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Current Status and Technological Breakthroughs of BIM Application in Prefabricated Construction

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Abstract. This study thoroughly examines the current application and technological breakthroughs of Building Information Modeling (BIM) technology in prefabricated construction. Driven by strong national policy support, BIM technology has been widely adopted throughout the entire lifecycle of prefabricated buildings—from design and production to construction and operation—significantly enhancing design efficiency, construction precision, and management effectiveness. Through case studies, this research reveals significant progress in areas such as intelligent design optimization and refined construction management. For instance, in a construction project in Ziyang District, Yiyang City, BIM visualization not only substantially improved communication and coordination efficiency among participating entities but also enhanced the implementability of design solutions. However, current BIM implementation in prefabricated construction still faces numerous challenges, including inconsistent technical standards, poor software compatibility, low industry chain coordination, and a shortage of multidisciplinary talent. Looking ahead, breakthroughs in cutting-edge technologies such as blockchain, IoT, and big data are expected to empower BIM to enable more efficient data exchange and sharing, establish unified data standards, and drive prefabricated construction toward intelligent and digital development.

Keywords: BIM technology, prefabricated building lifecycle, technology application, blockchain

1. Introduction

As a pillar industry of the national economy, the construction sector is undergoing a critical phase of industrialization and digital transformation. China's 14th Five-Year Plan explicitly mandates the promotion of intelligent construction practices, identifying prefabricated construction as the core of new building industrialization. According to the State Council's "Guiding Opinions on Vigorously Promoting the Development of Prefabricated Construction," prefabricated buildings should account for 30% of all new construction floor area by 2026. Driven by national policies, regions across the country are actively developing the prefabricated construction industry, with prefabricated buildings emerging as a key direction for the sector's future growth. Concurrently, BIM technology has evolved from its origins as a parametric modeling tool into a comprehensive digital management platform covering the entire lifecycle—from design and production to construction and operations.

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The integration of BIM technology with prefabricated construction offers crucial technical support for the industry's advancement through efficient information integration and collaborative management. This study employs a combination of literature review and case analysis. By selecting representative prefabricated construction projects, it delves into the technical breakthroughs and innovations achieved through BIM application, examining both the specific outcomes and existing challenges across each BIM implementation phase. Its research significance lies in revealing and resolving practical bottlenecks such as information silos, disconnects between design and construction, and inconsistent standards. This approach aims to drive transformation toward intelligence and the industry's integration while providing critical theoretical support and practical guidance for achieving digital and intelligent construction in the building sector.

2. Overview of BIM technology

BIM is a digital construction tool based on trhee-dimensional digital models, spanning the entire lifecycle of a project from design and construction to operation. It integrates a building's geometric information, material properties, and management data, featuring characteristics such as integration, visualization, parametric design, and collaboration. In the application of BIM in prefabricated construction, this technology breaks down information barriers across all stages, consolidates all data into a single central model that is updated in real time, and enables full lifecycle management. By transforming 2D drawings into intuitive visualizations through multidimensional modeling, it delivers immediate clarity. Components within the model carry precise parameters, ensuring design consistency and efficiency. It also provides a unified working platform for multidisciplinary teams, significantly enhancing collaborative efficiency. BIM not only replaces traditional 2D drawings with 3D modeling to enhance design accuracy and communication efficiency but also centralizes project information management, supporting cost monitoring and cross-phase information coordination.

3. Current application of BIM technology in prefabricated construction

BIM technology is applied across four phases of the prefabricated building lifecycle: design, production, construction, and operation/maintenance.

3.1. Design phase

Taking a construction project in Ziyang District, Yiyang City as an example, the basement, mezzanine, and second floor utilize cast-in-place structures. During modeling, CAD drawings were imported into Revit software. Plugins like Olive Mountain converted CAD element information into Revit model lines, rapidly generating components such as walls, columns, and beams. Based on this component data, the system generated a 3D model and subsequently completed 2D drawing models for architectural and structural disciplines. BIM visualization significantly enhances communication and coordination efficiency among all participating units. It enables the construction unit to intuitively understand the project's finished appearance, facilitates efficient resolution of technical issues between designers and construction technicians, and improves the implementability of design solutions [1].

3.2. Production phase

Using the BIM-generated model, designers can meticulously plan the manufacturing and assembly processes for each prefabricated component. This enables detailed design refinement to ensure

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dimensions, forms, and connection methods meet assembly requirements. Specifically, BIM technology generates detailed fabrication drawings and production bills of materials, guiding factories in standardized production to boost efficiency and ensure consistent quality. For instance, drawings generated from the model can precisely mark bolt hole positions and dimensions, ensuring accurate component alignment. Additionally, BIM supports virtual assembly, allowing designers to simulate the assembly process within the model to identify and resolve potential issues in advance. This reduces on-site errors and rework, further optimizing assembly efficiency [2]. The production process is inherently a two-way feedback and dynamic adjustment mechanism. Construction teams can optimize schedules in real time based on production data within the BIM model, while manufacturing units can flexibly adjust component production rhythms and supply sequences according to on-site progress feedback [3].

3.3. Construction phase

3.3.1. Construction schedule management

Construction schedule management is a core component of project management, primarily implemented by the construction contractor. Taking a teaching building project as an example, it adopted a prefabricated concrete frame structure system and achieved a prefabrication rate of 65%. The large number of prefabricated components demanded high-level coordination in transportation organization and component installation. Simultaneously, the limited construction site required precise planning of site layout to accommodate prefabricated component storage and material supply needs. With a tight schedule, high demands were placed on interdisciplinary coordination. Accordingly, during the construction preparation phase, the project team utilized the BIM5D platform to simulate the construction progress multiple times and compare it with the established construction plan. This process identified several potential conflicts in construction and hoisting sequences, allowing for timely adjustments to the schedule. During the construction phase, the project employed the BIM5D platform for dynamic progress management [4].

3.3.2. Construction quality management

In project management, BIM5D tools integrate information across the entire lifecycle of design, construction, and operations, enabling centralized management and dynamic monitoring of project data. This significantly enhances the timeliness and accuracy of management decisions while effectively reducing schedule delays and cost wastage caused by information discrepancies. Leveraging Virtual Construction Models (VCMs), it establishes a multi-party collaboration platform that enables designers, engineers, contractors, and suppliers to share and update information in real time. This enhances information transparency and response agility, optimizes workflows, reduces misunderstandings and conflicts in collaboration, and comprehensively improves team efficiency. Simultaneously, this technology employs high-precision 3D visualization and pre-construction simulation to help project teams fully identify quality risks before construction commences, significantly reducing rework risks and improving project quality [5].

3.3.3. Construction safety management

In construction safety management, BIM5D leverages its dynamic simulation capabilities to pre-simulate various construction scenarios and systematically identify and assess potential safety risks. Through construction process simulation, it preemptively locates high-risk operation zones,

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implements safety alerts and protective measures, and develops precise safety training plans and emergency response protocols. Simultaneously, by integrating real-time progress and resource allocation monitoring, BIM5D ensures the timely provision of appropriate machinery and essential personal protective equipment (PPE) for different construction phases, thereby comprehensively enhancing on-site safety control levels [5].

3.3.4. Construction collaboration management

Communication Tools and Standardized Processes: Leveraging integrated communication tools within the BIM platform (such as real-time chat and video conferencing systems) enables online collaborative exchanges. Standardized multi-party communication processes and protocols are established to ensure timely and consistent information transfer among stakeholders.

Collaborative Workflows and Responsibility Definition: Establish structured collaborative design workflows, clearly defining each participant's tasks and scope of responsibility across different design phases. Designate dedicated coordination leads for each phase to ensure orderly design progression and effective management of information interfaces.

Conflict Detection and Resolution Mechanism: Implement a BIM-based collaborative conflict management system for immediate response and closed-loop resolution of design disputes. When consensus cannot be reached, initiate multi-party root cause analysis through BIM collaboration modules to identify issues and negotiate solutions. Final solutions are confirmed through voting mechanisms or expert reviews, with the entire decision-making process documented to establish a traceable and summarizable knowledge base for conflict resolution [6].

3.3.5. Construction collaboration management

The following are the four main aspects of construction collaboration management:

(1) Information Sharing Platform

The information sharing platform forms the foundation of construction collaboration management. By centrally storing project information—including design drawings, technical documents, schedule plans, and quality acceptance reports—on the BIM platform and linking this information to the BIM model, all project participants can conveniently access and utilize these resources. This centralized information management approach not only enhances transparency but also reduces misunderstandings and errors caused by information asymmetry. For example, in a large prefabricated building project, the BIM platform enabled the design, construction, and supervision teams to view the latest design revisions and construction progress in real time, ensuring that each phase of work could be adjusted based on the most current information.

(2) Communication Tools and Standards

Effective communication is central to collaborative management. BIM platforms offer various communication tools, such as chat windows and online video conferencing, facilitating real-time interaction among project team members. Additionally, establishing clear communication protocols is crucial. For instance, weekly online video meetings can be scheduled to discuss project progress and challenges, while urgent issues should be reported and addressed within 24 hours via chat windows.

(3) Workflows and Accountability

Well-defined workflows and responsibility assignments are the foundation of collaborative management. During construction, develop detailed workflows that specify the tasks and responsible parties for each phase. For instance, during prefabricated component installation, clearly delineate

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the duties of the hoisting team, installation team, and quality inspection team to ensure seamless execution at every stage. Simultaneously, designate dedicated personnel for coordination and information exchange during each design phase to guarantee accurate information transfer and timely resolution. In a hospital project, clearly defining team responsibilities ensured efficient installation of prefabricated components and minimized delays caused by ambiguous accountability.

(4) Conflict Resolution Mechanism

Conflicts are inevitable during collaborative design and construction. Establishing an effective conflict resolution mechanism is crucial. When issues or conflicts arise, they should be immediately documented and analyzed using the BIM platform. If consensus cannot be reached, the platform's collaboration module can be used to initiate multi-party meetings to jointly identify causes and negotiate solutions. When necessary, voting or expert review methods can be employed to confirm the final design solution.

3.4. Operations and maintenance phase

The full lifecycle of construction projects encompasses not only development, design, and construction but also high-quality operations and maintenance management in the later stages—a critical factor in shaping a construction company's brand image. Employing BIM technology to construct and manage modular building interiors is a vital method for enhancing space utilization. Taking building decoration as an example, BIM enables a more intuitive understanding of precise spatial information and visual effects, optimizing layouts to improve practical utility and facilitating efficient operation and scientific management of modular interiors [7]. Furthermore, the deep integration of BIM and IoT technologies provides an effective pathway for advancing intelligent building operations management. For instance, after deploying various sensors within a building, the BIM model can rapidly generate maintenance schedules based on equipment operational status and repair records. This enables smarter spatial control, energy consumption management, and enhanced operational efficiency, ultimately achieving energy conservation and consumption reduction goals [8].

4. Challenges and breakthrough directions

As Chinese construction enterprises enhance their technical capabilities and strengthen international competitiveness, practical experience reveals that the integration of BIM technology with prefabricated construction currently faces numerous challenges. These include an incomplete standard system, software requiring upgrades, low levels of industrial chain collaboration, and a shortage of talent and technical resources [9]. Additionally, the current industry fragmentation—where design institutes, prefabrication plants, and general contractors often operate as independent entities—lacks collaborative experience and information foundations built on BIM as a shared working platform. To address the aforementioned technical, managerial, economic, and industry-related challenges in BIM application for prefabricated construction, the construction sector should explore extensive integration of BIM with emerging technologies like IoT, big data, artificial intelligence, and blockchain.

4.1. RFID technology

Radio Frequency Identification (RFID) is a contactless automatic identification technology based on radio waves, widely applied in the digital construction and full lifecycle management of

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prefabricated buildings [10]. By embedding RFID tags or sensors within prefabricated components, critical data such as location, temperature, humidity, and vibration during production, transportation, and hoisting can be tracked in real time. This information is automatically synchronized with the BIM model, ensuring consistency between physical components and their digital representations. This comprehensively enhances precision in construction progress, quality control, and end-to-end traceability.

4.2. Design of BIM+VR-based remote construction collaboration platform

VR (Virtual Reality) technology integrates building models with virtual reality to simulate construction sites as digital animations. This enables the acquisition of precise parameter data, identification of quality risks at each stage, and optimization of technical parameters and design coordination, ensuring smooth project execution. Within the integrated VR-BIM collaborative management platform, the system enables strict supervision of construction personnel and workflow processes. For instance, equipping workers with positioning devices allows real-time tracking of their locations on-site, enabling comprehensive monitoring of personnel distribution. This effectively mitigates safety risks and significantly improves construction safety and quality [11].

4.3. Blockchain technology

Blockchain technology is a distributed ledger technology built upon cryptographic principles. It achieves this by packaging data into chronologically linked "blocks" and employing cryptographic algorithms to ensure each block is tightly connected to its predecessor, forming a continuously growing chain-like data structure [12]. This technology relies on core components like hash algorithms and asymmetric encryption. Through interactive verification mechanisms and its chained data structure, it guarantees that all recorded information is immutable once recorded, thereby ensuring data accuracy and reliability.

Leveraging blockchain infrastructure, independent accounts can be assigned to all participants in the prefabricated building supply chain (such as suppliers, logistics providers, and construction firms). This enables unified on-chain recording, end-to-end traceability, and efficient sharing of critical data. This approach not only effectively resolves issues of fragmented information and redundant verification but also significantly reduces costs and enhances efficiency. Blockchain technology employs a "block + chain" structure to ensure data immutability and traceability. Its distributed architecture enables decentralized storage and multi-party verification, while asymmetric encryption protects information security [13].

5. Conclusion

Currently, BIM technology has achieved certain results in its application to prefabricated buildings. Numerous projects have successfully applied BIM to solve practical problems, driving the development of prefabricated construction. However, challenges persist, including incomplete BIM application standards and poor data compatibility between different software, leading to inefficient information flow. A shortage of specialized talent and insufficient BIM proficiency among some practitioners hinder technology adoption. Additionally, high implementation costs reduce enthusiasm among enterprises, particularly small and medium-sized ones. Looking ahead, as technology advances and the industry evolves, BIM's application prospects in prefabricated construction will expand significantly. Technological breakthroughs are anticipated to enable more

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efficient data exchange and sharing, resolve software compatibility issues, establish unified data standards, and achieve seamless information integration among all stakeholders. Intelligent applications will also expand further. By integrating technologies like artificial intelligence and the Internet of Things, BIM will enable intelligent management throughout the entire lifecycle of prefabricated buildings, including smart production scheduling, intelligent construction monitoring, and automated operation and maintenance alerts. Through collaborative efforts across all stakeholders, BIM technology will unlock greater potential in the prefabricated construction sector. It will inject powerful momentum into the construction industry's pursuit of green, efficient, and sustainable development, driving prefabricated construction to become the mainstream model for future building development.

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