Research on the whole logic construction and design of intelligent construction of civil residence based on BIM

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Abstract. The level of urbanization in our country is constantly improving, and the demand for high-quality civil housing is growing day by day. In order to improve the quality of housing and living experience, the construction industry urgently needs to promote the innovation and application of intelligent construction models. Based on this, this paper studies the intelligent construction scheme based on building information modeling (BIM) technology for the residential field. Firstly, the technical framework of intelligent construction of residential buildings is constructed. Secondly, the BIM application scheme that runs through the whole life cycle of the project is designed. Then, the realization of key technologies is explored. Finally, the technical effect and economic benefit of the scheme are verified by case study. The research shows that this scheme can effectively improve the intelligent level and construction quality of civil housing, promote the transformation of the construction industry to information and green, and has good economic and application prospects.

Keywords: building information model; Residential buildings; Intelligent construction; Information technology

1 Introduction

In the context of societal development, the escalating demands for enhanced home living quality have outpaced the capabilities of traditional residential construction methods. Meeting the increasing desire for more intelligent living spaces necessitates a focus on technological research and applications. However, traditional residential construction models pose several challenges, including prolonged design cycles, inefficiencies, coordination difficulties among various specialties, and frequent design changes. These issues hinder the realization of truly intelligent residential projects, ultimately falling short of users' expectations for smart living. Consequently, there is a

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pressing need for the construction industry to transform its residential construction models towards intelligence by embracing advanced technology across the entire residential lifecycle. This study aims to establish an intelligent construction technology framework, develop an implementation strategy centered on Building Information Modeling (BIM), and assess their effectiveness through case studies. To provide a comprehensive context, this introduction will now delve into a thorough analysis of global and domestic trends in intelligent residential construction, highlighting challenges, opportunities, and successful practices in this evolving field.

2 Based on BIM, Residential Intelligent Construction Scheme

2.1 Technical Framework for Residential Intelligent Construction

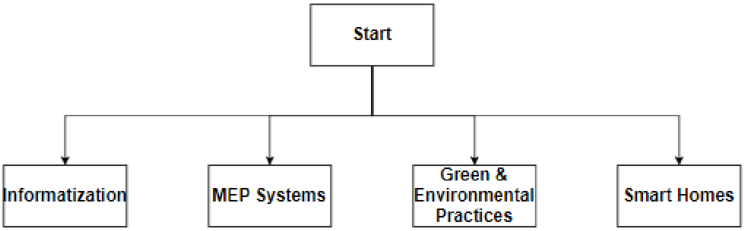

Fig. 1. echnical Framework for Residential Intelligent Construction

As is shown in Figure 1, to achieve the intelligent construction of residential buildings, it is necessary to integrate and utilize various advanced technologies to form a comprehensive solution. In terms of informatization, modern information technologies such as Building Information Modeling (BIM), the Internet of Things (IoT), and cloud computing are employed to achieve digitization and information management throughout the project lifecycle [1]. Among these, BIM technology can create three-dimensional digital building models with rich information, enhancing design collaboration and information sharing, significantly improving project design efficiency and quality. In terms of MEP (Mechanical, Electrical, and Plumbing) systems, the integrated design and construction of building electrical and weak current systems are promoted. Through systematic integration, various functions such as smart lighting, energy efficiency, and internet connectivity are realized, enabling centralized monitoring and optimized management of residential equipment and systems. In terms of green and environmental protection practices, renewable energy technologies such as photovoltaic power generation and ground-source heat pumps are comprehensively adopted. Additionally, green building materials and advanced energy-saving technologies are used to greatly reduce the consumption of resources and energy in construction, promoting ecological and environmentally friendly residential construction. In terms of smart homes, systems for audio-video, security, access control, lighting, and air conditioning are integrated to enable programmable and remote intelligent control. This provides customized home services to meet diverse resident usage needs [2].

2.2 Overall Framework of Residential Intelligent Construction Based on BIM

The overall framework of residential intelligent construction based on BIM spans three major phases: design, construction, and operation and maintenance [3]. In the design phase, BIM technology is applied to various specialized designs, facilitating information sharing and collaborative design optimization through the creation of parametric models. Subsequently, in the construction phase, BIM models are employed for advanced construction simulation, refining actual construction plans, and monitoring project progress, quality, and other indicators [4]. Moving into the operation and maintenance phase, a "digital twin" model is established, dynamically linked with real operational data, enabling real-time monitoring of building performance and facilitating intelligent operation and maintenance management. It is evident that the BIM digital model spans the entire lifecycle, significantly enhancing work efficiency and quality management across all stages. These three phases are closely interconnected through information technology, collectively advancing the intelligent construction of residential buildings.

2.3 Key Technologies and Implementation Pathways

The utilization of Building Information Modeling (BIM) technology is pivotal for intelligent construction. BIM models, created using specialized software, are three-dimensional parametric structures that amalgamate extensive information from fields like architecture, structure, and MEP[5]. These models not only contain geometric data but also performance metrics and relational constraints, fostering intelligent design collaboration. For seamless integration, standardized information protocols are employed, ensuring design consistency through interdisciplinary clash detection and optimization. BIM models also facilitate performance analyses, encompassing thermal environments, energy-saving potential, and 4D construction simulations. These simulations aid in informed decision-making. For intelligent systems, addressing network architecture design and system integration is essential. The architecture should cater to the connectivity of various intelligent devices, leading to a network topology tailored to the project. Building on this foundation, information exchange standards are set, achieving interconnected home services. Cloud computing and big data further enhance this by establishing a unified home data platform, offering intelligent customized services. In renewable energy, building-integrated photovoltaic solutions are crafted based on project needs, including component selection and installation methods. Ground-source heat pump systems are designed considering building needs and regional climates, ensuring adaptability and economic viability [6-8].

3 Case Validation and Analysis

3.1 Project Overview

As shown in Table 1, Ming Xi Hua Ting is a significant residential project situated in the Huilongguan area of Changping District, Beijing. Construction of the project commenced in 2021, covering an expansive 2.8-hectare area and boasting a total construction area of approximately 28,000 square meters. The development comprises three distinct buildings, including two 15-story towers and one 12-story tower. With a total investment of approximately 350 million yuan, Ming Xi Hua Ting is designed to epitomize an intelligent and low-carbon residential community, focused on providing a high-quality living environment and smart home services[9].The project adopts an assembly-based integral structure and leverages various advanced technologies such as intelligent systems, photovoltaic power generation, ground source heat pumps, BIM, VR, 3D printing, among others. These technologies are integrated to create a personalized and intelligent living space that emphasizes security, smart appliances, and health monitoring. Ming Xi Hua Ting serves as a prominent example of intelligent and low-carbon architecture, aiming to set new standards for modern residential developments[10].

Table 1. Project Overview

Project information	argument
Project name	Ming Xi Hua Ting
Project location	Huilongguan District, Changping District, Beijing
Item type	Large multi-storey, multi-family refined decoration house
Start time	The year 2021
Floor space	2.8 hectares
Floor area	About 28,000 square meters
Total investment	About 350 million yuan
Construction objective	Intelligent, low carbon residential community
Major technology	Assembly integral structure, intelligent system, photovoltaic power generation, ground source heat pump, BIM, VR, 3D printing, etc

3.2 BIM based intelligent design scheme

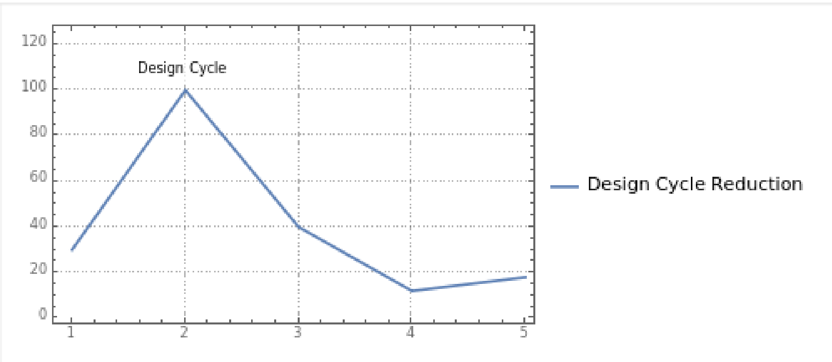

Fig. 2. Comparison of time in the design phase

As is shown in Figure 2, the implementation of BIM design in the Ming Xi Hua Ting project led to a substantial 30% reduction in the overall design cycle compared to traditional CAD design. This reduction was particularly evident in the schematic design phase, which decreased from 3 months to 2 months, and the construction drawing design phase, shortened from 5 months to 3 months. This time-saving advantage is primarily attributed to BIM's ability to enable parallel design across multiple disciplines, eliminating the sequential coordination delays inherent in traditional design processes. Furthermore, BIM's continuous model clash detection and conflict resolution capabilities successfully addressed 128 clashes between interior design and structural design schemes, demonstrating a high resolution rate. Additionally, BIM design substantially reduced the number of design changes, cutting them by approximately 40% compared to traditional paper-based design. Incorporating BIM-enabled simulations for daylighting, energy efficiency, and heating and ventilation, Ming Xi Hua Ting optimized the building's form and window-to-wall ratio. This led to a 12% increase in daylighting time for primary living spaces and a notable reduction in the building's heat transfer coefficient from 2.8 W/m² to 2.2 W/m². Consequently, there was an estimated 18% reduction in heating energy consumption over the course of a year. In summary, the application of BIM technology in the project's design phase significantly improved efficiency, design quality, and reduced design alterations.

3.3 Implementation effect evaluation

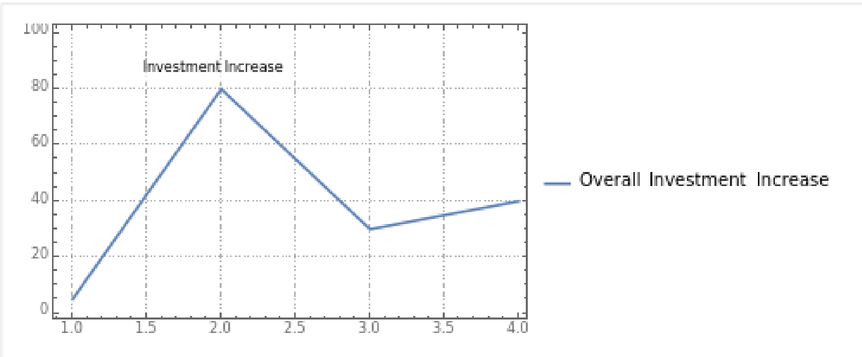

Fig. 3. Comparison of investment costs

As is shown in Figure3, the Ming Xi Hua Ting project experienced a 5% increase in overall construction phase investment costs compared to similar traditional construction projects. The majority of this cost increase, around 80%, was attributed to investments in intelligent systems, photovoltaics, ground-source heat pumps, and other renewable energy technologies. However, BIM technology implementation had significant cost-saving benefits. During the design phase, BIM reduced design errors, improving design efficiency by 30% and minimizing the need for costly corrections. It also facilitated interdisciplinary collaboration, shortening the design cycle and enhancing quality. Construction scheme optimization through BIM reduced on-site alterations by about 40%. In summary, while there was a slight increase in initial investment due to advanced systems, the utilization of BIM led to cost savings in design and construction phases. As a result, the project's overall lifecycle costs were approximately 8% lower than traditional methods, with a higher return on investment. This underscores the economic viability and benefits of BIM-based intelligent construction.

3.4 Comparison with Traditional Construction Methods

The Mingxi Huating project, utilizing a BIM-based intelligent construction approach, exhibits several advantages over traditional construction methods. Firstly, BIM technology has significantly shortened the design period, reduced design alterations, and improved design quality. Secondly, during the operation and maintenance phase, BIM application has reduced maintenance costs and enhanced operational efficiency. Most importantly, despite the initial investment required, the overall lifecycle costs are approximately 8% lower than traditional methods, with a higher return on investment. These results demonstrate the significant economic advantages of BIM technology in the construction of residential buildings.

4 Conclusion

This study introduces an intelligent construction approach for residential buildings using Building Information Modeling (BIM), offering both innovation and practicality. We've established a technical framework for intelligent construction and designed a BIM-based process covering the entire project lifecycle. The study also explores the application of BIM, intelligent systems, and renewable energy. A case study confirms the scheme's effectiveness in reducing costs, improving design quality, and promoting energy efficiency. Economically, the approach is beneficial. Overall, this research contributes to the modernization of residential construction in China, with future efforts focusing on refining techniques and broadening practical applications.

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