

# Research on high-rise building risk identification and safety risk factor analysis

**Xueqi Zhao**

The College of Resources and Environmental Engineering, Wuhan University of Science and Technology, Wuhan, 43000, China

csims76800@student.napavalley.edu

**Abstract.** High-rise building is the trend of the future construction industry and the symbol of the continuous development of urbanization in China. However, safety accidents often occur during the construction of high-rise buildings, which bring people property losses, and sometimes even endanger the safety of life. Therefore, in order to effectively reduce the construction safety accident rate and improve the level of risk management, the construction of high-rise building safety risk focus on and research. This paper first analyzes the construction characteristics of high-rise buildings and accident types. According to the accident cause theory and hazard identification method, the major hazard sources in high-rise building construction are identified. Finally, this paper analyzes the construction of high-rise building risk factors. This paper can provide a theoretical basis for the construction of high-rise building safety risk assessment system, and provide a scientific and reliable risk management platform for the relevant units, so as to improve the safety awareness and risk management level of construction personnel.

**Keywords:** High-rise building, construction safety, risk factors, hazard sources.

## 1. Introduction

With the accelerating process of urbanization, the demand for high-rise buildings is also increasing. However, there are many risk factors in high-rise building construction projects, such as: complex construction process, more dangerous operations and high-altitude operations. Safety accidents occur frequently, resulting in a large number of casualties and property losses. Therefore, it is urgent to reduce the accident rate. Many achievements have been made in the study of construction safety management by domestic and foreign scholars. Lingard et al. [1] put forward the “4E” safety development strategy, which includes law, project, environment, management etc. Raamkuma and Indhu [2] used CFA-SEM analysis to infer that design factors, physical factors, and safety environmental factors have a significant impact on risk management.

There are still many problems in China's safety management of the construction process, such as non-standard operation of enterprises, inadequate handling of major safety accidents, and inadequate education and training of construction safety personnel. The safety management of high-rise building construction often lacks systematic control and evaluation, which is a major pain point in the market. Based on this, this paper first introduces the construction characteristics and accident types of high-rise buildings, followed by the identification of major hazard sources in high-rise buildings, and finally

analyzes the risk factors in high-rise building construction to provide a certain theoretical basis for the construction of risk assessment system.

## **2. High-rise building construction safety basic theory**

### *2.1. High-rise building construction characteristics*

#### **(1) Long construction cycle and susceptibility to environmental impact**

Generally speaking, the engineering and construction market can range from months to years. For high-rise buildings, their own structure is very complex and the construction scale is also relatively large. Even very simple high-rise building structures can take about two years to complete. In addition, the construction of high-rise buildings is also susceptible to environmental influences. The climate is constantly changing in different seasons, and the natural environment and overall temperature are also constantly changing. Some building materials are prone to deformation due to thermal expansion and contraction, and may even undergo qualitative changes.

#### **(2) Large engineering volume and complex content**

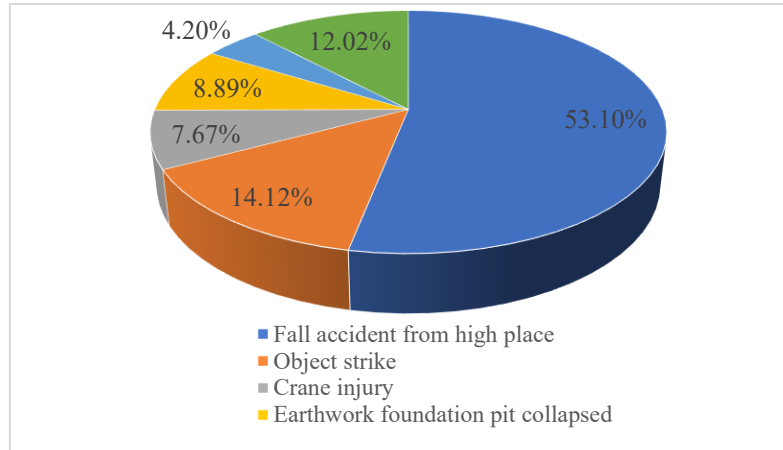
Due to the high floors and complex structure of high-rise buildings, there are many construction procedures and links, which sometimes cannot avoid cross operation of multiple types of work. Therefore, it is easy to encounter organizational management and cooperation issues between different processes during the construction process. In addition, the construction scale of high-rise buildings is relatively large, requiring a large number of professional equipment, materials, tools, and technical personnel.

#### **(3) Large excavation depth and high cost**

The foundation burial depth of high-rise buildings is generally relatively deep. According to relevant regulations, the foundation burial depth of high-rise buildings should not be less than 1/12 of the building height [3]. In order to meet people's needs, modern high-rise buildings usually have underground parking lots, which increases the excavation depth and difficulty of high-rise construction. The complex processes of earthwork excavation, foundation pit support, foundation treatment, and deep dewatering directly affect the construction period and cost. In addition, there are many new technologies used in high-rise buildings, such as reverse construction and composite foundation technology [4].

#### **(4) There are many high-level operations with high risk factors**

Compared to traditional buildings, high-rise building construction involves many high-altitude operations higher than ten floors. The vertical transportation volume of high-rise buildings is large. During construction, it is not only necessary to solve the vertical transportation of building materials, construction equipment, and personnel, but also to reasonably select vertical transportation machinery. Not only should communication and garbage disposal issues be properly arranged during the construction process, but various high-altitude safety protection measures should also be taken. Special attention should be paid to the careful management and use of water, electricity, and fire to avoid accidents, which can improve work efficiency and grasp the timeline [4].



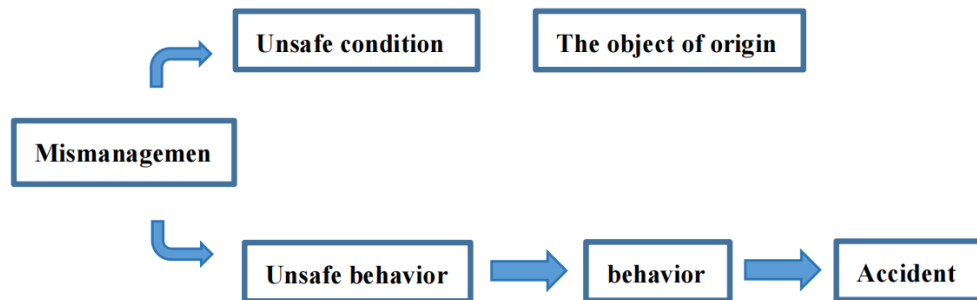
**Figure 1.** Proportion of types of construction safety accidents [5].

### 2.2. Types of accidents in high-rise buildings

From figure 1, it can be seen that the types of safety accidents in high-rise building construction mainly include high-altitude falls, object strikes, crane injuries, collapse of earthwork foundation pits, construction equipment injuries, electric shock, and others. Among them, the proportion of falling from high places exceeds half, reaching 53.10%; The second is object strikes, accounting for 14.12%; The last one is construction equipment injuries, accounting for 4.20%.

### 2.3. Theory of Causes of Accidents in High rise Buildings

The theory of accident causation is an accident mechanism and accident model extracted from the analysis of the essential causes of a large number of typical accidents. It can reflect the regularity of accidents and provide scientific basis for qualitative and quantitative analysis of accident causes. In the famous Bird's theory, management defects are the most fundamental cause of accidents. The second factor is personal and work conditions, including management errors, equipment and materials, temperature and humidity, noise, dust, etc. Bode believes that unsafe behavior of people and unsafe state of things are the direct cause of accidents, and the last factor is losses, as accidents do not necessarily cause harm, But the losses from accidents happen from time to time. Bird's model for accident cause analysis is shown in figure 2.



**Figure 2.** Accident Cause Analysis Model.

The model further divides the causes of objects into causal and harmful factors. The former refers to objects (machinery, objects, substances) that cause accidents, while the latter refers to objects that directly cause harm to humans. In terms of human issues, distinguish between the perpetrator and the victim. The former refers to the person who caused the accident, while the latter refers to the person who was injured during the accident.

### 3. Identification and management of hazard sources in high rise building construction

#### 3.1. Principles

Considering multiple factors, the classification of major hazard sources should follow the following principles:

- (1) Starting from operability, classify major hazards based on their location, equipment, and facilities.
- (2) According to the principle of similarity and compatibility, it is carried out hierarchically based on the characteristics of each major type of hazard source.

There are two main methods for hazard classification:

- (1) Static classification method for hazard sources. The classification criteria remain unchanged or the classification results do not change with the number of hazard sources participating in the classification.
- (2) Dynamic classification method for hazard sources. The number of hazard sources changes, and the criteria for classification are variable or both.

#### 3.2. Hazard identification method

*3.2.1. Intuitive experience method.* Intuitive experience method includes control method and analogy method. Based on national regulations and relevant standards, the staff will identify and analyze the construction environment, process, equipment, and safety management situation based on their own experience. This method is relatively subjective and requires high levels of professionalism, years of employment, and judgment ability of the staff [6].

*3.2.2. System security analysis method.* This method includes safety checklist method, pre hazard analysis method, as well as hazard and operability research, accident tree analysis, cause and effect analysis method to identify construction hazards [7]. Generally speaking, accident tree analysis, event tree analysis, and cause and effect analysis can provide qualitative analysis of hazard sources and quantitative analysis of hazards. Therefore, it has significant advantages in application and a relatively wide range of applications.

#### 3.3. Identification of major hazards in high-rise building construction

Identifying the hazards of high-rise buildings is the most fundamental and important step in construction. Before construction, it is necessary to identify the hazards present during construction, and then conduct safety assessment and control of project risks [8]. After identifying the unsafe state of objects and unsafe behavior of people, effective preventive measures are formulated for the construction process to ensure the smooth completion of the project. Table 1 shows the major hazards in high-rise building construction.

**Table 1.** Analysis of risk factors of construction project with high risk [6].

Construction project with greater risk	Potential major risk factors	Main types of accidents
Deep Foundation Pit Project	Deep Foundation Pit, complex foundation treatment	Mechanical injury, object strike
Scaffolding Engineering	Not in accordance with the norms to build scaffolding; operators do not wear safety protection supplies; erecting materials piled up randomly	Fall, object strike, collapse
Project on the edge	No enclosure	fall from height
Template works	Unreasonable support setting; support system defects; demoulding; incorrect operation	fall from height, object strike, collapse
Demolition blasting works	Use of inflammable and explosive dangerous goods; improper protection	Explosion, poisoning, flying stone wounding

**Table 1.** (continued).

Excavation works	Improper support; improper border protection	Collapse, fall from height
Lifting and hoisting engineering	Wire rope not up to standard, items not securely tied, personal protective equipment not properly equipped	Crane injury, mechanical injury
Temporary electricity for construction	Leakage, short circuit, static electricity, lightning	Electric shock

#### **4. Construction of Risk Assessment System Based on 4M1E Theory**

To construct a safety risk assessment system for high-rise building construction, it is necessary to quantify safety risks through the theoretical system of safety risk identification and establish corresponding safety risk assessment index systems. Based on the principle of "4M1E", this paper conducts an investigation from five aspects: personnel, materials, equipment, environment, and management.

Firstly, it is necessary to clarify the principles that need to be followed. When constructing a safety risk indicator system for high-rise building construction, it is necessary to follow the principles of systematicity, scientificity, operability, comprehensiveness, and the combination of qualitative and quantitative analysis.

Next, in order to effectively establish a safety risk assessment index system for high-rise building construction, risk factor analysis is carried out to establish a good foundation for the effective creation of this risk assessment index. Similar to other construction engineering safety risk factors, the risk factors of super high-rise buildings are also closely related to people, materials, and other aspects, as follows:

##### **(1) Personnel factors**

At the construction site of high-rise buildings, people are the main factor driving the project. Meanwhile, unsafe human behavior is also a major cause of accidents. This requires us to analyze the factors that affect personnel in order to effectively prevent accidents from occurring. In terms of personnel factors, specific influencing factors mainly include basic safety literacy, technical operation level, physical health status, work experience, and relevant qualification requirements.

##### **(2) Material factors**

Building materials are the fundamental requirements of engineering, and the quality of materials determines the overall quality of the building. Only by ensuring the quality of materials can the engineering quality be guaranteed to be qualified, and the final building safety index can be met. The risk indicators of material factors mainly include: material quality, material transportation, material procurement and storage.

##### **(3) Equipment factors**

Due to the large quantity and complex content of high-rise buildings, various mechanical equipment is required during the construction process. Only by ensuring the safety and qualification of equipment can mechanical accidents be avoided and engineering efficiency be improved. The risk indicators of equipment factors mainly include: safety protection of equipment, safety inspection of mechanical equipment, selection standards of mechanical equipment, reliability inspection of large equipment, management of large mechanical equipment, and control of construction equipment installation and dismantling [5].

##### **(4) Environmental factors**

Environmental factors involve a wide range and are highly variable, and the construction environment of different engineering projects often varies. Therefore, comprehensive consideration should be given to risk prevention based on specific construction characteristics, which can be subdivided into construction site environment, low-quality land conditions [9], construction climate conditions, construction lighting, construction noise, and dust.

#### (5) Management factors

The safety management system supporting high-rise buildings is not yet perfect, and related safety management issues cannot be effectively resolved. The main risk influencing factors include: the allocation of safety management institutions and positions, the safety management system at the accident site, safety education and training for construction workers, on-site safety settings, supervision and implementation of accident emergency rescue systems, and the development and implementation of safety technologies [10].

### 5. Conclusion

This paper introduces the basic theory of high-rise building construction, identifies major hazards of high-rise buildings, and analyzes specific risk factors from five aspects of "human, machine, material, law, and environment" based on the 4M1E theory. The use of scientific methods provides a theoretical basis for implementing a risk management platform. High rise construction enterprises can use risk management platforms to enhance the safety risk management capabilities of engineering projects, control and prevent construction safety risks. Based on the relevant evaluation results, first identify the weak parts during the construction process. Then, relying on the comprehensive high-rise building construction safety risk assessment index system covering all aspects of the project, the construction safety assessment plan is quantified, and the reasons are analyzed based on the results, and corresponding solutions are proposed. To ensure the smooth completion of high-rise building construction operations. Reduce the incidence of accidents in high-rise building construction and improve overall environmental safety.

To construct a scientific safety risk assessment system as mentioned above. Firstly, it is necessary to fully collect relevant information on high-rise building construction before research, such as safety management standards, processes, relevant project experience, construction requirements, etc., to establish a good foundation for research work. Secondly, a theoretical system for identifying safety risks in high-rise building construction is established through the theory of this article and other relevant materials. Thirdly, based on the theoretical system of identifying safety risks in high-rise building construction, establish a comprehensive evaluation index system for super high-rise building construction safety risks covering all aspects of the project, and select appropriate evaluation methods to evaluate safety production. Fourthly, based on the results of the safety risk assessment index system for high-rise building construction, analyze the reasons and propose corresponding solutions, so that the control system can play a good role in preventing and solving high-rise building construction problems.

### References

- [1] Lingard H, Pirzadeh P A and Oswald D A. 2019 Erratum for "Talking Safety: Health and Safety Communication and Safety Climate in Subcontracted Construction Workgroups" by Helen Lingard, Payam Pirzadeh, and David Oswald *J. Constr. Eng. & Manag.* **(11)** 98-107
- [2] Raamkumar J S and Indhu B A 2022 Study on the Assessment of Risk Management in High-Rise Buildings *Adv. Const. Manag.* **(32)** 47-56
- [3] Sun Y M and Zhang R Q 2020 Research on the Characteristics of High-Rise Building Construction and Concrete Quality Control *Eng. Constr. Design* **(10)** 215-216
- [4] Kong D H 2017 Construction features and key technologies of super high-rise building *Constr. Tech.* **(09)** 41-42
- [5] Lu C 2023 *Research on High rise Building Construction Safety Risk Management Based on Combination Weighting Cloud Model* Shandong Jianzhu University
- [6] Qian X P 2021 Identification of hazards and accident prevention in high-rise building construction *Constr. Safety* **(06)** 72-74
- [7] Guo J D 2021 Identification of hazards and accident prevention in high-rise building construction *Urban Housing* **(S1)** 237-238
- [8] Zhang F W and Liu H 2021 Discussion on Dynamic Identification and Control of Dangerous Sources in Construction Engineering Build. Tech. Develop **(22)** 5-7

- [9] Ni M Y 2016 Safety Risk Assessment of High rise Building Construction Based on Matter Element Analysis Theory journal of WUT(Information & Management engineering) **(03)** 293-296
- [10] Liu W J 2023 Research on Safety Risk Assessment of High rise Building Construction Shandong Jianzhu University