Research on Risk Identification and Supervision Intervention Mechanisms in the Construction Phase of Building Projects

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Abstract: The construction phase is the most concentrated and high-risk stage of building projects, characterized by diverse risk types and complex influencing factors. It directly impacts project quality, safety, schedule, and cost control. Scientifically identifying potential risks during construction and establishing effective supervision intervention mechanisms have become critical challenges in engineering management. This study focuses on the construction phase. It first analyzes the characteristics and causes of risks during construction, constructing a risk identification framework encompassing dimensions such as safety, quality, schedule, cost, and environment. Second, based on the responsibilities and functions of supervision work, it explores intervention mechanisms in three key stages: risk pre-control, risk handling, and post-risk assessment, proposing an integrated model linking risk identification and supervision intervention. Finally, optimization pathways are proposed from three dimensions—institutional policies, technical means, and organizational safeguards—to provide systematic references for risk management during the construction phase of building projects. Findings indicate that a refined risk identification methodology coupled with a robust supervision intervention mechanism not only effectively reduces the probability and severity of construction risks but also enhances the proactivity and scientific rigor of supervision work. This holds significant implications for advancing the standardization and intelligent management of construction projects.

1. Introduction

With the continuous expansion of China's construction industry and the increasing complexity of engineering projects, risks during the construction phase have become increasingly prominent[1]. As the core implementation stage, construction is a critical period prone to accidents and quality issues. Frequent occurrences of safety incidents, schedule delays, quality defects, and cost overruns severely impact the economic and social benefits of projects. Scientifically identifying potential risks during construction and establishing effective supervision intervention mechanisms have become critical research topics requiring in-depth exploration in construction project management[2].

Both theoretically and practically, construction risk management has garnered extensive attention from scholars worldwide[3]. Overseas research pioneered systematic risk management studies, developing a comprehensive framework encompassing risk identification, assessment, and control. Domestic research, however, has primarily focused on practical engineering applications, concentrating on safety risks, schedule management, and quality control. Current risk identification methods during construction remain relatively limited, lacking systematic and dynamic approaches[4]. The role of supervision in controlling construction risks has not been fully leveraged, and intervention mechanisms remain imperfect. The application of information and intelligent technologies in construction risk management requires further advancement.

This paper focuses on the construction phase, establishing a systematic risk identification framework to analyze primary risk types during the construction process[5]. Integrating supervisory responsibilities with practical work, it proposes a three-tiered intervention mechanism encompassing risk pre-control, risk handling, and post-risk assessment. Optimization pathways are proposed across

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institutional policies, technical means, and organizational safeguards. The study's innovations include: first, multidimensional risk identification through systematic methods; second, intervention mechanisms tailored to different risk phases, integrating risk recognition with supervision; third, exploring intelligent development directions for construction risk management by leveraging emerging information technologies[6]. This study aims to provide theoretical support and practical guidance for risk identification and supervision intervention during the construction phase of building projects, thereby enhancing risk management capabilities and promoting overall improvements in engineering quality and safety assurance.

2. Risk Identification Framework for Construction-Phase Building Projects

Risks during the construction phase exhibit characteristics such as high unpredictability, broad impact scope, and multi-factor coupling[7]. Construction sites involve substantial human resources, materials, and machinery, coupled with complex and variable environmental conditions, resulting in significantly higher frequency and destructive potential of risk events compared to other phases. Common construction risks encompass not only traditional safety hazards but also multifaceted factors including quality, schedule, cost, environment, and policy. In risk management practice, comprehensive and systematic identification and classification of construction phase risks are essential to establish a foundation for subsequent supervision interventions and risk control[8]. The probability of risk occurrence during the construction phase can be expressed as follows:

$$P_i = \frac{n_i}{N} \quad (1)$$

Regarding risk identification methods, traditional approaches such as expert judgment, analytic hierarchy process (AHP), and Delphi method can be employed[9]. Additionally, quantitative methods like fuzzy comprehensive evaluation and grey system analysis can be utilized to scientifically assess complex risk factors. In recent years, with the advancement of big data, Internet of Things (IoT), and artificial intelligence (AI) technologies, dynamic risk identification based on data mining has emerged as a research hotspot[10]. Real-time monitoring of construction site data—including personnel behavior, equipment operational status, and environmental parameters—enables early warning of potential risks, enhancing the accuracy and timeliness of risk identification.

Regarding risk classification systems, construction phase risks are typically categorized into five major types: First, safety risks, primarily manifested as accidents such as collapses, falls from heights, and machinery injuries; second, quality risks, encompassing substandard materials, deviations in construction techniques, and issues with concealed works; Third, schedule risks involving project delays, poor workflow coordination, and inadequate resource allocation; fourth, cost risks manifesting as budget overruns, price fluctuations, and contract disputes; fifth, environmental and policy risks such as extreme weather, heightened environmental requirements, and regulatory changes. Scientifically categorizing these risks enables supervisors to implement targeted measures at different stages.

Establish a “multi-dimensional, multi-tiered” risk identification framework for the construction phase. This framework is grounded in risk characteristics, employs identification methods as tools, and is supported by a classification system, forming a dynamic, scalable risk management structure. Through this framework, systematic identification of construction phase risks is achieved, providing theoretical foundations and data support for constructing supervision intervention mechanisms, thereby enhancing the overall level of construction phase risk management.

3. Establishing Construction Phase Supervision Intervention Mechanisms

Supervision intervention mechanisms during construction are crucial for ensuring project execution and mitigating risks. Their core lies in integrating supervision throughout the entire risk management process. In practice, supervisors must not only implement preemptive controls—reducing risk probability through construction organization design reviews, technical briefings, and risk warning systems—before incidents occur; but also intervene promptly during risk occurrence to implement emergency response for safety incidents, quality rectification, and progress control measures, minimizing risk losses. Furthermore, supervision must conduct post-event assessment and feedback to summarize lessons learned, refine the risk database, and feed supervision knowledge and risk prevention experience back into design and construction management, forming a dynamic closed-loop management system. Building upon this foundation, this paper categorizes the supervision intervention mechanism into three distinct levels for detailed examination: risk pre-control, risk handling, and post-risk assessment and feedback.

3. The Role and Mechanism of Supervision in Risk Pre-control

Risk pre-control during the construction phase is a critical step in preventing potential risks from escalating into actual accidents. Supervision plays a vital role in organizing, supervising, and guiding this process. Through reviewing construction organization designs, supervision can proactively identify potential safety hazards and technical flaws in construction plans, proposing optimization suggestions to ensure the rationality and feasibility of construction schemes. Supervision plays a role in technical briefings and construction plan deliberations, clarifying construction requirements and key control points to contractors. This enhances construction personnel's awareness and response capabilities regarding potential risks, reducing the likelihood of accidents at their source. The expected loss is quantified through the following formula:

$$I_i = \sum_{j=1}^{m} w_j \cdot s_{ij} \tag{2}$$

The total risk exposure is calculated by combining multiple risk factors as shown below:

$$RPN_i = P_i \cdot S_i \cdot D_i \tag{3}$$

Supervisors also establish and implement risk warning systems to monitor critical indicators during construction. Dynamic monitoring of high-risk processes, key structural nodes, critical construction machinery, and environmental factors enables timely detection of anomalies. Warning notifications prompt contractors to implement corrective actions. This mechanism enhances proactive supervision and accelerates contractor response, achieving early risk detection and prevention. The distribution of construction risk categories is illustrated in Figure 1:

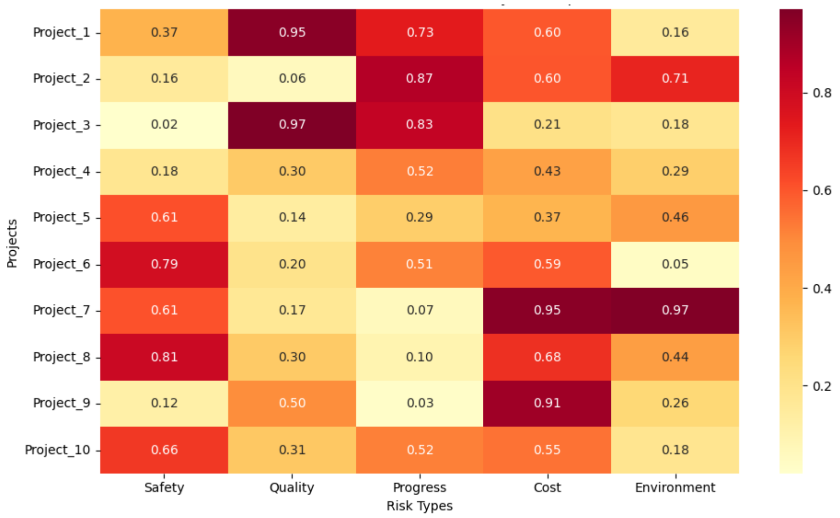

Figure 1 Risk Probability vs Impact Heatmap

At the institutional level, supervision bodies can establish risk ledgers and responsibility lists, aligning various risks with corresponding supervisory duties while clarifying management requirements and responsible parties for each phase. This systematic, process-oriented approach fosters a standardized risk prevention and control system, elevating the standardization and scientific rigor of construction management. The role of supervision during the risk prevention and control phase extends beyond mere oversight and inspection. It emphasizes proactive risk management through scheme review, technical guidance, and early warning systems, laying a solid foundation for subsequent construction phases in terms of safety, quality, progress, and cost management.

3.2 Intervention Measures by Supervision in Risk Management

When risk events occur during the construction phase, timely and effective response measures are crucial for minimizing losses and preventing accidents from escalating. In this process, the supervisor, acting as a third-party manager and overseer, assumes core responsibilities for organizational coordination, guidance on execution, and oversight of implementation. When safety incidents occur, the supervisor must promptly activate emergency protocols, conduct a comprehensive assessment of the incident site, guide the construction unit in implementing safety isolation, personnel evacuation, and initial incident response, and coordinate with relevant departments to initiate rescue operations and investigations. This ensures the incident is promptly controlled and prevents secondary damage.

Regarding quality issue resolution, supervisors oversee contractors' corrective actions for substandard work or construction deviations through on-site inspections, testing, and remediation tracking. They must verify the reasonableness and feasibility of remediation plans, monitor the process and outcomes to ensure thorough resolution, and document lessons learned to prevent recurrence. The efficiency of supervision intervention is represented by the following expression:

$$EL_i = P_i \cdot C_i \quad (4)$$

Supervisors also play a vital role in addressing schedule delays and cost risks. When construction plans deviate from the original schedule or budget anomalies arise, supervisors mitigate the impact of delays on subsequent work by coordinating contractor resources, optimizing work sequences, and enforcing contract terms, while effectively controlling cost expenditures. This risk management mechanism emphasizes proactive intervention and full-process tracking by supervisors, enabling timely mitigation of construction risks and ensuring smooth project progression. The core function of supervision in risk management lies in rapid response, scientific guidance, and comprehensive oversight, forming a closed-loop system for integrated safety, quality, schedule, and cost management. This provides robust safeguards for risk control during the construction phase.

3.3 Functions of Supervision in Post-Risk Assessment and Feedback

Following resolution of risk incidents, post-assessment and feedback during the construction phase are critical components for achieving closed-loop management and continuously enhancing risk management capabilities. In this phase, supervision primarily undertakes functions of information collection, analysis and summarization, and experience feedback. Supervisors should systematically collect all types of risk incidents occurring during construction and the implementation status of intervention measures, establishing a risk database to provide reference for subsequent construction projects. By analyzing information such as accident causes, handling measures, cost impacts, and schedule effects, supervisors can identify weaknesses in construction management and potential risk points. The cost–benefit ratio of monitoring activities can be formulated as follows:

$$E_i = 1 - \frac{R_{i,after}}{R_{i,before}} \quad (5)$$

Supervisors must evaluate the effectiveness of contractors' corrective actions and risk resolution outcomes to assess the efficacy of intervention measures, compiling written assessment reports. These evaluations not only monitor risk control effectiveness for the current project but also guide construction and supervision practices for similar projects, enhancing the scientific rigor and standardization of construction management. The correlation between supervision intervention intensity and risk reduction is shown in Figure 2:

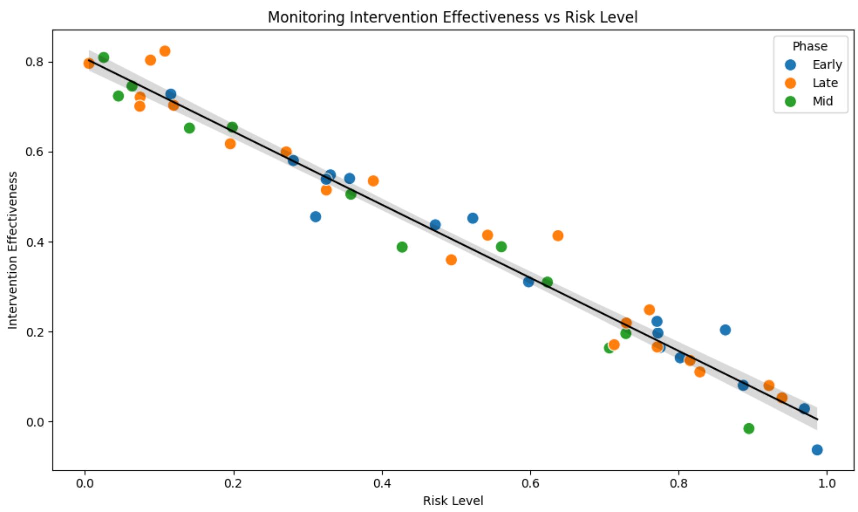

Figure 2 Monitoring Intervention Effectiveness vs Risk Levels

Supervisors feed back summarized risk experiences and management lessons into design, construction, and supervision systems. This optimizes construction plans, refines supervision processes, and improves risk prevention methods, achieving knowledge transfer and continuous management enhancement. This closed-loop feedback mechanism progressively elevates the overall level of risk identification, intervention, and management during construction, providing robust support for the long-term safety, quality, and efficiency of construction projects.

4. Optimization Pathways for Construction Phase Risk Management and Supervision Intervention Mechanisms

During construction, the effectiveness of risk management and supervision intervention mechanisms directly impacts project quality, safety, and economic efficiency. Institutional frameworks and policies form the foundational safeguards for construction phase risk management. First, relevant regulations and standards for construction risk management should be refined to clarify the responsibilities and authority scope of contractors and supervision agencies in risk prevention and control. For instance, establish operational protocols for high-risk processes and define the supervision authority's intervention rights in quality, safety, and progress management. Second, implement risk management assessment and incentive mechanisms, integrating risk management performance into the evaluation systems of construction contractors and supervision agencies to motivate all parties to proactively engage in risk identification and intervention. Additionally, encourage government authorities and industry associations to issue guiding policies promoting standardized and normalized safety, quality, and environmental management at construction sites, ensuring the implementation of risk management measures at the institutional level. The optimization of intervention mechanisms is mathematically modeled in the following equation:

$$RI = \sum_{i=1}^{n} w_i \cdot R_i \quad (6)$$

With the advancement of construction informatization and intelligentization, technological tools play an increasingly vital role in risk management and supervision intervention. BIM (Building Information Modeling) technology enables visualization management throughout the entire construction lifecycle, allowing early detection of potential risks in design and construction while enhancing the scientific rigor of risk prevention and control. Integrating IoT, sensors, and monitoring systems enables real-time tracking of critical site indicators—including personnel behavior, equipment operation status, environmental conditions, and construction progress—to achieve dynamic risk identification and early warning. Leveraging big data and artificial intelligence, historical project risk data is analyzed to predict potential risk trends, providing data-driven support for supervision decisions and enabling intelligent, refined risk management.

Personnel competence and organizational systems are core elements for implementing risk management. First, supervision personnel must possess systematic engineering management knowledge and extensive construction experience, while regularly undergoing training in risk management, safety management, and new technology applications to enhance risk identification and intervention capabilities. Second, optimize the construction project organizational structure by establishing a multi-tiered, clearly defined risk management and supervision system to ensure dedicated personnel oversee risk monitoring at every construction stage. Finally, strengthen information sharing and collaboration mechanisms between construction units and supervision agencies to facilitate timely risk communication and coordinated responses, maximizing the overall effectiveness of risk management.

Through the synergistic optimization of institutional policy safeguards, technical support systems, and personnel organizational guarantees, a multidimensional, multilayered, and dynamic risk management system for the construction phase can be formed. This system enhances the scientific nature of risk identification and the proactivity of supervision intervention, providing a solid guarantee for the safety, quality, and efficiency of construction projects. It holds significant theoretical value and practical significance.

5. Conclusion

This paper examines risk management in the construction phase of building projects. It systematically analyzes the characteristics and causes of construction-phase risks, establishing a risk identification framework encompassing safety, quality, schedule, cost, and environmental dimensions. Based on supervision responsibilities and practical work, it proposes a three-tiered supervision intervention mechanism covering risk pre-control, risk handling, and post-risk assessment. Through research on optimization pathways across institutional, technical, and organizational dimensions, a systematic, dynamic, and actionable risk management and supervision intervention system for the construction phase has been established. The findings indicate:

Scientific risk identification methods enable comprehensive identification of potential risks during construction, providing reliable grounds for supervision intervention; Effective implementation of the supervision intervention mechanism across risk prevention, mitigation, and post-assessment phases reduces the probability and severity of construction risks, enhancing process safety and project quality; Continuous improvement in construction risk management levels through institutional safeguards, technical support, and personnel optimization achieves holistic optimization of project safety, quality, and efficiency.

With the advancement of informatization and intelligentization in the construction industry, risk management and supervision intervention mechanisms during the construction phase will evolve toward digitalization and intelligence. The deep application of technologies such as big data analytics, BIM modeling, IoT, and artificial intelligence will further enhance the precision and timeliness of risk identification while strengthening the proactive intervention capabilities of supervision. Concurrently, continuous refinement of institutional policies, reinforcement of supervision team development, and enhancement of experience feedback mechanisms are essential to achieve ongoing optimization of construction risk management. This will provide a solid foundation for ensuring the safety, quality, and sustainable development of construction projects.

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