BIM-Based Smart Parking: A New Paradigm Postprint

Authors: Du Rui, Li Mingzhu, Geng Wei, Hu Zhiduo

Date: 2018-10-26T21:05:10+00:00

Abstract

General contracting projects for stereo parking facilities impose stringent requirements on detailed design, collaborative construction, and operational management. The organic integration of critical content at each project node with Building Information Modeling (BIM) technology to deliver value constitutes the research focus of this project. During the planning phase, quantitative simulation analysis is conducted to ensure the rationality of site selection. In the design phase, multi-disciplinary collaborative design is implemented to meet design depth requirements. Comprehensive pipeline optimization is performed to guarantee clear heights on each parking level, while thorough structural stress analysis ensures compliance with safety performance criteria. Construction simulation, cost control, and quality monitoring throughout the virtual construction process cover all aspects of design and construction management, ensuring successful project implementation. Secondary development based on the BIM model enables data transmission and information interconnection between software and hardware systems. The BIM-based intelligent parking management system enhances

Full Text

Preamble

Title: New Thinking on Smart Parking Based on BIM Technology

Authors: Du Rui[1], Li Mingzhu[1], , Geng Wei[2], Hu Zhiduo[1]
(1. Jilin Jianzhu University, Changchun 130118, China; 2. China State Construction Northern Investment Co., Ltd., Shenyang 110000, China)

Abstract: Three-dimensional parking lot general contracting projects impose stringent requirements on detailed design, collaborative construction, and operations management. The central focus of this research involves the organic integration of critical project components with Building Information Modeling

(BIM) technology to maximize its value. During the planning phase, quantitative simulation analysis ensures rational site selection. In the design phase, multi-disciplinary collaborative design guarantees design depth requirements, while comprehensive pipeline integration optimization ensures adequate floor-to-floor clear heights throughout the parking structure, and thorough structural stress analysis satisfies safety performance criteria. Construction simulation, cost control, and quality monitoring during virtual construction cover all aspects of design and construction management, ensuring successful project implementation. Secondary development based on the BIM model enables data transmission and information interconnectivity between hardware and software. The BIM-based intelligent parking management system enhances operational and comprehensive management levels while optimizing technical and economic indicators across the project lifecycle.

Keywords: BIM; Performance Analysis and Simulation; Collaborative Design; Secondary Development
Classification Code: TU17
Document Code: A

1 Project Overview

The three-dimensional parking garage project at Changchun Jingyuetan National Tourist Scenic Area is located at the main entrance of Jingyuetan National Forest Park, adjacent to the Jingyue Street intersection. The total construction area is 40,232.40 m^2 (including 30,197.15 m^2 above ground and 10,035.25 m^2 underground). This project is classified as a Class I open parking garage. The main structure is a three-story frame system. BIM technology permeates every aspect of the project's design and construction management. The professional models, spanning from architectural to structural disciplines, embody a three-dimensional concept that reduces land occupation while increasing parking capacity. This project represents one of the largest, most automated, and most functionally comprehensive parking garages in the province's scenic areas.

The project rendering is shown in [Figure 1: see original paper].

2.1 BIM Application Objectives

Positioned as a full lifecycle BIM management research project, this initiative employs project management methodologies and BIM technical tools to break through information transmission bottlenecks between disciplines and processes. The objectives include achieving precise guidance of actual construction through BIM design models and conducting secondary development to satisfy functional requirements and operational needs during the post-construction phase.

2.2 Application Measures

During the planning phase, simulation software performs real-time modeling of traffic network operations in the parking lot's surrounding area to ensure rational building volume. In the schematic design phase, the BIM technology platform integrates with GIS software to evaluate, organize, and analyze design conditions, completing site analysis and massing studies while conducting comprehensive assessments with environmental impact evaluations. During the construction drawing design phase (detailed modeling stage), BIMSpace's central file enables more accurate data transmission between disciplines, with design verification against relevant national codes and standards to ensure design compliance and accuracy.

In the bidding and construction phase, the 3D BIM model is imported without loss for quantity takeoff, providing electronic bidding management, subcontractor management, procurement management, and contract administration. Project-wide control encompasses schedule management, 5D simulation, visual progress tracking, cost control, change order management, and billing/invoicing. Upon project completion, the digital construction model and related information, along with all construction documentation, are integrated for further development during the operational and maintenance phase of the three-dimensional parking garage, achieving full lifecycle management. By leveraging the open interface of the BIM model, an operations management software platform has been developed to enable intelligent management of the three-dimensional parking facility based on the BIM model.

2.3 Software and Hardware Environment

Based on the project's BIM application requirements, the software and hardware environment was configured as shown in .

Table 1 Software Configuration

Software	Function
AutoCAD	3D modeling, 2D drawing synthesis
AutoCAD Civil 3D	Professional excavation design
Autodesk Revit	Multi-disciplinary modeling for architecture, MEP, and analysis
Revit-YJKS	Structural design
Autodesk Navisworks	Project model integration, review, clash detection, walkthrough, construction simulation, and animation
BIMSPACE	Project model integration, overall construction layout, construction management

Software	Function
BIM 360 Glue	Multi-disciplinary collaborative design, project file management, personnel permission management
Autodesk 3ds Max	Cloud-based collaborative work, model lightweighting, clash detection, walkthrough, project model integration, rendering, visual effects, and animation

3.1 Surrounding Traffic Flow Simulation and Analysis

Given the highly complex traffic conditions around the parking lot, which accommodate multiple driving behaviors simultaneously during the same time period (as shown in [Figure 2: see original paper]), VISSIM microscopic traffic simulation software was employed for real-time traffic flow modeling. The analysis utilized car-following models, lane-changing models, and route choice models to evaluate road network performance, priority rules at conflict areas, network node assessments, and vehicle travel times (as shown in [Figure 3: see original paper]), simulating individual vehicle driving behaviors at each simulation time step. A traffic flow simulation model for signalized intersections was established to simulate parking space searching behavior, parking lot capacity, and their impacts on parking behavior, providing a scientific basis for site selection and determining the parking lot's volume (as shown in [Figure 4: see original paper]). The traffic simulation results directly determined the parking lot's scale.

3.2 Multi-Disciplinary Collaborative Design

The engineering design requires all components to use fair-faced concrete, with structural features including special-shaped columns and steel frame systems with precast fair-faced concrete facade panels. Since components designed for minor earthquakes cannot guarantee seismic performance during major earthquakes, PKPM static pushover analysis was employed for supplementary verification (as shown in [Figure 5: see original paper] and [Figure 6: see original paper]).

Revit MEP deepening design enables clash detection and rational arrangement of installation spaces, ensuring that MEP systems and other disciplines do not interfere with construction [2]. BIM technology was adopted during the early project stage for pipeline integration and concurrent detailed design (as shown in [Figure 7: see original paper]).

During the bidding process, the Revit model was imported into Glodon GCL (civil quantity takeoff), GGJ (rebar quantity takeoff), and GQI (installation

quantity takeoff) software for quantity calculation and cost estimation, providing electronic bidding management, subcontractor management, procurement management, and contract administration (as shown in [Figure 8: see original paper]).

During construction, Project, Glodon site layout software, and BIM5D were utilized for project-wide control of schedule management, 5D simulation, visual progress tracking, cost control, change order management, and billing/invoicing (as shown in [Figure 9: see original paper] and [Figure 10: see original paper]). These measures significantly improved efficiency and reduced costs.

3.3 BIM-Based Intelligent Parking Management System

An intelligent management system for the three-dimensional parking lot was developed based on BIM building information, GIS data, and vehicle information. The data architecture is illustrated in [Figure 11: see original paper]. The system enables automatic vehicle identification and parking route planning within the parking facility, while the user-friendly visual interface of the BIM model provides a foundation for the operations platform display [3].

The BIM model provides three-dimensional visualization and stores attribute information such as parking space numbers and dimensions. The integrated platform combines BIM models with real-time GIS data to generate optimal routing and parking space allocation for vehicles, enabling real-time data storage, analysis, and final visualization, analysis, and display [4]. Through the perception layer, network layer, and application layer of the Internet of Things (IoT), the system achieves comprehensive perception, data transmission, processing, and control of the three-dimensional parking facility.

The integration of BIM+GIS+IoT technologies leverages their respective advantages to solve critical parking problems in smart mobility, achieving information interconnectivity between data and technologies (as shown in [Figure 12: see original paper]), thereby providing new concepts and thinking for intelligent transportation solutions.

4 Project Application Results

Through comprehensive BIM technology application, the project achieved an information-based construction process during design and construction phases, saving both time and costs. The specific outcomes include: (1) resolution of tourist parking difficulties; (2) alleviation of traffic congestion near the scenic area; (3) scientific planning of parking facility functions and improved parking efficiency; (4) efficient optimization of design processes through three-dimensional collaborative design; and (5) reduced construction costs and improved construction efficiency through virtual construction research.

5.1 Innovations

As a parking facility project, this initiative innovatively integrates BIM technology with other relevant technologies. During the early phases, diversified, multi-disciplinary BIM technology guided project design and construction. In later phases, secondary development of BIM software was performed to creatively establish a BIM model-based parking management system, achieving high-level integration between hardware devices and software.

5.2 Lessons Learned

Scientific planning before construction constitutes the critical foundation for parking facility functionality. Unified platform real-time interaction ensures data uniqueness and timeliness, effectively avoiding repeated inter-disciplinary information transfers, reducing information transmission errors between disciplines, and improving design efficiency and quality. Establishing data interfaces that bridge hardware and software connections can maximize BIM technology's value.

References: [1] Ge Jian, Zhang Fuxing. Research on the Adaptability of BIM in the Design of Large Shopping Center Basements[J]. China Survey and Design, 2016(07):72-75.
[2] Du Rui, Li Mingzhu. Research on the Application of BIM Technology in Mechanical and Electrical Construction Systems—Taking Shenyang Diamond Hill Investment Plaza Project as an Example[J]. Basic Construction, 2018(16):92-95.
[3] Xu Jian. Research on Secondary Development of Revit System Software[J]. Railway Technology Innovation, 2014(05):39-41.
[4] Liu Shukun. Research on Parking Guidance System Based on ZigBee[D]. Qingdao University of Technology, 2016.

Author Biographies:
Du Rui (1995-), male, from Hulunbuir, Inner Mongolia, holds dual bachelor's degrees in Building Environment and Energy Application Engineering and Engineering Management (BIM Direction) from Jilin Jianzhu University. His primary research focuses on BIM technology application and building technology science.
Corresponding Author: Li Mingzhu, male, master's supervisor, primarily engaged in research related to BIM and HVAC systems.

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