Postprint: 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 schemes, tight schedules, and green construction, BIM (Building Information Modeling) technology is employed to address problems encountered in traditional construction. Advanced information-based construction technologies are extensively applied on-site to achieve visualization of complex engineering projects, perform parametric modeling, and simulate construction processes using virtual three-dimensional models, thereby enabling timely identification and adjustment of issues. This approach yields the most accurate fundamental engineering data, facilitates cost management throughout the entire project lifecycle, enables sharing and reuse of engineering data across all stages, and ensures the project fully meets green building evaluation requirements. Building upon the Suqian Port project, the specific applications of BIM technology in the construction phase are further investigated, including detailed design application, visualization technology, integration with high-tech technologies, and 5D technology.

Full Text

Preamble

BIM Technology Application in the Canal Suqian Port Project

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Abstract

Taking the Jiangsu Suqian Port and the first-phase warehousing project as the foundation, and considering the characteristics of stringent design requirements, complex solutions, tight schedules, and green construction, this paper addresses the problems encountered in traditional construction by employing

BIM (Building Information Modeling) technology. The project extensively utilized advanced information-based construction technologies on site to achieve visualization of complex engineering, parametric modeling, and construction simulation using virtual 3D models, enabling timely problem identification and adjustment. This approach yields the most accurate engineering baseline data, facilitates whole-process cost management, and enables sharing and reuse of engineering data throughout the project lifecycle, ensuring compliance with green building evaluation requirements. Building on the Suqian Port project, this study further investigates specific applications of BIM technology during the construction phase, including detailed design applications, visualization technology, integration with high-tech technologies, and 5D technology.

Keywords: Building Information Modeling technology; visualization technology; 5D

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Since the beginning of the 21st century, the construction industry has been one of the pillar industries of China’ s national economy. In recent years, the implementation of relevant national policies has undoubtedly provided greater development opportunities for the construction sector. Currently, construction projects face increasingly stringent detailed design requirements, more complex construction schemes, and increasingly tight schedules. Traditional modes of information communication and management can no longer meet these demands, giving rise to a convenient and efficient management concept [1, 2].

BIM technology (Building Information Modeling) is a multi-dimensional model information integration technology that provides advanced management concepts [3]. Through dedicated BIM management platforms, three-dimensional information transmission and sharing can be achieved. In traditional modes, the primary causes of claims and disputes are erroneous communication and incomplete information. BIM-based information management can effectively prevent such issues at their source. BIM technology creates architectural, structural, and MEP models containing information related to design, construction, and management of construction projects, thereby achieving actual control over the entire project lifecycle. BIM technology provides clear solutions and advanced technical platforms for design-construction integration, while also addressing existing problems in the construction engineering field such as weak integrity and poor coordination. It plays an important role in improving the construction and management levels of building projects and holds significant meaning throughout the entire lifecycle of construction projects.

This paper takes the Canal Suqian Port as an example, using BIM technology for modeling and dynamic construction simulation to achieve scientific project management.

1. Project Overview

The Canal Suqian Port is located in the Suqian Port Industrial Park along the canal center. The current construction project involves the expansion and upgrading of the Beijing-Hangzhou Canal hub port, with Buildings 1# and 2# being two green three-star 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. Specifically: Building 1# (with high-low span structure) has a semi-underground floor, a high span of 6 above-ground floors, and a low span of 1 floor; Building 2# has a high span of 3 above-ground floors and a low span of 2 above-ground floors, with the low span' s main structure being steel. The rendering is shown in Figure 1 [Figure 1: see original paper].

This paper further investigates the specific applications of BIM technology during the construction phase by combining the Suqian Port project, including detailed design applications, visualization technology, integration with high-tech technologies, and 5D technology. The two office buildings in this project are green buildings, thus requiring high standards for the "four savings and one environmental protection" (energy, land, water, and material savings, plus environmental protection), construction management, and operation management. From the beginning of the project, careful planning was conducted with the management concept of creating green buildings through green construction and smart construction sites. The site extensively adopted advanced information-based construction technologies to ensure the project meets green building evaluation requirements. The BIM application technology roadmap is shown in Figure 2 [Figure 2: see original paper].

2.1 Parametric Modeling Based on BIM

Before conducting BIM modeling for the project, the first step is to establish a parametric component family library. In the Canal Suqian Port project, there are numerous component types and parameter categories that are similar. Considering the need to avoid modifications and adjustments to the entire project model due to drawing changes and engineering modifications, while also accounting for progress control and cost control, the project established a parametric component family library based on BIM technology' s parametric characteristics. This library supports real-time and convenient modifications—if parameters of a certain component type in the family library are modified, these changes apply to all instances of that type, thereby achieving bidirectional synchronization between the database and the model.

During BIM implementation, considering the requirements of the Canal Suqian Port project, a standardized family library was developed incorporating parametric data such as dimensions, materials, density, and cost. Additionally, a project-specific family library was developed, including system families, standard component families, and built-in families. The application of this parametric family library in the project allows subsequent querying and modification work to directly access family library data and perform operations according to actual conditions, significantly improving work efficiency. The establishment of the parametric family library has proven highly effective in the Canal Suqian Port project [4].

The project utilized Autodesk' s Revit software for modeling, following a three-step process: first, identifying CAD construction drawings to gain a general understanding of the building structure and MEP equipment layout; second, becoming familiar with Glodon modeling standards; and finally, importing CAD files into Revit software and using Revit' s 3D model components to model according to the grid lines, elevations, and other information in the construction drawings. For incomplete parts in the 3D components, modelers needed to draw corresponding family files themselves. The parametric model established for the Canal Suqian Port project is shown in Figure 3 [Figure 3: see original paper], comprising: (a) architectural model of Building 1#, (b) architectural model of Building 2#, (c) structural model of Building 1#, (d) structural model of Building 2#, (e) plumbing model of Building 1#, and (f) plumbing model of Building 2#.

2.2 BIM-Based Detailed Design Application

Design changes during construction directly impact project schedule and cost. If poorly managed, schedule and cost objectives cannot be guaranteed. BIM-based detailed design applications can reduce changes at their source, thereby changing this situation. This project employed visual building information models to refine designs before generating construction drawings. Designers could more intuitively identify design imperfections through 3D design and correct errors before delivering design deliverables, thereby reducing subsequent design changes. Even when design changes occur during construction, BIM technology enables effective management and dynamic control of these changes.

Addressing the complexity of the Canal Suqian Port project, BIM technology was used for modeling and integration. According to detection task requirements, the model to be inspected was selected, and BIM model' s 3D visualization was utilized for inspection to avoid issues such as collisions between curtain wall GRC and concrete structures, collisions between curtain wall gutters and main steel structures, and collisions between MEP and steel structures. According to the collision report, the Canal Suqian Port and the first-phase warehousing project identified over 4,000 collision points, all of which were hard collisions. The collision report is shown in Figure 4 [Figure 4: see original paper]. Revit was used to establish a comprehensive MEP model, and Navisworks was employed for pipeline collision detection, optimization, and arrangement to ensure high consistency between the model and actual site construction. For identified pipeline collision issues, BIM technology was used for pipeline optimization, with before-and-after comparisons shown in Figure 5 [Figure 5: see original paper]. Simultaneously, the project design team applied Revit software for detailed design, using the 3D model to automatically generate various plans, sections, and detail drawings. Combining actual site conditions and construction progress, and according to design specifications, codes, atlases, and owner requirements, the project department has successively completed detailed design drawings for site layout, secondary structural columns, steel structure engineering, friction dampers, and other aspects since project commencement, obtaining owner and supervision unit signatures for confirmation to promptly guide site construction.

2.3 BIM-Based Visualization Technology

In the Canal Suqian Port project, traditional paper-based technical briefings suffered from weak practicality and cumbersome methods. The adoption of BIM technology' s 3D model visualization briefing is more vivid and objective, offering stronger practicality, as shown in Figure 6 [Figure 6: see original paper]. Given the extensive use of disk-lock scaffolding on site with complex processes involving numerous pins at connections, the 3D model briefing method provides strong visibility to ensure safe scaffolding erection. Moreover, with complex MEP structures and multiple specialties on site, discrepancies between installation and drawings are prone to occur. Visual briefing based on 2D drawings through established MEP pipeline models can significantly improve installation accuracy.

Considering the tight project schedule and complex construction environment, with varying professional competence among construction personnel, information communication asymmetry may occur, potentially leading to construction errors or delays. The BIM team used Navisworks software for 4D (3D+Time) construction simulation to guide site construction and ensure the project can be completed on schedule with high quality. The construction simulation implementation process involves establishing a BIM model, incorporating construction plans, data, site conditions, and schemes into the model, and using BIM software for construction simulation. The construction progress simulation and control process is shown in Figure 7 [Figure 7: see original paper].

2.4 Integration of BIM and VR Technology

This project imported the engineering model established with BIM technology into Unity 3D for processing, then utilized VR equipment for VR demonstration. VR technology can transform two-dimensional architectural planning drawings on paper into more spatially perceptible models, allowing decision-makers to enter virtual buildings from any perspective to experience and observe the work. From materials and dimensions to lighting, they can truly experience the scene, spatial dimensions, and achieve dynamic roaming combined with VR experience equipment for more realistic experiences (as shown in Figure 8 [Figure 8: see original paper]).

2.5 Integration of BIM and 3D Scanning Technology

During construction, communication among different project teams and across complex project scopes is difficult. BIM technology adds schedule and cost information to 3D models to form 5D models, enabling more intuitive presentation of all project-related information, which is particularly critical for coordination among various project teams. However, during the construction phase, effective means are needed to apply the model to management. Therefore, this project adopted 3D scanning technology as a link connecting the BIM model with the actual site. 3D scanning technology was used to scan buildings under construction or after completion, generating point cloud models that reflect the physical building' s internal structure and spatial positional relationships. The 3D scanning composite image is shown in Figure 9 [Figure 9: see original paper]. 3D scanning technology comprehensively records site conditions with complete data acquisition. The obtained point cloud model is compared and verified with the established BIM model, enabling timely adjustment and correction of construction errors to ensure consistency between the physical building and the BIM model. Its greatest feature is non-contact measurement, which effectively solves complex measurement problems on site. The greatest benefit of scanning technology for the project site lies in optimizing the cumbersome work methods primarily relying on steel tapes and traditional drawings. Its application process roadmap is shown in Figure 10 [Figure 10: see original paper].

2.6 BIM-Based 5D Technology

BIM technology adds schedule and cost information to 3D models to form 5D models. Centered around the BIM platform, various professional models are integrated, including architectural, structural, and MEP models, comprehensively considering schedule, quality, safety, and cost information during the construction process. Leveraging the analyzable and calculable characteristics of BIM models, the technology supports project cost control, schedule control, and material management, helping managers achieve refined management and effective decision-making to improve quality, shorten schedules, and control costs. In this project, the BIM5D software platform was used to import models established with Revit and other software into BIM5D for integration, forming a complete BIM application model that links the model with construction drawings, schedule plans, and cost plans.

In the Canal Suqian Port project, Navisworks, 5D BIM, and other software were used for site analysis and green building 3D simulation. A project-level dedicated management platform was developed. Under the premise of ensuring safety and quality requirements, management through BIM technology maximizes resource conservation and minimizes environmentally negative construction activities to achieve the "four savings" (energy, land, water, and materials) and create green buildings. Through rational utilization of construction land, site analysis in the early design stage, and space management during operation management, the goal of saving construction site area is achieved, earning points for green construction. BIM technology assists in earthwork calculation, simulates land settlement and site drainage design, and analyzes firefighting operation surfaces to set up the most economical and reasonable firefighting equipment. Design plans for drainage floor drains on each level and collection of non-traditional water sources such as rainwater enable water recycling for water conservation purposes. BIM technology, through comparison between the BIM model and actual site conditions, enables material statistics and quota-based material issuance for material conservation. Using BIM quantity surveying technology, parametric embedding and QR codes make equipment and materials traceable, enabling location management during construction. The QR code-based material supply chain management information system process diagram is shown in Figure 7. Before equipment and material procurement, parameters for family library components were completed, and 5D-BIM was used for quota-based material issuance to avoid secondary transportation and unnecessary losses, 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, increasing number of participating units, higher functional requirements, and massive project information. Currently, construction projects face increasingly stringent detailed design requirements, more complex construction schemes, and increasingly tight schedules. Traditional modes of information communication and management can no longer meet these requirements, while BIM provides a rational and efficient management platform that can effectively improve project production efficiency and achieve refined and standardized management objectives. BIM technology has been successfully applied to project management of the Canal Suqian Port and the first-phase warehousing project. Combined with the Suqian Port project, this paper further investigated specific applications of BIM technology during the construction phase, including detailed design applications, visualization technology, integration with VR technology, integration with 3D scanning technology, and 5D technology. BIM technology plays an important role throughout the entire project lifecycle, leveraging its advantages to supervise the entire process. Today, with increasingly fierce market competition, utilizing BIM technology to improve project construction and management levels has become imperative. Simultaneously, during practical application, BIM technology should be continuously improved to promote sustainable development of the construction industry.

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