Analysis and Management of Risk Factors in High-rise Building Engineering

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Keywords: High-rise buildings; Safety accidents; LEC; Grey theory.

Abstract: High-rise buildings are the mainstream of modern architecture. However, due to the characteristics of high-rise buildings, such as many layers, complex construction technology, large amount of work, and exquisite technical requirements, the incidence of safety accidents in the construction process is very high. This paper determines the index weight through LEC and studies the risk factor analysis and management of high-rise buildings by using grey theory, which has certain theoretical guidance significance for the construction process.

1. Background

With the improvement of living standard and urbanization construction, there are more and more high-rise buildings in order to meet the infinite demand of people with limited land resources, which play a role in economic development. Statistics show that the total output value of China's construction industry was 21.3954 trillion yuan in 2017, an increase of 10.5% over the same period last year, the increase was 2038.7 billion yuan. By 2018, the total output value of China's construction industry had reached 23.5 trillion yuan, an increase of 9.9% over the same period last year [1].

With the rapid development of the construction industry, many risks in the construction industry are unavoidable. On the one hand, they are caused by the characteristics of high-rise buildings, and on the other hand, they are existing and potential risks in the construction process. Due to the large scale and quantity of high-rise buildings, numerous employees, high-altitude work, close contact between man and machine [2], all work is in dynamic change, once the safety accident occurs, the consequences are very serious. According to data released by the ministry of housing and urban-rural development of the People's Republic of China, there were 692 production safety accidents and 807 deaths in the construction industry in 2017, 58 more accidents and 72 more deaths than in the same period of 2016, up 9.15% and 9.8% respectively. But only the first half of 2018 China's construction industry safety accidents have occurred 1732, 1752 people dead construction accident statistics [3].

In this context, we need to find out the causes of accidents, take corresponding positive measures to reduce the occurrence of high-rise building accidents, avoid unnecessary losses, improve construction safety and standardization of high-rise building construction.

2. Main Content

Risk management is how to minimize the risk management process in a risky environment, through the risk identification, risk assessment, choose according to evaluation result on the basis of the effective ways to deal with risks, have a purpose, in a planned way to deal with risks, implementation of real-time monitoring and properly handle the loss of risks, for the economic interests of the largest engineering with minimum cost [4][5]. At present, the common risks in the construction of high-rise buildings in China are mainly shown in Table 1:

Table 1. Types of safety accident risks in the construction process of high-rise buildings [6]

Accident Type	primary cause	proportion
High-altitude falling	Safety awareness of high-altitude workers is shallow; Low quality of protective equipment equipped for aerial work; Construction site of four holes and five edges border protection is not good	35%
Electric shock accident	Weather causes the electrical equipment to suffer rain, wind, rust and other conditions; Site safe electricity distance, illegal operation, unsafe electricity management system is not perfect, the system is not strict	20%
Object strike accident	Personal awareness and construction machinery and equipment protection is not in place; Improper operation of construction machinery operators; The inspection is not strict and does not meet the inspection standards	15%
Mechanical injury accident	Poor construction conditions on the project site; Low operating level of personnel; The weather is not ideal	10%
Collapse accident	Poor quality of construction equipment; Incomplete protection measures; Improper placement	5%

High-rise building engineering is an integrated system composed of human, material, machine, method, ring, and pipe [7]. Therefore, to identify the risk factors in the construction of high-rise buildings, from all aspects of the system, to find out the impact of the project construction risk factors.

(1) Human factors

Personnel management is the most complex and the biggest difficulty in production management. People's shallow safety awareness, unsafe behavior, and management level will directly affect the quality of the project [8]. In the process of risk management of high-rise building construction, it is necessary to focus on the human factors to improve the awareness of personnel, so as to better identify the risks, follow the "three do not let go" principle, find out the potential risks that affect the safety of the project.

(2) Material factors

Materials are the most basic production elements of sustainable construction of engineering projects. The quality of materials also determines the quality of engineering. There are risks in the process of materials entering the site and on site waiting for use. Therefore, in the process of risk identification of high-rise building construction, it is necessary to do a good job in material inspection and material control, to make the risk management work more smoothly and lay a solid foundation for the follow-up work.

(3) Mechanical equipment factors

In the construction process of high-rise building engineering, a large amount of mechanical equipment is needed. In the process of personnel use, there are a lot of risks. In order to ensure the safety of the construction process, qualified personnel must do the acceptance work before the mechanical equipment enters the site to avoid engineering accidents caused by equipment quality problems. Routine maintenance and maintenance of old equipment on site should be carried out to maximize the benefits in subsequent construction.

(4) Method factors

All kinds of documents and rules and regulations contained in the construction process of a project are the theoretical basis for the guidance of the construction process and are indispensable. With the rapid development of the construction industry, there are more and more new construction methods. For the actual construction process of high-rise buildings, all kinds of construction methods are restricted by various relevant factors in the process of practice, and there are unpredictable variables, which lead to accidents accordingly. Therefore, in order to ensure the safety of the project, the regulations must be strictly followed. For the new process, we also need to explore and demonstrate, but also to formulate corresponding countermeasures, strict supervision.

(5) Environmental factors

A good working environment is more conducive to motivating staff to work. The engineering construction environment is complex, and the structure construction of the project is basically the open-air operation, the potential risk is difficult for us to predict, has a great impact on the safety of construction. Sometimes the quality of the working environment will also determine human factors, so the protection of the rights and interests of construction and management personnel of engineering projects will reduce the risk incidence rate to a certain extent. This requires us to clearly understand the environment of the project in the construction process, and strive to ensure the optimization of engineering quality.

(6) Management factors

The construction management of high-rise buildings includes three aspects: the management of on-site personnel, the management of materials and materials, and the management of the work itself. With the diversification of various influencing factors, it is of great significance to ensure the construction safety and completion quality to manage these key factors well.

Reference of housing and urban-rural development of the national construction safety production situation analysis report as well as the accident letters posted of housing and urban-rural development, high-rise building safety accidents happen mainly in four to five in the collapse edge, mechanical equipment, construction, scaffolding, construction, electricity, etc., site safety evaluation index system for building high-rise building provides a general direction. Through collating and analyzing the recent high-rise building accident data, the risk evaluation index system is established by using analytic hierarchy process, and the construction site risk evaluation model is constructed according to the first-level index and second-level index in the evaluation system [9].

The research contents of this paper are analyzed from the following aspects, including four population and five risk; equipment risk; foundation pit protection risk; scaffolding risk and electricity risk level 1 index, like this is shown in Fig.1.

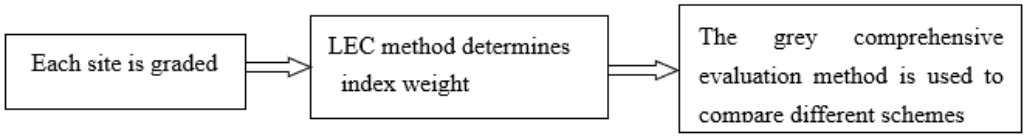

Figure 1. Procedure for evaluating the model

2.1 LEC Determines the Weight of Indicators

(1) Determination of L value of accident probability

By collecting the data of previous high-rise building construction safety accidents and relevant literature on the value of L, the value standard is stipulated. The probability of a construction accident is closely related to the death rate of personnel. The higher the probability of accident, the higher the corresponding death rate of personnel. The minimum score of accident probability is set as 0.1, and the inevitable score is set as 10. It depends on the situation between the two. The following table values are also based on this standard.

Table 2. Value criteria of probability (L) of accidents

The Possibility of An Accident	Score Value	The Possibility of An Accident	Score Value
Totally Predictable	10	Impossible	0.5
A Great Possibility	6	Highly Impossible	0.2
General Possibility	3	Practically Impossible	0.1
Small Possibility	1		

(2) The exposure time of personnel to dangerous environment E

In a whole life cycle, the project just started, the management work, also is in a state of attaches great importance to the construction of personnel and management personnel work safety consciousness is generally high, accident probability is small, Slowly over time, the safety consciousness of personnel on site is reduced and the performance of all kinds of mechanical equipment is also decreased compared with that before entering the site. The more frequently workers are exposed, the greater the potential for injury. See the following table for details:

Table 3. Frequency of exposure to a hazardous environment (E)

The Frequency of Exposure to Hazardous Environments	Score Value	The Frequency of Exposure to Hazardous Environments	Score Value
Continuous Exposure	10	Exposure once a month	2
Working Hours Exposure	6	Several exposures per year	1
The Occasional Exposed	3	Very rare	0.5

(3) Score C of possible consequences once an accident occurs

In this paper, the classification of the grade of consequences is based on the provisions of the death toll in the accident grade of our country and combined with the safety accidents occurred in the construction process, the following accident grade standards are formulated, as shown in the following table:

Table 4. Value Table of Grade D Caused by Accidents

The Consequences of The Accident	Score Value
≥30 people died	100
10 - 29 people died	45
3-9 people died	15
2 people died, or 3-19 were seriously injured	7
1 people died, or <3 were seriously injured	5
3 were seriously injured	3
Minor injuries	1

In this paper, according to the above table scores, it is determined by D=L×E×C calculation, and the grey comprehensive evaluation method is used for comparison.

3. Case Study

3.1 Project Summary

Xiayi international spring city is in the northwest corner of the intersection of changshou avenue and south ring road in xiayi county. It covers an area of 200,000 square meters and a building area of 49950 square meters. The specific project overview is shown in Table 5.

Table 5. Project overview

The Name of The Project	Xiayi International Spring City Residential Area
The Construction Unit	Zhoukou sitong construction co. LTD
Time Limit for A Project	360 days
The Quality Requirements	One-time acceptance
Safe Construction Target	No major safety accidents, as far as possible zero death accidents, no adverse effects, ensure the realization of civilized construction

3.2 The LEC Method

(1) Use the LEC method to determine the weight of risk factor evaluation index (Table 7), where

E (degree of exposure to risk) shall be determined according to the actual situation of the project;

C (possible consequences of the occurrence of the accident) shall be determined by experienced experts according to the specific circumstances of project implementation;

The determination of L value is calculated from the national statistics of building safety accidents in recent years, and the data in the following table are obtained for Table 6 captions

Table 6. Accident probability of first-level indicators

Level Indicators	**The probability**
Four Holes Five Limbs	31%
Machinery and Equipment	18%
The Foundation Template	16%
The Scaffold	15%
The Line to Get an Electric Shock	5%

Table 7. Risk scores of indicators

First-level Evaluation Index	**Probability (L)**	**Exposure to Risk (E)**	**Consequences (C)**	**Hazard D=L*E*C**
Four Holes Five Limbs	10	2	5	100
The Scaffold	5	2	7	70
Machinery and Equipment	6	3	7	126
The Foundation Template	5	2	10	100
The Line to Get an Electric Shock	0.5	3	5	7.5

According to the risk score of first-level indicators in the table, the weight of each first-level indicator can be determined. The calculation steps are as follows:

The weight of four holes and five adjacent sides is 100/ (100+70+126+100+7.5) =0.25.

Similarly, the weight of scaffold protection, mechanical equipment protection, foundation pit formwork protection, and electric shock protection are respectively 0.17, 0.31, 0.25 and 0.02.

(2) Calculation of weight of secondary evaluation index

According to the formula, the risk scores of secondary indicators are calculated, as shown in Table 8.

Table 8. Second-level index D (risk score)

The Evaluation Index	Accident Probability (L)	Exposure to Risk (E)	Consequences (C)	Hazard Score D=L*E*C
Fall Protection	6	2	5	60
Object Strike Protection	3	2	5	30
Tower Crane	3	3	10	90
Construction Machinery	0.5	3	7	10.5
Foundation Pit collapse Protection	0.5	0.5	15	3.75
Template Protection	0.5	2	15	15
External Circuit Protection	0.2	3	5	3
Temporary on-site Electrical Protection	0.1	3	5	1.5

According to the D value of the table, determine the weight of the second-level index:

The weights of fall protection and object strike protection are respectively 0.67 and 0.33;

The weight of the tower crane and construction machine is 0.88 and 0.10 respectively;

The weight of foundation pit collapse protection and formwork protection is 0.20 and 0.80 respectively;

The weights of external power line protection and field power protection are 0.67 and 0.33 respectively;

The weights of the secondary evaluation index system of high-rise building construction site are shown in table 9:

Table 9. Weights of Secondary Indicators

The Secondary Indicators	The Weight
Object Strike Protection	0.33
Fall Protection	0.67
Construction Machinery	0.10
The Collapse of the Template	0.88
Foundation Pit protection	0.81
Tower Crane	0.2
Temporary Power on Site	0.33
An Electric Line	0.67
Protective Railings	0.40
Scaffolding	0.32
Safety Net	0.32

According to the constructed evaluation index system and the weight of various indexes, the site management personnel were hired to grade the selected sites according to the standards of the site, and a score table was established through the convergence of the scores [11]. There are 11 secondary evaluation indexes in table 10 below. The standard is the standard site, 1 is the international spring city, and 2 and 3 are the control sites.

Table 10. Comparison of indicators between sites

Standard Values	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
	85	85	85	85	85	85	85	85	85	85	85
1	87	85	89	80	80	85	70	85	86	87	89
2	86	88	86	90	78	79	85	83	88	84	82
3	80	75	75	86	84	86	87	75	80	80	84

According to the theory of grey comprehensive evaluation system, Take the maximum values of all kinds of secondary index tables in the three sites as follows {87,88,89,90,84,86,87,85,88,87,89 } as the reference sequence; Calculate the construction relatedness of each site, for standard sites

$$\min_i \min_k \left| X_0(k) - X_i(k) \right| = 1 , \qquad \max_i \max_k \left| X_0(k) - X_i(k) \right| = 9 \tag{1}$$

The correlation coefficient of the standard construction site is

(0.732,0.733,0.568,0.407,0.723,0.578,0.846,1,0.733,0.733,0.647);

The correlation coefficient of international spring city construction site is calculated as shown in table 11:

Table 11. Correlation coefficient

	0.733	0.733	0.568	0.407	0.723	0.578	0.846	1	0.733	0.733	0.647
1	1	0.8	1	1	0.5	0.627	0.32	0.878	0.8	1	1

Finally, the correlation level between construction sites was calculated

$$r=\Sigma w(k)\times\xi(k) \tag{2}$$

The standard is 0.689 and 0.783 for site 1, which is higher than the average level.

It indicates that the risk management level of xiayi international spring city is good, and the on-site personnel at all levels are conscientious, abide by the operating procedures, and do their utmost to ensure the quality of the project; All kinds of materials and equipment meet inspection standards before entering the site; Managers have strong coordination ability, timely communication with superiors; Identify all kinds of risks, carefully evaluate the probability of all kinds of risks and the corresponding consequences, make full preparations to deal with the risks, with full grasp of the risk will greatly reduce the risk.

3.3 Risk Response

The above first-level and second-level indicators have a significant impact on the smooth progress of high-rise building construction, and major aspects are selected for key control.

First, the overall quality of personnel. The quality of personnel will determine the quality of high-rise buildings. Operators should strictly follow the company's rules and regulations, managers

should choose those with rich management experience, special process construction personnel should be trained and qualified and hold the certificate.

Second, the quality of materials. Unqualified materials will have a negative impact on the whole project. There should be a clear series of relevant quality inspection and management standards system, such as warehousing of materials, to supervise the whole process of quality inspection and prevent unqualified and defective products from entering the construction site.

Third, it is scaffold construction whose work quantity is heavy, construction difficulty. During construction, the transverse and longitudinal connection of scaffolding shall be close, and the soil quality and hydrology of the construction site shall be considered when the construction site is set up.

The fourth is the weather risk. High-rise buildings are built in the open air, and the weather varies from region to region. Long-term abnormal weather will delay the construction period. Therefore, it is necessary to make a comprehensive forecast of the weather before construction and take measures to deal with the bad weather.

Fifth, mechanical equipment. Its management is divided into three aspects: use, inspection, and maintenance. Before use, check and record the performance of all aspects of the equipment to ensure that the equipment is in good condition and can be used at any time [11]; With the change of processing time and the aging of mechanical equipment, timely adjustment and compensation should be taken to do the maintenance work and ensure the quality requirements.

Six, the danger of working at altitude. In the process of working at high altitudes, safety construction should be ensured and protective measures should meet the requirements. Eliminate the current prohibition of unauthorized personnel into the construction site, to avoid falling events.

4. Conclusion

There are many security problems in the field of high-rise buildings, which mainly come from two aspects. One is the risk brought by high-rise buildings themselves that are different from general buildings; the other is the imperfect management system in the construction of high-rise buildings, and the implementation of management work is not in place. The problem of risk management needs to be paid attention, because once the risk problem is ignored, the consequences will not only endanger the safety of site personnel but also affect the construction progress and social stability of the project. This paper takes risk management as the entry point, from the three stages of risk identification, risk assessment and risk response to the comprehensive description of high-rise building construction management. Through the risk identification of high-rise buildings, the safety risk evaluation index of high-rise buildings is constructed, and a set of risk evaluation system is formed. To demonstrate with examples, sort out the probability of each indicator, and the index weight of the overall factors, get comprehensive evaluation points, according to the advantages and disadvantages of the order; Countermeasures are proposed for the high-frequency accidents in construction. However, there are still many deficiencies in this paper, which can be improved from many aspects.

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