Original Research Article

Omniscient Pte.Ltd.

Research and Practice on BIM-Based Integrated Data Management in Smart Construction

Qing-Yu He, Shi-Hong Huang[*]**, Wen-Kai Jiang**

School of Management Science and Engineering, Guangxi University of Finance and Economics,Nanning, Guangxi, 530000, China

*Correspondence to: Shi-Hong Huang, School of Management Science and Engineering, Guangxi University of Finance and Economics,Nanning, Guangxi, 530000, China, E-mail: 171098543@qq.com

Abstract: With the accelerating digital transformation of the construction industry, BIM-based integrated data management for smart construction has become a core pathway to improving project efficiency. This study focuses on the research and practical exploration of BIM-based integrated data management in smart construction. It first explains the concept and clarifies its significance in supporting smart construction. Key technologies are then analyzed, including BIM data standards, data collection and transmission, storage and management, data analysis and mining, and collaborative work platforms. Subsequently, practical implementation paths are proposed, such as planning development, establishing standardized specifications, building integrated platforms, strengthening data-quality management, and cultivating professional talents. The aim is to promote efficient data integration and scientific data management in smart construction through systematic research and practice, enhance the informatization and intelligence level of construction projects, and provide theoretical support and practical references for the digital transformation of the construction industry.

Keywords: BIM; smart construction; integrated data management; key technologies; implementation paths

Introduction

In the context of the digital transformation of the construction industry, smart construction has become an inevitable development trend. BIM (Building Information Modeling), as a core supporting technology, provides a rich data foundation for smart construction. However, smart construction involves multiple stages and disciplines, and its data sources are extensive and diverse in format. Traditional management models can no longer achieve effective data integration and efficient utilization, resulting in severe information silos that hinder the deep development of smart construction. Therefore, research and practice on BIM-based integrated data management in smart construction are urgently needed. By constructing a scientific integrated data management

system, breaking data barriers, and achieving deep data fusion and sharing, project efficiency and quality can be significantly improved, accelerating the industry's transition into a new era of intelligent construction.

1 Connotation of BIM-Based Integrated Data Management for Smart Construction

(1) BIM-based integrated data management for smart construction is a management concept that takes Building Information Modeling (BIM) as its core and comprehensively integrates data across the entire lifecycle of a construction project. It breaks through the traditional issues of fragmented and isolated data, systematically aggregating data from all project stages including planning, design, construction, and operation. These data include not only geometric information—such as the dimensions, shapes, and locations of building components—but also non-geometric information such as material properties, construction processes, and cost estimates. Together, they form a rich and complete data set that provides a solid foundation for smart construction.

(2) It emphasizes deep data integration and interaction. Under an integrated management framework, data from different disciplines and stages can be seamlessly connected and collaboratively utilized. Design data can provide precise guidance for construction, while feedback from construction processes can be used to optimize design schemes in a timely manner. Operational data can be traced back to the design and construction stages to support maintenance and management. Such deep data interaction breaks down disciplinary barriers, enabling all stakeholders to communicate and collaborate efficiently on a unified data platform, thereby improving overall project performance and quality.

(3) BIM-based integrated data management for smart construction also features intelligent decision-support capabilities. By analyzing and mining large volumes of integrated data, it uncovers potential patterns and trends hidden within the data. These analytical insights can provide project managers with scientifically grounded decision recommendations, such as optimizing construction schedules, allocating resources more effectively, and predicting project risks. This facilitates a shift from experience-based decision-making to data-driven decision-making, enhances the intelligent management level of construction projects, and

promotes the industry's development toward greater efficiency, sustainability, and green construction[1].

2 Key Technologies for BIM-Based Integrated Data Management in Smart Construction

2.1 BIM Data Standards and Interoperability Technologies

BIM data standards and interoperability technologies serve as the cornerstone of integrated data management in smart construction. BIM data standards define unified rules for the various elements within a building information model, including their attributes, classifications, and data storage formats. For example, standardized naming conventions and dimensional accuracy requirements for building components ensure consistency and compatibility of BIM data produced by different stakeholders and software systems. This prevents communication barriers caused by inconsistent data formats. Interoperability technologies focus on addressing challenges in data exchange across different software and systems. Given the diversity of software used in the construction industry, interoperability solutions—such as developing universal interfaces and adopting standardized data exchange formats like IFC (Industry Foundation Classes)—break down software barriers and enable seamless flow and sharing of BIM data across platforms. This not only enhances communication and collaboration among project participants but also ensures that data can be fully utilized throughout the building lifecycle. Ultimately, these technologies provide strong support for collaborative smart construction practices and drive the industry toward greater informatization and intelligence.

2.2 Data Collection and Transmission Technologies

Data collection and transmission technologies form the critical link between the physical and digital realms of smart construction. In terms of data collection, various advanced methods are used to obtain comprehensive information. Sensor technologies can monitor structural stress, strain, temperature, and other parameters in real time, providing essential data for structural safety assessments. Laser scanners capture three-dimensional coordinate data of building surfaces at high speed, generating high-precision point cloud models that support quality inspection and progress tracking. Meanwhile, mobile terminal

devices enable construction personnel to conveniently record construction progress, quality inspection results, and other manual data. Data transmission focuses on efficiency and stability. Wireless communication technologies such as Wi-Fi facilitate high-speed data transfer within localized areas, while 5G—featuring high bandwidth and low latency—supports real-time transmission of large-scale and long-distance data, meeting the needs of remote monitoring and collaborative operations. A hybrid network architecture that combines wired and wireless communication further enhances reliability, ensuring that collected data are transmitted accurately and promptly to the data center. This lays a solid foundation for subsequent data integration and analysis.

2.3 Data Storage and Management Technologies

Data storage and management technologies ensure the security, integrity, and availability of smart construction data. In terms of storage architecture, distributed storage systems have become mainstream. By distributing massive construction data across multiple physical nodes and incorporating data redundancy mechanisms, such systems significantly enhance reliability—data remain intact even if certain nodes fail. Combined with cloud computing, storage resources can be dynamically and flexibly expanded according to data growth at different project stages, preventing resource waste. In terms of data management, establishing a robust data classification and coding system is essential. Data are categorized precisely based on type, source, and intended use, with each dataset assigned a unique code to facilitate efficient retrieval and accurate usage. Strict data access control mechanisms are implemented to assign differentiated access permissions according to stakeholders' roles and responsibilities, thereby ensuring data security[2].

2.4 Data Analysis and Mining Technologies

Data analysis and mining technologies are key tools for unlocking the value of smart construction data. Data analysis involves cleaning, organizing, and transforming the collected construction data. Data cleaning removes duplicated, erroneous, and missing data to ensure high data quality; data organization arranges disordered data into structured forms; and data transformation converts data into analyzable formats. For instance, analyzing construction progress data

can visualize deviations between planned and actual progress, allowing potential delays to be identified early. Data mining goes a step further by discovering underlying patterns within the data. Association rule mining uncovers hidden relationships between different data items, such as correlations between material consumption, construction progress, and project costs. Cluster analysis groups similar construction projects or components, helping summarize common characteristics and extract valuable lessons learned.

2.5 Collaborative Platform Technologies

Collaborative platform technologies act as a critical engine for enabling efficient cooperation among all stakeholders in smart construction. Centered on the BIM model, such platforms integrate data from the entire project lifecycle, including design, construction, and operation. Through a unified interface, stakeholders can access and share project information in real time. Whether related to design modifications, updates in construction progress, or quality inspection reports, information can be quickly transmitted and responded to on the platform. For example, when a designer updates the model, construction personnel immediately receive the latest information and can adjust their plans accordingly. The platform offers powerful communication and collaboration functions, supporting online discussions, file annotations, task assignment, and progress tracking, enabling seamless interaction among multidisciplinary and distributed teams. With integrated video conferencing and instant messaging tools, the platform enhances communication efficiency and facilitates remote collaboration.

3 Practice Paths for BIM-Based Smart Construction Data Integration Management

3.1 Developing a Data Integration Management Plan

Formulating a scientifically sound data integration management plan is fundamental to the success of smart construction projects. The plan should closely align with project characteristics and objectives, clearly defining the overall framework and direction for data integration management. The first step is to determine the management scope, covering full lifecycle data including design, construction, and operation stages. Specific goals should then be established, such as improving construction efficiency, reducing costs,

and enhancing quality. Based on these goals, detailed implementation steps should be formulated, outlining tasks and timelines for each project phase and allocating resources appropriately. Additionally, the plan must consider technological trends and evolving industry demands, allowing flexibility and scalability. For instance, in large-scale and complex projects, the plan should emphasize workflows and mechanisms for multi-stakeholder collaboration, while in innovative projects, it should encourage the adoption of new technologies and methods[3].

3.2 Establishing Data Standards and Norms

Establishing unified data standards and norms is a critical step in BIM-based smart construction data integration management. Data standards encompass formats, coding rules, classification systems, and other aspects. Consistent data formats ensure compatibility and interoperability between different software and systems. For example, adopting internationally recognized IFC formats facilitates BIM model sharing among all stakeholders. Data coding rules assign unique identifiers to construction components and information, supporting efficient data retrieval and management. Classification standards organize data based on attributes and intended use, ensuring orderly data management. Additionally, data quality standards should define requirements for accuracy, completeness, and consistency. A strict data review mechanism must be implemented to validate collected and entered data, ensuring compliance with the established standards and norms.

3.3 Building a Data Integration Management Platform

Establishing a robust data integration management platform is a core support for smart construction. The platform should integrate comprehensive functions including data collection, storage, processing, analysis, and visualization. In terms of data collection, it should support multiple data sources such as sensors, mobile terminals, and various software systems to achieve real-time acquisition and transmission of on-site data. For data storage, a distributed architecture should be adopted to ensure secure storage of massive data and efficient access. Data processing functions should include cleaning, transformation, and mining of collected data to extract valuable insights. Advanced

algorithms and models can be applied in the analysis module to provide scientific support for project decision-making. Visualization functions should present complex data through intuitive charts, reports, and 3D models. Moreover, the platform must possess strong openness and scalability to facilitate integration with external systems and future functional upgrades.

3.4 Strengthening Data Quality Management

Strengthening data quality management is a crucial guarantee for BIM-based smart construction data integration management. Data quality directly affects the accuracy and reliability of project decisions. First, a comprehensive data quality management system should be established, clarifying quality objectives, responsibilities, and workflows. Attention should be paid to the data acquisition stage, ensuring that collection devices are accurate and stable, and standardizing operator procedures to minimize errors. During data transmission, reliable technical measures should be adopted to prevent data loss or tampering. Stored data should be regularly backed up and maintained to ensure integrity and availability. A strict data quality review mechanism should be implemented to audit collected, entered, and stored data, allowing errors to be promptly identified and corrected. Real-time monitoring and evaluation of data quality can be performed using analytical techniques, with corrective actions taken based on the results.

3.5 Training Professionals for Data Integration Management

Cultivating professionals skilled in data integration management is a key factor in the development of smart construction. Smart construction involves multidisciplinary knowledge, requiring talents who understand both construction technologies and information technologies. Universities and vocational colleges should optimize their curricula to offer relevant courses, cultivating professionals with expertise in architecture, computer science, and management. Enterprises should strengthen employee training by providing targeted technical and managerial programs to enhance staff capabilities in data integration management. Training content should cover BIM technology, data analysis, and information system management. Furthermore, employees should be encouraged to participate in practical projects

to gain hands-on experience and improve problem-solving abilities. Talent incentive mechanisms should be established, offering rewards and promotion opportunities to high-performing staff to attract and retain skilled professionals[4].

Conclusion

The research and practice of BIM-based smart construction data integration management have brought a new development opportunity to the construction industry. Through a series of explorations, we have successfully established a comprehensive data integration management system, enabling efficient data flow and in-depth utilization across all stages, from design and construction to operation and maintenance. This has significantly enhanced the precision of project management and the scientific basis of decision-making. Such an approach not only optimizes construction processes and reduces costs but also improves engineering quality. Looking ahead, with continuous technological advancements, data integration management will become increasingly intelligent and efficient. It is essential to continue in-depth exploration, fully leverage its advantages, and drive the construction industry toward greener, smarter, and more sustainable development, creating higher-quality buildings and greater industry value.

References

[1] Tian Jincai, Li Bin. Analysis of the Application Value of BIM Technology in Construction Project Management[J]. China Management Informationization, 2022, 20(10): 48–49.

[2] Zhang Lianying, Yu Fei. Construction of a BIM-based Project Progress-Cost Collaborative Management System Framework[J]. Project Management Technology, 2022, 12(12): 43–46.

[3] Xu Yongge, Lu Peng. Organizational Integration of Large-Scale Construction Projects Based on BIM[J]. Journal of Railway Science and Engineering, 2021, 13(10): 2092–2098.

[4] Xie Xiaoming. Research on the Application of BIM Technology in Construction Equipment Operation and Maintenance Management[J]. Construction Economy, 2023, 41(12): 74–78.