

Analysis of Quality and Safety Management Paths for Housing Construction Engineering from the Perspective of Smart Construction Sites

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Keywords: Smart Construction Site; Housing Construction Engineering; Quality and Safety Management; Digitalization

Abstract: Against the backdrop of digital transformation in the construction industry, the concept of smart construction sites is being widely adopted. As modern housing construction projects become increasingly complex, leveraging the advantages of smart construction sites to enhance the quality of housing construction engineering has become a key focus within the entire industry. This paper briefly outlines the concept of smart construction sites, expounds on the importance and main modules of strengthening quality and safety management in housing construction engineering from this perspective, and proposes scientific and rational management paths. These include comprehensive digital integrated management of all elements, innovating intelligent equipment and processes, establishing risk early warning and dynamic response mechanisms, building a whole-process quality traceability system, and implementing collaborative supervision. The aim is to provide reference suggestions for the high-quality development of housing construction engineering.

1. Introduction

Housing is the basic unit for urban development; the scale and quantity of housing construction will continue to increase. Housing construction quality and safety is closely related to the life of the people and property safety, but also to promote social harmony development foundation guarantee. As time goes on, traditional quality and safety management models of housing construction engineering have gradually shown some limitations. The Intelligent Construction Site: This is a smart construction site, where Internet of Thing (IoT), big data and cloud computing are being used to know about the equipment, material and people at the jobsite in real-time. This aids managers in correctly understanding how project progress and quality and safety statuses look. So, in-depth study quality and safety management path of housing construction engineering under the view of smart construction site, is an important measure to promote the intelligence development of construction industry.

2. Overview of Smart Construction Sites

Smart construction sites are a major product of deep integration among big data, artificial intelligence, the Internet of Things and traditional construction—demonstrating that the construction industry is heading towards intelligence and modernization. Smart construction site is a new mode that takes the initiative to monitor their activities and trajectory accurately, identify the members position on the construction site flexibly, it can be realized by integrating all in one smart sensor system with plus intelligent devices that protect construction safety comprehensively. They also use monitoring equipment to be able to collect data on temperature, humidity, dust concentration and other environmental parameters — enabling construction managers to implement dust suppression and cooling based on actual site conditions — greatly improving the construction site environment. The applications of cloud computing and big data analysis technologies in terms of smart construction sites enables the deep exploration and analysis of huge volumes of data sets. Insofar, managers can use the mobile terminal management platform to supervise the construction progress and quality with efficient collaborative management. In addition, smart construction sites

are also the core force for green development of the construction industry. The intelligent energy management system can adjust the running time and state of equipment to minimize the energy consumed in construction, and construction waste classification systems can increase the recycling rate of construction waste during construction; thus believe that housing construction engineering based on proper implementation of smart controls have a strong supporting role for efficient sustainable development.

3. Importance of Strengthening Quality and Safety Management in Housing Construction Engineering from the Perspective of Smart Construction Sites

3.1 Ensuring the Life and Property Safety of the People

Quality and safety are two of the main components in housing construction projects as a fundamental condition for ensuring the life and property safety of people ^[1]. With the emergence of smart construction sites, big data and IoT technologies can be applied to housing construction quality and safety management by monitoring data from different stages of the construction process. Whenever abnormal information is detected, the system will warn by itself so that potential threats to safety can be handled in time and eliminate the hidden danger of safety. At the same time, supportive smart construction sites enable quality and safety management in housing construction to accurately control quality so that each construction process conforms to specifications, minimize later maintenance costs while protecting the interests of construction units and owners. Quality and safety management in housing construction under the background of smart construction site with the support of technology becomes strong backing for ensuring social life and property safety as well as an important guarantee measure to promote the stable development of the construction industry.

3.2 Promoting the Healthy Development of the Construction Industry

Quality and safety management in housing construction engineering under smart construction site is a vital element contributing to the stable development of the whole construction industry. From the point of view of quality assurance, housing construction engineering management model under smart construction sites reaching to ensure that each brick, each steel bar is qualified. It is backed by data analysis and helps construction enterprises quickly find and solve process problems, as well as guarantee the quality of housing buildings. In addition, the quality and safety management of smart construction sites can also adhere to the concept of quality and safety management, allow for the timely elimination of backward production capacity and non-compliant enterprises, and centralize resources into high-quality areas and provide a fundamental guarantee for the standardized intelligent development of construction industry.

4. Main Modules of Quality and Safety Management in Housing Construction Engineering from the Perspective of Smart Construction Sites

4.1 Comprehensive Resource Collaborative Management Module

AbstractQuality and safety management in housing construction engineering from the perspective of smart construction sites is enabled by innovative synchronous decision support methods that integrate IoT, big data and BIM technologies through a model of resource collaborative management. This management model encourages data-driven decision-making based on the use of smart safety helmets and environmental monitoring equipment to collect construction data in real-time, which is then analyzed dynamically through the cloud platform. Secondly, the complete resource comprehensive management model can utilize facial recognition and safety helmet placement functions to identify attendance and tie results with pay allocations to prevent future financial disputes. In addition, this module also includes a risk graded management and control mechanism that can quickly investigate potential safety hazards, intelligently identify violations and dangerous behaviors on site, so as to realize the multi-element collaborative

optimization relationship between construction quality, safety and progress, thus greatly improving the rectification rate of safety hazards.

4.2 Multi-dimensional Data Decision Support Module

For example, the quality and safety management in housing construction engineering under smart construction sites depends on a multidimensional data decision support module to improve the level of refinement of management. This module fuses technologies like IoT and massive information evaluation to list data for diverse parts of the development site, growing a statistics pool on numerous troubles such as construction progress, safety inspections, etc. Meanwhile, construction enterprises first apply machine learning algorithms to carry out in-depth mining on historical data, automatically generating heat maps of quality and safety hazards as decision-making references for managers. The multi-dimensional data decision support module turns the quality and safety control of housing construction from passive handling to active prevention, greatly improving the pass rate of first detection acceptance and provides decision-making basis support for smart construction site development based on data.

4.3 Intelligent Safety Risk Early Warning Module

The rational and coordinated combination of quality and safety management in housing construction engineering, under the guidance of smart construction site concept, was an effective way to realize the smooth development toward intelligentization. Of these, the intelligent risk early warning module is a deep integration of the IoT and AI technology which deploys high precision sensors at different locations across the site [2]. As a result, construction enterprises can quickly understand their business circumstances with the help of big data analysis algorithms, deeply mine massive information data, accurately identify risk patterns and development trends. Once the risk signals are captured, it can be timely pushed to managers, assisting housing construction engineering managers with crafting risk response strategies in a matter of seconds, lowering safety accident risks while also providing an intelligent safety defence line for housing construction quality and safety.

5. Quality and Safety Management Paths for Housing Construction Engineering from the Perspective of Smart Construction Sites

5.1 Implementing Comprehensive Digital Integrated Management of All Elements

For Quality and Safety Management in Housing Construction Engineering from Smart Construction Site Perspective, this paper emphasizes through the dynamic composite configuration of construction personnel, equipment, method comprehensive digital integrated management of all elements based on data-driven approach. To use BIM and GIS technology to form the digital mapping of engineering entity and construction environment, integrate mining geological survey, design drawing, construction simulation data etc., establish a model of 3D visual dynamic update. Based on this, enterprises should also build a smart construction site middle-platform system that combines quality, safety, progress, cost and other modules to achieve data interworking and business connection between each element. Track the entire potentially recyclable history of materials, from steel to concrete, from RFID chips to integrating with blockchain technology makes those test reports permanent. The process should blend historical engineering data and real-time monitoring information to create a machine-learning-based quality and safety risk forecasting system. Establish an assessment matrix with a high-level safety of more than 200 differentiating risk factors for key processes like the pouring of concrete and deep foundations, derive accident risk probability using the Monte Carlo method. In addition, quality and safety management also need to make full use of big data and artificial intelligence (AI) algorithms for cross-analysis and deep mining, establish early warning models of quality and safety risks to assess the risk situation in real time, automatically push warning information to relevant responsible persons and improve the efficiency and timeliness of management. Paraphrased:Based on this, POETISH organize digital

collaboration platforms to realize transparency, sharing and online collaboration of quality & safety data processes. With the global grasp of project situation for decision-makers, the project level is responsible for executing tasks and forming a new ecology in which all personnel participate in quality and safety management.

5.2 Innovating Intelligent Equipment and Processes

From the perspective of smart construction sites, in quality and safety management of housing construction engineering, it is necessary to take technological innovation as the main driving force, and construct a smart management and control system integrating equipment, process and management. In terms of equipment, deploy composite smart terminals, embed multi-modal sensors in large equipment like tower cranes and construction elevators to collect operational status, load data, and environmental parameters in real-time, achieving millisecond-level response for anomaly warnings through edge computing. At the same time, construction enterprises should combine UWB high-precision positioning systems to create dynamic profiles of personnel, actively intervening in risky behaviors [3]. On this basis, housing construction enterprises should promote intelligent production lines for prefabricated buildings, integrate technologies like machine vision and flexible grasping to automatically control component production processes, controlling errors within $\pm 0.5\text{mm}$. They can also use AI analysis technology to real-time check key protective measures like edge protection and opening covers, automatically generate rectification work orders) and push them to responsible persons. Innovation lies not only in hardware but also in the reengineering of process management workflows. The core of process management reengineering is promoting the dynamic integration of BIM technology with the construction process, associating data collected by IoT with the BIM model to achieve visual collaborative management of information such as construction progress, quality acceptance, and safety hazard handling, enabling final management decisions to be evidence-based and driving housing construction engineering towards the modern goals of zero accidents, zero defects, and high efficiency.

5.3 Establishing Risk Early Warning and Dynamic Response Mechanisms

Quality and safety management in housing construction engineering from the perspective of smart construction sites must build risk early warning and dynamic response mechanisms, deeply integrating technologies like IoT, big data, and AI to carry out risk identification, assessment, early warning, and handling. Construction enterprises should deploy intelligent sensors, drones, and other equipment to collect data on structural stress, settlement displacement, environmental temperature, and humidity in real-time. Build a full-element digital base based on BIM model and construction progress information. Use edge computing nodes to perform preliminary cleaning and preprocessing of all raw data, ensuring that the timeliness and accuracy of data are guaranteed, so as to provide basic support for risk analysis. It can automatically initiate emergency plans and assign logistics tasks to be executed once a warning has been issued. It locates hidden danger points quickly and accurately so that site managers can immediately handle it as soon as they receive a message on their mobile terminals. The system archives all warning events and handling records, creating a traceable knowledge base. Construction enterprises should also closely combine with the concept of smart construction site, build intelligent early warning analysis center, upload collected data to cloud smart management platform, apply big data analysis and AI algorithm to deep mine, conduct regular in-depth comprehensive analysis and review on early warning data through cloud-based technology as a technical means further improve the quality and safety level of housing construction engineering.

5.4 Implementing Collaborative Supervision

Collaborative supervision of quality and safety management in housing construction engineering under the perspective of smart construction site. To achieve real-time data sharing among multiple parties such as housing construction departments, construction units and supervision parties by standardizing data interface specifications. In the collaborative supervision phase, construction enterprises should also combine big data analysis technology with on-site inspection records and

historical accident data related to engineering quality problems to establish a dynamic evaluation system of construction enterprise quality risk assessment based on blockchain technology to ensure that the key node data cannot be tampered with during the entire process, providing a credible basis for tracing housing construction engineering quality traceability^[4]. Construction enterprises are also required to establish a collaborative governance mechanism led by the government that involves third-party institutions, and connect quality and safety performance with credit evaluation and bidding. Additionally, quality and safety management of collaborative supervision should be based on cloud computing, IoT, and BIM technologies to establish a smart construction site collaborative management cloud platform. A consolidated view of all subsystems like quality inspection, safety monitoring, personnel management (i.e. training records, certifications etc.) – giving a composite Worksite Analysis to ensure feasible data sharing between design, construction, supervision and regulatory units through a single view portal. The constituent collaborative management platform will standardize the project quality and safety control process, specify the responsibility of construction unit as leading role, and online task assignment, closed-loop manage hidden danger rectification and electronic signing up processes should be used to play the advantage of collaborative supervision. Housing construction engineering managers should record quality and safety data as per the collaborative platform, be routine in the establishment of digital credit files, connect these files with the special credit system for industry regulators, motivate all parties to effectively take part in collaborative management, and construct a positive collaborative mechanism for housing development quality safety management.

6. Conclusion

In summary, quality and safety management in housing construction engineering is transitioning towards digitalization and intelligence. The emergence of smart construction sites has improved the refinement level of engineering project management and, aided by data-driven decision-making mechanisms, formed a new model for quality and safety management. Therefore, construction enterprises should proceed from the perspective of smart construction sites, implement comprehensive digital integrated management of all elements, innovate intelligent equipment and processes, establish engineering risk early warning and dynamic response mechanisms, and implement collaborative supervision during housing construction quality and safety management, providing a fundamental guarantee for the high-quality development of housing construction engineering.

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