Promoting Smart Construction Site Development to Boost Construction Industry Development: Postprint

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Date: 2018-10-26T00:00:00+00:00

Abstract

The construction industry constitutes a crucial material production sector and one of the pillar industries of China' s national economy; simultaneously, it represents a high-risk industry characterized by frequent safety accidents. Strengthening construction site safety management, reducing accident frequency, effectively managing construction' s environmental impacts, eliminating various non-compliant operations and uncivilized construction practices, and enhancing construction project quality constitute a significant research topic within the construction industry. The smart construction site represents a concrete manifestation of the smart city concept within the construction engineering sector, embodying a novel management philosophy for the entire project life cycle. Smart construction site utilizes infrared thermal imaging fire monitoring and alarm systems, integrated dust and noise detection systems, BIM technology applications, VR safety experience systems, spray and sprinkler systems, intelligent inspection APPs, smart weighbridges,

Full Text

Promoting Intelligent Construction Site Development to Advance the Building Industry

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Abstract

The construction industry serves as a crucial material production sector and pillar industry of China' s national economy, yet it remains a high-risk field

plagued by frequent safety incidents. Strengthening construction site safety management, reducing accident frequency, effectively controlling environmental impacts, eliminating illegal operations and uncivilized construction practices, and improving engineering quality represent critical research priorities for the sector. The intelligent construction site embodies the smart city concept within the building industry, representing an innovative approach to whole-life-cycle project management. By leveraging technologies such as infrared thermal imaging fire monitoring and alarm systems, integrated dust and noise detection systems, BIM applications, VR safety experience systems, spray and sprinkler systems, smart inspection APPs, intelligent weighing systems, UAV technology, and wireless energy monitoring systems, intelligent sites enable effective management of project safety, quality, economics, and environmental performance.

Keywords: Intelligent construction site; BIM technology application; Dust detection system

1. Project Overview

1.1 Project Introduction

The Grand Canal Hub Port Expansion and Upgrading Project comprises two green three-star office buildings (Buildings 1# and 2#) with a total construction area of 15,431.18 square meters and a contract value of 120 million RMB. As green buildings requiring whole-life-cycle management, the project demands strict adherence to the "Four Savings and One Environmental Protection" principle (energy, land, water, and material conservation plus environmental protection), along with rigorous construction and operations management. All construction activities must follow the *Green Building Evaluation Standard* (GB50378-2014) and the *Green Building Evaluation Technical Guidelines 2015 Edition.*

2. Creating a Safe and Intelligent Construction Site

2.1 Enhancing Safety Awareness Among Construction Personnel

To diversify safety education for construction workers, the project employs 3D model animations to simulate real safety accidents. To more directly improve on-site safety consciousness, we introduced VR technology and established a dedicated VR safety experience zone. When combined with headset equipment, VR scenarios provide users with an immersive visual experience—upon donning the VR glasses, participants feel physically present at the construction site, with the entire project displayed in lifelike detail that seems tangible. The VR safety experience zone employs four distinct presentation methods (visual, auditory, linguistic, and dynamic actions) and utilizes three different modes of representation (planar, stereoscopic, and three-dimensional). This approach allows participants to engage personally, experiencing and internalizing safety

concepts through direct involvement, ensuring that every construction worker comprehends the critical importance of safety awareness. [Figure 1: see original paper] [Figure 2: see original paper]

2.2 Achieving Comprehensive Site Coverage Management

Traditional inspection methods inevitably create blind spots in safety management, including high-altitude edges, cantilever scaffold facades, and dangerous areas at the tips of large equipment, all harboring potential safety hazards. By introducing UAVs for aerial site patrols to supplement safety supervision, we can control drones to reach locations that are inaccessible or invisible to human inspectors, capturing clear photographs to verify structural reliability. The infrared thermal imaging fire monitoring and alarm system enables setting of dangerous temperature thresholds on thermal imaging displays—when monitored areas exceed these thresholds, the system displays real-time temperatures and triggers alarms, effectively nipping fires in the bud. Through the application of these two intelligent devices, we have achieved comprehensive, 死角-free site management. [Figure 3: see original paper] [Figure 4: see original paper] [Figure 5: see original paper] [Figure 6: see original paper]

3. Building High-Quality Engineering

Construction quality directly impacts national economic development and people's lives and property, making quality management paramount. To ensure that every link and component meets standards without causing negative impacts or quality accidents, the project employs a dual approach using Smart Inspection APPs, QR code information management technology, and BIM technology for comprehensive quality control.

3.1 Identifying Design Issues Through BIM to Reduce On-Site Changes

Traditional drawing reviews involve coordination between technical personnel from various construction departments and design institute professionals. However, due to professional limitations, construction personnel often fail to identify cross-disciplinary issues affecting their own specialties. To resolve this challenge of incomplete drawing reviews and poor interdisciplinary coordination, the project integrates all professional drawings into a unified BIM model for review by specialized BIM engineers. This approach successfully identifies design problems in advance, reducing subsequent structural damage during construction, minimizing material waste during finishing works, and preventing on-site adjustments caused by inadequate drawing comprehension, thereby ensuring construction aligns perfectly with design intent. [Figure 7: see original paper]

3.2 Leveraging Internet Technology to Enhance Rectification Execution

The Smart Inspection APP serves as a "mobile terminal + cloud service" platform for multiple on-site roles. By importing drawing information models into the APP, users—including general contractors and subcontractor personnel—can interact through this unified platform. Applied throughout the construction process, the APP manages quality, safety, progress, materials, and changes, moving the entire closed-loop workflow of task assignment, rectification, and completion verification onto a mobile platform. This creates permanent, authentic records of all processes, significantly reducing the repetitive, time-consuming work typical of traditional project management while improving efficiency, reducing costs, and enhancing overall project quality. [Figure 8: see original paper]

3.3 Integrating BIM and QR Code Technology to Create a New Management Paradigm

QR code technology offers large information storage capacity, convenient data access, low cost, and easy production, making it widely applicable. QR codes can directly display critical details for each construction process, including acceptance times, responsible persons, technical disclosure contents, construction characteristics and difficulties, equipment status, and acceptance records, enabling full traceability of issues. By scanning QR codes with smartphones, workers and staff can access diverse information on corporate culture promotion, safety technical disclosures, equipment management, safety hazard identification, and safety operation procedures, facilitating easier consultation, preservation, and communication. [Figure 9: see original paper] [Figure 10: see original paper]

4. Creating Economical Engineering Projects

Material and utility costs account for 60-80% of total project expenses, with steel and ready-mixed concrete representing particularly large proportions. However, construction sites face numerous management challenges: (1) vulnerabilities in material acceptance such as falsified weighing data, improper weighing procedures, weight cheating, multiple weighings for one truck, and forged documents; (2) heavy manual workload and low management efficiency; (3) inability to implement remote monitoring; (4) failure to promptly detect and address weighing discrepancies; (5) inaccurate material cutting and severe waste; (6) mismatches between material lists and actual site conditions, preventing effective cost control; and (7) widespread water and electricity waste that is difficult to manage. Analysis of these issues reveals that adopting intelligent material management systems and BIM5D technology can effectively resolve these problems, enabling intelligent and informatized on-site material management.

4.1 Application of Intelligent Weighing Technology

Intelligent weighing technology utilizes IoT integration of weighbridges, cameras, high-speed scanners, and printers to automatically collect business data previously entered manually, ensuring data authenticity, accuracy, and timeliness while reducing workload for material management personnel. Through data analytics, the system automatically captures and multi-dimensionally analyzes data, providing management and decision-makers with the most accurate and timely basis for decisions while maximizing management effectiveness. This application not only significantly reduces human intervention but also strengthens business control, reduces shipping and receiving risks, improves work efficiency, and lowers material costs. [Figure 11: see original paper]

4.2 Application of BIM5D Technology

BIM (Building Information Modeling) represents a "visual" digital building model constructed using the most advanced 3D digital design and engineering software. Its ultimate goal is to enable effective resource planning, financial risk control, energy conservation, cost savings, pollution reduction, and efficiency improvement throughout all project phases—from design and construction to operation—thereby achieving true whole-life-cycle management. The introduction of BIM5D technology provides essential foundational data for construction processes. During construction, linking the BIM model with bill of quantities enables automatic calculation of material quantities for steel, concrete, formwork systems, and other components. After importing pricing data, the system performs budget-versus-actual cost analysis, strengthening construction cost management and ensuring economic benefits. [Figure 12: see original paper]

4.3 Application of Wireless Energy Monitoring Systems

Wireless energy monitoring and efficiency management systems constitute a critical component of green building energy management, encompassing energy-efficient equipment selection, energy-saving retrofits, monitoring system installation, and energy conservation promotion. This project employs the infomed v2 cloud-based smart energy management platform integrated with water- and electricity-saving equipment to monitor and control consumption in production, office, and living areas, comparing actual usage against target indicators. This system demonstrates significant energy-saving effects for consumption management, enabling effective energy monitoring and warranting greater attention for its guiding significance in promoting building energy efficiency. [Figure 13: see original paper] [Figure 14: see original paper]

5. Building Environmentally Friendly Engineering

China' s atmospheric environment continues to deteriorate, with dust pollution becoming a major pollution source, particularly from construction activities. Construction workers and machinery generate substantial dust that increases

particulate concentration and exacerbates air pollution. With atmospheric pollution growing increasingly severe, controlling dust pollution and improving air quality remains an urgent priority.

5.1 Application of Spray and Sprinkler Systems

By utilizing the permanent rainwater collection system during the structural construction phase, the project implements automated dust suppression through spray and sprinkler equipment activated in coordination with real-time dust monitoring systems when predetermined thresholds are exceeded. This approach conserves traditional water sources while achieving true green construction. Dust suppression through spraying converts pressurized water into mist via nozzles, ensuring optimal atomization effects and angles that significantly reduce water consumption while increasing collision probability and velocity between dust particles and water droplets to improve dust removal efficiency. This process increases gas humidity, causing dust particles to coagulate, enlarge, and settle, thereby achieving dust reduction and air purification. The site achieves comprehensive dust suppression coverage by installing water supply pipelines on tower cranes, external scaffolding, and perimeter enclosures, effectively controlling dust pollution. [Figure 15: see original paper]

Integration of BIM Applications with Green Construction. BIM technology enables comprehensive prediction and deployment analysis for the "Four Savings and One Environmental Protection" principles in green construction. By extracting and setting target values from national standards for this project, we implement refined management to achieve the ultimate goal of green building certification.

The application of BIM technology, intelligent construction, big data analytics, and cloud platforms represents the current development trend in construction informatization. These implementations make project management more transparent and construction management more standardized, enabling more regulated and efficient project management. This approach facilitates whole-life-cycle project performance, enhancing the brand influence of PowerChina Construction Group.

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