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Green Construction Management Challenges and Optimization Strategies in Civil Engineering Based on Smart Buildings

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Abstract: Against the backdrop of comprehensive advancement in new-type smart city and smart building construction, green construction in civil engineering has become a core driver for the transformation, upgrading, and low-carbon sustainable development of the construction industry. The popularization and application of smart building technologies furnish technical support for refined, digital, and intelligent management and control of green construction in civil engineering, and meanwhile bring transformative challenges to traditional construction management modes. At present, domestic green construction management for civil engineering still suffers from insufficient technology integration, deficient data systems, lagging management systems, and inadequate overall planning, which hinder the realization of core objectives of consumption reduction, emission reduction, quality improvement, and efficiency boost throughout the whole green construction process. Accordingly, from the perspective of smart building development, this paper systematically sorts out core pain points in green construction management of civil engineering, and puts forward targeted optimization strategies from four dimensions: technology integration, data development, system improvement, and concept upgrading. It aims to promote in-depth integration of intelligent technologies into the whole green construction workflow, build a closed-loop digital construction management system, and facilitate the high-quality sustainable development of the construction industry toward green, intelligent, and modern orientations.

Keywords: Smart building; Civil engineering; Green construction; Construction management; Optimization strategy

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1. Introduction

With the continuous advancement of new-type urbanization in China, the scale of civil engineering construction keeps expanding. Construction industry activities generate massive energy consumption, dust, noise, and construction waste, making the sector a key object of regulation for domestic energy saving, emission reduction, and ecological environmental protection work. Competent authorities, including the

Ministry of Housing and Urban-Rural Development, have successively issued a series of policy documents related to the "dual carbon" goals, green building standards, and smart construction site specifications, explicitly requiring the construction industry to fully implement green construction modes and accelerate the promotion and in-depth application of smart building technologies. Relying on digital technologies such as big data, Internet of Things, artificial intelligence, BIM, and cloud computing, smart buildings can realize dynamic monitoring, intelligent analysis, and precise management and control over the whole construction process. By adopting smart building technologies, construction enterprises can effectively tackle long-standing industrial problems of traditional green construction management, such as extensive control, delayed supervision, and low efficiency.

2. Core pain points of green construction management in civil engineering under the background of smart buildings

2.1. Insufficient in-depth integration between intelligent technologies and green construction, with formalistic application

At present, some domestic construction enterprises hold biased perceptions regarding the application of smart building technologies. They apply Internet of Things monitoring, BIM modeling, intelligent monitoring, and other technologies to superficial links, including project bidding and tendering, construction demonstration, and completion acceptance, yet fail to deeply integrate intelligent technologies into core green construction scenarios such as dust control, noise management, energy consumption management, construction waste disposal, as well as water and electricity conservation. Construction management personnel seldom carry out real-time supervision, hidden danger investigation, and dynamic adjustment via intelligent platforms. Consequently, monitoring data from intelligent devices cannot directly support green construction decision-making [1].

On-site operation of construction teams still mainly follows traditional experience-driven practices. Construction workers are accustomed to conventional construction techniques and find it difficult to actively cooperate with data collection and intelligent supervision by intelligent equipment. The integration of intelligent technologies and green construction remains at the superficial level of hardware stacking, and the core value of technologies empowering green construction cannot be brought into play. In addition, some enterprises suffer from repeated procurement and idle waste of intelligent equipment. Disconnection exists between technology application and construction scenarios, which raises project construction costs and renders intelligent supervision for green construction a mere formality.

2.2. Imperfect construction data system and low efficiency of digital management and control

At this stage, some civil engineering construction projects have not established standardized and integrated green construction data systems. Data from various intelligent monitoring devices are independent of one another with poor compatibility. Data concerning dust monitoring, energy consumption statistics, waste transportation, water resource consumption, and material loss are stored separately in disparate systems [2]. Data interoperability, sharing, and joint analysis cannot be achieved across enterprise data systems, resulting in prominent data silo problems.

Construction management personnel lack standardized specifications for data management. First, at

the execution level, green construction data collected by construction staff are plagued by inconsistent statistical calibers, missing data, distorted data, and delayed updates. Second, at the management level, enterprises are incapable of sorting, dynamically archiving, and conducting in-depth analysis of full-process construction data. Third, at the decision-making level, project management teams cannot accurately judge the status of green construction, identify environmental protection hidden dangers, or optimize construction schemes based on authentic and complete construction data. Higher-level authorities cannot grasp the real-time dynamics of green construction projects, and project sites fail to keep timely alignment with industrial regulatory standards. Green construction management still relies on manual inspection and paper-based records, featuring low overall control efficiency and insufficient precision.

2.3. Lagging green construction management systems and absence of assessment and incentive mechanisms

Rapid iteration of smart building technologies has led to obvious lagging of traditional green construction management systems [3]. Current domestic green construction management specifications are mostly formulated for conventional construction modes. Administrative departments in charge of the industry have not formulated corresponding control standards, operating specifications, and restraint mechanisms for smart construction scenarios. Traditional management systems cannot adapt to new types of construction scenarios such as intelligent equipment application, digital supervision, and smart operation and maintenance. The existing *Guidelines for Green Construction* (Jianzhi [2007] No.223) also contain no clear stipulations on the validity of intelligent monitoring data or early warning response workflows.

Some construction enterprises have not established dedicated smart green construction management systems with ambiguous division of post responsibilities, giving rise to loopholes or discontinuity in work coordination among technical departments, construction departments, and safety and environmental protection departments. Without unified overall planning for green construction work across departments, duplicated work and management gaps are apt to occur [4]. Meanwhile, some construction enterprises lack sound assessment and incentive mechanisms, and fail to incorporate the effectiveness of intelligent green construction into staff performance appraisal, project award evaluation, and team-based assessment, reward, and punishment systems. It is hard to arouse staff's enthusiasm and initiative. Problems including irregular construction, extensive operation, equipment idling, and data falsification occur frequently, which greatly weaken the binding force of green construction management systems.

2.4. Weak awareness of green construction concepts and inadequate overall planning

On the one hand, management teams of some construction enterprises hold one-sided development concepts that prioritize progress and economic benefits while underestimating environmental protection and supervision. Taking project construction progress and economic returns as core assessment objectives, they regard green construction as extra work, and carry out passive green construction activities merely to meet basic requirements for project acceptance and qualification review. They have insufficient understanding of the value of smart empowered green construction, and are reluctant to proactively invest capital, workforce, and technical resources to advance intelligent green construction development [5].

On the other hand, construction management personnel possess relatively weak awareness of green construction concepts. Their management work is confined to basic tasks such as dust abatement and waste clearance during the construction phase, ignoring full-cycle green supervision covering project design,

material procurement, construction preparation, and later-stage operation and maintenance. Lacking systematic and holistic overall planning for project-wide green construction work, problems such as resource waste, excessive energy consumption, and inadequate environmental protection measures tend to emerge during construction. Hence, it is difficult to improve the overall quality and comprehensive benefits of green construction.

3. Optimization strategies for green construction management under the background of smart buildings

3.1. Deepen scenario-oriented technology integration and realize full-process intelligent green supervision

Based on the full life cycle of projects, especially design and construction workflows, construction enterprises shall promote in-depth integration of smart building technologies and green construction scenarios. First of all, change the one-sided development mindset that emphasizes hardware while neglecting practical application. Combined with core green construction scenarios of civil engineering construction, including dust control, noise abatement, energy consumption management, water resource utilization, material conservation, and construction waste disposal, enterprises shall build targeted intelligent supervision systems. Relying on Internet of Things technologies, fully automatic monitoring devices shall be deployed on construction sites to realize round-the-clock real-time monitoring of indicators such as construction dust, construction noise, site temperature and humidity, exhaust gas, and wastewater discharge [6].

Second, fully integrate BIM technologies into the whole construction process. In the preliminary construction phase, construction staff may adopt BIM modeling to complete construction site planning, pipeline layout, and material quantity calculation. Three-dimensional models can be utilized to optimize construction schemes and reduce rework, material waste, and site occupation problems. During construction, dynamic BIM modeling shall be adopted to make real-time comparisons between construction progress and design standards, so as to precisely control construction energy consumption and excessive discharge of construction pollutants. BIM visualization technologies shall be applied to carry out standardized operations, standardize construction workflows, and reduce resource loss and environmental protection risks induced by human operations.

Finally, introduce artificial intelligence and big data analysis technologies to construct intelligent early warning systems. Early warning thresholds shall be set for common issues such as excessive noise during construction peaks, dust diffusion under gale conditions, and high energy consumption in nighttime construction. The system can automatically identify irregular construction behaviors and over-limit data, and push early warning information to management staff terminals. Supported by intelligent early warning messages, construction personnel can implement precise supervision, realize pre-event prevention, in-process control, and post-event review for green construction problems, and raise the intelligence and refinement level of project green construction management and control.

3.2. Build an integrated data system and establish a closed-loop data supervision mode

Supported by digital smart building technologies, construction enterprises shall construct a unified, standardized, and integrated green construction data management system [7]. First, integrate data resources and interfaces from various on-site intelligent monitoring devices, management systems, and operation

terminals. Enterprises shall break data barriers among different systems, realize interconnection and centralized supervision of dust data, energy consumption data, material loss data, environmental protection governance data, and construction progress data, and unify collection standards, statistical calibers, and update frequencies for various construction data, so as to effectively mitigate problems of missing, distorted, and delayed data.

Second, establish regular mechanisms for data collection, sorting, archiving, and analysis. Staff shall collect core on-site green construction data on a daily basis, complete classified data summarization periodically, and conduct in-depth data analysis every month. Through data comparison, links featuring high energy consumption, high pollution, and heavy waste in construction can be accurately identified. On this basis, optimize construction techniques, adjust construction schemes, and improve environmental protection control measures in light of analytical results. Build cloud-based data-sharing platforms to open up data transmission channels among industrial competent departments, enterprise management, project sites, and construction teams, and furnish data support for project decision-making.

Third, construct a full process closed-loop data supervision mode covering data collection, data analysis, problem rectification, scheme optimization, and effect review. In response to green construction problems reflected by data, construction management personnel shall formulate special rectification plans and clarify responsible persons and time limits for rectification [8]. Construction teams shall strictly implement rectification requirements, promptly correct irregular problems, re-input rectified construction data into the system, and continuously verify rectification effects, so as to form a complete closed loop for data management and comprehensively improve digital supervision efficiency.

3.3. Improve the management system and perfect assessment and incentive mechanisms

Competent industrial departments shall revise and improve existing green construction management specifications in light of development trends and actual conditions of smart building and green construction industries. First, add special standard clauses related to intelligent construction supervision, digital data management, and intelligent equipment application. Competent authorities shall clarify industrial access standards, operating specifications, and regulatory requirements for smart green construction, and provide institutional grounds for enterprises to carry out smart green construction management. Build green construction management systems adapted to smart construction scenarios in combination with new industrial regulations and project realities. Refine management systems for links including technology application, data management, on-site supervision, environmental protection governance, and equipment operation and maintenance; clarify post responsibilities for technical departments, construction departments, safety and environmental protection departments, and front-line teams; and achieve clear rights and responsibilities, well-defined division of labor, and coordinated cooperation among all posts [9].

Second, establish regular supervision and inspection mechanisms. Enterprise management personnel shall conduct special inspections for smart green construction on a regular basis, check the operating status of intelligent equipment, data collection quality, and implementation of green construction measures, promptly investigate loopholes in system execution, and dynamically optimize and improve systems targeting deficiencies in institutions and unreasonable workflows, so as to ensure that management systems adapt to on-site construction demands. Meanwhile, enterprises shall focus on perfecting assessment and incentive mechanisms and incorporate the effectiveness of intelligent green construction into the enterprise-wide performance assessment system.

Third, establish sound differentiated reward and punishment mechanisms. Enterprises shall grant positive incentives such as bonuses, honor evaluation, and promotion to departments and individuals who properly implement green construction, apply intelligent technologies in a standardized manner, and achieve outstanding supervision results. For staff at posts with irregular construction, equipment idling, data falsification, substandard green construction performance, and inadequate rectification implementation, impose penalties including circular criticism, performance deduction, and post adjustment. By combining rewards with punishments, fully arouse all staff's initiative and enthusiasm in implementing smart green construction work and guarantee the effective implementation of all management systems.

3.4. Transform management concepts and strengthen full-cycle green overall planning for projects

First, proactively change the traditional one-sided development concept that prioritizes economic benefits over environmental protection. Enterprise management teams shall fully recognize the strategic value and practical significance of intelligent green construction for industrial transformation, enterprise development, and project quality and efficiency improvement. Integrate green construction and intelligent supervision into core project management objectives, and make every effort to promote the implementation of smart green construction modes [10].

Second, in the preliminary project preparation phase, project planning personnel shall formulate exclusive overall smart green construction schemes according to project characteristics. Conduct overall planning for site layout, material procurement, equipment configuration, technology selection, environmental protection measures, and other work, and avoid resource waste and construction environmental pollution from the source. For instance, procurement staff shall give priority to selecting green, energy-saving construction materials and intelligent construction equipment to lay a solid foundation for green construction.

Third, implement refined green supervision throughout the whole construction workflow. Management personnel shall coordinate environmental protection work in each construction link, and keep real-time supervision over construction energy consumption, pollutant discharge, and resource utilization. Upon project completion acceptance, project teams shall complete follow-up work including site restoration, waste removal, equipment recovery, and data review to realize full-cycle green supervision. All project staff shall foster a sense of responsibility for proactive green construction, consciously standardize construction behaviors, and actively cooperate with intelligent supervision work.

4. Conclusion

The rapid development of smart building technologies brings brand new opportunities for the transformation and upgrading of civil engineering green construction management, and also sets higher standards for traditional construction management modes. Centering on technological innovation, construction enterprises shall deepen the integration of smart building technologies and green construction scenarios, actively carry out comprehensive and systematic optimization measures, effectively tackle various drawbacks and practical problems in traditional green construction management, and give full play to the empowering value of smart technologies. In the future, the construction industry shall keep delving into the field of smart green construction, continuously optimize management modes, innovate technology application and improve institutional systems, promote the low-carbon, green, intelligent and high-quality development of the civil

engineering construction industry, and facilitate the implementation and advancement of national "dual carbon" strategy and new type urbanization construction.

Disclosure statement

The author declares no conflict of interest.

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