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Assessment of the Impact of the Introduction of BIM on the Core Competitiveness of Large Building Construction Companies

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Abstract: In the context of the digital transformation of the construction industry, this study examines the impact of Building Information Modelling (BIM) technology on the core competitiveness of large building construction enterprises. Through literature review and case study analysis, the mechanism by which BIM technology operates is systematically explored from four dimensions: technology, management, market, and innovation. It is found that BIM technology enhances construction efficiency and quality through 3D modelling and virtual construction, improves the accuracy of construction drawings, and reduces the construction timeline. In the management dimension, it fosters collaborative design, dynamic cost control, and risk assessment. In the market dimension, BIM technology boosts bidding competitiveness and creates technical barriers through visualisation solutions and comprehensive lifecycle services. In the innovation dimension, it advances green building and optimises complex engineering through integration with AI, GIS, and other technologies. Despite the challenges posed by technical barriers and skill shortages, the application of BIM technology represents an inevitable trend for enterprises aiming to enhance their core competitiveness, which necessitates continuous promotion through technical collaboration and talent development.

Keywords: BIM technology, Large building construction firms, Core competitiveness, Influence mechanism, Digital transformation.

1. Introduction

In the digital transformation of construction, large companies face dual challenges. Market competition is intensifying with relaxed entry barriers, pitting them against both domestic rivals and international giants. Competition has shifted from price to technology, management, and services. Meanwhile, project complexity rises with large projects like super-high-rise complexes and smart transportation hubs, requiring integration of multiple systems, cross-region collaboration, and green, intelligent construction, demanding better corporate management.

The flaws of traditional construction management models are becoming more obvious. Methods of information transfer that rely on paper drawings and manual communication are cumbersome and

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prone to losing or distorting information, making real-time data sharing and dynamic updates impossible. Low collaboration between departments and resource allocation based on experience often leads to issues like material waste and project delays, greatly hindering corporate growth.

In this context, examining the impact of Building Information Modelling (BIM) technology on the core competitiveness of large-scale construction companies is crucial. BIM technology consolidates data throughout a building's entire lifecycle using three-dimensional information models, enabling construction progress simulation, dynamic cost management, and visual oversight of quality and safety. This not only helps companies identify key areas for technological advancement and promotes the deep integration of management and technology but also offers practical guidance for industry digital transformation, boosting overall industrial efficiency and global competitiveness.

This study will examine the use of BIM technology in large construction companies, using methods like literature review, case study, and field research to systematically analyze changes across four areas—technological innovation, project management, market competition, and business model innovation—before and after BIM adoption. It aims to uncover how BIM technology improves a company's core competitiveness and to identify replicable transformation pathways.

2. Overview of developments and practical foundations

After decades of development, BIM has evolved from its initial stages to full maturity. From the 1970s to the late 1990s, CAD (Computer-Aided Design) technology first appeared; at that time, it was capable of only simple 2D drawing and basic 3D modelling. Restricted by hardware performance and software capabilities, its capacity to integrate information was limited. At the beginning of the 21st century, professional BIM software began to thrive, such as ArchiCAD and Revit, achieving the integration of geometric and functional data while supporting energy analysis, collision detection, and other functions, thereby pushing the industry into the era of 3D modelling. In recent years, the profound integration of BIM technology with artificial intelligence and big data has led to dynamic BIM, which simulates construction progress through time-dimensional information.

The global BIM market is experiencing robust growth. The market size is projected to increase from $7.0 billion to $16.3 billion between 2019 and 2025, with a CAGR (Compound Annual Growth Rate) of 15.15%, according to data from Valuates Reports [1]. North America holds the largest market share based on advanced construction management systems. The Asia Pacific region is growing the fastest, driven by policy initiatives in countries like Japan and South Korea, along with strong demand from emerging markets such as China and India. The Chinese market is particularly promising, with the market size soaring from $4.05 billion to $36 billion between 2016 and 2022, achieving a CAGR of 30%. BIM technology is extensively applied for design optimisation and construction simulation in 37 smart construction pilot projects in Xiongan New Area, significantly enhancing project management efficiency.

The rapid popularisation of BIM technology is driven by policy. On June 16, 2015, the Ministry of Housing and Construction issued the "Guiding Opinions on Promoting the Application of Building Information Modeling Technology", upgrading it to a national strategy. The "13th and 14th Five-Year Plans" further emphasised the use of BIM in construction. Local governments mandate BIM for government-invested large projects and large public buildings funded by enterprises. For instance, Shenzhen Dapeng New District requires that since January 1, 2023, all new projects exceeding 10 million yuan and 1,000 square metres must implement BIM technology across all phases: land use, planning, bidding, construction, management, completion, and acceptance.

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3. Mechanism of BIM's influence on the core competitiveness of construction enterprises

3.1. Technical dimensions

BIM's 3D visualization and virtual construction functions help construction workers accurately locate components, simulate complex processes, and optimize construction links, reducing rework and material waste [2]. For example, in tower crane lifting simulations, BIM accurately calculates lifting ranges and angles, optimizes installation positions, improves lifting efficiency, and reduces delays from improper positioning

BIM's visualisation delivery and construction simulation facilitate workers' understanding of construction requirements and nodes. The model integrates real-time construction data, supporting the dynamic discovery and rectification of quality issues [3], achieving accurate control throughout the entire process. Taking Tianjin 117 Building as an example, this project is a super high-rise building with a structural height of 596.5 m. Through the application of BIM technology, it has realised comprehensive fine management of construction and produced 11 of China's best.

3.2. Management dimensions

BIM breaks down information silos, enabling efficient collaboration among disciplines on a unified platform and reducing rework from communication issues [4]. For example, at the Shanghai National Convention and Exhibition Centre, BIM models helped identify and resolve collision issues in advance, enhancing design efficiency and construction safety. BIM also integrates precise component and quantity information, aiding cost management by allowing quick and accurate quotations during bidding and dynamic cost monitoring during construction, enabling real-time comparisons and timely adjustments to keep costs under control.

The BIM model integrates precise component information and quantity data, which greatly facilitates cost management. During the bidding stage, the model can swiftly generate accurate quotations based on the simulated quantities in BIM alongside the historical cost database [5]. Throughout the construction process, BIM enables dynamic cost monitoring, which allows for real-time comparisons between actual progress and material consumption against the budget. Managers can promptly identify deviations and quickly develop optimisation plans (e.g., adjusting procurement strategies, optimising construction sequences) to maintain controllable costs.

BIM, combined with project data (geology, climate, schedule, etc.), can create a risk assessment model. By analysing the data, it can identify potential risks (e.g., the impact of adverse weather on the schedule, the risk associated with deep foundation pit safety) and quantitatively assess them [6]. When the risk factors reach the warning threshold, the system can issue a timely alarm, prompting managers to take preventive measures to nip the risks in the bud, thereby significantly enhancing project safety and risk resistance.

3.3. Market dimension

In the bidding stage, large construction companies can integrate BIM technology with VR and AR to create 3D visualisation models and construction simulation animations (such as step-by-step demonstrations of deep foundation pit support and simulations of steel structure roof lifting), transforming technical solutions into intuitive visual outcomes [7]. Owners can wear VR and AR devices to experience the building space to be constructed or even simulate the fire evacuation path, visualising the reasonableness of the design scheme, thereby enhancing the score of the technical

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bid. This visualisation capability has become a key barrier and a significant advantage for large enterprises in bidding for complex projects over small and medium-sized enterprises (SMEs) that still rely on CAD drawings.

In the pre-qualification process, government investment projects often consider BIM application experience a significant advantage for pre-qualification. Large enterprises can present BIM results from past projects (such as the BIM as-built model of Shanghai Tower alongside enterprise-level BIM standard documents to demonstrate the maturity of their technical systems. Furthermore, large enterprises maintain permanent independent BIM centres, equipped with skilled teams and having invested millions in hardware and software (e.g., laser scanners, BIM collaboration platform), creating a "threshold effect" in the pre-qualification process.

At the bid evaluation stage, large enterprises can present the value-added offer strategy of full-cycle service, relying on the BIM model to provide an integrated solution of "construction + operation and maintenance". In practice, BIM modelling can offer robust support for the full-cycle operation of the project [8]. In this project, BIM models containing O&M (Operation & Maintenance) information can be committed to being delivered to the owner, extending the one-time construction profit to the subsequent O&M services, thereby forming a differentiated offer. SMEs, however, are constrained by technology and resources and lack O&M capabilities, making it challenging for them to propose similar programmes, further widening the market gap with SMEs.

3.4. Innovation dimension

The application of Artificial Intelligence (AI) technology in the field of building construction has opened new development opportunities for construction enterprises. The combination of BIM and AI technology facilitates the intelligence and informatization of construction management and decision-making by deeply analyzing and mining the data within the model. For instance, by employing AI algorithms to analyse the construction progress data in the model, construction personnel can depend on the results to forecast the risk of delays in the construction schedule, take preventive measures in advance, and enhance construction efficiency.

If BIM and GIS(Geographic Information System) are thoroughly integrated, large-scale building construction enterprises can demonstrate their advantages in linear projects (e.g., highways and pipeline corridors). For instance, in the cross-regional pipeline corridor project, using BIM+GIS to construct a three-dimensional realistic model of the entire line can automatically optimise the pipeline arrangement and reduce the volume of earth excavation by integrating geological data [9]. In contrast, small and medium-sized enterprises (SMEs) struggle with complex geographic data and have low participation in such projects. Large enterprises use BIM to integrate professional energy analysis tools (e.g., License) to accurately simulate building energy consumption, sunlight, ventilation, etc [10]., and optimise design solutions to reduce carbon emissions [11]. For example, in the zero-carbon park project, BIM can be employed to simulate the layout of photovoltaic panels and the integration of energy storage, to establish a carbon database and to achieve quantitative management of the carbon footprint. Small and medium-sized enterprises (SMEs) are constrained by high software costs and limited modelling analysis capabilities, and largely remain at the level of selecting energy-saving materials.

4. Empirical analysis and case studies

In the Xiongan Business Service Centre project, China State Construction Group created a 3D BIM model integrating architecture, structure, and electromechanics. This enabled early resolution of

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design conflicts, identifying over 1,200 pipeline collisions and layout issues, raising construction drawing accuracy to over 98%, reducing design changes by 40%, and shortening construction time by about 15%. The team established a full lifecycle data management platform for digital control from design to delivery. The 3D drawing review report improved efficiency by 60%. In constructing the smart park, BIM was integrated with IoT technology, resulting in a digital twin platform with high-precision simulation for 900,000 square metres and access to data from over 50,000 equipment, enabling a two-way mapping of physical and virtual parks.

Despite advancements, traditional BIM applications still have potential in integrating emerging technologies. Current project BIM primarily focuses on basic modelling and collision checking, while combining AI and IoT(Internet of Things) is still exploratory. In construction risk early warning, data access for pit monitoring is established, but intelligent algorithm integration is lacking, resulting in no automatic risk level assessments or intelligent disposal plans. While a BIM collaboration platform exists, real-time information sharing relies on manual triggering, causing over 48-hour lags in model updates, affecting multi-disciplinary collaboration efficiency. Notably, China Construction Group is working on intelligent BIM data flow using tools like Flying Book, achieving 70% improvement in data processing efficiency through real-time linkage between statistics and model changes.

In the Pudong Airport South underground transport hub project, SCCG(Shanghai Construction Group Co., Ltd) developed a digital management system with six modules and 40 applications. Their concrete material information management system achieves intelligent management for 20,000 piles, maintaining a material loss rate of 1.2% through a code signing mechanism, 60% lower than traditional methods. The digital process management system collects construction parameters for nearly 1,000 diaphragm walls in real-time, improving acceptance efficiency by 50% and creating a traceable quality control chain. During pit construction, over 3,000 monitoring points integrated via IoT facilitate 3D visualisation of safety risk warnings, reducing potential accident likelihood during excavation by 85%.

The project won first prize in the 10th Shanghai BIM Technology Application Competition, focusing on deep BIM integration with the construction process. In pile foundation work, the BIM model generates processing parameters for reinforcement cages, combined with welding robots for intelligent part production with ±2mm accuracy. During the electromechanical installation, Shanghai Construction Engineering used BIM for 4D simulations, optimising pipeline layout and reducing cross work, improving comprehensive support bracket installation efficiency by 35%. The team developed a "one box, one code" temporary power management system for real-time monitoring of power box status and fault location via IoT, reducing response time to less than 5 minutes. These practices set a replicable model for underground projects and boosted SCCG's competitiveness in municipal engineering.

5. Challenges and responses

5.1. Key challenges

The application of BIM technology is currently facing two core obstacles: First, the implementation of BIM technology has a high threshold, involving a variety of professional knowledge and necessitating rapid updates and iterations. This requires enterprises to continually invest resources for upgrades. Secondly, there is a shortage of professionals; the industry urgently needs a large number of skilled individuals proficient in BIM technology. However, the scarcity of such talent and the difficulty of recruitment impose pressure on enterprises that wish to cultivate their own

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workforce, which involves long cycles and high costs [12]. Additionally, there is a lack of professional talent in the industry who are adept in BIM technology.

5.2. Coping strategies

In terms of technology, building construction enterprises should actively collaborate with software developers, research institutions, and peers to address technical challenges and share experience and resources, facilitating the implementation of technology. Regarding talent development, enterprises should establish a diverse training system: on one hand, enhancing internal training to improve the technical proficiency of existing staff; on the other hand, strengthening partnerships with educational institutions to cultivate BIM talent [13].

6. Conclusion

BIM technology plays a vital role in boosting the core competitiveness of construction companies. From a technical standpoint, BIM effectively enhances construction efficiency and quality, optimizes construction plans, and minimizes errors and rework. From a management perspective, BIM encourages collaborative management, strengthens cost control and risk management, and helps companies better address various project challenges. In terms of market competitiveness, BIM can improve a company's bidding ability, laying the groundwork for capturing a larger market share. Regarding innovation, integrating BIM with other technologies drives technological advancement in the construction industry, expanding a company's market potential. Despite technical hurdles and talent shortages, companies can successfully advance BIM adoption through increased collaboration and talent development. The deep integration and innovative use of BIM have become crucial in enhancing the core competitiveness of large-scale construction firms.

In the future, the value of BIM technology will be further enhanced: the deep integration of BIM and artificial intelligence will significantly boost the intelligence of design optimization, construction simulation, progress prediction, and risk management, providing stronger support for management decision-making; as an information carrier throughout a building's entire life cycle, BIM will become the central hub of smart construction and smart operation and maintenance. By thoroughly analyzing the planning, design, construction, and operational data contained in BIM, companies can continually improve processes, implement predictive maintenance for facilities, and increase service value, thereby consistently strengthening and elevating their core competitiveness throughout the entire project lifecycle.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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