Research on risk identification and dynamic control technology of municipal road construction

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Abstract: This paper discusses the importance of municipal road construction risk management, and focuses on risk identification and dynamic control technology. First of all, it introduces the methods of identifying municipal road construction risks, including expert investigation, brainstorming and fault tree analysis, and analyzes the contents of risk identification, covering natural environment, construction technology, management and organization, laws and regulations, economic and social risks and so on. Secondly, the process and method of municipal road construction risk assessment are expounded, including risk identification, qualitative analysis, quantitative assessment and dynamic monitoring, and key control measures such as optimizing construction scheme, strengthening emergency response, adopting environmental protection measures and using information means are put forward. Finally, the connotation, core objectives, key technical components and advantages of dynamic risk control technology for municipal road construction are introduced in detail, and it is emphasized that this technology can realize real-time risk perception, accurate prediction and active intervention, and effectively improve the timeliness, accuracy and systematicness of risk management.

1. Introduction

As an important part of urban infrastructure, municipal roads are of great significance for promoting economic development and improving the quality of life of residents. However, the municipal road construction process is complex, involving many participants and various types of operations, and it faces many uncertainties and risks. In recent years, with the acceleration of urbanization, the number of municipal road construction projects has been increasing, the construction scale has been expanding and the construction environment has become increasingly complex. All these factors make the risk of municipal road construction more prominent, which brings severe challenges to the safety, quality, progress and cost control of the project.

Effective risk management is the key to ensure the smooth construction of municipal roads. Traditional risk management methods often focus on static risk identification and evaluation, which is difficult to adapt to the ever-changing risk environment in the construction process. Therefore, it is not only of great theoretical value, but also of great practical significance to study how to dynamically identify and control risks in municipal road construction.

2. Risk identification of municipal road construction

2.1 Risk identification method

Risk identification is the first and most critical step of risk management. Only by accurately identifying the potential risks can we carry out targeted risk assessment and risk control. In municipal road construction, risk identification can help project managers find problems in time and take measures to prevent risks from turning into accidents, thus ensuring the smooth progress of the project [1].

There are many common methods to identify the risk of municipal road construction, including expert investigation, that is, organizing experts to discuss with engineering characteristics, construction environment and historical data to identify potential risks; Brainstorming method,

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through collective discussion to stimulate team creativity, brainstorming to find risks; Fault tree analysis, which uses systematic analysis to construct accident causal logic tree and trace the root of risk; Checklist method, according to the list of key links in construction, check item by item to find potential problems; And the risk list method, which forms a list by sorting and classifying known risks, is convenient for system identification and subsequent evaluation [2-3]. These methods have their own emphasis and can be combined to improve the comprehensiveness and accuracy of risk identification.

2.2 Content of risk identification

The contents of municipal road construction risk identification cover many aspects (as shown in Table 1), mainly including natural environmental risks, such as uncontrollable natural factors such as geological disasters and extreme weather; Construction technical risks, involving problems such as unreasonable construction technology, improper methods or technical scheme defects; Management and organizational risks, manifested in poor project management, unclear responsibilities or poor internal coordination; Legal and regulatory risks refer to compliance problems caused by failure to go through the examination and approval procedures according to regulations or violation of relevant laws and regulations on environmental protection and safety [4]; Economic risks, including financial uncertainties such as material price fluctuation, insufficient capital supply or cost overrun; And social risks, such as public opposition to the project, land acquisition and demolition disputes or poor communication and coordination with stakeholders.

Table 1 Contents of municipal road construction risk identification

Risk category	Specific content
Natural environmental risk	Geological disasters, extreme weather, etc.
Construction technical risk	Unreasonable construction technology and method, etc.
Management and organizational risk	Poor project management, insufficient organization and coordination, etc.
Legal and regulatory risks	Failing to go through relevant formalities as required, violating environmental protection laws and regulations, etc.
Economic risk	Material price fluctuation, lack of funds, etc.
social risk	Public opposition, improper coordination of stakeholders, etc.

2.3 Implementation of risk identification

The implementation of municipal road construction risk identification usually follows the following steps:

(1) Firstly, an identification team composed of project manager, technical director and safety officer is established.

(2) Then collect construction drawings, geological reports and surrounding environment and other materials, and carry out on-site investigation;

(3) Then, a risk seminar was held by means of expert investigation and brainstorming to systematically identify potential risks;

(4) On this basis, the identification results are classified to form a risk list, and the risk is evaluated according to the possibility and influence degree, which provides a basis for subsequent risk management.

3. Risk assessment of municipal road construction

3.1 Evaluation process and method

Risk assessment of municipal road construction is a process of systematic identification, analysis and evaluation of various uncertain factors that may affect the smooth progress of the project before and during the project implementation [5]. Its purpose is to predict potential risks in advance and provide a basis for formulating effective coping strategies, thus ensuring construction safety, controlling costs, ensuring construction period and maintaining social stability. With the acceleration of urbanization and the improvement of project complexity, this link has become an indispensable core content of modern project management.

The risk assessment process of municipal road construction is shown in Figure 1. Firstly, the potential risk sources are comprehensively identified through on-site investigation, expert consultation, historical data analysis and brainstorming, such as evaluating soil stability by combining geological reports or finding hidden danger areas by using unmanned aerial vehicles; Then, the risk matrix is used for qualitative analysis, the probability and influence degree of risks are graded, and the risk value is accurately calculated by combining with quantitative models such as Monte Carlo simulation to realize scientific ranking [6]; At the same time, establish a dynamic monitoring mechanism, rely on sensors and Internet of Things technology to monitor the construction status in real time, and timely warn new risks [7]; Finally, we formulate coping strategies for high-risk items and take measures such as avoidance, transfer, mitigation or acceptance to form a whole process and closed-loop risk management system.

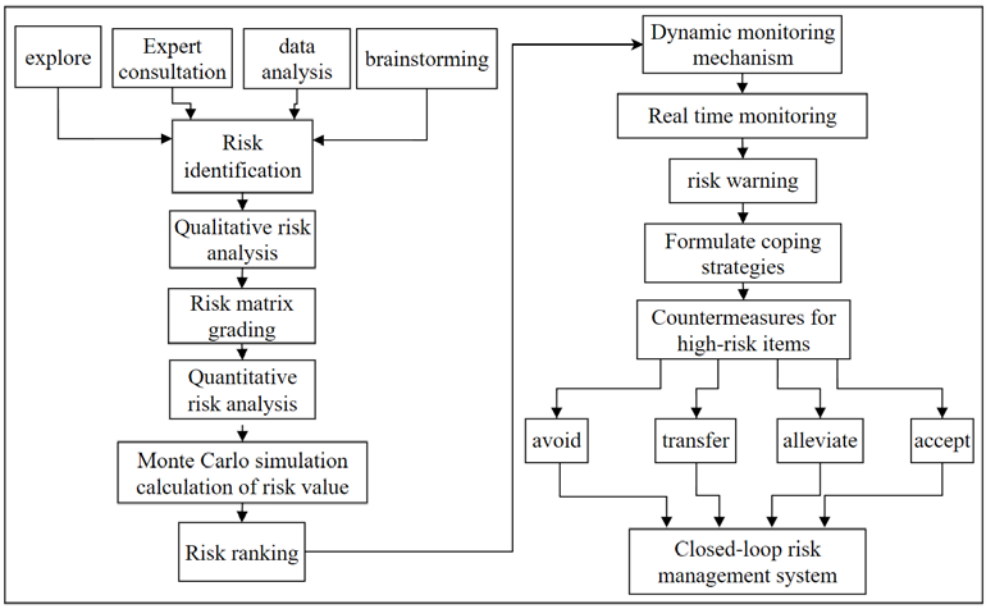

Figure 1 Risk assessment process of municipal road construction

3.2 Key control measures

Improve the standardization and safety of operation by optimizing construction scheme, strengthening preventive management such as equipment maintenance and safety training; Establish a perfect emergency response system, formulate special plans, clarify the disposal process and exercise regularly to enhance the coordinated response ability of emergencies; Take environmental protection measures such as setting up dust-proof and noise-reducing facilities, strengthening environmental monitoring, and strengthening public communication through information publicity to alleviate social contradictions; At the same time, relying on BIM modeling, intelligent monitoring and other information means to achieve data integration and dynamic control, and promote scientific risk decision-making and efficient management [8].

Effective risk assessment can not only reduce the accident rate, but also promote the rational allocation of resources and cost saving. In the future, with the deepening application of AI and big data technology, the risk management of municipal road construction will evolve in the direction of intelligence and refinement, further promoting the transformation and upgrading of the industry. At

the same time, the improvement of dynamic adjustment mechanism is helpful to meet the complex and changeable urban development needs and realize the safe and sustainable development of engineering construction.

4. Dynamic control technology of municipal road construction risk

4.1 Technical connotation and core goal

Dynamic risk control technology of municipal road construction is a systematic method integrating engineering monitoring, data fusion, intelligent analysis and feedback control, aiming at solving the pain points of lagging risk identification, delayed response and insufficient pertinence of measures in traditional static management. Its technical connotation can be summarized as taking the construction process as the time axis, and realizing real-time risk perception, accurate prediction and active intervention through the closed-loop process of multi-source data real-time collection → dynamic risk assessment → hierarchical early warning and dynamic regulation → effect feedback optimization.

The core objectives include:

(1) Risk controllability controls risk events in the embryonic stage through dynamic monitoring and early warning;

(2) Timely response shortens the time window from risk occurrence to disposal and reduces losses;

(3) Scientific decision-making is based on data-driven quantitative risk analysis, optimizing control measures;

(4) The adaptability of the system adapts to the differentiated requirements of different construction stages and different environmental conditions.

4.2 Key technical composition

4.2.1 Real-time perception technology of multi-source risk information

Multi-source risk information real-time sensing technology can continuously and dynamically monitor various key parameters in the process of municipal road construction by deploying intelligent sensor networks with high precision, low power consumption and anti-interference ability, and realize comprehensive data acquisition. It covers multi-dimensional information such as geology and environment, structural safety, operation behavior and external interference, and relies on the Internet of Things platform to realize real-time data transmission and centralized storage, providing a reliable data base for dynamic evaluation and intelligent early warning of construction risks.

4.2.2 Dynamic risk assessment model and algorithm

Based on real-time monitoring data, combined with engineering experience and theoretical analysis, a dynamic evaluation system of risk state is constructed to quantify the current risk level and predict its evolution trend. The main methods include establishing multi-level risk indicators by using index system method, determining the weight by analytic hierarchy process (AHP) or entropy-coupling weighting method, and calculating the comprehensive risk value by combining fuzzy comprehensive evaluation or matter-element extension model; Using data-driven model, the association between historical cases and real-time data is mined by machine learning algorithms such as random forest and LSTM, and short-term risk trend prediction is realized [9]; And build a digital twin system of BIM+GIS fusion, map the monitoring data to 3D virtual scene, visually present the risk location and influence scope, and realize the visual and intelligent dynamic evaluation of construction risk.

4.2.3 Hierarchical early warning and dynamic regulation mechanism

According to the risk level (I-level extremely high risk to IV-level low risk), a differentiated response system is established. When the real-time monitoring data exceeds the preset threshold,

the system automatically pushes early warning information to managers, supervisors and owners through APP, SMS or big screen; Then, according to the risk level, the graded disposal measures of "immediate intervention-local adjustment-global optimization" are implemented, such as immediately stopping work and starting emergency plans for Grade I risks, adjusting process parameters and strengthening detection for Grade II risks, and taking preventive measures such as adding drainage for Grade III risks; At the same time, relying on the smart site platform, the construction unit, pipeline unit, traffic management and other multi-party collaborative linkage are realized to ensure the rapid response and efficient implementation of emergency response and traffic guidance and reform programs, and form a closed-loop dynamic control mechanism.

4.2.4 Effect feedback and iterative optimization

By comparing the monitoring data before and after the implementation of risk control measures, the control effect is evaluated and the model optimization is fed back. For example, if the prediction error of a certain kind of risk is large, the model parameters are corrected by supplementing the field test data to improve the subsequent prediction accuracy. At the same time, the typical risk case base is accumulated to provide reference for similar projects.

4.3 Technical advantages and application value

Compared with traditional static risk management, the core advantages of dynamic risk control technology for municipal road construction are as follows: through real-time monitoring and intelligent early warning, it realizes the transformation from "post-treatment" to "pre-prevention and in-process control", shortens the risk response time from hour level to minute level, and significantly improves the timeliness; Relying on multi-source data fusion and intelligent algorithm, the accuracy of risk location can reach centimeter level, which greatly enhances the accuracy of risk identification and response measures; The system covers all the elements of "man-machine-material-law-environment", and co-ordinates social risks such as technical safety, traffic congestion and residents' complaints, which is more systematic; The accumulated risk data and evaluation model can form a reusable knowledge base, support the risk management optimization of subsequent projects, promote the development of industry standardization, and have good sustainability.

In the future, with the development of technologies such as 5G communication, edge computing and deep integration of BIM/CIM, the dynamic control of municipal road construction risks will evolve to a more intelligent and integrated direction: by deploying edge computing nodes in the construction site, the localized real-time processing of monitoring data can be realized, and the response delay can be reduced to less than 1 second, which significantly improves the real-time performance of the system; With the help of AR/VR technology, the risk scenario is visually simulated to enhance the intuition and interactivity of decision support. The scope of risk management and control will extend from the construction stage to the road operation and maintenance period, so as to realize continuous monitoring and early warning of road diseases and build a construction-operation integrated risk management system covering the whole life cycle of the project.

5. Conclusion

The combination of various methods can comprehensively and accurately identify the natural, technical, management, legal, economic and social risks in construction; Identify potential risk sources through on-site investigation, expert consultation and data analysis, and make scientific evaluation and ranking by using tools such as risk matrix and Monte Carlo simulation, and establish a dynamic monitoring mechanism to warn emerging risks in time; With the help of multi-source data real-time perception, dynamic evaluation model, hierarchical early warning and regulation mechanism, the dynamic risk control technology of municipal road construction realizes real-time perception, accurate prediction and active intervention of risks, improves the timeliness and accuracy of management and control, strengthens the system and promotes industry standardization;

In the future, with the development of technologies such as 5G, edge computing and deep integration of BIM/CIM, risk dynamic control will develop in a more intelligent and integrated direction, realizing localized real-time processing, AR/VR visualization to assist decision-making, and covering the whole life cycle of the project.

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