Research on construction engineering safety Risk Control based on IAHP-TOPSIS

Abstract: Based on the improved analytic hierarchy process (IAHP) and TOPSIS method to build the construction project safety evaluation index system used to evaluate the safety management of construction projects in the construction stage, so as to control the safety risk of the project, prevent the occurrence of safety accidents, and improve the level of safety management. Through make a statistical analysis of the recent safety accidents in construction projects in China, comprehensively consider the four aspects of human, object, environment and management, establish 12 evaluation indexes of construction project safety management. Through improved analytic hierarchy process (AHP) to determine evaluation index weights vector, combined with the ideal solutions for sorting method, put forward a IAHP method and TOPSIS method based on the safety evaluation model.The research results show that the model can accurately show the deficiencies of the safety management of the evaluation object, and directly reflect the safety management level of the evaluation object. The research conclusion is consistent with the actual situation of the project, which can provide guidance for the improvement of safety redundancy and safety risk control of construction engineering.

Key words: IAHP method;TOPSIS method;Safety management;Risk control

0 Introduction

With the continuous progress of human society and the rapid development of science and technology, occupational health and safety attracts more and more attention **[1]**.It is of great significance to avoid safety accidents to protect the life, health and safety of workers.

As one of the high-risk industries, the construction industry is prone to all kinds of safety accidents in the construction process due to ambiguous safety concepts, poor self-protection awareness and poor working environment **[2]**.How to effectively to avoid safety accident, the domestic and foreign scholars have conducted a lot of research work, think people's unsafe behavior and unsafe status of objects, unsafe factors of environment and Management defects are the main factors of safety accidents, often referred to as "4M" elements: the Men, the Machine or the Matter , the Medium and the Management.The interaction and combination of these factors in a certain period of time lead to the occurrence of safety accidents, which is the focus of safety accident control. In the construction industry, WANG X F**[3]**,Jia X et al. **[4]** argues that effective organizational support from the management side to workers can significantly improve workers' safety behavior. Zhai R et al. **[5]** proposed that attaching importance to safety factors related to people is the premise to ensure construction safety.Du T et al. **[6]** studied the construction safety evaluation of construction projects by using AHP and fuzzy comprehensive evaluation method, established the project construction safety evaluation index system, and formulated the specific inspection items and scoring rules of the second-level index of safety evaluation. WU T Y et al.**[7]** developed a method to evaluate construction safety management to evaluate construction safety management. In 1931, Heinrich, a famous American safety engineer, completed Industrial Accident Prevention: A Scientific Approach, a classic work in the history of safety research, and proposed Heinrich's Law in 1941:Through the statistical analysis of 550,000 mechanical accidents, it is believed that the unsafe behavior of people and the unsafe state of things are the direct causes of accidents, and it is proposed that the center of safety work is to prevent the unsafe behavior of people, eliminate the unsafe state of machinery or materials, interrupt the chain of accidents and avoid the occurrence of accidents**[8]**.In terms of theoretical research Dağdeviren et al.**[9]** Based on the analysis of the factors affecting the construction safety uncertainty,using data fuzzy processing and analytic hierarchy process to build the project construction behavior safety management evaluation model,A fuzzy analytic hierarchy process (FAHP) is proposed to determine the level of error-behavior risk in a working system. Patel,D.A et al.**[10]** using structure equation model (SEM), the empirical test the safety climate (SC), hazard management (HM), security budget (SB), safety rules and regulations (SR), employee safety behavior (WB) influence on project safety performance (SP), puts forward safety climate and safety and hazard management for the safety of the employees working behavior and project safety performance have a positive effect.

The above results are based on the analysis of the main factors of accidents. On this basis, this paper reviews the existing research results, carries out statistical analysis on the safety accidents occurred in China's construction projects in recent years. On the basis of existing experience and methods, IAHP-TOPSIS safety evaluation model is designed by applying IAHP and TOPSIS methods, so as to carry out the safety production system of construction projects Scientific and reasonable evaluation and case analysis to verify its effectiveness.

1. Construct the safety evaluation index system

IAHP method is used to decompose the multi-objective decision problem into several levels of criteria and indicators.The weight value of each index is calculated by fuzzy quantization of qualitative index.Then, TOPSIS method is used to sort the weight values obtained by IAHP.Through the organic combination of IAHP method and TOPSIS method, the construction engineering safety evaluation model based on IAHP-TOPSIS is constructed to evaluate the construction engineering safety production, so as to better prevent safety accidents.

1.1 Establish a hierarchical structure model

This paper takes residential construction engineering as the research object, based on the recent official safety accidents as the basic data, applies the decomposition method to analyze the problem structure, divides the influencing factors into levels and structures, and establishes a hierarchical structure model from top to bottom.The hierarchy is divided into: A-highest level (target layer), B-intermediate layer (criterion layer) and C-lowest layer (index layer). The upper layer factors dominate all or part of the elements in the adjacent lower layer, forming a hierarchical relationship, as shown in Figure 1 below.

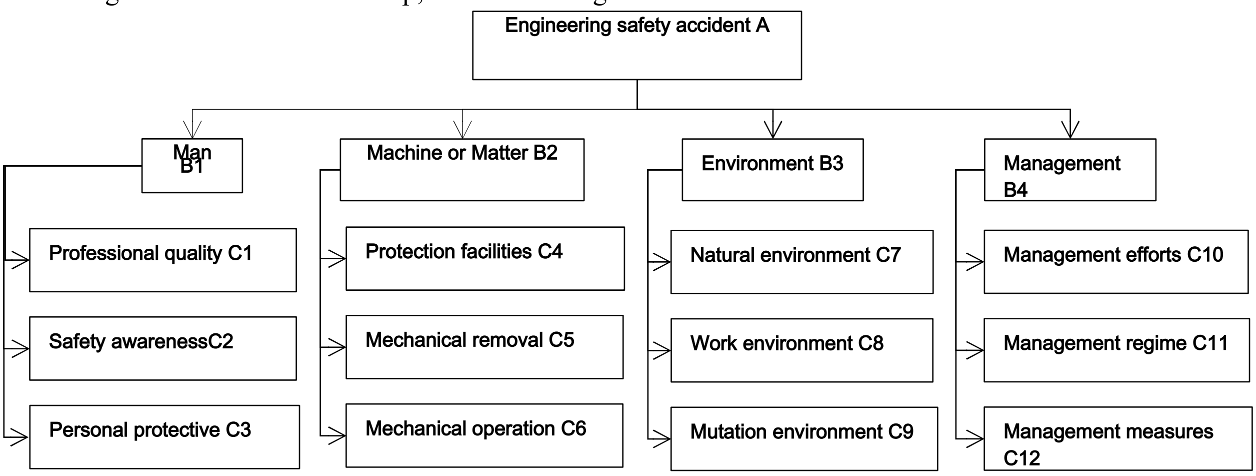

Fig. 1 Tree hierarchy model

Through the statistical analysis of 100 safety accidents in recent domestic construction projects, focuses on the 29 representative safety accidents in them, draw a conclusion: The dominant factors that cause safety accidents are usually easy to identify, while the hidden factors need to be investigated and studied in detail before a conclusion can be drawn. In most cases, the superposition and accumulation of recessive factors will become the cause or inducement of dominant factors, and will be transformed into dominant factors under certain conditions, thus leading to the occurrence of accidents.Recent safety accident statistics in China are shown in Table 1.

Tab. 1 Statistical table of safety accidents ①

Time	Location	Cause	Death toll	Dominant factors	Recessive factors
2020.06.27	Foshan,Guangdong	Formwork collapse	3	B3	B4
2020.05.19	Baotou, Inner Mongolia	Fall of construction lift	3	B2	B1,B4
2020.05.16	Yulin,Guangxi	Fall of construction lift	6	B2	B3,B4
2020.04.18	Yuanyang,Henan	Soil collapse	4	B1	B4
2020.01.05	Wuhan,Hubei	Collapse of high formwork	6	B1	B4
2019.11.20	Qingyang,Gansu	Tower crane overturning	3	B2	B1,B4
2019.11.15	Zhengzhou,Henan	Foundation pit collapse	3	B3	B1,B4
2019.10.28	Guizhou,Guiyang	Collapse of construction body	8	B4	B1,B2
2019.09.26	Chengdu,Sichuan	Foundation pit collapse	3	B3	B1,B4
2019.09.01	Nyingchi,Tibet	Tower crane overturning	3	B2	B1,B4
2019.08.28	Zhengzhou,Henan	Tower crane collapsed	3	B2	B1,B4
2019.06.16	Langfang,Hebei	Foundation pit collapse	3	B3	B1,B4
2019.04.25	Hengshui,Hebei	Fall of construction lift	11	B2	B1,B4
2019.04.10	Yangzhou,Jiangsu	Foundation pit collapse	5	B3	B1,B4
2019.01.23	Huarong,Hunan	Tower crane collapsed	4	B2	B1,B4
2018.12.29	Minhang,Shanghai	Foundation pit collapse	3	B3	B1,B4
2018.12.10	Hanzhong,Shaanxi	Tower crane collapsed	3	B2	B1,B4
2018.10.15	Heze,Shandong	Tower crane collapsed	3	B2	B1,B4
2018.10.04	Tianmen,Hubei	Fall of construction lift	3	B2	B1,B4
2018.09.10	Pudong,Shanghai	Poisoning choke	3	B3	B1,B4
2018.08.31	Dezhou,Shandong	Support frame collapsed	6	B1	B2,B4
2018.08.24	Hefei,Anhui	Poisoning choke	3	B3	B1,B4
2018.07.02	Bijie,Guizhou	Tower crane collapsed	3	B2	B1,B4
2018.06.29	Baodi,Tianjin	Electric shock	3	B1	B3,B4
2018.05.17	Wuzhishan,Hainan	Tower crane collapsed	4	B2	B1,B4
2018.04.09	Shantou,Guangdong	Fall of construction lift	4	B2	B1,B4
2018.02.08	Hechi,Guangxi	Tower crane collapsed	3	B2	B1,B4
2018.01.24	Xuchang,Henan	Fall of construction lift	4	B2	B1,B4
2018.01.21	Fuyang,Anhui	Fall of construction lift	3	B2	B1,B4

①Source: Ministry of Housing and Urban-Rural Development of the People's Republic of China(MOHURD)

From the four dimensions of human, object, environment and management, the influencing factors of construction engineering safety behavior are statistically analyzed, and the causes of accidents are divided by factors (Table 2 below). The data show that human factors and management factors account for a large proportion, which are the main causes of building safety accidents.

Tab. 2 Statistical table of accident factors

Accident statistics	B1	B2	B3	B4
Dominant factors	4	16	8	1
Recessive factors	23	2	2	28

The joint action of influencing factors leads to the occurrence of safety accidents, but the importance of influencing factors should be further studied.Take the fatal accident caused by falling of construction lift in Hengshui, Hebei as an example,according to the investigation report: Bolts in standard section of construction elevator not installed, acceptance and commissioning do not meet the requirements and standards of industry norms are the direct cause of the accident (dominant factor).The indirect causes (Recessive factors) are the indifference of the relevant units to the work safety, the disordered management, the non-standard system and the incomplete system.

The fishbone analysis of the accident is shown in Figure 2 below.

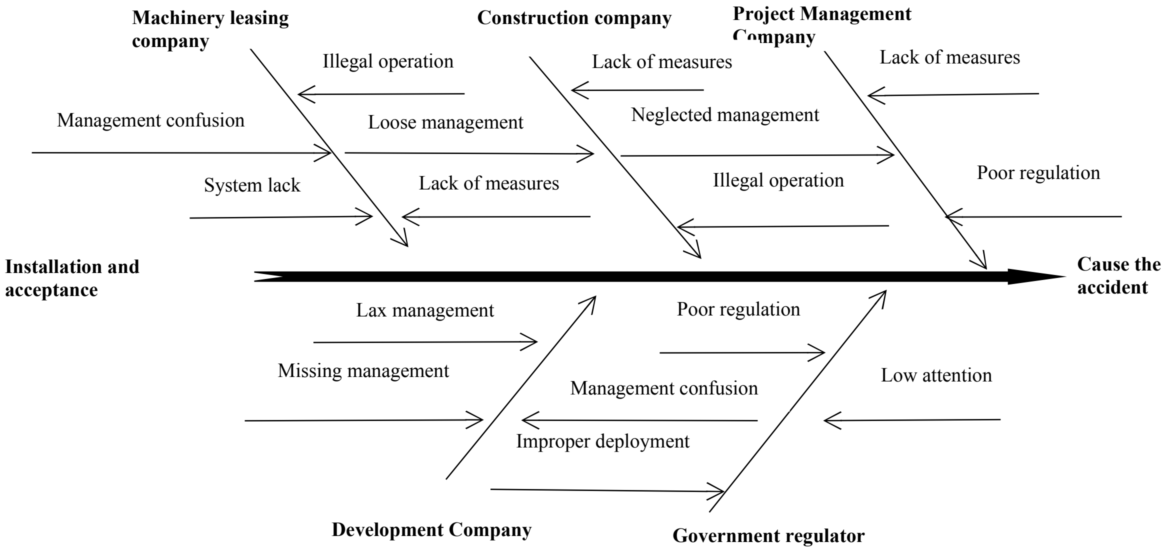

Fig. 2 Fishbone analysis diagram

The analysis results show that the management factors are the important factors leading to the occurrence of safety accidents. The poor management of mechanical leasing companies directly leads to the occurrence of accidents, and the management factors of other companies indirectly lead to the occurrence of accidents.It is pointed out that the chain reaction and interaction among the influencing factors, such as the lack of control, the accumulation of problems and the insufficient safety redundancy, are the main reasons for the occurrence of safety accidents.

The occurrence of safety accidents is not only caused by the action of one factor, but often the result of the chain reaction of two or more factors**[11-12]**.The direct causes of accidents are usually relatively clear, while the indirect causes involve a wide range of factors, and the causal relationship often appears among various factors, and the weight of each factor will be different.

1.2 Construct comparison judgment matrix

A good scaling system should have both good application characteristics and good internal structure.For sorting under a single criterion,All kinds of scale methods have order preserving properties.Statistical analysis of safety accidents shows that:The contribution rate of the influence factors of the criterion layer to the target layer does not differ significantly ，the strength of the nature is close,the 1-9 scale is not conducive to accurately expressing the relative importance of each element. Even if it can be given, it cannot objectively reflect the judgment of decision makers, resulting in the distortion of decision results and reduced credibility.Guo P et al. **[13]**was proposed another fractional scale method(5 /5, 5. 5 /4. 5, 6 /4, 6. 5 /3. 5,… , 8. 5 /1. 5, 9 /1) ，and given their RI results.Compared with the 1-9 scale, it is more reasonable when the nature and strength of influencing factors are close.Because the 1-9 scale has good uniformity, perceptibility and memorability, it is more advantageous to use the 1-9 scale when there are obvious differences in the properties and intensities of the factors affecting the index layer.Combined with the characteristics of construction projects, the criterion layer adopts 5/5-9/1 scale method to construct the judgment matrix.The index layer adopts 1-9 scale method to construct the judgment matrix.The relative importance criteria are shown in Table 3- Table 4

Tab. 3 Criteria for judging the importance of indicators

Scale selects	Equally important	Slight important	Little important	Even more important	Obviously important	Very important	Strongly important	More strongly important	Extremely important
5/5-9/1	5/5	5.5/4.5	6/4	6.5/3.5	7/3	7.5/2.5	8/2	8.5/1.5	9/1
1-9	1	2	3	4	5	6	7	8	9

Tab. 4 R.I. value table for random consistency index

Order and scale	1	2	3	4	5	6	7	8	9
5/5-9/1	0	0	0.1690	0.2598	0.3287	0.3694	0.4007	0.4167	0.4370
1-9	0	0	0.52	0.89	1.12	1.26	1.36	1.41	1.16

Invite three safety experts and two senior project managers to combine the construction characteristics of the construction project ，make statistical analysis on the influencing factors of safety accidents in recent years ，exclude the effect of force majeure ，comprehensive Assessment Comments ，to study and compare the importance degree of influencing project safety behavior.After several rounds of discussion and analysis,the judgment matrix of target layer, criterion layer and index layer is obtained, as shown in Table 5-9 below.

Tab. 5 A - B judgment matrix

A-B	B1	B2	B3	B4
B1	5/5	6/4	7/3	4/6
B2	4/6	5/5	6.5/3.5	3.5/6.5
B3	3/7	3.5/6.5	5/5	2.5/7.5
B4	6/4	6.5/3.5	7.5/2.5	5/5

Tab. 6 B1-Ci(i=1,2,3) Judgment matrix

B1-Ci	C1	C2	C3
C1	1	1/3	4
C2	3	1	5
C3	1/4	1/5	1

Tab. 7 B2-Ci(i=4,5,6) Judgment matrix

B2-Ci	C4	C5	C6
C4	1	1/6	3
C5	6	1	7
C6	1/3	1/7	1

Tab. 8 B3-Ci(i=7,8,9) Judgment matrix

B3-Ci	C7	C8	C9
C7	1	1/5	3
C8	5	1	7
C9	1/3	1/7	1

Tab. 9 B4-Ci(i=10,11,12) Judgment matrix

B4-Ci	C10	C11	C12
C10	1	1/3	5
C11	3	1	7
C12	1/5	1/7	1

1.3 Calculate the comprehensive weight of each influencing factor to the overall goal

The weight calculation methods include arithmetic average method, geometric average method and characteristic root method,in this paper, the geometric average method is used to calculate.

Weight calculation steps:

1. The elements of judgment matrix are multiplied by rows.
2. Take the result to the NTH power.
3. Normalize the resulting vector,and then get the weight vector.

the calculation formula as follow:

$$w_i = \left(\prod_{j=1}^{n} a_{ij}\right)^{1/n} / \sum_{k=1}^{n} \left(\prod_{j=1}^{n} a_{kj}\right)^{1/n}, \quad i = 1,2,3,\ldots,n \tag{1}$$

By substituting the data of judgment matrix A-B in Table 5 into equation (1), the weight vector of criterion layer can be obtained as follows:

$$w = (0.2831, 0.2070, 0.1206, 0.3893)$$.

Consistency check:

Find the maximum eigenvalue ,the calculation formula as follow.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(Aw)_i}{nw_i} \quad (2)$$

By calculation, the maximum eigenvalue of matrix A-B is 4.007.

1. Consistency test of judgment matrix ，Consistency index calculation formula as follow.

$$C.I. = \frac{\lambda_{max} - n}{n - 1} \quad (3)$$

Calculate the consistency ratio and its formula as follow.

$$C.R. = \frac{C.R.}{R.I.} \quad (4)$$

The R.I. value is found in Table 4, if C.R.<0.1, It satisfies the consistency.

After calculation, the consistency test result is C.R.=0.0089<0.1, pass the test.

According to the above calculation, the weight value of the criterion layer index is that,W1=0.2831 ，W2=0.2070 ，W3=0.1206 ，W4=0.3893.

Similarly, the weight value of each index in the index layer can be obtained.After calculation, the Bi-C (i = 1,2,3,4) matrix passed the consistency test.The calculation results are shown in Table 10 below.

Tab. 10 Weight sequence

Target layer	Criterion layer	Weight value	Index layer	Hierarchical order		
				Single sort	Total sort	Sort
Engineering safety accident occurred	The Human factor B1	0.2831	Professional quality of operators C1	0.2797	0.0792	6
			Safety awareness of operators C2	0.6267	0.1774	2
			Operator's self-protection ability C3	0.0936	0.0265	9
	The Machine or the Matter factor B2	0.2070	Degree of perfection of protective facilities C4	0.1713	0.0355	7
			High standard for mechanical installation and removal C5	0.7504	0.1553	3
			Normal machine and tool operation C6	0.0782	0.0162	11
	The Medium factor B3	0.1206	Regional natural environment C7	0.1884	0.0227	10
			Normal working environment C8	0.7306	0.0881	5
			Unpredictable environments C9	0.0810	0.0098	12
	The management factor B4	0.3893	Degree of management control C10	0.2790	0.1086	4
			Management system C11	0.6491	0.2527	1
			Management measures C12	0.0719	0.0280	8

2. Principle of TOPSIS algorithm

TOPSIS method is a common method in finite scheme multi-objective decision analysis.By calculating the relative closeness between the evaluation scheme and the ideal solution,at the same time, considering the distance between the positive ideal solution and the negative ideal solution，the conclusions obtained are scientific and reliable.

2.1 Construct the weighted standardized decision matrix

Suppose there are *A* schemes to form the scheme set $A=\{A1,\ A2,\ \cdots,\ Am\}$，Each scheme has *X* attributes, Attribute set $X=\{X1,\ X2,\ \cdots,\ Xn\}$，the corresponding judgment index is denoted as $Xij(i=1,2,\cdots,m;j=1,2,\cdots,n)$，Where Xij represents the j evaluation index in the i program.Establish the initial judgment matrix $D=\{X_{ij}\}_{m\times n}$.

The low priority index of judgment matrix D is homogenized and dimensionless.The weight vector $w=(w_1,\ w_2,\dots w_n)$ determined by analytic hierarchy process is multiplied by each column element of matrix D to obtain the weighted decision matrix V.

$$V=\begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}=\begin{bmatrix} w_1x_{11} & w_2x_{12} & \cdots & w_nx_{1n} \\ w_1x_{21} & w_2x_{22} & \cdots & w_nx_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ w_1x_{m1} & w_2x_{m2} & \cdots & w_nx_{mn} \end{bmatrix} \quad (5)$$

2.2 Determine positive and negative ideal solutions and distances to calculate approach degree

TOPSIS method is a kind of order optimization method based on the similarity of ideal target in multi-attribute decision making.The sum of positive and negative ideal solutions V^+ and V^- are expressed as follow.

$$V^+=\{\max V_{ij}|j=1,2,3,\dots n\} \quad (6)$$

$$V^-=\{\min V_{ij}|j=1,2,3,\dots n\} \quad (7)$$

The distance of each scheme was measured by the N-dimensional Euclid distance,the distance from each scheme to positive and negative ideal solutions is calculated by the following formula.

$$S_i^+=\sqrt{\sum_{j=1}^{n}(v_{ij}-v_j^+)^2} \quad (8)$$

$$S_i^-=\sqrt{\sum_{j=1}^{n}(v_{ij}-v_j^-)^2} \quad (9)$$

To calculate the degree of closeness with the ideal solution, calculate according to the following formula.

$$L_i^+=\frac{S_i^-}{S_i^++S_i^-},\quad 0\le L_i^+\le 1,\quad i\in m \quad (10)$$

L_i^+ is the closeness degree between the evaluation object and the positive ideal solution, the larger L_i^+ is, the closer the corresponding object is to the positive ideal solution,when the scheme is optimal, L_i^+ =1.When the scheme is the worst, L_i^+ =0.The closer to the optimal solution,the closer L_i^+ gets to 1,on the contrary,the closer to the worst solution,The closer L_i gets to 0.By sorting the value of the closeness degree of the evaluation object, the evaluation of the scheme is realized.

3. Application case

Prefabricated building has the advantages of fast construction speed, small environmental impact, energy conservation and environmental protection, etc. In this section, prefabricated building projects are selected for analysis, and an IAHP-TOPSIS comprehensive judgment model is established for safety evaluation of prefabricated building construction, so as to provide new solutions to problems existing in safety management of prefabricated building construction.

This section selects four prefabricated projects under construction for analysis ， the evaluation model is built according to the above modeling methods to compare and analyze the comprehensive management level of each project under construction.

3.1 Prefabricated building construction safety evaluation system

The factors that influence the safety behavior of prefabricated buildings can also be summarized as follows ， unsafe human behavior ， unsafe state of objects ， unsafe environmental factors and management defect.By studying the domestic safety accident case data and relevant literatures at home and abroad in recent years and combining with the indicators in the hierarchical structure model above, 12 main indicators that affect the construction safety of prefabricated buildings are designed **[14]-[18]**, as shown in Table 11 below.

Tab. 11 Prefabricated construction safety evaluation index system

Target layer	Criterion layer	Index layer	Attribute
Prefabricated building construction safety evaluation index system	The human factor X1	Operators's professional level X11	Quantitative indicators
		Operators's safety awareness X12	Qualitative indicators
		Operators's risk aversion ability X13	Qualitative indicators
	The object factor X2	Protective equipment and articles X21	Quantitative indicators
		Installation, dismantling and maintenance of large machines and tools X22	Quantitative indicators
		The operation of mechanical equipment X23	Quantitative indicators
	The environmental factors X3	Natural climatic environment X31	Qualitative indicators
		Workplace environment X32	Qualitative indicators
		Sudden natural disasters X33	Quantitative indicators
	The management factors X4	Control the intensity of the project X41	Qualitative indicators
		Control system and management system X42	Qualitative indicators
		Emergency treatment and measures for accidents X43	Quantitative indicators

By referring to the existing research results in the field of construction safety of prefabricated buildings, the assessment dimensions and weights are established for the qualitative indicators, providing a basis for the quantification of qualitative indicators.Based on the investigation reports of recent safety accidents in China and experts' opinions, the safety degree of qualitative indicators is divided into five grades: very important, important, generally important, unimportant, and very unimportant.The evaluation score interval is divided into [100,80],(80,60],(60,40],(40,20] and (20,0].As for the quantitative evaluation index, it is based on relevant industrial laws and regulations and relevant requirements of production standards,combined with the current development status of China's construction industry,
the evaluation index that does not meet the requirements is evaluated by the subtraction method, with a full score of 100

points and deduction until the end.

Operator's professional level

3 points will be deducted for each worker under the age of 18 or over 55.Operators education level is lower than junior high school, each deduction 1 point.2 points will be deducted for each worker whose working experience is less than half a year.4 points will be deducted for each person whose health condition may affect their normal work.5 points will be deducted for each worker whose professional level is not up to the job requirement.

Protective equipment and articles

5 points will be deducted for fire fighting equipment that is not fully equipped and damaged. 30 points will be deducted for failing to establish a protective equipment management system. 3 points will be deducted for failing to implement the system strictly and 3 points will be deducted for failing to warn dangerous areas.

Installation, dismantling and maintenance of large machines and tools

No installation and removal plan has been made or the plan has not been approved,deduct 20 points.Special operators who fail to obtain the qualification certificate will be deducted 5 points per item.10 points will be deducted if it is put into use without acceptance.10 points will be deducted for daily maintenance without special personnel.5 points will be deducted for other violations,Each item.

The operation of mechanical equipment

The installation of construction machines and tools cannot meet the standards and requirements of the specification and deduction of 5 points per item.5 points will be deducted for each missing protection device of construction equipment.5 points will be deducted for each item if the routine inspection record is not filled in as required or the record is not clear or true.If the equipment is not used as required, 5 points will be deducted for each item.

Sudden natural disasters

Based on the assessment of the project location, 10 points will be deducted each time for earthquakes, floods and hurricanes in recent ten years, and 5 points will be deducted each time for snowstorms, rainstorms and hailstones.

Emergency treatment and measures for accidents

If the emergency plan is not made or if the emergency plan is not made completely ，20 points will be deducted. The responsibilities of the responsibility group are not clearly divided,5 points will be deducted for each item.5 points will be deducted for each item of incomplete emergency facilities and equipment and 5 points will be deducted for insufficient emergency supplies and special funds.

3.2 Sample analysis based on IAHP-TOPSIS

The inspection team consists of five inspection members to inspect and review the four projects under construction.The project numbers are P1, P2, P3, P4,According to the evaluation index system in the previous section,The score values of the qualitative evaluation indicators were weighted average by the inspection team members.For the quantitative evaluation index,it is uniformly given by the inspection team after comprehensive review.The initial score values of each project are obtained, as shown in Table 12.

Tab. 12 Project initial score value

Projects	Initial score											
	X11	X12	X13	X21	X22	X23	X31	X32	X33	X41	X42	X43
P1	87	76.3	80.2	78	85	80	79.4	81.5	80	85.4	87.3	85
P2	82	74.5	83.1	82	80	85	78.2	77.3	80	82.1	86.1	85
P3	85	81.2	76.7	85	80	80	78.6	84.9	80	83.3	83.4	80
P4	80	79.6	79.3	87	85	80	79.5	82.5	80	83.7	85.2	80

According to Table 12, To establish the initial judgment matrix D .The dimension of matrix D is uniform.

$$D=\begin{bmatrix}87 & 76.3 & 80.2 & 78 & 85 & 80 & 79.4 & 81.5 & 80 & 85.4 & 87.3 & 85\\ 82 & 74.5 & 83.1 & 82 & 80 & 85 & 78.2 & 77.3 & 80 & 82.1 & 86.1 & 85\\ 85 & 81.2 & 76.7 & 85 & 80 & 80 & 78.6 & 84.9 & 80 & 83.3 & 83.4 & 80\\ 80 & 79.6 & 79.3 & 87 & 85 & 80 & 79.5 & 82.5 & 80 & 83.7 & 85.2 & 80\end{bmatrix}$$

substitute into formula (5),get the weighted decision

The weight matrix W established in Table 10 and matrix D

matrix V.

$$V=\begin{bmatrix}8.4564 & 13.5356 & 2.1253 & 2.769 & 13.2005 & 1.296 & 1.8024 & 7.1802 & 0.784 & 9.2744 & 22.0607 & 2.38\\ 6.4944 & 13.2163 & 2.2022 & 2.911 & 12.424 & 1.377 & 1.7751 & 6.8101 & 0.784 & 8.9161 & 21.7575 & 2.38\\ 6.732 & 14.4049 & 2.0326 & 3.0175 & 12.424 & 1.296 & 1.7842 & 7.4797 & 0.784 & 9.0464 & 21.0752 & 2.24\\ 6.336 & 14.121 & 2.1015 & 3.0885 & 13.2005 & 1.296 & 1.8047 & 7.2683 & 0.784 & 9.0898 & 21.53 & 2.24\end{bmatrix}$$

According to formula (6) and (7), positive ideal solutions and negative ideal solutions are determined as follows.

$$V_{+}=[8.4564 \quad 14.4049 \quad 2.2022 \quad 3.0885 \quad 13.2005 \quad 1.377 \quad 1.8047 \quad 7.4797 \quad 0.784 \quad 9.2744 \quad 22.0607 \quad 2.38]$$

$$V_{-}=[6.336 \quad 13.2163 \quad 2.0326 \quad 2.769 \quad 12.424 \quad 1.296 \quad 1.7751 \quad 6.8101 \quad 0.784 \quad 8.9161 \quad 21.0752 \quad 2.24]$$

Calculate the Euclid distance by according to formulas (8), (9) and (10), and the closeness degree is calculated as shown in Table 13.

Tab. 13 Calculation results of relative proximity

Projects	S_i^+	S_i^-	L_i^+
P1	0.9798	2.5429	0.7218
P2	2.5625	0.7521	0.2269
P3	2.1587	1.4481	0.4015
P4	2.2301	1.4057	0.3866

The calculation results show that the relative closeness of the comprehensive index of P1 project is 0.7218, which ranks the best among the four projects.The ranking of the advantages and disadvantages of the four projects is P1>P3>P4>P2.In other words, P1 of the four projects has the best overall control over the project.

3.3 Project Evaluation

From the above data and evaluation results, it can be seen that the safety management of P1 project is solid and meticulous, and there are few potential accidents within the project.This is the result that the project management department attaches importance to safety and management.There is little difference between P3 and P4 in their attention to safety production, even better than P1 in some elements, but the overall score was lower,this indicates that the two enterprises have some deficiencies in safety management and still need to be strengthened in improving safety management.Project P2 has the weakest security control ability, this indicates that the project is not deep enough for safety production management and has poor initiative.

For a single factor, the overall control is the best, not necessarily every control is the best.Let's take X2 as an example, it is easy to calculate P1 as 83.4, P2 as 80.7, P3 as 80.8, P4 as 84.9. The results show that although P1 does the best in overall control, there is still room for improvement in X2 control.Although P4 has good control in X2, it has weak control and management over human factors, which ultimately leads to a low management level.

4. Conclusion

Research and analysis show that the main factors causing the accident can be attributed to the failure of management, and the rigor and systematization of management can effectively avoid the occurrence of the accident. Building safety accidents are rarely inevitable accidents, most of which can be avoided by effective management beforehand.

（1）Through the recent safety accident statistical analysis,based on the principles of IAHP and TOPSIS, the safety accident evaluation system of prefabricated buildings was established.From the human factor, the object factor, the environmental factor and the management factor four main aspects to determine the influence of construction safety production of 12 sub-indicators, the IAHP-TOPSIS safety evaluation model is established to intuitively reflect the comprehensive level of the evaluation objects.The model can comprehensively reflect the key points of safety management in the process of building construction and can provide technical support and theoretical support for safety management in building construction.

（2）In this study, analytic hierarchy process (AHP) was applied to stratify and divide the multiple indexes affecting project safety production, avoid subjective judgment caused by many indicators, causing the result distortion. The example shows that the IAHP-TOPSIS safety evaluation model is effective.It is also basically consistent with the actual management of the evaluated project and has engineering practicability.

IAHP-TOPSIS safety evaluation model is simple in form, easy to construct and widely used.The building safety evaluation model based on IAHP-TOPSIS has important guiding significance for the study of safety risk control in the construction of building engineering in China.This evaluation method is not only applicable to construction engineering, but also to highway engineering, railway engineering, municipal engineering, etc. It has guiding significance in the same kind of the projects and corresponding reference value in the similar projects.

There are also some limitations in this study. First, the construction of the initial judgment matrix still has artificial subjectivity and regional limitations, which will cause distortion of the results in the evaluation of architectural projects under different construction backgrounds.Second, the evaluation results only assess the degree of safety control and guide the focus of safety management, but it is difficult to make a correct judgment on the social harmfulness of safety accidents and the level of accidents.

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