	Recommended by experts
8	Organizational Ability	The company has a good history of BIM implementation	Emphasizes the company's accumulated experience and successful cases in BIM implementation, providing support and guarantees for future projects.	3
9		Applicability of organizational structure	Institutional arrangements and operational mechanisms for the BIM department setup, positions, responsibilities, authorities, workflows, and related requirements in the company.	7

Serial No.	Dimension	Key Element	Explanation	Frequency
10		Completeness of work processes	Refers to whether the company's BIM implementation processes are standardized and effective, ensuring smooth operation from planning to execution.	3
11		Company members' support level	Includes the support level of both management and all employees for BIM implementation, with management support being crucial to drive resource allocation and decision execution.	3
12		The company has a standard performance benchmark	Develop performance plans, implement performance management, conduct evaluations, and feedback for improvement in a cyclical management process to enhance overall BIM performance.	3
13		Organizational innovation and R&D capabilities	Refers to the company's innovation in BIM technology and secondary development capabilities, able to customize and optimize BIM software based on demands to improve project efficiency.	5

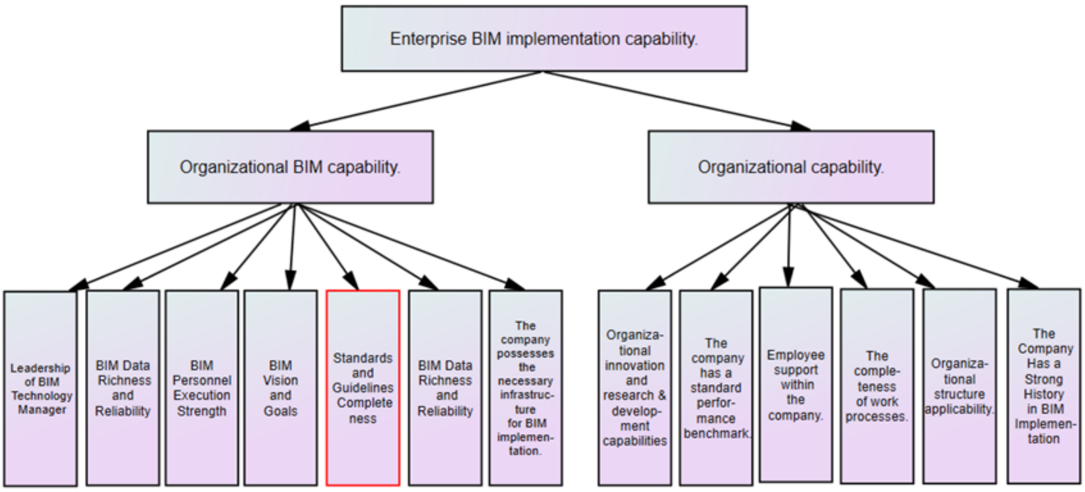

Figure 2: Key BIM Implementation Capabilities for Small and Medium-Sized Construction Enterprises

V. Discussion

Through a systematic literature review and frequency statistical analysis of the key elements of BIM implementation capabilities, the results show that six key elements appeared seven times or more. Ranked from highest to lowest frequency, they are: the company possessing the infrastructure required for BIM implementation, BIM vision and goals, the completeness of BIM implementation standards and guidelines, the completeness of the BIM training system, the applicability of the organizational structure, and the execution strength of BIM personnel. Additionally, experts unanimously believe that "leadership of the BIM technology manager" plays a crucial role in BIM implementation. Therefore, this paper will focus on the above seven core elements of BIM implementation capabilities and propose specific strategies to enhance BIM implementation capabilities for small and medium-sized construction enterprises based on their actual situation.

Company Possessing the Infrastructure Required for BIM Implementation

The effective implementation of BIM relies on solid infrastructure support, including public data environments (ECDE), BIM software (purchased or self-developed), computers and related hardware, network resources, and supporting tools. However, small and medium-sized construction enterprises often face challenges in terms of funding, technological accumulation, and resource integration. Therefore, they need to develop strategies that suit their own development to enhance BIM implementation capabilities, optimize resource allocation, and improve BIM application efficiency. Based on the characteristics of small and medium-sized construction enterprises, this paper proposes the following optimization strategies:

1.Gradually Improve BIM Software, Hardware, and Network Environment

(1) Prioritize Purchasing Core BIM Software and Control Costs Reasonably: Due to limited funding, small enterprises can prioritize purchasing cost-effective BIM software with high functionality integration, such as software that includes modeling, collaborative management, and construction simulation features, to reduce investment costs and improve efficiency. For some high-end BIM applications, a leasing model or shared resources with partners can be adopted to reduce initial investment pressure.

(2) Optimize Hardware Configuration and Reduce Equipment Costs: Traditional BIM applications rely heavily on high-end computer equipment. Small and medium-sized enterprises can reduce the demand for high-performance hardware through cloud and edge computing technologies. For example, using cloud-based BIM modeling and storage can reduce the configuration requirements for local servers and workstations. At the same time, GPUs, storage devices, etc., should be reasonably configured to ensure smooth BIM operations while optimizing investment costs.

(3) Establish an Efficient and Stable Network Environment to Improve Data Transfer Efficiency: Adopt a combination of local area network + cloud storage to improve the access efficiency of BIM data in the enterprise. For example, using private clouds or enterprise-level NAS storage systems can ensure data security while improving data collaboration capabilities across multiple teams and projects, thereby enhancing the overall efficiency of the BIM workflow.

2.Promote the Construction of an Enterprise-Level Public Data Environment (ECDE)

(1) Build a Centrally Managed BIM Data Storage Platform: Small and medium-sized enterprises can build an enterprise-level BIM database or cloud-based data management platform based on their business needs, centralizing the storage, management, and sharing of BIM data, ensuring that project teams can quickly access and retrieve historical data, thereby improving work efficiency.

(2) Enhance BIM Data Standardization Management to Avoid Information Silos: Develop internal BIM data management regulations, unify data formats and categorization methods, ensure the reusability of data across projects, and reduce issues caused by incompatible data leading to repeated modeling. This will improve the consistency and sharing of BIM data across the enterprise.

(3) Strengthen Cross-Department Data Collaboration to Improve Project Management Efficiency: Use the ECDE platform to integrate design, construction, and operation phases, enabling real-time data updates. For

example, construction teams can directly access the latest BIM design files, avoiding construction errors caused by data delays or version conflicts, thereby improving overall project management efficiency.

2.Strengthen BIM Resource Security Management and Reduce Data Risks

(1) Establish a BIM Data Security Guarantee System to Prevent Data Leaks: Small and medium-sized enterprises should formulate security strategies such as access control, data backup, and encrypted transmission to address potential data security risks. For example, a multi-level access control mechanism should be implemented to ensure that different roles can only access data within their authorized scope, preventing sensitive information from being leaked.

(2) Conduct Regular BIM Data Security Training to Raise Data Protection Awareness: Organize data security training for enterprise managers and BIM technical teams to enhance their understanding of data privacy protection, compliance management, and other aspects, ensuring that data security management systems are properly executed.

3.Improve BIM Resource Localization and Efficient Application Capability

(1) Promote Domestic BIM Software to Reduce Enterprise Dependency: In recent years, BIM software development in China has rapidly advanced, with increasingly complete features. Small and medium-sized enterprises can prioritize using domestic BIM solutions in line with national policy guidance, gradually reducing their dependence on imported software, enhancing enterprise autonomy, and reducing long-term usage costs.

(2) Use Intelligent BIM Tools to Improve Work Efficiency: Based on the actual needs of the enterprise, introduce intelligent BIM plugins and tools, such as automated quantity takeoff, intelligent clash detection, AI-assisted optimization, etc., to improve the application efficiency of BIM, reduce the workload of manual modeling and data processing, and further enhance the overall effectiveness of BIM work within the enterprise.

4.Establish BIM Resource Management Mechanisms to Ensure Long-Term Sustainable Development

(1) Formulate BIM Resource Management Regulations and Optimize Software and Hardware Usage: Establish a management system for BIM resource allocation, updates, and maintenance, and define software license management, hardware upgrade plans, and network resource optimization, ensuring that BIM resources are utilized effectively and continuously updated and optimized.

(2) Clarify BIM Management Responsibilities to Ensure Stable BIM Operations: Designate responsible personnel for BIM resource management to ensure that all BIM software, hardware, data storage, and network resources remain operational. For example, a BIM technical support team should be established to resolve issues that arise during BIM application and enhance the stability of BIM implementation.

(3) Promote BIM Resource Sharing to Improve Return on Investment: Through an internal resource-sharing mechanism across projects, encourage departments and project teams to share BIM software, hardware, and data resources, avoid redundant investment, and improve the utilization efficiency of BIM resources.

For small and medium-sized construction enterprises, the construction of BIM infrastructure must balance investment costs, technical adaptability, and long-term development. Enterprises should plan BIM software and hardware, optimize data management, strengthen security measures, and fully utilize localized software and intelligent tools within the constraints of limited resources. By improving infrastructure and establishing a sound BIM resource management mechanism, small and medium-sized construction enterprises can enhance BIM application efficiency while controlling costs, laying a solid foundation for their digital transformation.

BIM Vision and Goals and the Completeness of BIM Implementation Standards and Guidelines

The BIM vision and goals of an enterprise determine the direction of BIM technology promotion, while the completeness of BIM implementation standards and guidelines directly impacts the effectiveness of its application. Together, these two elements form the enterprise's BIM strategy, playing a core supportive role in the long-term development of BIM. However, small and medium-sized construction enterprises (SMEs) often face challenges such as limited funding, insufficient technological reserves, and imperfect management systems, making it difficult for them to replicate the BIM practices of large enterprises. Therefore, formulating a practical, flexible, and detailed BIM strategy is crucial to enhancing BIM implementation capabilities.

1. Develop a Practical and Feasible BIM Strategy
(1) Based on the enterprise's development needs, create short-term (1-3 years) and long-term (3-5 years) BIM development plans to ensure clear goals and feasible execution, avoiding blind imitation or resource waste.
(2) Focus on BIM applications in design optimization, cost control, and construction management to make precise investments and improve ROI (Return on Investment).
(3) Adjust strategies flexibly according to industry trends to maintain adaptability and avoid falling into BIM implementation difficulties due to market changes or policy adjustments.

2. Optimize the BIM Strategy Implementation Mechanism
(1) Create concise and efficient BIM management documents, such as standard operating procedures (SOPs) and job responsibility lists, to avoid increased execution difficulties due to excessive documentation.
(2) Adopt a "small steps, fast pace" strategy by initially implementing BIM in pilot projects, gradually accumulating experience, and then expanding, reducing implementation risks and increasing success rates.
(3) Establish a BIM implementation evaluation mechanism, regularly summarize experiences, and form reusable implementation templates to reduce trial-and-error costs and enhance the sustainability of BIM applications.

3. Standardize Enterprise BIM Standards and Reduce Technical Barriers
(1) Develop simplified and practical BIM application standards based on national standards and the enterprise's actual needs, ensuring both compliance and operability.
(2) Prioritize the use of open-source or domestic BIM software to reduce technical barriers and maintenance costs, while also reducing dependence on foreign software.
(3) Establish a standardized BIM data management system to increase data reusability, reduce redundant modeling, and improve collaboration efficiency.

4. Promote Refined BIM Applications to Increase Practical Value
(1) Focus on construction management, cost control, and quality monitoring to ensure that BIM truly addresses production pain points, avoiding "formalistic BIM."
(2) Fully leverage government policies and industry association support, applying for special subsidies and technical support to reduce the economic burden of BIM implementation.
(3) Use the "external training + internal mentorship" model, offering short-term external training to quickly enhance technical capabilities, while also cultivating internal BIM talents to reduce long-term reliance on external experts.

5. Strengthen Industry Cooperation and Integrate BIM Resources
(1) Collaborate with BIM consulting firms, universities, and other partners to compensate for technical shortcomings and reduce trial-and-error costs using external professional resources.
(2) Share BIM databases and component libraries to improve modeling efficiency, reduce redundant labor costs, and enhance project implementation efficiency.
(3) Participate in the formulation of industry BIM standards to improve the enterprise's industry influence in BIM and enhance competitiveness.

Small and medium-sized construction enterprises should focus on practical strategies, lightweight management, precise applications, and resource integration when formulating BIM implementation strategies that align with their development needs. By planning properly, optimizing implementation mechanisms, standardizing processes, advancing refined applications, and strengthening industry cooperation, these enterprises can not only reduce BIM implementation costs but also increase the practical benefits of BIM, thereby driving digital transformation and achieving sustainable development.

BIM Training System Completeness, BIM Personnel Execution, and BIM Technical Leader's Leadership

The capability of BIM personnel is a core factor in the success of BIM implementation in construction enterprises, encompassing the completeness of the BIM training system, the execution ability of BIM personnel, and the leadership of the BIM technical leader. A comprehensive BIM training system provides systematic and targeted training for BIM personnel, improving their skill levels and shortening the BIM technology implementation cycle. The execution ability of BIM personnel ensures that the BIM team can efficiently complete BIM tasks and achieve project goals. The leadership of the BIM technical leader, under limited resources, formulates reasonable BIM development strategies to promote the implementation and upgrade of BIM technologies in the enterprise. These three aspects interact and promote each other, collectively determining the maturity of the enterprise's BIM capabilities. To address challenges faced by small and medium-sized construction enterprises during BIM implementation, such as talent shortages, insufficient training investment, and imperfect management mechanisms, the following strategies can help enterprises enhance their BIM implementation capabilities and improve the professional level and execution of BIM teams:

1. Strengthening the Leadership of the BIM Technical Leader

BIM technical leaders in small and medium-sized construction enterprises often hold multiple roles, with limited BIM management skills and decision-making influence, and lack industry certification.
(1) Prioritize selecting personnel with BIM management experience as the BIM technical leader: Develop BIM core personnel within the existing management team to ensure that the technical leader has both management capabilities and a BIM technical background.
(2) Enhance the professional abilities of the BIM technical leader: Encourage and fund technical leaders to obtain advanced BIM certifications and relevant professional titles to increase their decision-making power within the enterprise.
(3) Optimize the positioning of the BIM technical leader: Assign them a core role in the implementation of the enterprise's BIM strategy, ensuring their participation in BIM planning, decision-making, and resource allocation to enhance the stability of the enterprise's BIM development.

2. Improving BIM Personnel Execution

There is a shortage of professional BIM talent, and small enterprises often struggle to attract high-end talent. Additionally, BIM teams may lack experience, and job-role matching is insufficient.

(1) Flexibly allocate BIM personnel and optimize job-role matching: Allocate BIM personnel based on project needs, using a combination of “core teams + external experts” to ensure that BIM implementation capabilities match project requirements.
(2) Encourage current employees to obtain BIM certifications and improve execution: Provide internal training and certification incentives. The company can collaborate with online courses or universities and training organizations to encourage employees to obtain intermediate and advanced BIM certifications, improving the overall skill level. Establish a certification reward system to provide subsidies or promotion incentives to employees who obtain BIM certifications, thus increasing their learning motivation. Develop a BIM talent pool and optimize personnel reserves by managing employees who already hold BIM certifications, ensuring that project teams have sufficient BIM talent support.

3. Promoting the Development of a BIM Talent Training System

Small and medium-sized enterprises often lack a systematic BIM talent training mechanism, have limited training resources, and face high risks of talent attrition.
(1) Build an internal BIM training system: Develop a BIM talent training plan based on the actual needs of the enterprise and align the training content with project requirements to enhance BIM practical abilities. Adopt a “project-driven training” model where employees learn by engaging in real BIM projects to improve their skills through practice. Rely on industry resources, collaborate with universities, research institutions, and industry associations to obtain external training support.
(2) Establish a scientific talent evaluation and promotion mechanism: Incorporate the performance of employees in BIM projects into evaluations to ensure that talent assessment criteria align with the enterprise’s BIM development goals.
(3) Set up a BIM career development channel: Develop career development plans for different positions, such as BIM engineers, BIM modelers, and BIM managers, to improve talent retention.

Small and medium-sized enterprises face challenges such as talent shortages, limited funds, and imperfect training systems during BIM implementation. Therefore, they need to adopt a strategy of “core team development + external cooperation support + flexible incentive mechanisms” to enhance BIM personnel capabilities. By strengthening the leadership of BIM technical leaders, optimizing BIM personnel allocation, establishing a training system, introducing flexible talent cooperation models, and improving team collaboration mechanisms, small and medium-sized enterprises can effectively improve BIM implementation capabilities and provide talent support for the successful implementation of their BIM strategy.

Suitability of Organizational Structure

The following strategies for enhancing BIM implementation capabilities in small and medium-sized construction enterprises fully consider the characteristics of limited resources, high flexibility, and sensitivity to market changes:
1. Optimize Organizational Structure and Management Mechanism
(1) Streamlined and Efficient Structure: Small and medium-sized construction enterprises should establish a streamlined and efficient BIM organizational structure based on their scale and business characteristics. Define the roles and responsibilities of BIM departments clearly to avoid redundancy and ensure that each position adds maximum value. For example, key positions such as BIM manager, BIM modeler, and BIM application engineer can be set up, with clear collaboration relationships between these roles.
(2) Flexible Management Mechanism: Establish a flexible organizational management mechanism to ensure smooth communication and efficient decision-making during BIM implementation. Given the limited resources

in small and medium-sized enterprises, the focus should be on the practicality of mechanism documents, avoiding overly complex processes. For example, a regular project meeting system can be adopted to promptly address issues that arise during BIM implementation.

(3) Incentives and Training: Implement incentive measures to encourage employees to actively engage in BIM technology learning and application. Given the relatively small size of small and medium-sized enterprises, internal training, external learning exchanges, and other methods can be used to enhance employees' BIM skill levels. For example, a reward mechanism for BIM technology application can be established, offering material and mental incentives to employees who perform outstandingly in BIM projects.

Discussion of Other BIM Implementation Capability Factors

1. The company has a standard performance benchmark

Enterprises should establish clear BIM performance goals to ensure alignment with the overall corporate strategy. Small and medium-sized construction companies can break down BIM performance goals into specific projects and roles, ensuring that every employee understands their work objectives. In addition, a continuous performance improvement mechanism should be established to regularly assess and optimize the BIM implementation process. Due to the relatively flexible decision-making process in small and medium-sized enterprises, BIM implementation strategies can be quickly adjusted based on assessment results. Finally, it is important to encourage all employees to participate in BIM performance management, enhancing employee engagement and participation through performance assessments and feedback mechanisms. Internal training and team-building activities can help strengthen employees' understanding and recognition of BIM performance management.

2. Cultivating Organizational Innovation Capabilities

(1) Innovation Culture: Foster a corporate culture that encourages innovation and stimulates employees' creative awareness. Small and medium-sized construction enterprises can encourage employees to propose new BIM application ideas and methods through internal competitions and innovation rewards.

(2) Technology Integration: Actively explore the integration of BIM technology with other emerging technologies, such as VR, drones, etc. Small and medium-sized construction enterprises can leverage their flexibility to quickly experiment with new technologies and identify new business growth opportunities.

(3) Industry-Academia-Research Cooperation: Strengthen industry-academia-research collaborations with universities and research institutions to enhance the company's innovation capabilities. Through cooperative projects, small and medium-sized construction enterprises can introduce advanced technologies and concepts to improve their BIM technology levels.

3. Employee Support for the Company

Employees in small enterprises often lack sufficient knowledge of BIM and lack motivation to apply it. Senior management may not have a strong willingness to invest in BIM, often only responding to policy or market pressures. Information barriers exist between departments, leading to a lack of collaboration awareness.

Improvement Strategies:

(1) Senior Leadership Drive, Enhancing BIM Strategic Buy-In: Management should establish a clear BIM vision, set specific BIM development goals, and advocate the value of BIM in improving project costs, efficiency, and competitiveness within the company.

(2) Establish BIM Incentive Mechanisms: Implement performance evaluations and bonuses, such as rewarding

teams that successfully apply BIM in engineering projects.
(3) Tiered Training to Improve BIM Skills: Offer targeted BIM training for different levels (management, technical staff, construction personnel) to lower the entry barrier and improve overall acceptance.
(4) BIM Pilot Projects to Promote Full Participation: Select small projects as pilot projects, develop a step-by-step implementation plan, and help departments recognize the advantages of BIM through practice.

4. Completeness of Work Processes

Small and medium-sized construction enterprises often face issues such as the lack of standardized BIM processes, leading to chaos and disorder during implementation. Internal team division is unclear, resulting in poor information handoff; data from construction, design, and operation stages are isolated, lacking unified coordination.

Improvement Strategies:
(1) Establish BIM Standardized Processes: Develop BIM implementation standards that suit the company's specific needs (e.g., modeling standards, data storage rules).
(2) Introduce BIM Collaborative Platforms: Use tools like BIM 360, Revit, etc., to optimize data transmission among teams and reduce communication loss.
(3) Implement Clear BIM Role Definitions: Define roles such as BIM Manager, Modeling Personnel, and Construction Coordinator to ensure smooth process execution.
(4) Create a "BIM+" Management Model: Combine BIM with project management, cost control, and schedule management to form a visualized workflow, improving overall efficiency.

5. The Company Has a Good History in BIM Implementation

Small and medium-sized construction enterprises may have some past BIM project experience, but due to team turnover and technological iteration, this knowledge is difficult to pass on. Successful cases have not been systematically summarized, making it difficult to leverage existing results for new projects. Some companies have attempted BIM, but failed due to improper implementation or high costs, which may affect confidence in subsequent applications.

Improvement Strategies:
(1) Establish a BIM Knowledge Base: Collect internal successful BIM case studies, technical challenges, and solutions, creating reference documents for future use.
(2) Build a BIM Expert Team: Form a professional BIM team through internal training and external recruitment, enhancing technical accumulation and application promotion.
(3) Organize Experience Sharing Sessions: Regularly invite team members from successful BIM projects to share their experiences, enhancing the overall team's capabilities.
(4) Use a "Small Steps, Fast Pace" Strategy to Gradually Deepen BIM Application: Start from basic modeling and gradually move to more advanced applications (such as collision detection, schedule simulation, etc.), reducing implementation difficulty and improving acceptance.

6. BIM Data Richness and Reliability

Due to unstable data sources, a lack of unified data management mechanisms, and hardware and software limitations, data storage and sharing become challenging for small and medium-sized construction enterprises. Additionally, BIM model data may not match the actual construction situation, affecting its application value.

Improvement Strategies:
(1) Establish BIM Data Standards: Develop enterprise-level BIM data standards to ensure data format uniformity and complete attribute information, avoiding the impact of data quality issues on application.
(2) Build a BIM Data Management Platform: Introduce cloud-based data storage and sharing systems to ensure that departments can access and update BIM data in real-time.
(3) Regular Data Maintenance and Verification: Develop a BIM data maintenance plan to regularly check the consistency of the model with the construction site, ensuring data accuracy and reliability.
(4) Promote "BIM+Smart Construction": Combine sensors, IoT, and other technologies to improve the real-time and accuracy of BIM data, achieving more intelligent project management.

In summary, this paper provides an in-depth analysis of the key factors affecting BIM implementation capability in small and medium-sized construction enterprises, identifying and summarizing 13 core influencing factors. Corresponding improvement strategies have been proposed for these factors. Based on this, the paper systematically organizes and summarizes the proposed strategies, ultimately constructing a framework for improving BIM implementation capabilities in small and medium-sized construction enterprises (see Figure 3), with the aim of providing theoretical support and practical guidance for the promotion and application of BIM technology in such enterprises.

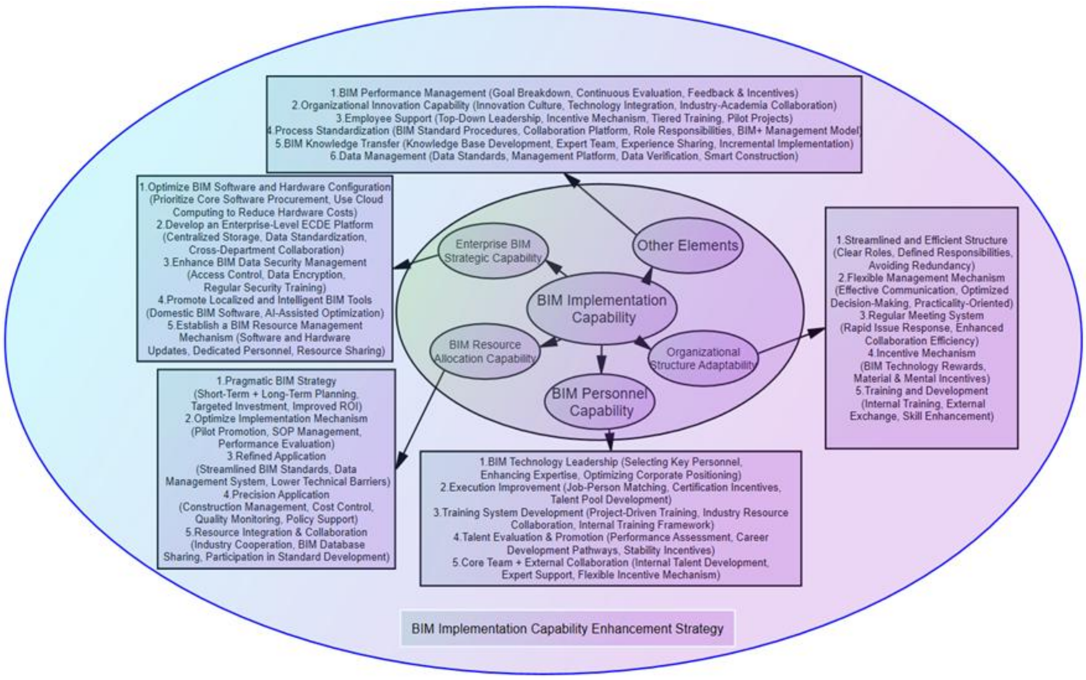

Figure 3: Framework for Improving BIM Implementation Capabilities in Small and Medium-Sized Construction Enterprises

VI. Conclusion

Research Summary

Research Summary

This study explores the key elements of BIM implementation capability in small and medium-sized construction enterprises through a systematic literature review and semi-structured expert interviews. By analyzing 36 relevant articles, 18 BIM implementation capability elements were identified. In addition, combining insights from interviews with 12 experts, the following key elements were determined: (1) Organizational BIM capability elements: whether the company possesses the necessary infrastructure for BIM implementation, the completeness of the BIM training system, the comprehensiveness of BIM implementation standards and guidelines, the clarity of BIM vision and goals, the execution ability of BIM personnel, the richness and reliability of BIM data, the historical accumulation of the company in BIM implementation, and the leadership of the BIM technical leader; (2) Organizational capability elements: the adaptability of the organizational structure, the completeness of workflows, the support from company members, the establishment of standardized performance benchmarks, and the organization's innovation and R&D capabilities.

Based on the frequency analysis of these elements and expert opinions, this study focuses on seven core elements: infrastructure development, clarity of BIM vision and goals, completeness of BIM implementation standards, the soundness of the BIM training system, adaptability of organizational structure, execution ability of BIM personnel, and leadership of the BIM technical leader. Ultimately, a strategy framework for improving BIM implementation capability in small and medium-sized construction enterprises is proposed to provide theoretical support and practical guidance for these enterprises.

Research Contributions

This study systematically organizes and analyzes the factors affecting BIM implementation capabilities in small and medium-sized construction enterprises in Hainan, China, filling a research gap in this field and providing a theoretical foundation for subsequent studies. Enterprises can refer to the proposed strategies for BIM strategy, BIM resource allocation, BIM personnel management, and organizational implementation to make informed decisions based on their specific characteristics and enhance their BIM implementation capabilities.

In terms of theory, this study not only summarizes the existing literature but also makes significant contributions to the identification and classification of BIM implementation capability elements, enriching the theoretical framework of BIM implementation in the construction industry. On a practical level, the findings provide valuable references for SMEs and policymakers, especially in areas such as BIM strategic planning, resource allocation, personnel training, and organizational implementation, offering guidance for industry practices.

Research Limitations

Although this study provides a comprehensive analysis of BIM implementation capability elements, there are still some limitations. Firstly, the research is based on a systematic literature review and expert interviews, lacking large-scale empirical data to support the findings. Therefore, the scientific validity and applicability of the conclusions still require further verification. For example, the importance of each factor and its actual weight in practical applications need to be supplemented and refined through follow-up surveys or case studies.

Secondly, the study primarily relies on expert interviews from SMEs in Hainan Province, which may be limited by regional and industry characteristics. Future research could consider conducting similar empirical studies in other regions or countries to verify the universality of the proposed framework. The construction market and policy environment in Hainan may differ from other regions, so comparing the findings with practices from other provinces may help enhance the applicability of the conclusions.

Furthermore, the sample size of expert interviews in this study is relatively small (only 12 experts), which may limit the representativeness of the results. While expert interviews provide valuable insights, a small sample size may not fully reflect the diverse perspectives within the industry. Future research can expand the sample size to capture a broader range of viewpoints, improving the generalizability of the findings.

Finally, this study heavily relies on literature review, which could introduce biases from publishing trends or language barriers. To strengthen the comprehensiveness and accuracy of the research, future studies should consider non-English literature and multilingual sources to avoid biases from a narrow data pool.

Despite these limitations, the BIM implementation framework proposed in this study holds practical value. However, due to the lack of validation through real-world case studies, the direct application value of the framework in policy-making and corporate decision-making remains unclear. Future research should conduct case studies or real-world validation to further assess the practical effectiveness and feasibility of the framework, helping SMEs enhance their BIM implementation capabilities and providing specific guidance for policymakers.

References

[1] Abdallah, A., Doloi, H. And Holzer, D. (2023), "Exploring The Application Of Bim In Tanzanian Public Sector Projects Using Social Network Analysis", Built Environment Project And Asset Management, Vol. 13 No. 4, Pp. 552-573. Https://Doi.Org/10.1108/Bepam-01-2023-0026

[2] Ahuja, R., Sawhney, A., & Arif, M. (2018). Developing Organizational Capabilities To Deliver Lean And Green Project Outcomes Using Bim. Engineering, Construction And Architectural Management, 25, 1255–1276. [Crossref]

[3] Ahuja, R., Sawhney, A., Jain, M., Arif, M., & Rakshit, S. (2020). Factors Influencing Bim Adoption In Emerging Markets–The Case Of India. International Journal Of Construction Management, 20, 65–76. [Crossref]

[4] Al-Mohammad, M.S., Haron, A.T., Esa, M., Aloko, M.N., Alhammadi, Y., Anandh, K.S. And Rahman, R.A. (2023), "Factors Affecting Bim Implementation: Evidence From Countries With Different Income Levels", Construction Innovation, Vol. 23 No. 3, Pp. 683-710. Https://Doi.Org/10.1108/Ci-11-2021-0217

[5] Araujo, C.M.B.D. And Alves, J.L. (2024), "How To Unlock Bim Capabilities In The Design Phase To Project Success For Long-Term Organization Development?", Engineering, Construction And Architectural Management, Vol. Ahead-Of-Print No. Ahead-Of-Print. Https://Doi.Org/10.1108/Ecam-08-2024-1038

[6] Bi, X. (2018). Research On The Impact Of Bim Capability On Project Management Performance (Master's Thesis). China University Of Mining And Technology, Xuzhou.

[7] Chen, Y., Li, D., & Yang, J. (2019). Research On The Bim Capability Maturity Measurement Of Construction Projects Based On Sem. Journal Of Civil Engineering And Management, 36(2), 61-69. Https://Doi.Org/10.13579/J.Cnki.2095-0985.20190311.001

[8] Du, J. (2024). The Dilemmas And Breakthroughs Of Bim Technology Application In Small And Medium-Sized Construction Enterprises. Journal Of Taiyuan City Vocational Technical College, 3(3), 53–55. Https://Doi.Org/10.16227/J.Cnki.Tycs.2024.0139.

[9] Dworkin, S.L. Sample Size Policy For Qualitative Studies Using In-Depth Interviews. Arch. Sex. Behav. 2012, 41, 1319–1320. [Google Scholar] [Crossref] [Pubmed] [Green Version]

[10] Fan, Y., & Li, X. (2022). Research On The Dilemmas And Solutions Faced By Small And Medium-Sized Enterprises In The Construction Industry Under The Background Of Intelligent Construction. Urban Architecture Space, 6, 254-256.

[11] Giel, B., & Issa, R. R. A. (2014). Framework For Evaluating The Bim Competencies Of Building Owners. In Computing In Civil And Building Engineering (2014) (Pp. 552-559).

[12] Gong, Y., & Duan, Z. (2022). Research On The Key Path Of Digital Transformation Of Construction Enterprises Considering Scale Differences. Construction Economy, 43(2), 84–89. Https://Doi.Org/10.14181/J.Cnki.1002-851x.202202084

[13] Han, H., & Sun, G. (2020). Evaluation System Of Bim Technology Application Capability In Engineering Consulting Institutions Based On Entropy Weight Topsis. Construction Economics, 41(1), 104-109. Https://Doi.Org/10.14181/J.Cnki.1002-851x.202001104