Postprint on the Application of BIM Technology in the Canal Suqian Port Project

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Abstract

Based on the Jiangsu Suqian Port and Storage Phase I Project, and considering its characteristics of high design requirements, complex solutions, tight schedules, and green construction, BIM (Building Information Modeling) technology is employed to address problems encountered in traditional construction. On-site deployment of extensive high-tech information-based construction technologies enables visualization of complex engineering projects, parametric modeling, and construction simulation using virtual 3D models for timely problem identification and adjustment. This approach yields the most accurate fundamental engineering data, facilitates whole-process cost management, and ensures engineering data is shared and reused throughout the project lifecycle. Comprehensive efforts are undertaken to guarantee the project fully meets green building evaluation requirements. Drawing upon the Suqian Port project, further research investigates specific applications of BIM technology during the construction phase, including detailed design application, visualization technology, integration with high-tech technologies, and 5D technology.

Full Text

Preamble

Research on BIM Technology Application in the Canal Suqian Port Project

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Abstract

Based on the Jiangsu Suqian Port and Storage Phase I Project, this study addresses the challenges of traditional construction methods in the context of stringent design requirements, complex solutions, tight schedules, and green construction principles. By leveraging Building Information Modeling (BIM) technology and extensively applying advanced information-based construction techniques on site, the project achieved visualization of complex engineering tasks, parametric modeling, and construction simulation through virtual 3D models, enabling timely issue identification and adjustment. This approach yielded the most accurate engineering baseline data, facilitated whole-process cost management, and enabled the sharing and reuse of engineering data throughout the project lifecycle, ensuring compliance with green building evaluation standards. Drawing on the Suqian Port Project, this paper further investigates specific applications of BIM technology during the construction phase, including detailed design applications, visualization technologies, integration with high-tech tools, and 5D technologies.

Keywords: Building Information Modeling; Visualization Technology; 5D Technology

Since the beginning of the 21st century, the construction industry has remained one of China's pillar economic sectors, with recent national policies providing unprecedented development opportunities. However, contemporary construction projects increasingly demand higher levels of detailed design, more complex implementation schemes, and tighter construction schedules. Traditional modes of information communication and management can no longer meet these requirements, necessitating the emergence of a more convenient and efficient management philosophy [**?**, **?**].

BIM (Building Information Modeling) is a multi-dimensional model information integration technology that provides advanced management concepts [**?**]. Through dedicated BIM management platforms, three-dimensional information transmission and sharing can be realized. In traditional project delivery, claim and dispute events primarily stem from erroneous or incomplete information transmission; BIM-based information management can effectively prevent such issues at their source. BIM technology creates integrated architectural, structural, and MEP models containing comprehensive information relevant to design, construction, and management, thereby enabling practical control over the entire project lifecycle. BIM provides clear solutions and advanced technical platforms for design-construction integration while addressing persistent challenges in the construction domain such as weak integrity and poor coordination. It plays a crucial role in enhancing both construction and management standards throughout the entire project lifecycle. This paper uses the Canal Suqian Port Project as a case study to demonstrate scientific project management through BIM-based modeling and dynamic construction simulation.

1. Project Overview

The Canal Suqian Port is located in the Suqian Port Industrial Park along the Grand Canal. The current construction project involves the expansion and upgrading of the Beijing-Hangzhou Canal hub port, specifically Buildings 1# and 2#, which are two three-star green office buildings. The project site covers an area of 12,992 m^2 with a total construction area of 1,541.18 m^2. The main structure is a frame structure. Building 1# features a high-low span configuration with one semi-underground floor, six above-ground floors in the high-span section, and one floor in the low-span section. Building 2# comprises three above-ground floors in the high-span section and two floors in the low-span section, with the low-span section employing a steel structure. The project rendering is shown in [Figure 1: see original paper].

Drawing on the Suqian Port Project, this paper further examines specific BIM applications during the construction phase, including detailed design, visualization technology, integration with advanced technologies, and 5D technology. As both office buildings are green building projects, they impose stringent requirements on the "four savings and one environmental protection" principles (energy, land, water, materials, and environmental protection), construction management, and operations management. From the project' s inception, meticulous planning was undertaken with the management philosophy of creating a green building through smart construction sites. The extensive on-site adoption of advanced information-based construction technologies ensures full compliance with green building evaluation criteria. The BIM application technology roadmap is illustrated in [Figure 2: see original paper].

2.1 Parametric Modeling Based on BIM

Before initiating BIM modeling for the project, establishing a parametric component family library is essential. The Canal Suqian Port Project features numerous similar component types and parameter categories. To avoid comprehensive model revisions due to drawing changes or engineering modifications while simultaneously enabling progress and cost control, the project developed a parametric component family library based on BIM's parametric characteristics. This library supports real-time and efficient modifications—any parameter adjustment to a specific component type automatically applies to all instances of that component type, thereby achieving bidirectional synchronization between the database and the model.

During BIM implementation, a standardized family library was developed to incorporate parametric data including dimensions, materials, density, and cost, alongside a project-specific family library comprising system families, standard component families, and in-place families. The application of this parametric family library in the project enabled direct data retrieval for subsequent queries and modifications, significantly improving work efficiency based on actual conditions [?]. The project utilized Autodesk Revit software for modeling through a three-step process: first, interpreting CAD construction drawings to understand the building structure and MEP systems; second, familiarizing with Guanglianda modeling standards; and third, importing CAD files into Revit to construct 3D models using Revit' s components according to grid lines and elevation data from the 2D drawings. For incomplete sections in the 3D components, modelers created corresponding family files manually. The parametric models developed for the Canal Suqian Port Project are shown in [Figure 3: see original paper].

(a) Building Model of 1#

(b) Building Model of 2#

(c) Structural Model of 1#

(d) Structural Model of 2#

(e) Plumbing Model of 1#

(f) Plumbing Model of 2#

2.2 BIM-Based Detailed Design Application

Design changes during construction directly impact project schedule and cost, and poor change management can jeopardize both schedule and budget targets. BIM-based detailed design applications can reduce changes at their source, fundamentally altering this dynamic. This project employed visual building information models to refine and modify designs before generating construction drawings, enabling designers to more intuitively identify design deficiencies and correct errors before delivering design deliverables, thereby minimizing subsequent design changes. Even when changes occurred during construction, BIM technology enabled effective management and dynamic control of these modifications.

Addressing the complexity of the Canal Suqian Port Project, BIM modeling and integration were employed to select target models for inspection tasks. The three-dimensional visualization capabilities of BIM models were utilized to identify potential collisions, preventing issues such as conflicts between GRC curtain walls and concrete structures, clashes between curtain wall gutters and primary steel structures, and collisions between MEP systems and steel structures. According to collision detection reports, over 4,000 hard collision points were identified in the Canal Suqian Port and Storage Phase I Project. The collision report is shown in [Figure 4: see original paper]. Revit was used to establish comprehensive MEP models, while Navisworks performed pipeline collision detection, optimization, and arrangement to ensure high consistency between the model and actual site conditions. For identified pipeline collisions, BIM technology facilitated pipeline optimization, with before-and-after comparisons shown in [Figure 5: see original paper]. Concurrently, the project design team utilized Revit for detailed design, automatically generating plans, sections, and detail drawings from the 3D model. Based on site conditions, construction progress, design specifications, codes, atlases, and client requirements, the project team completed detailed design drawings for site layout planning, secondary structural columns, steel structures, friction dampers, and other aspects since project commencement, obtaining client and supervision approval to guide on-site construction promptly.

2.3 BIM-Based Visualization Technology

In the Canal Suqian Port Project, traditional paper-based technical briefings suffered from limited practicality and cumbersome procedures. BIM-based 3D model visualization briefings provided more intuitive, objective, and practical solutions, as shown in [Figure 6: see original paper]. Given the extensive use of disk-lock scaffolding on site with its complex connection processes, 3D model briefings offered enhanced visibility to ensure safe scaffolding erection. Moreover, the complex MEP systems with multiple specialties were prone to installation deviations from drawings; visual briefings based on 2D drawings and 3D MEP models significantly improved installation accuracy.

Considering the tight schedule, complex construction environment, and varying professional competencies among workers, information asymmetry could lead to construction errors or delays. The BIM team employed Navisworks software for 4D (3D+Time) construction simulation to guide on-site construction, ensuring timely and high-quality project completion. The simulation process involved integrating construction plans, data, site conditions, and methodologies into the BIM model for comprehensive simulation, with the schedule simulation and control workflow illustrated in [Figure 7: see original paper].

2.4 Integration of BIM and VR Technology

The project imported BIM models into Unity 3D for processing and enhancement, subsequently utilizing VR equipment for immersive virtual reality demonstrations. VR technology transforms two-dimensional architectural plans into spatially realistic models, enabling decision-makers to enter virtual buildings from any perspective to experience and observe the design. From materials and dimensions to lighting, stakeholders can authentically experience spatial scenarios and dimensions, achieving dynamic walkthroughs with VR equipment for more realistic experiences, as shown in [Figure 8: see original paper].

2.5 Integration of BIM and 3D Scanning Technology

During construction, communication across different project teams and throughout complex project scopes presents significant challenges. BIM technology incorporates schedule and cost information into 3D models to create 5D models that intuitively display all project information, which is particularly critical for coordinating work among various teams. However, applying these models to construction management requires effective auxiliary means. Therefore, this project employed 3D scanning technology as a bridge connecting BIM models to the actual site. 3D scanning of ongoing or completed construction generated point cloud models that reflect the physical building' s internal structure and spatial relationships, as shown in [Figure 9: see original paper]. This technology comprehensively documented site conditions with complete data acquisition. By comparing the acquired point cloud models with the established BIM models, construction deviations were promptly identified and corrected to ensure consistency between the physical building and the BIM model. The key advantage is non-contact measurement, which effectively addresses complex measurement challenges on site. Scanning technology optimizes the cumbersome traditional methods of manual steel tape and blueprint-based operations, with the application workflow illustrated in [Figure 10: see original paper].

2.6 BIM-Based 5D Technology

BIM technology integrates schedule and cost information into 3D models to form 5D models. Centered on the BIM platform, this approach integrates specialized models including architecture, structure, and MEP systems while comprehensively considering schedule, quality, safety, and cost information throughout the construction process. Leveraging the analytical and computational capabilities of BIM models, the technology supports cost control, schedule management, and material management, enabling managers to achieve refined management and effective decision-making for improved quality, shortened schedules, and controlled costs. This project utilized the BIM5D software platform to import models from Revit and other software for integration, creating a comprehensive BIM application model that linked models with construction drawings, schedule plans, and cost plans.

In the Canal Suqian Port Project, Navisworks and 5D BIM software were employed for site analysis and green building 3D simulation. A project-level dedicated management platform was developed to maximize resource conservation and minimize environmentally negative construction activities while ensuring safety and quality requirements, achieving the "four savings" (energy, land, water, materials) and creating a green building. Through rational site utilization, site analysis during the design phase, and space management during operations, the project achieved land conservation to earn green construction credits. BIM technology assisted in earthwork volume calculations, simulated land settlement, designed site drainage, and analyzed firefighting operation areas to establish the most economical and reasonable fire equipment layout. The design planned drainage outlets on each floor to collect rainwater and other non-traditional water sources for recycling, achieving water conservation. By comparing BIM models with actual site conditions, material statistics and quota-based material issuance were implemented for material conservation. BIM-based quantity surveying technology, combined with parametric embedding and QR codes, enabled traceable equipment and materials and location-based construction management. The QR code-based supply chain management information system workflow is shown in Figure 7. Before equipment and material procurement, component parameters in the family library were completed, and 5D-BIM was used for quota-based material issuance to avoid secondary transportation and unnecessary waste, significantly reducing material consumption and saving costs.

3. Conclusion

With rapid economic development, China' s large-scale construction projects are increasingly characterized by growing investment, numerous participating units, higher functional requirements, and massive information volumes. Current projects demand increasingly sophisticated detailed design, more complex implementation schemes, and tighter schedules. Traditional information communication and management models can no longer satisfy these requirements, whereas BIM provides a rational and efficient management platform that effectively improves project productivity and achieves refined and standardized management objectives. BIM technology has been successfully applied to project management in the Canal Suqian Port and Storage Phase I Project. Drawing on the Suqian Port Project, this paper further investigated specific BIM applications during the construction phase, including detailed design, visualization technology, integration with VR technology, integration with 3D scanning technology, and 5D technology. BIM technology plays a crucial role throughout the entire project lifecycle, leveraging its inherent advantages to supervise the entire process. In today' s increasingly competitive market, utilizing BIM technology to enhance project construction and management levels has become imperative. Simultaneously, continuous improvement of BIM technology through practical application will promote sustainable development in the construction industry.

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Note: Figure translations are in progress. See original paper for figures.