Study on Construction Safety Management and Risk Early Warning Mechanism of High-rise Building Engineering

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Keywords: construction safety management; risk early warning; high-rise building engineering

Abstract: Because of its high risk, complexity and uncertainty, high-rise building construction poses a severe challenge to safety management and risk early warning. This paper discusses the construction of high-rise building construction safety management and risk early warning mechanism, and makes in-depth research from the aspects of risk identification and evaluation, early warning system design, early warning index system, early warning model selection and early warning threshold setting. A comprehensive early warning index system is constructed in five dimensions: personnel, equipment, materials, environment and management, and the application of early warning models such as statistical analysis, fuzzy comprehensive evaluation and neural network is analyzed. In addition, the paper puts forward the corresponding safety management countermeasures and implementation paths from three levels of technology, management and system, including popularizing intelligent monitoring system, strengthening equipment management, implementing standardized protection, building an efficient collaborative management system and improving safety management system. By constructing a scientific and efficient safety management and risk early warning mechanism, the accident rate of high-rise building construction can be effectively reduced, and the life safety of construction workers and the smooth progress of the project can be guaranteed.

1. Introduction

High-rise building construction has three characteristics: high risk, high complexity and high uncertainty. Its working environment involves multiple hazards such as high altitude, deep foundation pit and cross operation, and is significantly affected by geological conditions, climate factors and technical difficulties [1]. The traditional safety management mode relies on manual inspection and empirical judgment, which has some defects such as information lag, passive response and blind area coverage, and it is difficult to meet the requirements of dynamic risk management and control [2]. Therefore, building a scientific and efficient safety management and risk early warning mechanism has become a key issue to be solved urgently in the industry. Through real-time monitoring and intelligent early warning, the risk can be changed from "post-treatment" to "pre-prevention" and the accident rate can be reduced.

2. Risk identification and evaluation of high-rise building construction safety

High-rise building construction safety risks come from the complex interaction of multi-dimensional factors such as working environment, construction technology and personnel management, among which environmental risks such as aerial work, deep foundation pit and insufficient edge protection are particularly prominent because of large vertical height and many cross operations [3]; The process links such as formwork support, lifting and scaffolding are prone to hidden dangers due to complex technology and manual operation; Management problems such as lack of safety training, illegal operation and poor supervision further aggravate the possibility of accidents, so it is necessary to systematically identify and control all kinds of risks in the whole construction cycle by combining methods such as site investigation, historical data and expert

  DOI: 10.25236/icacel.2025.093

evaluation [4].

In the stage of safety risk assessment, the identified risks need to be analyzed qualitatively and quantitatively to determine the priority of management and control. The common methods include the risk matrix method that divides the risk level through the possibility and severity matrix, the fuzzy comprehensive evaluation method that uses the membership function to deal with uncertain factors such as management defects, and the digital means that dynamically simulates the construction process with BIM technology to identify collisions and safety hazards [5]; The assessment results should form a detailed risk list including risk points, responsible subjects and response time limit, providing scientific basis and data support for the formulation of subsequent risk early warning and control measures.

3. Construction of risk early warning mechanism

3.1 Design principle of early warning system

3.1.1 Principle of comprehensiveness

Covers all key links and potential risk factors in the construction process, including personnel, equipment, materials, environment and management, etc., to ensure that all kinds of potential safety hazards are monitored and warned without omission. For example, we should not only consider the risk of aerial work, but also pay attention to the safety of underground construction; We should not only pay attention to the normal operation of mechanical equipment, but also pay attention to the operation norms of construction personnel.

3.1.2 Scientific principle

Based on scientific methods and theories, using statistics, risk management and other knowledge to determine early warning indicators and establish models, so that early warning results are reliable and accurate. Through data analysis, we can reveal the risk law, avoid misjudgment or omission caused by subjective assumptions, and provide objective basis for decision-making.

3.1.3 The principle of timeliness

It can collect data in real time or near real time, and quickly analyze and process it to get early warning information, so as to give an alarm in time before the risk has evolved into an accident, so that relevant personnel have enough time to take measures to prevent and control it. This requires the system to have efficient data transmission, processing capacity and response speed.

3.1.4 Dynamic principle

In view of the fact that the construction process of high-rise buildings is a constantly changing process, the risks will change accordingly. Therefore, the early warning system should be able to adjust the early warning indicators, thresholds and model parameters in time according to the changes in actual conditions, so as to adapt to the construction characteristics and risk conditions at different stages and maintain its effectiveness and adaptability.

3.1.5 The principle of operability

The designed early warning system should be easy to understand, easy to implement, the early warning indicators easy to obtain and measure, the early warning model not too complicated, and the proposed countermeasures are feasible, which can be effectively implemented in the construction site, and really play its early warning role, rather than an armchair strategist.

3.2 Early warning index system

The early warning index system covers five aspects: personnel, equipment, materials, environment and management, and is used to comprehensively evaluate the construction safety situation (Table 1). Personnel-related indicators focus on qualification level, safety training and illegal operation, reflecting team quality and safety awareness; Equipment related indicators monitor the safety status of equipment through intact rate, failure rate and operation parameters to prevent mechanical accidents; Check the quality qualification and storage conditions of materials related indicators to ensure structural safety and prevent secondary disasters; Environmental related indicators consider meteorological conditions and site characteristics to avoid construction risks caused by external factors; Management-related indicators emphasize system soundness, inspection frequency and hidden danger rectification efficiency, which provides guarantee for reducing accident risk.

Table 1 Construction safety early warning index system

Early warning indicator category	Specific indicators	Explain
Personnel-related indicators	Proportion of people without certificates	Reflect the qualification level of construction personnel
	Monthly safety education and training duration	Reflect the safety training
	Number of operation records in violation of safety regulations	Reflect the illegal operation
Equipment-related indicators	Equipment availability	Reflect the overall condition of the equipment
	Equipment failure rate	Reflect the equipment failure
	Wear degree of key components	Reflect the status of key parts of equipment
	Regular maintenance situation	Reflect the equipment maintenance
	Working load data	Reflect equipment operation parameters
Material related index	Quality qualification of building materials	Reflect material quality
	Material storage condition	Reflect the compliance of material storage
	Reinforcement strength	Reflect material properties
	Concrete mix proportion	Reflect the material ratio
	Storage measures of flammable and explosive materials	Reflect fire and explosion prevention measures
Environmental related indicators	Temperature, humidity, wind speed, rainfall	Reflect meteorological conditions
	Site flatness	Reflect the site environment
	Distance from surrounding buildings	Reflect the surrounding conditions of the site
Management related indicators	Degree of soundness of safety management system	Reflect the perfection of management system
	Frequency and effect of	Reflect the safety

	safety inspection	inspection
	Rectification rate of hidden dangers	Reflect the handling of hidden dangers

3.3 Early warning model selection

Statistical analysis model finds out the probability distribution law of accidents and the relationship with various factors through statistical analysis of historical accident data, and then predicts the possibility of accidents in the future [6]. Common time series analysis models can be used to analyze accident trends that change with time; Regression analysis model can determine the influence degree of some variables on the accident and help identify the main risk factors [7]. Because many risk factors in high-rise building construction are fuzzy, it is difficult to describe them accurately, and this model is just suitable. Fuzzy comprehensive evaluation model uses the method of fuzzy mathematics to transform qualitative evaluation into quantitative results, comprehensively considers the comprehensive influence of various factors, comprehensively evaluates the construction safety situation, and gives a relatively comprehensive safety grade judgment [8]. Neural network model has strong self-learning and adaptive ability, which can automatically extract features from a large number of sample data and establish complex nonlinear mapping relationship [9]. When it is applied to risk early warning, it can deal with many interrelated and complex input variables, and accurately predict the output results after training, which is especially suitable for solving the complex risk prediction problem under the influence of multi-factors in high-rise building construction. With the development of information technology, a huge amount of data resources have been accumulated in the construction site. Using ensemble learning algorithm, integrating the advantages of multiple single models, and combining with big data analysis technology to deeply mine these multi-source heterogeneous data can capture risk signals from different angles, improve the accuracy and stability of early warning, and better deal with uncertain risks in high-rise building construction.

3.4 Early warning threshold setting

Referring to industry standards, specifications and practical experience of similar projects, combined with the specific characteristics and technical requirements of this project, a normal benchmark range is determined for each early warning index. For example, according to the relevant building codes, what is the maximum allowable deflection deformation of a certain scaffold as the reference value? According to the severity of the risk and the possible loss, the early warning levels are divided into different levels (low, medium and high), and corresponding threshold intervals are set for each level. When the index value enters a certain range, the corresponding level of early warning signal is triggered. If a key index exceeds a certain proportion of the benchmark value but has not yet reached the dangerous limit, it will issue an intermediate warning, and once it approaches or breaks through the dangerous limit, it will start an advanced warning [10]. Considering the changes of various conditions and the emergence of new situations in the construction process, a set of dynamic threshold adjustment mechanism is established. Regularly review and analyze the past early warning events and their disposal effects, and optimize and correct the threshold according to the actual false alarm rate and missed report rate; At the same time, with the progress of the project, the change of environment or the adoption of new construction technology, the threshold range of relevant indicators will be updated in time to ensure that the sensitivity and accuracy of the early warning system are always in a better state.

4. Safety management countermeasures and implementation path

In the high-rise building project, there are many safety risks in the construction site because of its characteristics such as large engineering quantity, complex technology, many aerial work and long cycle. In order to effectively prevent and control the occurrence of safety accidents, it is necessary to build a scientific and perfect safety management and risk early warning mechanism. Based on the relevant literature research, this paper puts forward the following safety management countermeasures and implementation paths from three aspects: technology, management and system.

4.1 Technical level

On the technical level, we should systematically reduce the safety risk of building construction from the source by comprehensively using advanced equipment, intelligent monitoring system and standardized construction technology. Specifically, it is necessary to vigorously promote the intelligent monitoring system integrating video monitoring, tower crane anti-collision, personnel positioning and BIM technology, and rely on the Internet of Things to realize real-time data collection and dynamic early warning of key links such as the operation state of large machinery, deformation of deep foundation pit and stability of high formwork; At the same time, strengthen the safety management of the entire life cycle of mechanical equipment, strictly enforce equipment access, conduct regular maintenance and testing, and ensure that special operation personnel are certified and equipped with remote monitoring and automatic alarm devices; In terms of construction technology, standardized protection should be implemented, advanced technologies such as prefabricated construction and climbing frames should be actively adopted to reduce high-altitude operations, and temporary electricity management should be standardized; In addition, a scientific safety risk identification and assessment model should be established, combined with methods such as WBS-RBS (Work Breakdown Structure Risk Breakdown Structure) or AHP (Analytic Hierarchy Process) to construct a two-dimensional warning system covering time and space dimensions, accurately identifying and controlling high-risk work environments, and comprehensively improving the intrinsic safety level of construction sites.

4.2 Management level

At the management level, efforts should be made to build an efficient collaborative management system to comprehensively improve the execution and emergency response capability of the construction site. Through the implementation of the project manager responsibility system, a "horizontal-to-edge, vertical-to-the-end" safety management network covering all participating units is established, and the responsibilities of all parties such as construction, construction and supervision are clearly defined to prevent buck passing; Strictly implement the dual prevention mechanism of classified management and control of safety risks and investigation and management of hidden dangers, and implement license approval and on-site supervision for high-risk links such as high-altitude operations, lifting and hot work; Strengthen the safety quality of personnel, improve the three-level safety education system, organize regular training and emergency drills, and especially strengthen the popularization of safety knowledge and the guidance of operational norms for migrant workers; In view of the complex site characteristics of multi-subcontracting and cross-operation, set up a unified coordination organization and hold regular safety meetings to ensure unified instructions and smooth information; Actively promote the construction of information management platform, integrate risk early warning, hidden danger reporting, rectification tracking and other functions, realize the digital and closed-loop operation of safety management, and effectively improve management efficiency and emergency response level.

4.3 Institutional level

System is the cornerstone to ensure the sustainable operation of safety management, which must be promoted from the multi-dimensional system of policy guidance, standard construction and supervision and accountability. The construction party shall strictly implement national laws and regulations such as Regulations on the Administration of Work Safety in Construction Projects and Standard for Safety Inspection in Construction (JGJ59), and carry out safety review, supervision and inspection according to law; Enterprises need to improve the internal safety management system, formulate a system covering safety objectives, risk assessment, emergency plans and assessment rewards and punishments, implement a safety performance linkage mechanism, and incorporate safety performance into project evaluation and personal promotion evaluation; At the same time, establish a third-party independent supervision mechanism, introduce qualified professional institutions to participate in major hazard monitoring, special program demonstration and process audit, and enhance the professionalism and objectivity of supervision; Improve the system of accident accountability and credit punishment, severely punish the units responsible for safety accidents according to law, and incorporate them into the "blacklist" of integrity in the construction market, and implement joint punishment such as bidding restrictions, forming a binding pattern of "one place is untrustworthy and everywhere is limited"; In addition, actively promote the formulation of industry standards and technological progress, support industry associations to issue safety technical guidelines in key areas such as high-rise buildings, encourage enterprises to develop and apply new protective equipment and intelligent construction technologies, and lead the overall safety level of the industry to continue to improve through institutional innovation.

5. Conclusion

Aiming at the high risk, complexity and uncertainty of high-rise building construction, this study deeply discusses the construction of safety management and risk early warning mechanism. By systematically identifying and evaluating all kinds of safety risks in the construction process, including risks in key links such as aerial work, deep foundation pit and formwork support, and combining five dimensions of personnel, equipment, materials, environment and management, a comprehensive early warning index system is established. Using statistical analysis model, fuzzy comprehensive evaluation model and neural network model, a scientific early warning model is constructed, which realizes dynamic monitoring and intelligent early warning of construction safety. At the same time, the countermeasures and implementation paths of safety management based on technology, management and system are put forward, and the importance of the application of intelligent monitoring system, the construction of collaborative management system and system guarantee is emphasized. This study not only provides theoretical basis and technical support for high-rise building construction safety management, but also provides feasible solutions for risk management and accident prevention in practical projects, which is helpful to promote the overall improvement of industry safety level.

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