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Research on Empowering Construction Efficiency with Smart Construction Site Technology

Peng Bai

Taishan University, Tai'an 271000, Shandong, China

Abstract: ***There are related problems in traditional construction engineering, such as low resource scheduling efficiency, difficult safety risk control, high volatility caused by manual quality supervision, and delayed progress caused by complex multi-disciplinary collaboration. The smart construction site technology based on the core architecture of the Internet of Things, big data, artificial intelligence, building information modeling, and cloud computing provides a new path for systematic solutions to these problems. This article deeply analyzes the precise management efficiency of the smart construction site technology system on core elements such as personnel, machinery, materials, methods, and environment in construction engineering, quantitatively evaluates its application value in planning optimization, process transparency, safety pre control, and quality stability improvement, and proposes solutions to the practical bottlenecks such as cost barriers, data integration challenges, skill gaps, and standard deficiencies in the implementation process of technology.***

Keywords: Smart construction site; Architectural engineering; BIM technology; Internet of Things; Big Data Analytics.

1. INTRODUCTION

Against the backdrop of continuous urbanization and the construction industry as a pillar industry of the national economy, improving the efficiency of construction projects has significant economic and social significance. However, the traditional extensive management model is increasingly revealing limitations such as fragmented construction site information hindering decision-making, passive safety monitoring dominated by manual inspections with low efficiency and lag, construction progress often encountering delays due to communication and coordination difficulties and inaccurate planning, and quality standards implementation often fluctuating with regulatory power and human factors. As a result, resource waste, cost control, safety risks, and project delays have become industry pain points. Smart construction site technology, through deep integration of information and physics, reshapes on-site management processes with digitalization as the core means, and is a key technological path to solve industry problems and empower efficiency leaps.

2. OVERVIEW OF SMART CONSTRUCTION SITE TECHNOLOGY SYSTEM

Smart construction site refers to a new management model that deeply integrates the full life cycle activities of construction projects using modern information technology. It is an information system that tightly couples the physical space and information space of construction sites through digital means. The smart construction site technology system consists of five components. Building Information Modeling technology is the primary carrier of building information, providing a project visualization collaboration platform and data ground; The Internet of Things is a physical network that connects all things in the geographic space of a project. It collects real-time data on the location of workers, machinery, production status of large equipment, material flow status, and important environmental data through various sensing devices, radio frequencies, and Beidou terminals; Cloud computing is a data center and computing hub, as well as an infrastructure for storing and processing massive amounts of heterogeneous data; Big data refers to the data sets and streams generated by business domains, sensors, and intelligent collection terminals, and is the computational object of big data analysis software; Analyzer software is a software that mines and analyzes data, using deep learning to analyze information on progress lag, quality risks, and security risks; Artificial intelligence is software that conducts more in-depth analysis of big data analysis results, such as image recognition of security risks and algorithm calculation of optimal material transportation routes. Smart construction site is a technological system that is coupled by these five dimensions.

3. MECHANISM ANALYSIS OF SMART CONSTRUCTION SITE TECHNOLOGY EMPOWERING THE EFFICIENCY IMPROVEMENT OF CONSTRUCTION PROJECTS

3.1 Dual Optimization of Human Resource Efficiency and Safety Level

Through the deployment of the Internet of Things, as well as technologies such as indoor positioning based on high-precision satellite positioning and the integration of Beidou positioning modules into safety helmets, traditional passive and inspection based human operations and safety management will be fundamentally overturned. Set up an electronic fence to accurately define the locked area. Based on the Beidou positioning module, it can be worn on people's bodies to provide alarm prompts and force them to leave or lock the equipment outside the safety fence, effectively reducing the number and proportion of incidents of electric shock and mechanical injury to personnel. In a super high-rise project in Shenzhen, the number of reported attempted mechanical injury incidents decreased by about 38% after implementation. Set up an intelligent safety helmet, which can be equipped with vital sign sensing detectors or gas sensors, to enable on-site personnel to immediately report to the background if they faint or enter an environment with abnormal gas concentration. The background platform will combine location to achieve rapid emergency rescue. The backend platform displays the real-time distribution of labor force in each construction area, and the project chief engineer can optimize resource allocation based on actual statistical data of the project, avoiding some process issues such as template installation and steel bar binding due to insufficient personnel allocation causing work delays.

3.2 Significant Improvement in Operational and Maintenance Efficiency of Mechanical Equipment

The main equipment for heavy construction should be connected to intelligent monitoring. The main equipment such as tower cranes and construction elevators are equipped with various sensors for temperature measurement, displacement, load capacity, acceleration, etc., which transmit the working parameters of the equipment, such as the amplitude, height, tilt balance, vibration, noise, etc. of the crane arm load capacity. The working curve and driver driving habits analysis are displayed on the remote large screen through the equipment curve chart, prompting the driver to engage in dangerous behaviors such as overloading and inclined lifting, and timely warning and archiving. Based on the statistical analysis of main equipment data, predict the wear and tear of some equipment, such as the replacement cycle of hydraulic actuators, main bearings, etc., and change the passive maintenance mode of "heavy use, light maintenance, heavy repair, light maintenance" in the past, in order to promote the concept of "light load, precise prevention" in maintenance.

3.3 Enhancement of Material Circulation and Storage Accuracy

The main building materials such as steel bars, cement, pipe fittings, valves, etc. are traced and controlled through QR code radio frequency identification technology throughout the entire process of smart construction sites, providing an effective solution for the rough control of material waste and loss in traditional materials. Smart construction sites use vehicles to scan documents for materials such as steel bars, cement, pipe fittings, valves, etc., associate them with cloud based material databases, and check whether the material models and quantities meet the entry plan to avoid errors and omissions; Internal management of warehouse materials, using intelligent shelves to identify pick-up locations, can quickly improve the efficiency of material sourcing in the warehouse and avoid work delays; The on-site installation task of the installation work surface is carried out by scanning the material labels with a handheld end, retrieving the corresponding drawing model process guidance, achieving precise installation, and avoiding the waste of installation resources caused by rebound rework; With the help of artificial intelligence based algorithms, the optimal time for material entry is dynamically calculated based on the construction schedule, accurate to the hourly level. Suppliers are required to deliver in batches, providing accurate material demand forecasting for large-scale projects such as continuous concrete pouring, to avoid on-site mixing truck pressure or insufficient supply.

4. CHALLENGES AND COUNTERMEASURES FACED BY THE IMPLEMENTATION OF SMART CONSTRUCTION SITE TECHNOLOGY

4.1 Balance Between Initial Cost Input Pressure and Long-term Returns

The initial funding for investing in the construction of smart construction site software and hardware is relatively

expensive, which has become a roadblock for small and medium-sized enterprises to participate. Large scale projects such as BIM center modeling, IoT data gateways, high-performance computing servers, computing nodes and edge devices, customized development and construction of video and AI analysis cloud platforms require significant one-time investments of millions of yuan. For small businesses with low overall profit margins, this is undoubtedly a considerable financial cost. In terms of response measures, the government should be guided to adopt financial special fund rewards, exemptions, and reductions policies to support smart construction demonstration projects. Large enterprises should be guided to output integrated solutions through their own technology service platform companies, and to alleviate the cost pressure of one-time procurement for enterprises through lightweight subscription sales. Establish a reasonable cost-benefit evaluation and prediction model that accurately reflects the long-term benefits of saving construction time, reducing management costs, and minimizing accident compensation after the implementation of smart construction sites. The data should guide the project construction party and the general contractor to pay attention to the long-term economic benefits of technology investment, thus forming a cycle of input-output. By guiding the industry to jointly build and share cloud platforms, the sales model of billing based on usage can further alleviate the initial burden.

4.2 Difficulty in Integrating Heterogeneous Data from Multiple Sources and Unifying Standards

The application of smart construction sites involves multiple platforms such as BIM models, IoT sensor networks, and schedule management systems. There are dozens of data structure formats with huge differences, forming information islands that make it difficult for the system to comprehensively collaborate and analyze. The key to the strategy lies in the mandatory promotion of the core metadata model defined in the national "Technical Standards for Smart Construction Sites", such as component coding system, personnel and equipment unique identification rules, and the elimination of data structure differences. Promote the development of a smart construction site system integration platform, with built-in unified data access adapters and conversion engines, to achieve standardized aggregation of multi-source data. At the practical engineering level, establish an information engineer position with professional capabilities in data governance, responsible for the verification, cleaning, conversion, standardized storage and maintenance workflow of data quality throughout the process, and build a project level data platform to distribute reliable and effective data source systems for heat maps, warnings, statistical reports, and decision support to various departmental business systems as needed, ensuring smooth and unobstructed data flow throughout the entire process.

4.3 Insufficient Ability of Professional Talent Team

The skill structure transformation of workers in the construction industry is slow, and they have little foundation in information technology application ability. On site operators, supervisors, and even construction management personnel often have a fearful mindset or low operational level towards the application of new technology equipment software, resulting in insufficient utilization of software system capabilities. Governance measures require governments at all levels and vocational colleges to clarify their teaching ideas, introduce targeted smart construction project management teaching courses, and accelerate the pace of talent cultivation in the industry. At the level of relevant enterprises, carry out corresponding hierarchical and continuous training on information technology capabilities, mainly targeting project managers and key personnel, to improve data based thinking ability and system platform operation level. The enterprise level is actively seeking cooperation with technology companies, providing corresponding technical support specialists on site, fully visiting frontline construction sites to solve operational problems in the application of smart system technology, and providing targeted guidance services. Incorporate the assessment proportion of smart system software applications into the corresponding project assessment and incentive mechanism, enhance internal learning motivation, and truly form a composite talent team with certain digital abilities among technical personnel and even management, thereby ensuring the effective implementation of smart management systems.

4.4 Cross Platform System Compatibility and Deep Integration Challenges

The technical routes and interface protocols of various smart construction site subsystem suppliers in the market are closed, leading to the formation of new islands and the difficulty of continuing collaboration. To overcome this obstacle, it is necessary to establish a national level certification mechanism, issue certification marks only to platforms that comply with open interface protocols, guide procurement direction, and avoid the problem of residual effects caused by closed technical system procurement. Promote a smart construction site platform solution based on microservice architecture, led by the platform's main framework developer, providing standard API interfaces for seamless integration of IoT subsystems, and facilitating on-demand selection and expansion of

functions. In the construction of large-scale demonstration projects, the bidder is required to promise that its technology stack will follow general standards, such as the industrial Internet identity analysis system, to ensure the interoperability of tools of all participants, and ultimately ensure the seamless connection between systems, deep integration, support the embodiment of overall value, improve the ecological efficiency system of the whole project, operate smoothly, coordinate well, and ensure interoperability to maximize the operation effect [5].

4.5 Increased Regulatory Risks for Data Security and Privacy Protection

There is a risk of privacy leakage and liability for collecting a large amount of construction site data, including sensitive personnel location information and important process and trade secrets of enterprises. In response to the construction layout work of the above-mentioned risk construction enterprises, strict technical control measures should be implemented in accordance with the requirements of the Cybersecurity Law and the Personal Information Protection Law at the beginning of construction. National encryption algorithms should be deployed end-to-end for transmission and storage, and data security should be ensured. Adhere to the principle of minimum necessity for data collection and processing, and arrange for hierarchical management of permissions to strictly control personnel's access to limited data content. Deploy a dedicated security audit network data recording platform to record all access content behaviors for traceability, in order to facilitate effective implementation of risk control management. Supervision can be effectively implemented to ensure that data processing and other activities are reasonable and legal, avoid project risk issues, form a good trust environment, promote the healthy development trajectory of the industry, achieve clear development, and be safe and reliable. It has been recognized by multiple parties and has great development space.

5. CONCLUSION

Therefore, smart construction sites use modern information technology to solve the long-standing shortcomings and deficiencies of low efficiency and high investment in traditional construction management processes. The relevant analysis and research in this article can see the disruptive impact on intelligent decision-making in engineering construction element management: improving construction plan execution efficiency based on resource allocation tools, enhancing safety risk control based on safety dynamic monitoring methods, ensuring stable and excellent quality based on quality process control and real-time monitoring, and maximizing the elimination of unnecessary idleness, waiting, and waste based on data analysis models to improve project efficiency. On this basis, smart construction sites will promote the reshaping of the construction management paradigm under the support of a new round of information technology, enhance the overall efficiency of the construction industry, and make the development direction increasingly clear. As a goal oriented approach, it will continuously improve the technical support system to promote the modernization of China's construction industry and its future vision. The long-term effects are obvious, and the impact is profound and significant.

REFERENCES

[1] Li Xiaolin Smart construction sites empower innovation and optimization of construction project management models [J]. Urban Construction, 2025, (18):37-39.
[2] Yang Siyuan Research on Empowering Civil Engineering Construction Management with Smart Construction Site Technology [J]. New Urban Construction Technology, 2025, 34 (03): 40-42
[3] Yan Xinjun, Zhang Shuai. 5G technology empowers smart construction sites [J]. Installation, 2021, (10):11-13.
[4] Qi Xiaoqiang, Tan Shuai, Huang Changlong, etc Research on the Application of Smart Construction Sites under the Background of "Internet of Things+" [J]. Intelligent Buildings and Smart Cities, 2021, (09):94-95.
[5] Chen Huan, Liu Qingying, Lan Zhuxin, Yu Zaiyang, Zhang Xuchun An effective way to build a smart site platform in the context of "Internet plus" [J]. Smart Building and Smart City, 2021, (02): 40-41+50.