Postprint: Application of BIM Technology in the Zhengzhou Museum New Hall Project

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Abstract

Large-scale venue projects are typically characterized by complex architectural forms, intricate structural systems, and numerous professional disciplines. Actual construction also confronts challenges including difficult construction organization, extensive process interleaving, and high construction complexity, which can be effectively resolved through the application of BIM technology [citation removed]. This paper primarily elaborates on how the Zhengzhou Museum New Hall project utilized BIM technology during both the design and construction phases to address the aforementioned issues, thereby achieving high-standard design, high-quality construction, and high-level management. Through this comprehensive implementation, the project established an owner-driven, whole-process, multi-stakeholder collaborative BIM implementation framework, formulated methodological experience for transitioning from design BIM to construction BIM, and summarized a management paradigm that integrates BIM with construction production business processes. Innovative management approaches were proposed for spatial positioning of complex steel structures during the design phase, the "detailing + fabrication + construction" technology for curved curtain walls, and BIM-based "schedule + resources + work" planning management. This project, through practical implementation, explored the application of BIM technology in large-scale venues; by applying BIM technology across various specialties, it summarized the contributions of BIM technology in facilitating project delivery, providing referential documentation and robust support for future BIM technology applications in large-scale venue engineering projects.

Full Text

Application of BIM Technology in the New Zhengzhou Museum Project

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Abstract

Large-scale venue construction projects are characterized by complex architectural forms, intricate structural systems, and numerous specialized disciplines. These projects face significant challenges in construction organization, process integration, and execution difficulty. The application of Building Information Modeling (BIM) technology offers effective solutions to these problems. This paper examines how BIM technology was applied during the design and construction phases of the new Zhengzhou Museum project to address these challenges and achieve high-standard design, high-quality construction, and high-level management. Through this comprehensive implementation, the project established an owner-driven, full-process, multi-participant collaborative BIM implementation system. The project developed methodologies and experience for transitioning from design BIM to construction BIM, and summarized a management model that integrates BIM with construction production business processes. New management approaches were proposed for complex steel structure spatial positioning during the design phase, "deepening + processing + construction"technology for curved curtain walls, and BIM-based "progress + resources + work" schedule management. This project provides valuable reference materials and strong support for future BIM applications in large-scale venue projects.

Keywords: BIM; Revit; Integration of Design and Construction; Schedule Management

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1. Project Overview

1.1 General Project Description

The new Zhengzhou Museum project has a total construction area of approximately 147,000 square meters, with two underground floors and five above-ground floors, reaching a height of 67.797 meters. Upon completion, it will become the second largest museum in China. The project embodies the design concept of "Center of China, Crown of the Yellow Emperor," using the promotion of Central Plains Yellow Emperor culture as its starting point. The architectural form is derived from the "imperial crown" symbolizing Yellow Emperor civilization, incorporating the visual language of a treasure bowl to create powerful curved dynamics that generate the main building image, expressing the splendid civilization history of the Central Plains region. The structural system adopts a hybrid structure of "steel-reinforced concrete columns + steel-reinforced concrete beams + core tube steel-concrete composite shear walls," with a roof system combining bolted spherical grid structures and bidirectional orthogonal steel pipe trusses. The project rendering is shown in [Figure 1: see original paper].

1.2 Key Project Challenges

The project faced four major challenges. First, design complexity: the architectural form was intricate, featuring an arched sloping steel roof and a curved curtain wall facade composed of double-curved glass, irregular GRC panels, ceramic plates, and aluminum panels, with a bowl-shaped curved GRC curtain wall on the north side. Steel structure spatial positioning was difficult due to numerous functional zones. Second, construction complexity: the project included ten irregular steel-reinforced concrete core tubes, complex steel plate shear walls and steel pipe columns, intricate intersections between steel structures and reinforcement bars, and substantial engineering quantities. Third, tight schedule: the project needed to be completed for the National Ethnic Games, with a total construction period of only 20 months. Fourth, extensive new technology applications: the project implemented ten major categories and 39 sub-items of the construction industry' s top ten new technologies, including numerous new technologies such as coupling beam dampers and buckling-restrained braces.

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2. BIM Organization and Application Environment

2.1 BIM Application Objectives

The overall objective of BIM application was to utilize BIM technology to achieve cost savings, schedule optimization, and creation of a high-quality project. Specific implementation targets included: (1) integration of design and construction to strengthen the integrated work model and reduce comprehensive costs; (2) refined design to resolve design issues in advance, improve building quality, and facilitate construction; (3) lean construction to achieve fine management through BIM technology; and (4) exploration of innovative applications to create a smart construction site by integrating VR, IoT, and other technologies with BIM.

2.2 Implementation Plan

The project established a BIM application guideline (defining BIM application objectives, expected implementation effects, and responsibilities of all parties), a BIM implementation plan (developing specific application points and implementation methods based on project characteristics to guide BIM work), and a BIM application system (establishing implementation regulations with reward and penalty measures to promote management improvement) [1].

2.3 Team Organization

The project established a BIM management organizational structure led by the construction unit with participation from design, construction, supervision, and consulting units, as shown in [Figure 2: see original paper]. The project also defined BIM collaboration modes and model splitting principles to create a fundamental working environment for BIM implementation personnel.

2.4 Software and Hardware Environment

The project utilized Revit 2016 as the core platform for creating architectural, mechanical, electrical, subcontractor, and site layout models. Tekla was employed for steel structure modeling and detailing, Navisworks for model clash detection, Fuzor and Lumion for architectural scheme design, model browsing, walkthroughs, animations, and VR applications, MIDAS for structural design analysis, Glodon BIM5D for project schedule, quality, safety, technical, commercial, and material management, and Glodon GMJ for formwork and scaffolding modeling. Hardware included computers, touch-screen computers, large-screen displays, VR headsets, and drones.

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3. BIM-Based Design Management

The design unit provided BIM models suitable for construction deepening, which were then reviewed by the owner's BIM consulting unit to achieve design models ready for construction model deepening. The design unit served a bridging role, being responsible for drawings while cooperating with the construction unit to complete construction models.

3.1 Design Phase Management Measures

During the design phase, the design unit established modeling standards and codes of conduct based on the construction unit' s requirements. The design unit clarified work content for different roles, optimized BIM implementation processes, defined BIM workflows, and quantified BIM work content, effectively and rationally dividing the complex BIM implementation into unit tasks to be completed sequentially until project requirements were met.

3.2 Design Phase Implementation Difficulties

Three major difficulties were addressed. First, inspired by the imperial crown concept, the Zhengzhou Museum project adopted the architectural scheme of "Crown of the Yellow Emperor, Vessel of Treasures" ([Figure 3: see original paper]), presenting challenges in spatial positioning for the large-scale building volume and long-span steel structure design. BIM implementation adopted an "auxiliary design" approach to ensure drawing quality, spatial requirements, and structural calculation needs while anticipating construction issues to guarantee progress [2].

Second, previous projects often had vague designs where deepening work lagged and affected construction. This project enhanced curtain wall design depth in the early stage through BIM parametric design, providing accurate data for subsequent curtain wall deepening and installation to ensure construction schedule and save costs. For the steel structure model, BIM parametric modeling technology converted calculation models into applicable Revit models to meet multi-disciplinary needs ([Figure 4: see original paper]). The steel roof BIM model was developed during the design phase to determine detailed member settings, complete complex component design and optimization based on the form, and solve previous issues of non-intuitive design and lagging deepening work.

Third, the project had over 90 different spatial usage zones, each requiring separate clearance height analysis considering floor-to-ceiling height, maximum beam depth affecting clearance, and finishing schemes. Pipeline integration optimization and clearance analysis were then performed considering pipeline installation space, maintenance space, and other comprehensive factors ([Figure 5: see original paper]).

4. BIM-Based Construction Management

After project commencement, the general contractor served as the overall coordinator, organizing all parties to lead BIM technology implementation.

4.1 Deepening Design

During construction, the principle of "who constructs, who deepens"was followed. The general contractor organized review meetings for construction drawings and models. After subcontractors submitted their requirements and the general contractor completed review, the integrated model was delivered to subcontractors for deepening design. Results were approved through multi-party coordination and construction unit review before being stamped and issued by the design unit. Upon receipt, the drawings guided site construction. This project reviewed and approved over 5,600 deepening design drawings and material statistics tables through the design institute and owner [3].

The complex intersections between steel structures and reinforcement bars posed significant construction challenges. By generating node details from the steel structure deepening model, construction efficiency was ensured, saving approximately 16 days of schedule and 677,000 yuan in construction costs. This achievement formed a provincial-level construction method in Henan Province and won the first prize for Henan Provincial QC.

4.2 Construction Management Applications

The construction phase achieved fine management through BIM, cloud platforms, big data, IoT, and smart equipment. Daily management was conducted based on BIM models and data, covering schedule, quality, safety, and cost. A BIM-based collaborative platform solved previous problems of low communication efficiency and difficult data storage [4].

(1) Site Layout Management: The site conditions were complex, with four center projects under simultaneous construction, surrounding pipe galleries, subway, and roads being excavated concurrently, and limited site space preventing circular roads. BIM technology was applied to establish site models and phased general layout arrangements ([Figure 6: see original paper]), enabling refined temporary construction modeling and quantity takeoff. Communication and decision-making efficiency improved by 80%, ensuring a rational and efficient site layout while controlling temporary construction costs within 1% of the contract value.

(2) Formwork and Scaffolding Design: The high-support formwork area reached 14,000 square meters with a maximum height of 24 meters, including some stepped variable-height systems that were complex to erect. Through software-based design and optimized layout with 3D visualization for site guidance, material quantity calculations were refined, saving approximately 90,000 yuan in formwork material rental costs compared to conventional estimation methods.

(3) Curtain Wall Construction: Layout points were created from the BIM model and imported into software, using a BIM layout robot for point positioning. The robot automatically aimed infrared lasers at actual points, precisely reflecting the BIM model on the construction site to ensure accuracy and improve efficiency ([Figure 7: see original paper]). GRC curtain wall panels were produced by importing the detailed curtain wall BIM model into a 3D CNC engraving machine, which read the data for mold processing to ensure component styles and textures met design and installation requirements. Installation was guided by simulated lifting construction to determine installation sequences, ensuring rational and efficient site operations ([Figure 8: see original paper]).

(4) Masonry Layout: To avoid masonry material waste, BIM masonry layout technology was used to produce layout drawings for approximately 7,300 square meters of walls. Combined with site management, masonry waste rate was reduced from the traditional 7% to 2%. The process involved using a Revit plugin for one-click opening creation from the architectural and MEP integrated model, then importing walls with required openings into BIM5D software for virtual masonry layout. Site installation followed the layout drawings for processing, masonry, and acceptance.

(5) Document Management: Project technical documents were uploaded to a cloud platform accessible via mobile phones and web browsers. A process library was created based on construction schemes, allowing all personnel to download and view information anytime. To date, access and downloads have reached 8,350 instances.

(6) Schedule Management: A BIM-based schedule management process was established ([Figure 9: see original paper]). The master schedule was developed through construction simulation, from which work plans were derived. During implementation, planned versus actual progress was compared, and resources such as personnel and materials were allocated for refined management by work sections based on site completion status. Relevant data was uploaded to the cloud platform for weekly production meetings to report completion status and supervise implementation. The principle of "everyone is responsible, evaluation at each level, timely incentives"established a sound schedule management system and thoroughly implemented performance assessment for all staff. As the latest project to start among four centers, this project has now caught up with the others in physical progress.

(7) Quality Management: With large floor areas and complex quality management, the project collected and tracked quality and safety issues based on the engineering BIM model. All staff were incorporated into the system, establishing a comprehensive quality and safety management process ([Figure 10: see original paper]). Tasks that previously required 2-3 days for rectification were completed in an average of 1 day, with a problem resolution rate of 94%, representing a 13% improvement over conventional projects. The platform integrated online and offline processes, automatically generating rectification orders and quality analysis reports for meeting presentations.

(8) Safety Management: Safety management applied the same processes and methods as quality management, with additional applications. Patrol points with scannable QR codes were installed near large equipment and hazard sources. Inspectors conducted regular checks by scanning QR codes to record electronic inspection information and provide detailed feedback. The project was also equipped with VR safety education equipment to strengthen safety management.

(9) Commercial Management: The model was divided into work sections for material quantity takeoff combined with the BIM model. Each work section model was precisely linked to the schedule plan to analyze monthly material requirements [5]. For example, concrete was issued using a quota system, with model-based quantities strictly controlling subcontractor material waste while smart weighbridges monitored material delivery and dispatch in real time. Each concrete pour strictly controlled waste within deviation limits. The project commercial department monthly compared planned material quantities, model quantities, and actual consumption to generate a three-calculation analysis table, achieving a concrete savings rate of 1.3% and realizing dynamic resource control.

(10) Other Applications: The project explored smart site technologies combined with BIM, using a smart site cloud platform integrated with BIM5D to ensure comprehensive coverage of schedule, labor, quality, safety, and environmental management, while vigorously promoting innovative green construction technologies. A smart cloud platform integrated monitoring cameras, patrol systems, tower crane monitoring, dust detection, and BIM5D for data sharing, enabling real-time monitoring of tower crane operations, site electricity and water usage, labor force numbers, site progress, and safety and quality issues for convenient and efficient site management. Two-dimensional barcodes were automatically generated and attached to components, enabling "express-style" management by scanning codes upon completion of corresponding workstation construction to feed component status back into the system.

5. Project Application Effects

Through BIM application in the design phase, measured design time savings reached 75 days, site construction time savings reached 80 days, with indirect benefits of approximately 4.8 million yuan. Through BIM application in the construction phase, direct economic benefits reached 1.31 million yuan, site construction time savings reached 51 days, with indirect benefits of approximately 15.3 million yuan.

6. Conclusions

This paper elaborates on BIM technology application in the new Zhengzhou Museum project. The project established an owner-driven, full-process, multi-participant collaborative BIM implementation system, formed methodologies and experience for transitioning from design BIM to construction BIM, and summarized a management model integrating BIM with construction production business processes.

6.1 Innovations

Three key innovations were achieved. First, the spatial positioning of complex steel structures in the design phase provided strong support for construction, promoted design-construction integration, and eliminated the need for secondary deepening design. Second, the "deepening + processing + construction" technology for curved curtain walls ensured high consistency between site construction and design models, promoting high-quality construction. Third, BIM-based "progress + resources + work" schedule management achieved refined project management and ensured the goals of cost savings, schedule optimization, and high-quality project delivery.

6.2 Lessons Learned

Four key lessons were identified. First, if the construction unit does not have dedicated BIM personnel, it should commission a consulting unit with corresponding capabilities to assist in management. Second, the design unit' s work division and model splitting should be conducted early. Third, the construction unit' s BIM technology application should be clarified at the project start stage. Fourth, the BIM application capabilities of all participating units should be comparable; otherwise, coordination workload will be substantial.

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