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# Evaluating Safety Impact Factors in Construction Projects through Multi-Entity Collaboration Using AHP

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## Abstract

This paper investigates the multi-party participation in construction safety management as the entry point, combines the theory of stakeholders, and it aims to apply the Analytic Hierarchy Process to assess the safety status of construction projects. Following the logic of "elements → decisions → behaviors", it identifies the influencing factors of construction safety management and constructs a scientific and dynamic safety management evaluation system. The core entities involved in construction safety management, such as construction units, construction companies, supervision units, government departments, and employees, are identified, and their responsibility boundaries and coordination mechanisms are analyzed. The Delphi method and Analytic Hierarchy Process (AHP) are used to establish a multi-level evaluation index system consisting of five dimensions: "organizational management, technical execution, risk prevention and control, emergency response, and collaborative efficiency". We consider projects in Jinzhou as the research case study. It is found that the main safety factors affecting the construction process are management factors, technical factors and personnel factors, followed by equipment problems and environmental problems. The implementation of safety responsibility system, safety education and training, safety rules and regulations and contract management should be the main focus. The research shows that effective evaluation system can quantify the collaborative efficiency of multiple parties and provide theoretical support and practical paths for the innovation of safety management models in the construction industry.

## Keywords

Building construction; Safety management; Multi-agent; Evaluation system; Sustainable cities and communities

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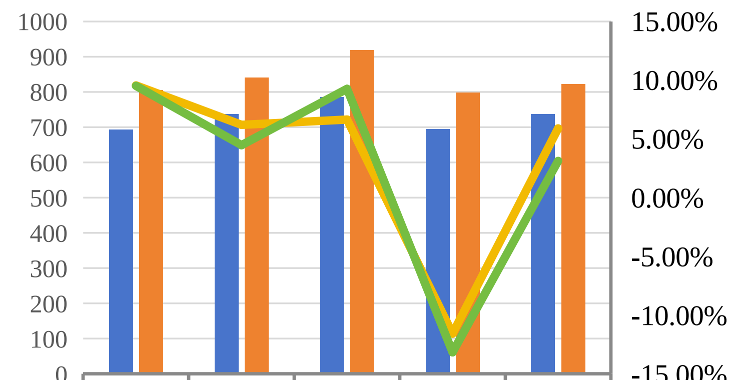
## Introduction

According to statistical data, from 2017 to 2021, there were 3,648 construction safety accidents across the country, resulting in 4,186 deaths (Yao, 2025). Figure 1 presents the statistical data of national construction safety accidents from 2017 to 2021. Over the past five years, the number of accidents and the number of deaths has generally shown fluctuating trends. The number of construction incidents and the number of deaths did not significantly decrease each year. The average number of construction incidents remained around 730, and the average number of deaths remained around 837. From 2017 to 2021, 2019 was the year with the highest number of construction safety accidents and deaths, with 786 accidents and 919 deaths.

Establishing an effective safety assessment system can quantify the collaborative efficiency among multiple parties and provide theoretical support and practical approaches for the innovation of safety management models in the construction industry.




| | 2017 | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|---|
| Number of accidents | 694 | 737 | 786 | 695 | 737 |
| death toll | 805 | 841 | 919 | 798 | 823 |
| Incidence rate of accidents | 9.56% | 6.20% | 6.65% | -11.58% | 5.90% |
| The rate of increase in the nu mber of deaths | 9.52% | 4.47% | 9.27% | -13.17% | 3.13% |

Figure 1 National construction safety accidents, 2017-2021

## Methodology

The construction process involves a large number of personnel and large mobility, complex processes, long cycles, complex and large quantities of mechanical equipment, and is greatly affected by seasonal climate, which leads to greater difficulty in safety management (Demirkesen, S. 2020). According to the statistics of the Ministry of Housing and Urban-Rural Development, the number of production safety accidents and deaths in the field of housing construction and municipal engineering have been on the rise in recent years (Yao, 2025).

There are 96 accident investigation reports (From 2017 to 2025, all regions of the country) were selected for in-depth analysis of the accidents, and frequency statistics were conducted on the causes of the accidents. By summarizing the causes with higher frequencies, the causes of the accidents were summarized. The results are shown in the table（Lan, 2025).

Table 1 Statistics on the causes of construction safety accidents，2017-2021

| **Direct cause** | **Frequency** | **Indirect cause** | **Frequency** | **Direct cause** | **Frequency** |
|---|---|---|---|---|---|
| Failed to notice the hazard sources (edge danger, opening danger, electric shock danger, mechanical injury, etc.); carelessness; lack of concentration | 76 | 79.17% | Inconsistent or inadequate safety education and training assessment (lacking in effectiveness, conducted merely as a formality, or completely absent) | 54 | 56.25% |
| Weak safety awareness (insufficient, weak, poor); Poor self-protection awareness; Insufficient safety prevention awareness | 46 | 47.92% | Inadequate safety management (chaotic and non-standard) | 50 | 52.08% |
| No safety equipment (safety belts, safety helmets, safety nets) were worn; no protective nets were set up. | 40 | 41.67% | Insufficient safety supervision (inspectorate) | 30 | 31.25% |
| Illegal work (illegally conducted work); Illegal construction; Illegal command | 24 | 25.00% | Insufficient investigation and rectification of potential safety hazards (incomplete, untimely, etc.) | 28 | 29.17% |
| Working without certification (for special equipment operators, high-altitude workers, tower crane operators, etc.) | 16 | 16.67% | Insufficient or absent safety technical briefing | 10 | 10.42% |
| Insufficient observation of the working environment, lack of knowledge about the working environment, unfamiliarity with the working environment, and failure to fully understand the on-site risks. | 12 | 12.50% | Lack of safety warnings (such as safety signs, safety reminders, etc.) | 8 | 8.33% |
| Time pressure | 6 | 6.25% | Unlawful subcontracting of projects | 4 | 4.17% |
| Work environment (strong wind, dim lighting, clean site, etc.) | 6 | 6.25% | | | |
| Tired | 2 | 20.8% | | | |

From the perspective of synergy theory, Bai Lihu of Northwest Normal University focuses on exploring the method and theoretical feasibility of replacing synergy theory into management mode and forming management synergy mechanism, so as to improve project management ability. Bai Lihu believes that: By introducing the idea of management collaboration, Zhou Haina constructed the management collaboration index system and evaluation model of construction projects. Taking a prefabricated building project of a university in Guangdong as an example, she verified the reliability of the above model, analyzed the situation and existing problems of project management collaboration, and proposed optimization strategies (Elshafei, G., Katunský, D., Zeleňáková, M., & Negm, A. 2022). Li Taoran, through the necessity analysis and correlation analysis of the safety management of construction project participants, proposed the construction project safety management system principles of multi-participation: the principle of full participation, the principle of initiative, the principle of enterprise subject, etc. and introduced social platform resources to build a two-level framework of construction project safety management with multi-participation (Yuan, C., Li, L. X., Su, X. W., & Du, R. J. 2025). By screening the key influencing factors, Zhang Lei selected information, objectives, organization, resources and culture, and based on this, built a collaborative effect evaluation system for program management (Qian, J., Siriwardana, C., & Shahzad, W. 2024). In addition, many scholars use maturity evaluation methods, fuzzy mathematics, set pair analysis (Elraaid, U., Badi, I., & Bouraima, M. B. 2024) and other evaluation methods to evaluate the construction safety management status (Leong, 2024; 2025a).

## Results and Discussion

Taking a construction project in Jinzhou as a case study, the construction project involves the construction unit, the general contracting unit, the subcontracting unit, the supervision unit, the supervision and management department and other subjects. The building construction project is to construct a building project. The project is divided into 3 buildings with a maximum of 22 storeys, and the remaining two buildings are 20 and 4 storeys high, with two basement floors. The base area of the foundation pit is about 6300m$^2$, and the depth of the foundation pit is 8.6 m. The excavation of the foundation pit has been completed, and the local civil construction is carrying out the binding of steel bars on the negative second floor of the basement.

The weights of evaluation indicators were calculated using the analytic hierarchy process. By constructing a judgment matrix, the determination of indicator weights was verified through consistency tests by 10 experts（The experts are from schools and are supported by associate professors or above, and they are also experienced professionals with a dual qualification as both teachers and practitioners.）, and the indicator weights were sorted hierarchically. The first-level weights were calculated and based on the secondary indicators of the analytic hierarchy process, the evaluation and calculation were conducted to obtain the conclusion as shown in Table 2.

Table 2 Summary of weights

| **Primary index** | **Weightage one** | **Secondary index** | **Weightage two** | **Total weight of the target layer** |
|---|---|---|---|---|
| Personnel factor (A1) | 0.1343 | Skill level (B1) | 0.0580 | 0.007791197 |
| | | Work with a certificate (B2) | 0.1001 | 0.013449979 |
| | | Psychological status (B3) | 0.2364 | 0.031753899 |
| | | Physiological condition (B4) | 0.6055 | 0.081355365 |
| Supervisory factor (A2) | 0.0348 | Government supervision (B5) | 0.607962213 | 0.021169736 |
| | | Social supervision (B6) | 0.272098516 | 0.00947469 |
| | | Enterprise internal supervision (B7) | 0.119939271 | 0.004176382 |
| Management factor (A3) | 0.5028 | Safety regulations and contract management (B8) | 0.134267417 | 0.067512275 |

| | | | | |
|---|---|---|---|---|
| | | Safety inspection (B9) | 0.040002645 | 0.02011411 |
| | | Implementation of the safety responsibility system (B10) | 0.477870475 | 0.240282591 |
| | | Safety input (B11) | 0.06855165 | 0.034469106 |
| | | Safety education and training (B12) | 0.273202413 | 0.018517022 |
| Equipment factor (A4) | 0.0678 | Safety protection facilities (B13) | 0.085 | 0.005761102 |
| | | Facility condition (B14) | 0.057 | 0.003863327 |
| | | Operating environment condition (B15) | 0.058 | 0.015093432 |
| Other factors (A5) | 0.2602 | Policies and regulations (B16) | 0.064 | 0.016654822 |
| | | Economic benefit (B17) | 0.033 | 0.008587642 |
| | | Construction method (B18) | 0.0580 | 0.007791197 |

$CR = 0.0078 \leq 0.1$ Pass the test

This paper takes a certain project in Jinzhou as the research object. Through questionnaire survey and analytic hierarchy process, the influencing factors are identified step by step, and the following conclusions are drawn through calculation. It is found that the main safety factors affecting the construction process are management factors, technical factors and personnel factors, followed by equipment problems and environmental problems. From the perspective of total weight, the implementation of safety responsibility system, safety education and training, safety rules and regulations and contract management should be the focus of management, from the specific project analysis, can provide a certain theoretical basis for building construction safety, and has certain significance for the future construction safety management (Leong, 2025b).

## Conclusion

This research takes the multi-party participation in construction safety management as the entry point, combines the theory of stakeholders, and for the scientific evaluation of the safety production status of construction projects, following the logic of "elements → decisions → behaviors", establishes a safety management dynamic mechanism model for construction projects, identifies the influencing factors of construction project safety management, and constructs a set of scientific and dynamic safety management evaluation system. Although achievements have been made, there are still some shortcomings and areas worthy of in-depth research in the future. We have to consider whether the evaluation system of safety management collaborative indicators can scientifically and comprehensively reflect the current situation of construction project safety management is the current research difficulty.

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