

Exploration of Smart Construction Site Management Applications Based on BIM

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ABSTRACT: This article takes a particular library project as an example, analyzing and exploring the application of BIM technology during the construction phase and investigating methods for intelligent management during this phase. By integrating BIM technology into construction site layout, the construction of smart construction site platforms, and construction management, it achieves efficient, intelligent, and visual construction. Through the combined application of BIM technology and smart construction sites, cloud platform information technology is used to effectively manage the construction phase. By integrating various intelligent technologies and methods such as BIM and GIS, the focus is on intelligent management of the construction site, establishing a comprehensive and efficient digital system platform for the construction site, and realizing intelligent management of the construction site.

KEYWORDS: Smart Construction Site; Construction Management; Building Information Modeling(BIM); Construction Phase; Construction Site Layout.

I. BIM+ SMART CONSTRUCTION SITE CONCEPT

1.1 BIM+ Smart Construction Site Concept

[1-4].The smart construction site is a novel integrated management model for engineering sites. It represents a deep integration of the Internet+ and the traditional construction industry, and it is a specific manifestation of the smart city and Internet+ concepts in the field of construction. The smart construction site mainly utilizes emerging intelligent construction technologies such as GIS, BIM, cloud platforms, and smart devices to reform and innovate the past construction site management work and interactive methods of the construction

industry. This innovation improves work efficiency on construction sites, overall control ability throughout the entire process, decision-making capacity for project plans, etc., striving to achieve visualization, simulation, precision, and intelligent management of the construction process.

Based on the BIM+ smart construction site technology application, through the integration of information technology and detailed management, we aim to improve resource utilization, streamline workflows, coordinate with various construction participants and workers, and achieve coordinated and collaborative construction site production management decisions. This reduces project management costs, enhances coordination efficiency, and reduces risks associated with quality, safety, and progress.

1.2 BIM-based Construction Management

BIM-based construction management mainly uses the virtual real-world visualization of BIM three-dimensional models. It integrates real-time information data, such as progress and cost, during the construction process into the BIM model, and then introduces it to the construction site management platform. [5] BIM provides a more intuitive, accurate, and detailed understanding of building construction and maintenance information, real-time data, and other related construction information.

(1) Data Integration and Sharing

The BIM model covers basic engineering information, detailed information data parameters of internal components, etc., and integrates a large amount of information data from various phases such as architectural structural design, on-site construction, engineering management, and completion delivery. By combining construction site management with BIM, it realizes the sharing of

engineering information data from all parties, facilitating coordination and interactive collaboration at various stages of work.

(2) Visualization of Construction Management

For real-time management of construction sites, monitor the construction process through the BIM model and remote device monitoring in real-time. Operators, maintenance staff, and relevant responsible persons carry out key control based on real-time information. BIM visualization technology is used to predict engineering information in advance for key projects and important parts, and feasibility simulation analysis is performed for the selection of important equipment, smoothly achieving remote visual construction management.

(3) Emergency Management Decisions and Simulation

By simulating unexpected situations and risk conditions in the construction process before starting work, construction workers receive emergency safety training, understanding and mastering related construction safety emergency measures. [6-7]. Construction management personnel predict and simulate various emergencies in advance, deploy management solutions in advance for different situations, and conduct decision analysis and optimization to ensure the construction process is safe and reliable.

The article explores the application of BIM technology, analyzes the application of BIM technology in site layout and smart construction site management, and investigates methods of intelligent management during the construction phase.

II. EXPLORATION OF BIM TECHNOLOGY APPLICATION

Based on Building Information Modeling (BIM), combined with current Internet+, cloud services, 5G technology, 3D scanning, VR, and other new technologies, applications are developed during the design and construction phases, realizing the informatization, digitalization, and intelligent management of engineering projects.

2.1 Main Technical Content

(1) Application in the Design Phase Based on BIM Technology

Using BIM technology's visualization and cloud server collaboration platforms, design quality is enhanced through performance analysis, professional coordination, and simulation optimization. This optimization from the initial phase improves work efficiency in subsequent stages.

Intelligent Analysis of Model Design: Intelligent construction analysis of BIM civil models assesses architectural design rationality and structural reliability.

Parametric Design: Integrates parameter information within the model for efficient modeling and detailed design.

Architectural Visualization: Transforms traditional 2D presentations into 3D visual models using BIM reverse engineering.

Design Reverse Review: BIM model reviews are cross-referenced with design drawings to address conflicts and errors in early stages.

Virtual Reality: Simulates real-world scenarios using BIM models for immersive experiences.

Comprehensive Analysis and Inspection: BIM outcomes from various professionals are integrated, and results from comprehensive analyses guide adjustments.

Unified Diagram and Model: Engineering construction data is compiled using BIM architectural model data and relevant standards.

(2) Application in the Construction Phase Based on BIM Technology

Building upon BIM design models, construction BIM is further refined, applied, and managed to anticipate and mitigate construction issues, thereby intensifying construction process management.

Visual Guidance: Construction workers are guided using the BIM model.

Real-time Tracking: BIM civil and site layout models, combined with modern construction management technologies, allow real-time monitoring of the construction site and personnel for safety.

Cost Management: The BIM model facilitates the export of engineering quantity information for cost management.

Progress Management: Scheduling and simulating construction processes are done using the construction site layout BIM model.

Data Sharing: BIM engineering data is uploaded to the cloud for collaborative work.

(3) Management Method Application Based on BIM Technology

By integrating BIM models from all stages and employing technologies like big data and cloud platforms, real-time management of construction sites is achieved.

(4) Prefabrication Based on BIM Technology

Directly extracting information from the model, which is compatible with CNC processing equipment, enables centralized intelligent manufacturing, improving material utilization and shortening the construction period.

(5) Visual Technical Handover for Construction Techniques

Using BIM's 3D information technology, complex technical processes are virtually and dynamically simulated for visual technical briefings to project construction personnel.

(6) Application of BIM + Smart Construction Site Technology

Innovating traditional construction management through the integration of BIM model data and establishing a comprehensive intelligent system centered around construction sites, maximizing the digital, networked, and intelligent advantages of smart construction sites.

2.2 Technical Application Advantages

(1) Advantages of Using BIM Technology in the Construction Phase: Direct and efficient communication of information; compared to traditional methods, issues are resolved ahead of time, improving communication efficiency. This resolves design phase drawing issues, avoids transferring these issues to the construction phase, reduces coordination efforts during construction, effectively reduces rework rates, accelerates construction progress, and optimizes construction quality. At the same time, the BIM management platform streamlines project issues, documents, models, and information.

(2) Modular Construction Based on BIM Technology: Through prefabricated factory components and modular assembly, material utilization is enhanced, and centralized processing of certain products ensures component quality, reduces energy consumption, realizes green construction, and saves construction costs.

(3) Visual Simulation Technical Handover for Construction Techniques: Directly introduces how to operate, addressing issues like lack of specificity and abstraction. In the early stages of a project, virtual construction simulations for structures and buildings are carried out using BIM, showcasing quality, safety, and civilized construction information, improving construction quality and efficiency.

(4) Application of BIM + Smart Construction Site Technology: Through integrated information technology, management is refined, resource utilization is improved, workflows are streamlined, and risks related to quality, safety, and progress are reduced.

III. OPTIMIZATION OF CONSTRUCTION SITE LAYOUT BASED ON BIM

The construction site layout is about organizing various work areas on the construction site planned by the construction unit, facilitating on-site construction activities for the workers. This involves taking into consideration the surrounding roads, rivers, residential buildings, and other environmental constructs, as well as the positions of various existing structures. A rational plan for the internal space of the site is needed, standardizing the arrangement of on-site construction roads, material stacking areas, personnel and vehicle entrances and exits, work areas, living areas, and other functional areas, as well as machinery like tower cranes. By creating layout plans and 3D simulation scenarios for the construction site at different stages, we can ensure that materials, equipment, and other resources required during the construction process are coordinated efficiently, facilitating the smooth flow of material and component production and transportation, ensuring orderly on-site construction.

Traditional site layouts use CAD flat drawings for display. They are typically planned by relevant site planners based on past construction experience. Many times, these planners rely directly on their past experience and intuition, which makes it difficult to determine if there are errors in the site layout scheme, or to anticipate actual problems in the on-site layout.

By leveraging BIM+GIS technology, a BIM site layout model can be created. Through the linkage function of the planning software map, the 2D layout drawings of the site are linked with the map, producing a 3D linked display. This combination of the site model with the actual geographical conditions allows for adjustments to the site layout based on the real situation.

By integrating the dynamic and visual capabilities of BIM technology during the construction site layout phase, the construction site can be arranged efficiently and reasonably. Comprehensive use of various smart, digital, and model-based techniques, through reasonable analysis and presetting of the actual site conditions and the actual construction needs at each stage, plans for the site layout and virtual construction simulation can be made. With 3D visualization, dynamic observation of site layout can be conducted, and the layout scheme can be adjusted in real-time based on the situation, achieving optimal site planning.



Figure 1: 3D Linkage Effect Diagram of Construction Site Surroundings

IV. IMPLEMENTATION SCHEME FOR SMART CONSTRUCTION SITES

To further study the application effects of smart construction sites, the BIM model is combined with the smart construction site system to establish a BIM + 5G Smart Construction Site system platform. This platform integrates routine construction activities, equipment maintenance, and other management actions with the smart construction site system. By utilizing the BIM + 5G Smart Construction Site management platform, it facilitates coordination and communication among all parties involved in the construction, enabling real-time and efficient control and management of the construction process. This ensures the efficiency of real-time management of construction quality, cost, and progress. It aims to achieve transparent and visual management of construction, maximizing the application value of technologies like BIM, 5G, and smart construction site cloud platforms.

Based on the actual situation of the engineering project, by integrating 5G with new technologies, an implementation scheme for a 5G Smart Construction Site based on BIM technology is formulated, realizing the application of smart construction technology in building engineering.

By merging traditional smart construction site technology with 5G and other technologies, an innovative smart construction site platform is developed. According to the actual operational

needs of the construction site, new technologies are optimized and applied, achieving a comprehensive understanding of the entire construction process. This collaboration involves all construction parties, providing a full perception of the construction process through intelligent analysis, VR real-scene experiences, and simulated construction building functions. The goal is to achieve intelligent, meticulous operation and management of construction projects, continuously enhancing the capability to monitor and control the construction process.

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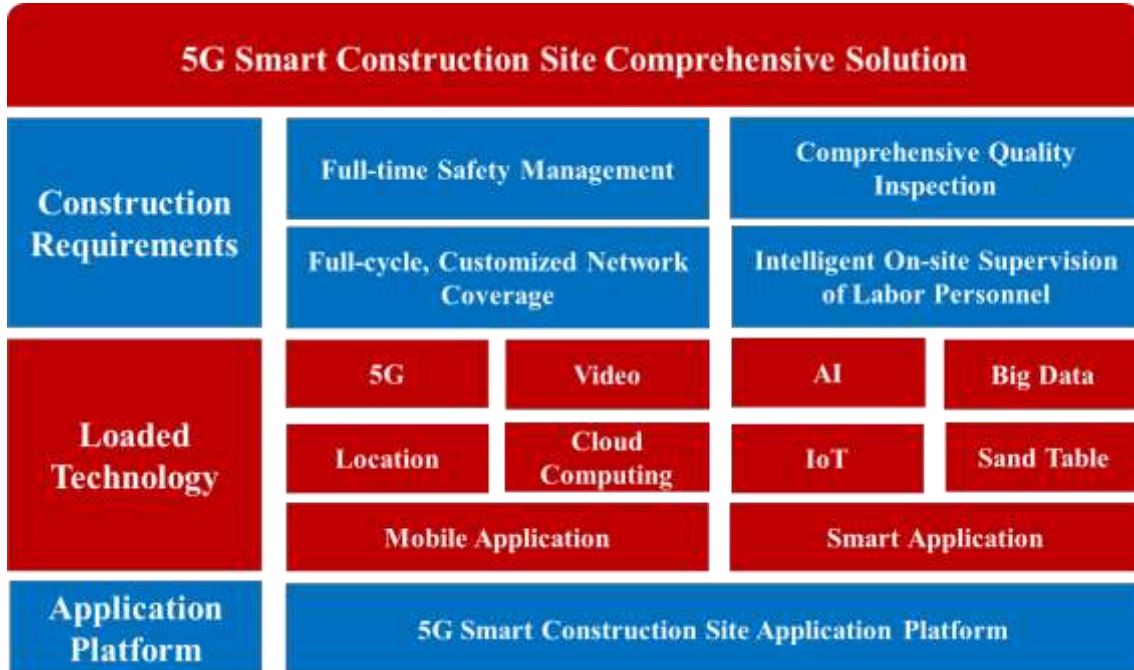


Figure 2: Overall Scheme of 5G Smart Construction Site

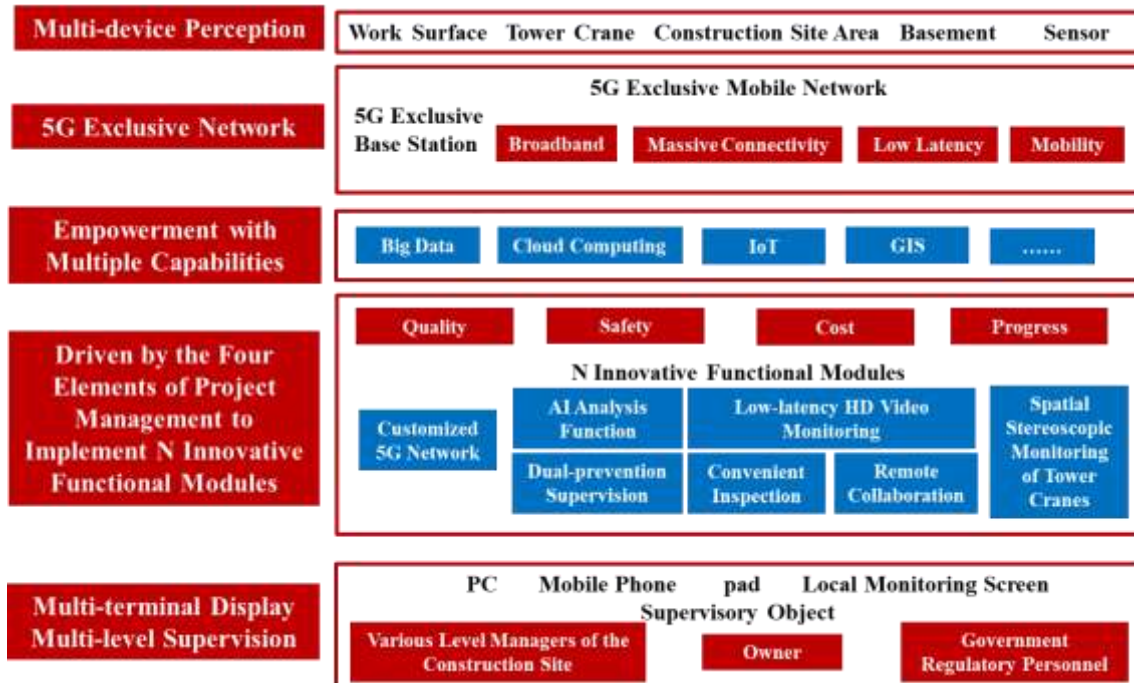


Figure 3: Architecture of Smart Construction Site Platform

(1) Customized 5G Network

A dedicated 5G network is set up at the construction site, providing efficient and fast network services at the same level as the telecom operators. This ensures full network coverage, empowers intelligent construction site management, and supports the stable and efficient operation of the

smart construction site platform, ensuring smooth and intelligent management.

(2) 720° 3D Monitoring of Tower Cranes

The intelligent analysis and monitoring of large machinery at the construction site are essential elements of construction focusing on people,

machinery, materials, methods, environment, and measurement. It is crucial for the management and control of smart construction sites. By setting up a 720° 3D monitoring system for tower cranes at the construction site, there is a three-dimensional supervision over the construction and safety conditions, allowing real-time dynamic management of construction machinery.

(3) 5G HD Video Surveillance

Deploy 5G high-definition video surveillance at the construction site. Key monitoring areas include vehicle entry and exit points, personnel access, living areas, work zones, and large machinery. The 5G HD surveillance connects to the smart construction cloud platform, transmitting 1080P high-definition videos in real-time, enabling long-distance real-time monitoring of the construction process and recording the workflow.

(4) Dual Protection Management System for Laborers

The construction site adopts a dual system of real-name authentication for workers entering the site and AI video analysis. Workers are efficiently and intelligently managed. When workers enter, identity verification is done using facial recognition, logging their work status in real-time. The video AI analysis system intelligently analyzes entries, ensuring construction workers are dressed safely and establishing a dual protection system for personnel access.

(5) 5G Mobile Inspection

QR codes are set up at potential hazard points. Combining personnel, high-definition surveillance videos, and mobile inspection devices, the patrol inspection tasks are efficiently completed using new technology, reducing the labor intensity of workers. Through mobile inspection, there is efficient coordination among the three parties for real-time unified supervision and inspection of the construction site, improving inspection efficiency and quality.

(6) 5G Remote Collaboration System

Using 5G mobile inspection devices, a 5G remote collaboration system is set up for construction projects. Construction site personnel use these devices for on-site patrol inspections, recording actual construction videos for remote interactive management. For technical difficulties or emergencies on-site, communication with managers and technical experts can be quickly established via remote collaboration to devise solutions. The 5G remote collaboration system ensures distant

supervision and documentation, ensuring the safety and smooth progression of the construction process.

(7) Construction Site Video AI Analysis System

For site management, live video surveillance of the construction site is fed into the AI video analysis system, targeting key areas of the construction project for AI algorithm analysis. Based on the live feed, timely alarms are triggered for perimeter protection, flames, and smoke, ensuring the safety of construction site personnel.

(8) Safety Training with VR Glasses

Set up a VR real-scene experience in the safety experience zone. Using VR devices combined with BIM models, potential issues in construction are simulated, training workers about on-site safety. This preemptively addresses potential construction accidents, reducing the occurrence rate of engineering mishaps.

V. SMART CONSTRUCTION MANAGEMENT SOLUTIONS

By utilizing the BIM-based construction management cloud platform, functionalities such as resource management based on 3D models, pipeline information queries, facility operation and maintenance planning are achieved. The equipment maintenance systems are integrated with map positioning, allowing maintenance personnel to be guided to identified problem points through the maintenance software.

(1) Quality Management

By connecting the BIM model to onsite cameras, real-time progress feedback from multiple projects is achieved. Through color indications on the BIM model, project delays can be quickly understood. By dispatching tasks based on progress, the accuracy and timeliness of progress data is ensured. Focusing on primary materials, maintenance, and inspections related to structural safety, on-site construction management and quality acceptance are emphasized. Quality control measures for the project are formulated. On-site measurement instruments are equipped with Bluetooth modules to provide real-time data to the collaborative platform. Quality inspectors conduct daily inspections via the platform, sending any quality issues to the responsible parties for rectification, thus eliminating quality problems, reducing risks, and improving construction quality.

(2) Safety Management

Comprehensive safety management of the project is conducted, with early warning systems for high-risk projects, ensuring the ultimate achievement of safety goals, improving work efficiency, customizing approval processes, and providing transparency in real-time. With the help of real-time HD video monitoring and comprehensive inspection procedures, there's all-around coverage of on-site construction safety. The smart construction operation and management cloud platform integrates the BIM model with video surveillance, allowing real-time monitoring of the construction site. Traditionally, emergency incident management was focused on time response and rescue. With BIM, there's an emphasis on prevention, alerts, and the entire incident management process. Using the BIM model, high scaffolding (high-risk projects) undergo 3D visualization for clearer understanding, improving construction efficiency and project quality. Videos explaining techniques like scaffolding setup, rebar tying, and concrete pouring are created for construction personnel, ensuring efficient work execution.

(3) Technical Management

The project leverages the BIM information cloud platform for technical management upgrades, moving technical management online. Drawings, plans, and BIM models are uploaded to the platform. With the aid of visual model matching, specialized plans, drawings, and 3D introduction videos for various sub-projects are shared online.

(4) Material Management

Using the BIM 3D model's virtual environment, a system is designed to query the stock and usage of materials on the construction site. Real-time concrete pouring amounts can be visually inspected. To enhance rebar control efficiency, rebar placement is planned based on structural drawings. The BIM model is exported as a GFC quantity exchange file and imported into rebar detailing software for data matching. The exported rebar cut lists are sent to the rebar processing workshop. The finished rebar is labeled with details like type and usage location, ensuring detailed and comprehensive material management.

(5) Personnel Management

Dynamic personnel information management is realized, collecting data, providing training, and managing attendance integrity. Personnel management starts with onboarding construction staff following safety norms and ends

with offboarding salary settlements. Relying on digital and smart construction technologies, data is analyzed in real-time, recording and understanding the daily health, safety practices, and work efficiency of construction staff, ensuring smooth and orderly construction processes. Entering workers wear safety helmets with location chips, enabling real-time monitoring of their positions and count through the smart construction system. Project managers can immediately understand the distribution of workers on site, individual attendance data, etc., thereby achieving precise and digital management of construction staff.

(6) Schedule Management

Throughout the construction process, the smart construction site progress management system platform is used to divide various work tasks, formulate related implementation plans, track and correct construction process progress, etc., to achieve visualization of the construction progress. At the same time, the project uses BIM technology for site planning, virtual construction simulation, which is convenient for reference during actual construction on site, avoids pitfalls in the project progress implementation process, and realizes dynamic management and visualization of construction progress.

(7) Cost Management

Cost management employs BIM5D technology. Through BIM modeling, errors during the design phase are reduced, calculating planned construction quantities and costs, thus minimizing manual calculation errors. The cost and design modeling process are dynamically synchronized, quickly comparing the differences in engineering quantities before and after changes. It forecasts resources and funds on a quarterly, monthly, and weekly basis, assisting in procurement planning and optimizing procurement plans and cash flow.

(8) Equipment and Machinery Management

In terms of machinery and equipment management, through intelligent analysis of the construction site layout, such as crane analysis, the running routes and entry and exit times of large construction machinery and equipment are reasonably arranged. Display machinery and equipment information in QR code format for easy understanding of the location, use, maintenance situation of machinery and equipment on the construction site, preventing equipment loss and damage.

By monitoring the operation status of large machinery and equipment, using facial recognition

systems to ensure rational operation of machinery, integrating equipment data through technologies like IoT, monitoring machinery in real time, and providing timely warnings and repairs in case of equipment failures ensures safe and efficient operation.

(9) Green Construction Management

Centered around the concepts of green and humane construction, a green construction site is built. Through automatic dust monitoring in the construction process, intelligent automatic dynamic dust control is achieved. The construction site is equipped with a dust and noise monitoring system, which monitors in real-time, carrying out comprehensive green control over construction site operations and ensuring the principles of nature and greenery are implemented everywhere on the site.

VI. CONCLUSION

Through BIM technology to establish a three-dimensional model for construction site guidance, the interactive methods, operations, and construction management modes of the construction industry have been changed. Integrating new technologies such as BIM, GIS, and 5G into the construction phase achieves comprehensive management at all stages of the construction site, real-time control of key construction processes, and collaboration with all parties for efficient and quality coordination. This results in a visual, intelligent, digital, and simulated construction process, achieving smart construction of architectural projects.

At present, with the advent of BIM+, the construction industry can genuinely address future industrialization challenges and build a new construction mode. From collaborative design, virtual construction to virtual operation and maintenance management, by using new technologies like cloud platforms, the productivity and efficiency of construction are enhanced, helping to realize the digital transformation of the construction industry.

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