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Study and Action Plan on the Key Factors Influencing Unsafe Behaviors by Construction Workers

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Abstract: As front-line workers on construction projects, construction workers have always had the highest accident rate among workers in various industries, a statistic that significantly impacts society. In this study, the 2–4 Model was used to identify 14 influencing factors affecting workers' unsafe behaviors, and a safety management index for construction workers was established. The fuzzy decision-making laboratory analysis method (Fuzzy-DEMATEL) and the interpretative structural model (ISM) were used to analyze the hierarchical structure, internal relations, and key influencing factors behind the unsafe behaviors in question, and the 14 factors affecting them were divided into five dimensions, including the technological environment, insufficient safety knowledge, and the corporate safety culture. The three most direct influencing factors (comprising eight key nodes in the constructed hierarchy) were found to be poor safety awareness, the violation of operating procedures, and skill errors. Therefore, the main paths toward reducing the level of unsafe behavior among construction workers include making changes in process equipment, addressing skill-related errors, ensuring adherence to operating procedures, improving safety awareness, and enhancing safety knowledge. In this study, we identify and classify the factors influencing unsafe behaviors by construction workers and propose scientific interventions with which to prevent the continued occurrence of safety hazards among them.

Keywords: construction workers; unsafe behavior; influencing factors; 2–4 Model; fuzzy DEMATEL-ISM

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1. Introduction

The construction industry is an important part of the national economy; however, its development has been plagued by frequent accidents and injuries [1–4]. In China, the numbers of traffic accidents and deaths within the construction industry have increased rapidly in recent years [5]. According to statistics from the Ministry of Emergency Management, China's construction industry has ranked first in total number of safety-related accidents among all industrial, mining, and commercial industries for nine consecutive years, and the numbers of accidents and deaths have continued to rise since 2016 [6]. Studies have shown that 90% of safety-related accidents occurring in the construction industry are closely related to unsafe behaviors by construction workers, so it is very important to control the risks of these behaviors [7]. In order to reduce safety-related accidents, it is necessary to analyze their causes [8]; thus, exploring the factors affecting unsafe behaviors by construction workers is a particularly important basis for effectively mitigating such behaviors scientifically and systematically.

Unsafe behavior by workers is the most important cause of construction accidents; it not only leads to injury and loss of life but also has negative impacts on the costs and progress of construction projects. Therefore, it is of great significance to study the factors influencing workers' unsafe behaviors. The influencing factors, formation mechanisms, and

pre-control methods of unsafe behaviors by construction workers are discussed in [9]. In one study, the authors developed and tested a model to understand unsafe behavioral mechanisms based on individual characteristics and the theory of planned behavior (TPB) [10]. A comprehensive IM-CWUB framework was proposed to understand the complex interactions among psychological factors, physiological factors, and unsafe behaviors [11]. In another study, it was found that the psychological distress experienced by construction workers and their relationships with seeking help were determined by their confidence in knowing how to get help and in talking to colleagues about mental health issues [12]. Ni et al. found that a work–family balance can promote safe behavior in construction workers [13]. In another study, the authors concluded that emotion has a significant influence on unsafe behaviors [14]. In reference, the authors showed that safety-related behavior is the main variable in the research of risk perception in the construction field [15]. The two-way effect of the consciousness of formal rules and the mentality of conformity also has certain impacts on unsafe behaviors by construction workers, as discussed in [16]. Li et al. showed that safety management and leadership are key factors in building safety-related behaviors [17]. Therefore, system dynamics have been used to explore the driving factors of ambivalence among construction workers to simulate the psychological process of reducing unsafe behaviors [18]. Psychological and physiological characteristics were also used to predict the conscious unsafe behaviors of construction workers [19]. Construction accident data mining based on a robust modeling process was additionally explored [20]. The reasons behind workers' unsafe behaviors were fully investigated from the perspective of behavioral psychology in [21]. A two-sided evolutionary game model, composed of workers and managers, revealed the evolution mode of workers' unsafe behaviors and was used to reduce the occurrence of unsafe behavior in [22]. A Bayesian network was also successfully used to explore the probability propagation path from unsafe behavior to accident [23]. The authors of established a fully convolutional neural network, which greatly improved positioning efficiency in various underground engineering applications [24]. The expansion of artificial intelligence (AI) modeling technology, combined with various research topics, has increased the difficulty for practitioners to determine appropriate methods and techniques [25], but machine learning is a major area of interest within the field of artificial intelligence, playing a pivotal role in the process of making construction "smart" [26]. However, a relationship between factors is not only the influence of a single factor on another single factor, but also the complex relationships of interdependence and interaction among multiple factors. Therefore, it is particularly important to systematically analyze the relationships between influencing factors and find the root causes, so as to carry out effective management; that is, identifying the interactions between workers' unsafe behaviors and their influencing factors is a prerequisite to taking targeted safety management measures. The purpose of this study is to explore and classify the factors affecting the unsafe behaviors of construction workers through a hybrid method design based on 2–4 Model Fuzzy-DEMATEL-ISM. The rest of this article is organized as follows: Section 2 explains the methodology and data collection procedures; Section 3 presents the implementation; in Section 4, the influencing factors are systematically analyzed based on fuzzy DEMATEL-ISM, and the limitations and future research directions of this work are summarized and discussed.

2. Materials and Methods

For this study, we adopted both qualitative and quantitative research methods. The Fuzzy-DEMATEL-ISM model was established through combining the accident-causing '2–4' model (2–4 Model) with the fuzzy decision-making laboratory analysis method (DEMATEL) and interpretative structural modeling (ISM). Through a series of calculations, the comprehensive influence matrix in the DEMATEL method was transformed into a standardized reachable matrix; then, the corresponding multi-level hierarchical structure model was constructed using the ISM method to analyze the hierarchical structure among factors.

2.1. Identifying Factors in the Construction Process via the 2–4 Model

In order to identify and classify the factors influencing unsafe behaviors by construction workers, we conducted our analysis according to the following steps.

2.1.1. 2–4 Model Application Introduction

The accident causation 2–4 Model is a newly developed accident causation model based on the accident causation chain, improved by using the principle of organizational behavior and referring to the definitions of safety culture and safety management [27]. The model divides the causes of accidents in an organization into the organizational and individual levels; the causes of accidents at the organizational level are divided into two further stages—the safety culture of the organization and the safety management system—and the causes of accidents at the individual level are also divided into two further stages—habitual behavior, and one-time behavior and physical state. That is, the causes of accidents are divided into two levels and four stages within the organization where the accident was caused. Therefore, it is called the 2–4 Model. The individual level includes not only front-line operators, but also managers; that is, all kinds of personnel at all levels in the organization are taken into comprehensive consideration. Factors including unsafe action, unsafe state, safety knowledge, safety awareness, safety habits, safety-related psychological factors, and safety physiological factors are also considered. Unsafe action is further divided into unsafe action, unsafe command, and unsafe operation. Unsafe state refers to the state of the matter that caused the accident or had an important impact on the occurrence of the accident (both may refer to the state in which the materials, tools, equipment, facilities, places, environment, etc., were kept). The organizational level includes the safety management system and safety culture. The choice of this model can allow us to conduct comprehensive and scientific analyses regarding the causes of an accident. The optimized accident factor analysis model is helpful to accurately express the causes of an accident and clarify the cross-relationships among the causes of the accident. The utilized model mainly improves on the basis of the Swiss cheese model, with the various causes of the accident visible on the model and clearly defined, so that it is easy to operate in the practice of accident causation analysis and prevention. The '2–4' model has previously been applied in the analyses of coal mines, construction accidents, and safety management, and the suggestions for accident prevention measures have been obtained, as shown in Figure 1.

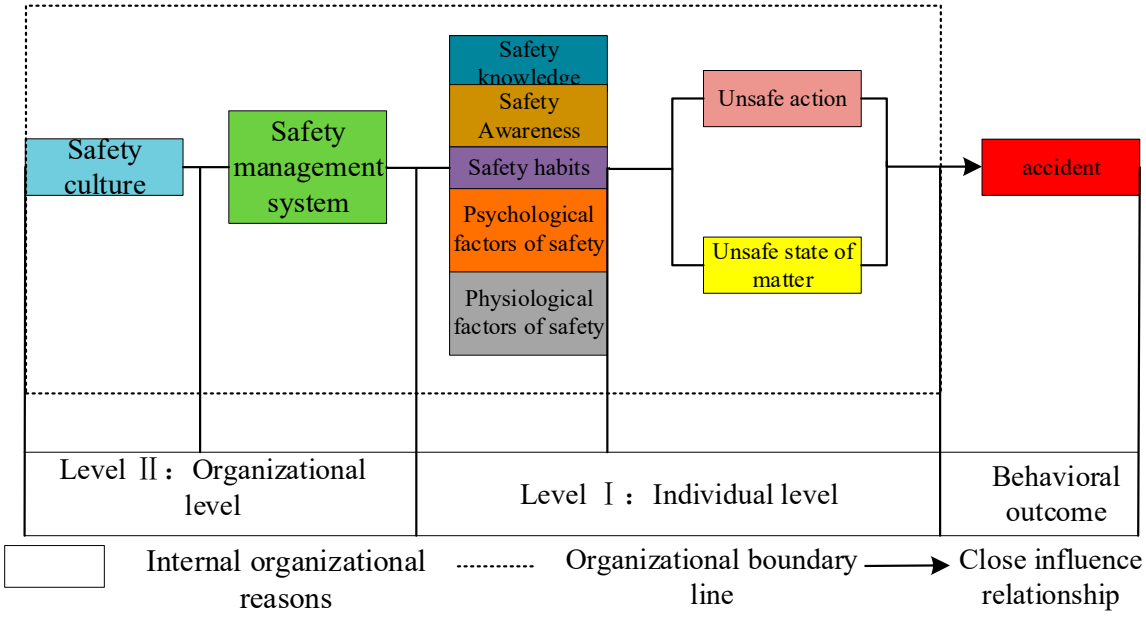


Figure 1. The '2–4' accident causation model.

2.1.2. 2–4 Model Validity Analysis

(1) Scientific analysis: Safety science is the science of accident prevention; safety investment belongs to the category of safety economics, an important part of safety science. Therefore, the fundamental purpose of safety investment should be accident prevention. The accident causation theory is a tool with which to find the causes of and prevent an accident; it is the core theory of safety science and can effectively achieve the purpose of accident control. Using the core theory of safety science to analyze and study the safety input index not only conforms to the development law of scientific research, but also helps to achieve the purpose of accident prevention. As an emerging modern accident-causing theory, the 2–4 Model has been used by many experts and scholars for accident analysis and has achieved good results. When combined with safety input analysis, the accident-causing factors of the 2–4 Model result in a more scientific research method.

(2) Independence analysis: The 2–4 Model can be used to present a clear accident causation chain and clearly define each module in the model, so that the accident causal factors exist alone. Therefore, the safety input of the content in the accident causation chain and the establishment of indicators can ensure the independence of the indicators and facilitate the selection of indicators.

(3) Systematic and hierarchical analyses: At present, most of the popular accident-causing models are based on system theory, which describes the accident process as a complex and interrelated event network, so that the accident-causing factors show a clear hierarchy and causality. The two levels and four stages in 2–4 Model make it systematic and hierarchical, which enable it to meet the requirements that low-level indicators are the basis and subdivision of high-level indicators, and high-level indicators are the guidance and synthesis of low-level indicators, so that the logical relationships among the various indicators is more obvious.

2.2. Integrated Fuzzy-DEMATEL-ISM-Structured Method

The decision-making trial and evaluation laboratory (DEMATEL) method can make full use of expert experience and knowledge to identify and analyze factors in complex networks. Based on matrix tools and graph theory, this method combines the experience and knowledge of experts to establish a relational matrix, explores the causal relationships between various factors within a complex network, and sorts their importance [27]. However, the DEMATEL method is based on expert experience and knowledge, which may present problems, such as excessive subjectivity and excessive individual differences among experts, which have great impacts on the research results. Therefore, in this study, we combined fuzzy set theory with DEMATEL, that is, we used the Fuzzy-DEMATEL method, and integrated triangular fuzzy numbers into the traditional DEMATEL method. Through converting the semantic evaluation of experts into corresponding triangular fuzzy numbers, the direct influence matrix was fuzzified. Thereafter, through the CFCS (Converting Fuzzy numbers into Crisp Scores) defuzzification method, proposed by Opricovic et al., the fuzzy numbers were transformed into accurate values. In order to further identify the hierarchical structure of the influencing factors in the system, the interpretive structural model (ISM) was introduced, enabling use of the model to establish the reachable matrix based on the Fuzzy-DEMATEL method and decompose the complex system into concise and clear subsystems through Boolean algebraic operations. Finally, a multi-level hierarchical structure model was constructed to analyze the relationships between factors.

In this study, the 2–4 Model was combined with the integrated Fuzzy-DEMATEL-ISM method to introduce the field of construction workers' safety management. Firstly, based on the statistical data from safety-related construction accidents and 2–4 Model analysis, the causal factors at the individual and organizational levels were obtained, and the index of factors influencing construction workers' unsafe behaviors was constructed. Subsequently, on the basis of this index, the Fuzzy-DEMATEL-ISM method was used to establish a hierarchical structure model through which to further analyze the correlation

between various factors, so as to provide support for the development of a construction workers' safety management and accident prevention system.

2.3. Construction of 2–4 Fuzzy-DEMATEL-ISM Model for Unsafe Behavior by Construction Workers

Through the Web of Science, China National Knowledge Infrastructure, etc., the construction accidents that occurred in China in recent years were retrieved. Details from 112 construction accidents that occurred from 2017 to 2023 were retrieved and explored. The cases with vague information were excluded, and 78 construction accidents were selected for analysis. Based on the Delphi method, 14 construction experts were invited to analyze the factors influencing unsafe behaviors by construction workers from the perspectives of unsafe action, unsafe physical state, individual factors, the safety management system, and safety culture. After discussion, the factors with great ambiguity were removed, and the factors affecting the safety management of construction workers were summarized. Based on the particularity of building construction and following the principles of scientificity, comprehensiveness, and operability, the index of factors influencing construction workers was established. The Fuzzy-DEMATEL-ISM-structured method was used to analyze the interactions among the factors influencing unsafe behaviors by construction workers, and the hierarchical structure model of the influencing factors of unsafe behavior was constructed, as shown in Figure 2.

2.4. Data Analysis and Credibility

In China, a questionnaire was distributed regarding the factors influencing unsafe behaviors by construction workers, and Chinese experts with rich work experience were selected from five different related construction fields to score, including construction units, design units, university research departments, prefabricated component production enterprises, and other units. The 14 factors presented in the questionnaire were scored, and the scoring criteria were divided into five levels: 0, 1, 2, 3, and 4. Experts in various fields reported the influences between two factors, according to their own work experience. Low impact between two factors was allotted 1 point, and so on, where 4 points represented a very high impact between two factors. Through sorting, it was found that there were 30 total questionnaires recovered, and the numbers of questionnaires in each aforementioned field were 8, 7, 7, 5 and 3, respectively. After eliminating invalid questionnaires, the remaining 11 valid questionnaires were converted into triangular fuzzy numbers, and the data were fuzzified; then, we used MATLAB R2021a software for data operation.

In order to determine the reliability and validity of the results, we took the following steps: a focus group, composed of participating experts, reviewed the results; then, another group of researchers (two researchers and two design experts familiar with content analysis), who did not participate, conducted further review of the results. The researchers were deeply involved in the research environment; they reviewed the research questions multiple times to ensure their feasibility and accuracy, sent research protocols to participants to prepare them mentally, and checked experts' ratings multiple times.

2.5. Analysis of Identified Causative Factors Using 2–4 Model

In this research, 78 typical construction accidents were studied, and the factors influencing unsafe behavior by construction workers were analyzed and sorted based on the 2–4 Model, as shown in Table 1.

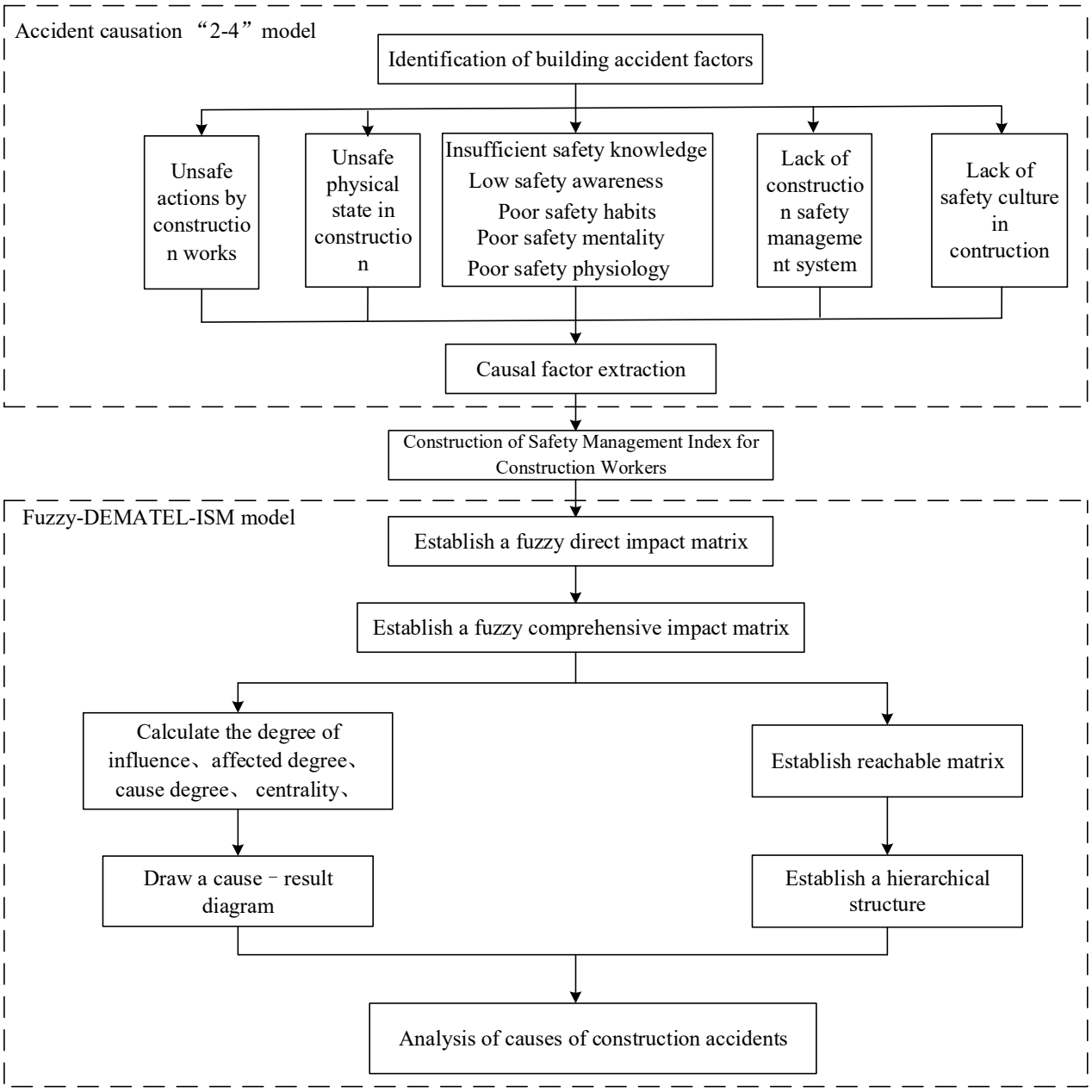


Figure 2. The 2–4 Fuzzy-DEMATEL-ISM model of influencing factors of unsafe behavior of construction workers.

2.6. Influencing Factors in Fuzzy-DEMATEL-ISM Modeling

Based on the Fuzzy-DEMATEL-ISM method, we analyzed the relationships between the factors influencing construction workers' safety management. The specific implementation steps are as follows:

Step 1: To determine the set of factors $F = \{F_1, F_2 \cdots, F_n\}$, a language evaluation set was constructed. The degrees of influence for each factor were divided into the following categories: very low influence, '1'; low influence, '2'; medium influence, '3'; high influence, '4'; and very high influence, '5'. Experts were invited to judge the relationships between influencing factors (Table 2).

Table 1. Factors influencing unsafe behavior by construction workers.

Level Grade	Level 1 Indicators	Level 2 Indicators	Level 3 Indicators	Ref.
Individual level	Unsafe action	Skill error S1	Non-standard operation/wrong operation mode adopted	[28]
		Changes in process equipment [29] S2	Equipment model, type, or manufacturer change/technological progress/change in occupational behavior	
		Violation of operating procedures S3	Closed monitoring system/ventilation system without authorization	[30]
	Unsafe and physical	Technological environment S4	Complex geological structure/uninstalled personnel positioning system/system or equipment quality problems	[31]
		Physical environment S5	Weather impact/noise, too much dust	[32]
	Safety knowledge	Insufficient safety knowledge S6	Low safety knowledge understanding/mastery	[33]
	Safety consciousness	Poor safety awareness S7	Unconscious operation error	[34]
	Safety habits	Poor safety habits S8	Weak vigilance/shortcut to save trouble	[35]
	Psychological safety factors	Adverse mental factors S9	Inattentiveness/fatigue, rush, impatience/lack of vigilance	[36]
	Physiological safety factors	Adverse physiological factors S10	Sick, taking medication/poor physical state/extreme excitement	[37]
Organizational level	Safety management system	Inappropriate human resource management S11	Insufficient staffing/employment of personnel, lack of qualification review	[38]
		Inadequate management of equipment S12	Improper equipment maintenance/faulty operation	[39]
		Unsound safety production management system S13	Rules and regulations emphasize production over safety	[40]
	Safety culture	Good corporate safety culture S14	Employee safety-first principle/good safety atmosphere	[41]

Table 2. Semantic transformation.

Semantic Variable	Score by Expert	Triangle Fuzzy Number
Very high impact (VH)	5	(0.75, 1.00, 1.00)
High Impact (H)	4	(0.50, 0.75, 1.00)
Medium Impact (M)	3	(0.25, 0.50, 0.75)
Low Impact (L)	2	(0, 0.25, 0.50)
Very low impact (VL)	1	(0, 0, 0.25)

Step 2: The initial direct influence matrix $A = |a_{ij}|_{n\times n}$, was established. The expert evaluation opinions were transformed into their corresponding triangular fuzzy numbers according to the expert language evaluation set. Triangular fuzzy numbers can be expressed as $X = (l, m, r)$, where l is the left value, that is, the conservative value; m is the intermediate value, which is the closest to the actual value; r is the right value, that is, the optimistic value [42]. $l \le m \le r$ was satisfied to obtain $X_{ij}^k = \left(l_{ij}^k, m_{ij}^k, r_{ij}^k\right)$, which indicates the degree of influence of factor i on factor j.

Step 3: The CFCS method was used to defuzzify the n-order direct influence matrix Z.

- The specific steps for the standardization of triangular fuzzy numbers are as follows, in Formula (1) to Formula (3):

$$lb_{ij}^k = \left(l_{ij}^k - minl_{ij}^k\right) \Big/ \Delta_{min}^{max}, \quad (1)$$

$$mb_{ij}^k = \left(m_{ij}^k - minm_{ij}^k\right) \Big/ \Delta_{min}^{max}, \quad (2)$$

$$rb_{ij}^{k} = \left(r_{ij}^{k} - minr_{ij}^{k}\right) \Big/ \Delta_{min}^{max}, \tag{3}$$

where lb_{ij}^{k}, mb_{ij}^{k}, and rb_{ij}^{k} are the standardized values of the left, middle, and right values of the triangular fuzzy number; Δ_{min}^{max} is the difference between the right value and left value; $\Delta_{min}^{max} = maxr_{ij}^{k} - minl_{ij}^{k}$ is the difference between the right and left values.

- The left and right values were normalized.

$$u_{ij}^{k} = mb_{ij}^{k} \Big/ \left(1 + ma_{ij}^{k} - la_{ij}^{k}\right), \tag{4}$$

$$v_{ij}^{k} = rb_{ij}^{k} \Big/ \left(1 + ra_{ij}^{k} - ma_{ij}^{k}\right), \tag{5}$$

where u_{ij}^{k} and v_{ij}^{k} are the standardized values of the left and right values, respectively.

- The clear value was calculated.

$$z_{ij}^{k} = mina_{ij}^{k} + \Delta_{min}^{max}\left[minu_{ij}^{k}\left(1 - u_{ij}^{k}\right) + v_{ij}^{k}v_{ij}^{k}\right] \Big/ \left[1 - u_{ij}^{k} + v_{ij}^{k}\right], \tag{6}$$

- The average value of the clear value was calculated, and the defuzzified direct influence relation matrix was obtained.

$$z_{ij}^{k} = \frac{1}{k}\sum_{k=1}^{k} z_{ij}^{k}, \tag{7}$$

$$Z = \left|z_{ij}\right|_{n\times n}, \tag{8}$$

- The direct impact matrix was standardized.

$$\lambda = 1 \Big/ \max_{1\le j\le n} \sum_{j=1}^{n} z_{ij}, N = \lambda Z' \tag{9}$$

According to the normalized direct relation matrix N, the comprehensive influence matrix T was obtained using Formula (10), where I is the unit matrix.

- The comprehensive influence matrix was calculated, as follows:

$$T = N(I - N)^{-1}, \tag{10}$$

Step 4: The degrees of influence, centrality, and cause were determined. In the comprehensive influence matrix T, the influence degrees of the corresponding factors were obtained by adding the rows of each element (f_i); the influence degrees of the corresponding factors were obtained by adding the corresponding factors according to column (e_i); the difference between an influence degree and the affected degree is its cause degree (M_i); the sum of the two is centrality (N_i); a positive value indicates that the characteristic is biased to the cause class; and a negative value indicates that the characteristic is biased to the result class. The relevant matrix is as specified in Formula (11).

$$\begin{cases} f_i = \sum_{j=1}^{n} t_{ij}, i = 1, 2, \cdots, n \\ e_i = \sum_{i=1}^{n} t_{ij}, j = 1, 2, \cdots, n \\ M_i = f_i + e_i, i = 1, 2, \cdots, n' \\ N_i = f_i - e_i, i = 1, 2, \cdots, n \end{cases} \tag{11}$$

Step 5: The overall impact matrix H was calculated. The comprehensive influence matrix T in the fuzzy DEMATEL does not take into account the influences of various factors on itself, so the unit matrix I needs to be added to the comprehensive influence matrix T. The matrix can not only reflect the mutual influence between factors, but also the influences of factors on themselves.

$$H = T + I, \tag{12}$$

Step 6: The reachable matrix K was established. λ is the threshold value; the larger the λ value, the more obvious the effect on structural simplification. In the actual analysis, it was necessary to determine the value of λ according to the complexity of the system. k_{ij} is the correlation value between the i factor and the j element.

$$k_{ij} = \begin{cases} 1, h_{ij} \geq \lambda \\ 0, h_{ij} < \lambda \end{cases} (i, j = 1, 2, \cdots, n), K = \left[k_{ij}\right]_{n \times n}, \tag{13}$$

Step 7: According to the reachable matrix, as shown in Formula (14), the reachable set X_i, the antecedent set Y_i, and the common set Q were determined, and the multi-level hierarchical structure model of the influencing factors was constructed.

$$\begin{cases} X_i = \left\{ F_j \middle| F_j \epsilon F, k_{ij} = 1 \right\} \\ Y_i = \left\{ F_j \middle| F_j \epsilon F, k_{ji} = 1 \right\} \ (i, j = 1, 2, \cdots, n), \\ Q = \left\{ F_i \epsilon F \middle| X_i \cap Y_i = X_i \right\} \end{cases} \tag{14}$$

Step 7 was repeated, extracting layer by layer and drawing the factor structure hierarchy map, until all factors were divided into levels, and the explanatory structure model was established.

Research Process

According to the implementation steps of the above analysis, five experts engaged in the field of construction engineering were invited to score the strength levels of the 14 influencing factors. Subsequently, the expert scoring opinions were collected, and the data were processed using MATLAB R2021 software. The fuzzy direct influence matrix Z, achieved via the CFCS method, was obtained.

- The fuzzy direct influence matrix was established.

According to the experts' judgment on the influence relationships among various factors, the direct influence matrix Z was constructed, as shown in Table 3.

Table 3. Fuzzy direct influence matrix Z.

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}
S_1	0.0417	0.5389	0.5389	0.3833	0.6167	0.8111	0.6167	0.6556	0.5389	0.6556	0.6556	0.5778	0.6944	0.5778
S_2	0.6556	0.0417	0.5778	0.6167	0.6167	0.6556	0.6556	0.5778	0.4611	0.4611	0.5389	0.6556	0.6167	0.4611
S_3	0.6167	0.6556	0.0417	0.6167	0.5778	0.6556	0.6167	0.4611	0.4222	0.5	0.5	0.5	0.6167	0.3833
S_4	0.225	0.4611	0.45	0.0417	0.4222	0.6556	0.5778	0.4222	0.4125	0.5	0.4611	0.5	0.4611	0.4611
S_5	0.5778	0.6556	0.6556	0.4611	0.0417	0.5778	0.6556	0.5778	0.4222	0.5778	0.4611	0.5	0.6167	0.3444
S_6	0.4611	0.5389	0.4611	0.3444	0.5389	0.0417	0.6167	0.6167	0.5	0.3444	0.4611	0.5389	0.5778	0.4125
S_7	0.5	0.4222	0.4611	0.4222	0.4222	0.6944	0.0417	0.6944	0.5778	0.6556	0.5778	0.5389	0.6944	0.3833
S_8	0.4875	0.6167	0.6556	0.4875	0.5389	0.5389	0.6944	0.0417	0.3833	0.5	0.4222	0.6167	0.6556	0.225
S_9	0.7722	0.5	0.5778	0.4611	0.3833	0.6167	0.7333	0.5389	0.0417	0.5778	0.5389	0.5778	0.6167	0.5
S_{10}	0.5	0.4611	0.6556	0.5	0.5389	0.6167	0.7333	0.5778	0.5778	0.0417	0.5	0.5389	0.7722	0.4222
S_{11}	0.6944	0.5778	0.6167	0.5	0.5778	0.5778	0.6556	0.4611	0.4222	0.3375	0.0417	0.5778	0.6556	0.3833
S_{12}	0.6944	0.5	0.6556	0.5	0.45	0.4611	0.5	0.5	0.4611	0.5778	0.5	0.0417	0.6556	0.3833
S_{13}	0.5389	0.6167	0.5389	0.375	0.5	0.6167	0.6167	0.5	0.4611	0.4125	0.5778	0.6556	0.0417	0.5778
S_{14}	0.6944	0.3833	0.4611	0.3833	0.4222	0.5389	0.5	0.4222	0.3833	0.4222	0.5	0.4611	0.4222	0.0417

- A comprehensive impact matrix was established.

According to Formulas (9) and (10), the fuzzy comprehensive influence matrix T was obtained from the fuzzy direct matrix Z, as shown in Table 4.

Table 4. Fuzzy comprehensive influence matrix *T* of influence factors.

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}
S_1	0.6074	0.6342	0.6594	0.5439	0.6178	0.7456	0.7343	0.6552	0.5644	0.6129	0.628	0.6618	0.7384	0.5261
S_2	0.6557	0.5533	0.6408	0.5516	0.5969	0.7041	0.7129	0.6244	0.5365	0.5717	0.5942	0.6478	0.7045	0.4958
S_3	0.6212	0.5974	0.5476	0.5271	0.5659	0.6723	0.6761	0.583	0.5076	0.5492	0.5627	0.6012	0.672	0.4647
S_4	0.4933	0.4949	0.5132	0.3892	0.4711	0.5797	0.5789	0.4969	0.4361	0.4732	0.4803	0.5175	0.5621	0.4084
S_5	0.6166	0.5969	0.6195	0.5094	0.5019	0.6627	0.6799	0.5955	0.5071	0.5575	0.5576	0.6006	0.6718	0.4593
S_6	0.5544	0.5363	0.5483	0.4543	0.5151	0.5443	0.6203	0.5516	0.4738	0.4866	0.5116	0.5556	0.6124	0.4286
S_7	0.6035	0.5661	0.5934	0.5002	0.5431	0.6698	0.6029	0.6036	0.5206	0.5612	0.566	0.6004	0.6753	0.46
S_8	0.5871	0.5746	0.6006	0.4966	0.5434	0.6373	0.6629	0.5134	0.4867	0.5319	0.5355	0.5948	0.6552	0.431
S_9	0.6608	0.5993	0.632	0.5266	0.5629	0.6909	0.7122	0.6122	0.4796	0.5773	0.5869	0.6307	0.6956	0.4942
S_{10}	0.6283	0.5941	0.6392	0.5298	0.5785	0.6886	0.7106	0.6145	0.5413	0.5118	0.5804	0.6247	0.7108	0.4836
S_{11}	0.6258	0.5843	0.6106	0.5097	0.5614	0.6583	0.6746	0.5782	0.5033	0.5268	0.5036	0.605	0.671	0.461
S_{12}	0.6124	0.5628	0.6022	0.499	0.535	0.6308	0.6431	0.5693	0.4967	0.5419	0.5461	0.5283	0.6568	0.451
S_{13}	0.6043	0.583	0.597	0.4914	0.5477	0.6561	0.6645	0.5772	0.5032	0.5301	0.562	0.6084	0.5929	0.4785
S_{14}	0.5497	0.4893	0.5175	0.4328	0.4746	0.571	0.5733	0.5003	0.4354	0.468	0.4883	0.5162	0.5615	0.3611

Thereafter, according to the formula, the influence factors were calculated to determine the influence degree f_i, influenced degree e_i, centrality M_i, cause degree N_i, and centrality ranking $Rank(M_i)$ factor attributes; the results are shown in Table 5, according to which the causal relationship diagram of the influencing factors is shown in Figure 3.

Table 5. Analysis results of the DEMATEL method.

S_n	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}
f_i	8.9295	8.5902	8.1479	6.8948	8.1363	7.3932	8.0661	7.851	8.4611	8.4364	8.0737	7.8754	7.9963	6.9389
e_i	8.4204	7.9666	8.3213	6.9615	7.6152	9.1114	9.2466	8.0752	6.9924	7.5	7.7032	8.2931	9.1804	6.4033
M_i	17.3499	16.5568	16.4693	13.8564	15.7515	16.5046	17.3127	15.9262	15.4535	15.9365	15.7768	16.1685	17.1767	13.3422
N_i	0.5091	0.6237	−0.1734	−0.0667	0.5211	−1.7183	−1.1805	−0.2243	1.4687	0.9364	0.3705	−0.4178	−1.1841	0.5356
$Rank(f_i)$	1	2	5	14	6	12	8	11	3	4	7	10	9	13
$Rank(e_i)$	4	8	5	13	10	3	1	7	12	11	9	6	2	14
$Rank(M_i)$	1	4	6	13	11	5	2	9	12	8	10	7	3	14
$Rank(N_i)$	6	3	9	8	5	14	12	10	1	2	7	11	13	4
factor attribute	cause	cause	result	result	cause	result	result	result	cause	cause	cause	result	result	cause

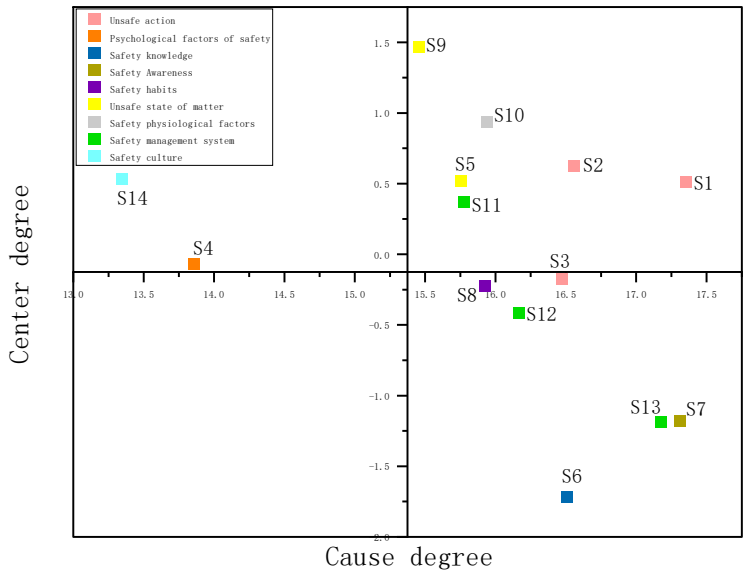


Figure 3. Causality diagram of factors influencing unsafe behaviors by construction workers.

- The reachable matrix was determined.

According to Formula (12), the comprehensive influence matrix was transformed into the overall influence matrix. According to the experts' suggestions and multiple trial calculations, the threshold $\lambda = 0.65$ was determined, and the reachable matrix K was obtained according to Formula (13), as shown in Table 6.

Table 6. Reachable matrix *K*.

S_n	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}	S_{11}	S_{12}	S_{13}	S_{14}
S_1	1	0	1	0	0	1	1	1	0	0	0	1	1	0
S_2	1	1	1	0	0	1	1	1	0	0	0	1	1	0
S_3	0	0	1	0	0	1	1	0	0	0	0	0	1	0
S_4	0	0	0	1	0	0	0	0	0	0	0	0	0	0
S_5	0	0	0	0	1	1	1	0	0	0	0	0	1	0
S_6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
S_7	0	0	0	0	0	1	1	0	0	0	0	0	1	0
S_8	0	0	0	0	0	1	1	1	0	0	0	0	1	0
S_9	1	0	1	0	0	1	1	1	1	0	0	1	1	0
S_{10}	0	0	0	0	0	1	1	0	0	1	0	0	1	0
S_{11}	0	0	0	0	0	1	1	0	0	0	1	0	1	0
S_{12}	0	0	0	0	0	1	1	0	0	0	0	1	1	0
S_{13}	0	0	0	0	0	1	1	0	0	0	0	0	1	0
S_{14}	0	0	0	0	0	0	0	0	0	0	0	0	0	1

- The hierarchy table of factors influencing unsafe behavior by construction workers was constructed.

The reachable set, the leading set, and the common set were calculated according to the reachable matrix, and then the hierarchy was determined. Finally, the hierarchy table of factors influencing unsafe behaviors by construction workers was constructed (Table 7), and the ISM model diagram was created (Figure 4).

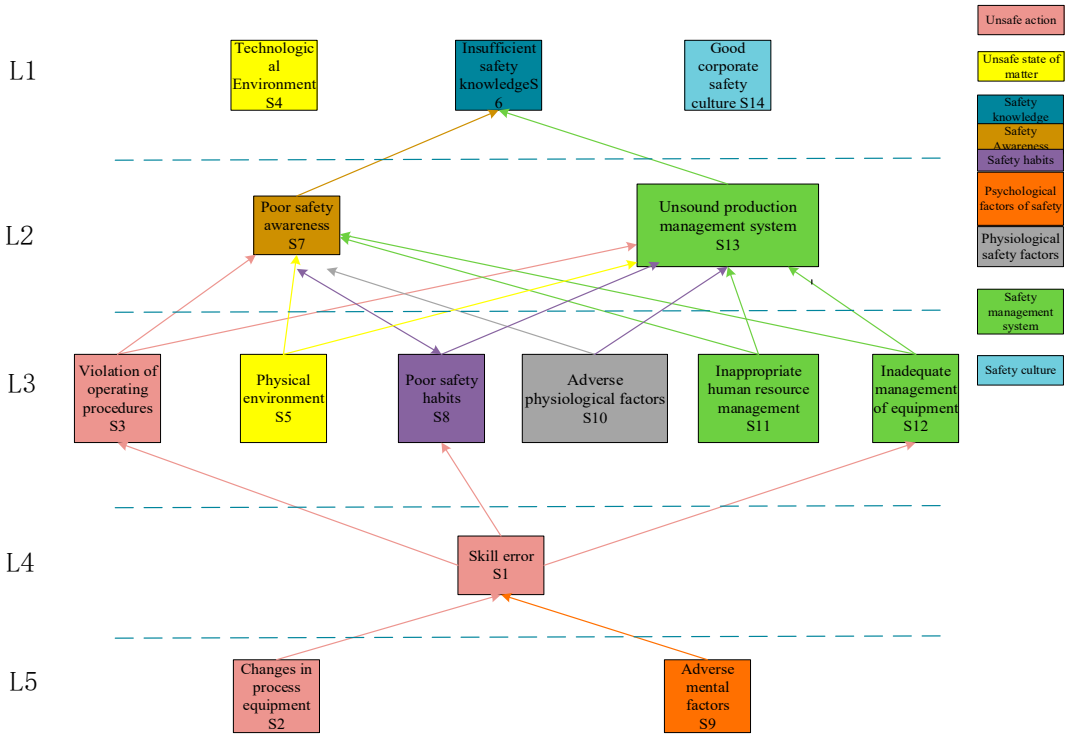


Figure 4. Multi-level hierarchical structure model of factors influencing construction workers' unsafe behaviors.

Table 7. Reachable matrix *K*.

n	**Reachable Set**	**First Set**	**Together**
1	1, 3, 6, 7, 8, 12, 13	1, 2, 9	1
2	1, 2, 3, 6, 7, 8, 12, 13	2	2
3	3, 6, 7, 13	1, 2, 3, 9	3
4	4	4	4
5	5, 6, 7, 13	5	5
6	6	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13	6
7	6, 7, 13	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13	7, 13
8	6, 7, 8, 13	1, 2, 8, 9	8
9	1, 3, 6, 7, 8, 9, 12, 13	9	9
10	6, 7, 10, 13	10	10
11	6, 7, 11, 13	11	11
12	6, 7, 12, 13	1, 2, 9, 12	12
13	6, 7, 13	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13	7, 13
14	14	14	14
Stratification continued after exclusion of cell lines 4, 6, and 14.			
n	Reachable set	First set	Together
1	1, 3, 7, 8, 12, 13	1, 2, 9	1
2	1, 2, 3, 7, 8, 12, 13	2	2
3	3, 7, 13	1, 2, 3, 9	3
5	5, 7, 13	5	5
7	7, 13	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13	7, 13
8	7, 8, 13	1, 2, 8, 9	8
9	1, 3, 7, 8, 9, 12, 13	9	9
10	7, 10, 13	10	10
11	7, 11, 13	11	11
12	7, 12, 13	1, 2, 9, 12	12
13	7, 13	1, 2, 3, 5, 7, 8, 9, 10, 11, 12, 13	7, 13
Stratification continued after exclusion of cell lines 7 and 13.			
n	Reachable set	First set	Together
1	1, 3, 8, 12	1, 2, 9	1
2	1, 2, 3, 8, 12	2	2
3	3	1, 2, 3, 9	3
5	5	5	5
8	8	1, 2, 8, 9	8
9	1, 3, 8, 9, 12	9	9
10	10	10	10
11	11	11	11
12	12	1, 2, 9, 12	12
Stratification continued after exclusion of cell lines 3, 5, 8, 10, 11, and 12			
n	Reachable set	First set	Together
1	1	2, 9	1
2	1, 2	2	2
9	1, 9	9	9
Stratification continued after excluding cell line 1.			
n	Reachable set	First set	Together
2	2	2	2
9	9	9	9
Cell lines 2 and 9 were extracted and stratification ended.			

3. Results and Discussion

3.1. Factor Importance and Attribute Analysis

3.1.1. Centrality Analysis

The centrality indicates each factor's degree of influence on unsafe behaviors by construction workers. The greater the value, the more significant the role of the factor in the whole system. It can be seen from Table 5 that S1 (Skill error), S7 (Poor safety awareness), S13 (Unsound safety production management system), and S2 (Changes in process equipment) rank as the top four among the 14 influencing factors, with centrality values of 17.3499, 17.3127, 17.1767, and 16.5568, respectively, showing that these factors are closely related to other factors throughout the system and are in important node positions. Among these main factors, S1 (Skill error) is the most important in the system of factors influencing unsafe behavior by construction workers; its degree of influence ranks first, indicating that S1 (Skill error) has a significant influence on other influencing factors and is thus the key node of influencing factors, playing a decisive role in the prevention of unsafe behavior by construction workers. This result is mainly because, during the process of construction, the skill-related mistakes of construction workers directly affect their safety; therefore, worker skill is the main influencing factor that can prevent unsafe behaviors by construction workers. At the same time, improving the safety awareness of construction workers would be the most effective means through which to avoid worker casualties caused by construction safety-related accidents. Construction management personnel should also improve and perfect the construction safety production management system, which has a multiplying effect on preventing safety-related accidents for construction workers. S14 (Good corporate safety culture) and S4 (Technological environment) are less important, with centrality values of 13.3422 and 13.8564, respectively, and the centrality values of other factors are greater than 14. S7 (Poor safety awareness) and S13 (Unsound safety production management system) were ranked first and second, with influence degrees of 9.2466 and 9.1804, respectively. S6 (Insufficient safety knowledge) was ranked third, with an influence degree of 9.1114. The influence degrees of other factors were less than 9, indicating that these three factors were most affected by other factors in the system. Through these three factors, the degrees of action of other influencing factors can be identified.

3.1.2. Causality Analysis

Taking the cause as the horizontal axis and center as the vertical axis, the Cartesian coordinate system was drawn to obtain the causality diagram, as shown in Figure 3. The original factor, with an R value > 0, is considered to be the influencing factor of the cause, and an R value < 0 indicates that the affected factor is a result shadow.

The causal factors are active factors. According to the data in Table 5, the determined causal factors are ranked from high to low, as follows: S9 (Adverse mental factors), S10 (Adverse physiological factors), S2 (Changes in process equipment), S14 (Good corporate safety culture), S5 (Physical environment), S1 (Skill error), and S11 (Inappropriate human resource management). The above factors are arranged in order, according to the degree of reason, which indicates that their initiatives in the system are gradually reduced; however, their improvement would help to improve the whole system and effectively improve the performance of construction safety management. These factors lead to unsafe behavior by construction workers by affecting other factors. At the same time, the reason factors are important in affecting unsafe behaviors by construction workers. The reason factors present in this study were S9 (Adverse mental factors), S10 (Adverse physiological factors), S2 (Changes in process equipment), and so on, according to the aforementioned results. The influencing factors were passive factors; the greater the absolute value of the cause degree, the more likely it was to be restricted by other factors. There are seven such factors, which can be seen in the order of their absolute values, from large to small, as follows: S6 (Insufficient safety knowledge), S13 (Unsound safety production management system), S7 (Poor safety awareness), S12 (Inadequate management of equipment), S8 (Poor safety

habits), S3 (Violation of operating procedures), and S4 (Technological environment). These factors would be affected by other factors, such as the poor safety habits of construction workers, the good safety culture of enterprises, and the poor mental factors of construction workers. In the analysis of the causal factors and centrality, S9 and S1 are first among the causal factors and centrality, respectively, while S2 is in the top four. At the same time, it can be seen from the hierarchical structure model of the factors influencing unsafe behaviors by construction workers that S1, S2, and S9 are the core influencing factors in the system.

3.2. Factor Correlation Analysis

According to the hierarchical structure diagram of the factors influencing unsafe behaviors by construction workers (Figure 4), the 14 influencing factors that lead to the occurrence of unsafe behavior are divided into three levels.

3.2.1. Surface Influencing Factors

The surface influencing factors are located in the L1 and L2 layers of the ISM model diagram and include the inducements of construction workers' accidents and the most direct factors affecting their unsafe behaviors. The surface influencing factors are composed of S4 (Technological environment), S6 (Insufficient safety knowledge), S14 (Good corporate safety culture), S7 (Poor safety awareness), and S13 (Unsound safety production management system). This shows that the lack of safety knowledge of workers during the construction process directly leads to safety-related accidents, while poor safety awareness and an imperfect safety production management system indirectly affects the safety knowledge reserve of workers. A good corporate safety culture creates a good safety atmosphere for construction workers, thus affecting their health, which directly leads to safety-related accidents. In the short term, taking preventive measures to strengthen the control of these factors will have a rapid and significant effect on reducing the safety-related accident rate for construction workers.

3.2.2. Surface Influencing Factors

The influencing factors of the middle layer are located at the L3 level in the ISM model diagram, which plays a pivotal role in the system, and associates unsafe behaviors by construction workers with the influences of the surface influencing factors. Factors at this level include S3 (Violation of operating procedures), S5 (Physical environment), S8 (Poor safety habits), S10 (Adverse physiological factors), S11 (Inappropriate human resource management), and S12 (Inadequate management of equipment). Such factors affect workers' behaviors through surface factors; Violation of operating procedures (S3) is a deep factor affecting the unsafe behaviors of construction workers. It causes safety-related accidents by affecting surface factors, such as safety awareness and the production management system. Similarly, the deep-seated influencing factors related to the construction workers themselves indirectly affect the safety knowledge and enterprise safety culture, which leads to safety-related accidents. In the process of developing safety management for construction workers, the deep-seated influencing factors have greater impacts on their safety than the surface influencing factors; therefore, more attention should be paid to them.

3.2.3. The Underlying Influences

The underlying influences are part of the root factors, including the L4 and L5 levels in the ISM model diagram. These underlying factors include S1 (Skill error), S2 (Changes in process equipment), and S9 (Adverse mental factors). The root cause is the most important factor in construction safety-related accidents. S9 (Adverse mental factors) affects the use of equipment and technology, thus causing safety-related accidents. The same is true for S1 (Skill error). Skill errors directly affect the quality of construction and are more likely to cause safety problems in the construction process, while S2 (Changes in process equipment) requires workers to have an in-depth understanding of technological progress, changes in occupational behavior, etc., making it a root causal factor. The ambiguity of workers'

changes in process equipment leads to skill errors and causes construction safety-related accidents. These factors affect the deep factors and indirectly lead to safety-related accidents. In the long run, taking measures to strengthen the control of these factors can prevent the occurrence of construction workers' safety-related accidents by addressing the root causes.

From the above analysis results, it can be seen that, in order to control the unsafe behaviors of construction workers, enterprises should increase training for workers' skills, improve their leaders' attention to safety, increase safety supervision, and gradually form a good safety atmosphere.

3.3. Analysis of Root Cause Influencing Factors

In this study, through the comprehensive analysis of the fuzzy DEMATEL model and the ISM model, we clarify the factors influencing unsafe behaviors by construction workers and quantify the correlation degrees and hierarchical relationships between various factors. Combining the rankings of centrality, influence, and cause, as well as the hierarchical structure of the ISM model, the root influencing factors were identified [30]. From the 14 influencing factors, the top three factors of the influence degree were selected to determine the key, the results of which are shown in Table 5. Among the studied factors, S1 (Skill error), S2 (Changes in process equipment), and S9 (Adverse mental factors) were all ranked in the top six in terms of influence and cause, which indicates that these factors have significant influence on other factors and occupy key positions in the whole factor system.

Specifically, S1 (Skill error), S2 (Changes in process equipment), and S9 (Adverse mental factors) are ranked in the top three—first, second, and third, respectively. They have significant influence on other influencing factors and are the key nodes among the influencing factors. Secondly, the same factors rank sixth, third, and first, respectively, for degree of reason, indicating that these factors, importantly, lead to unsafe behaviors by construction workers by affecting other factors. Finally, S1 (Skill error), S2 (Changes in process equipment), and S9 (Adverse mental factors) are located at the bottom of the ISM model diagram, suggesting that they are the root factors of the whole system. In summary, among the 14 factors influencing unsafe behaviors by construction workers, three root influencing factors were identified, namely S1 (Skill error), S2 (Changes in process equipment), and S9 (Adverse mental factors). This comprehensive analysis is expected to provide effective guidance for the prevention of unsafe behavior by construction workers in the future.

3.4. Influence Path Analysis

There are many influence paths in the structural model (see Figure 4). The influence paths are divided into three types: the main action path, the influence path of other deep-seated factors, and the influence path of non-deep-seated factors. The DEMATEL analysis results were combined with the ISM analysis results, and the comprehensive analysis results are shown in Table 8 to obtain the main action path. The first column represents the five levels presented in Figure 4. The second column denotes the factor of each level. The third column is determined by the centrality ranking in Table 5, which represents the relative importance of the factors at the same level. The fourth and fifth columns are based on the results of the ISM analysis; the interaction relationships, in the fourth column, indicate which factors are affected by the superiors, while the fifth column indicates which factors are affected by the subordinates. The sixth column is the key factor and main action path obtained using DEMATEL-ISM comprehensive analysis. The key factor identification method of this column is as follows: For the fifth- to second-level factors, the factors with the largest centrality on the same level and the highest influence on the lower level are regarded as the key factors [43]. From this, we can observe that the key factors of the fifth to the second layers are as follows: Changes in process equipment S2, Skill error S1, Violation of operating procedures S3, and Poor safety awareness S7. Since the first layer of Good corporate safety culture S14 is the causal factor, it is not the key factor. Technological environment S4 and Insufficient safety knowledge S6 are the result factors,

which do not affect other factors. Therefore, the factor with the largest centrality and the most influential factors affected by the superior is regarded as the key factor of this layer. It can be obtained that Insufficient safety knowledge S6 is the key factor of the first layer, and the above five factors fill in the key factor column of each layer in Table 8 to form the main action path, as follows: Changes in process equipment S2 → Skill error S1 → Violation of operating procedures S3 → Poor safety awareness S7 → Insufficient safety knowledge S6. Equipment model, type, or manufacturer change/technological progress/occupational behavior change in construction can lead to workers' skill errors and result in workers violating the operation procedures, which reflects the low awareness of workers' safety in construction, as well as the lack of safety knowledge. It can be concluded that the five factors in the above main action paths constitute the key factors behind unsafe behaviors by construction workers. It is suggested that the construction industry should focus on the safety hazards of these five factors and manage them layer by layer, from Changes in process equipment (S2) to Insufficient safety knowledge (S6), and take relevant measures from the three aspects of source, approach, and result to reduce the unsafe conditions for construction workers. In addition, when the potential safety hazards of these five factors are excluded, they can be checked, in turn, according to the relative importance ranking and the results of their interactions, and the root factors can be improved layer by layer until the system is optimal.

Table 8. DEMATEL-ISM comprehensive analysis results.

Hierarchy	Influencing Factor	Same Level Cause	Influence of Superiors	Lower-Level Influence	Hierarchy
L5	Changes in process equipment S2	1	nil	S1	L5
	Adverse mental factors S9	2	nil	S1	
L4	Skill error S1	1	S2, S9	S3, S8, S12	L4
L3	Violation of operating procedures S3	1	S1	S7, S13	L3
	Physical environment S5	6	nil	S7, S13	
	Poor safety habits S8	4	S1	S7, S13	
	Adverse physiological factors S10	3	nil	S7, S13	
	Inappropriate human resource management S11	5	nil	S7, S13	
	Inadequate management of equipment S12	2	S1	S7, S13	
L2	Poor safety awareness S7	1	S3, S5, S8, S10, S11, S12	S6	L2
	Unsound safety production management system S13	2	S3, S5, S8, S10, S11, S12	S6	
L1	Technological environment S4	2	nil	nil	L1
	Insufficient safety knowledge S6	1	S7, S13	nil	
	Good corporate safety culture S14	3	nil	nil	

There are six influence paths of other deep-seated factors, mainly referring to the influence paths of sub-bottom factors, such as Skill error S1 → Violation of operating procedures S3 → Poor safety awareness S7 → Insufficient safety knowledge S6. This path is also an effective way to improve the safety of construction workers by adopting reasonable policies and planning to reduce the occurrence of workers' accidents, so as to achieve the purpose of improving the safety and quality of workers. There are also five similar paths, such as Skill error S1 → Poor safety habits S8 → Unsound safety production management system S13 → Insufficient safety knowledge S6; Skill error S1 → Inadequate management of equipment S12 → Unsound safety production management system S13 → Insufficient safety knowledge S6; etc.

There are six influence paths of non-deep factors, mainly referring to the influence paths of other level factors, such as Physical environment S5 → Poor safety awareness S7 → Insufficient safety knowledge S6 (Lack of safety knowledge S6). A good physical construction environment affects the safety awareness of construction workers and, thus, affects the reserve of workers' safety knowledge. Relevant construction management personnel or enterprises can ultimately affect the safety knowledge of workers and prevent the occurrence of construction accidents by improving the physical work environment. Similarly, there are five related influence paths, such as Physical environment S5 → Unsound safety production management system S13 → Insufficient safety knowledge S6; Adverse physiological factors S10 → Unsound safety production management system S13 → Insufficient safety knowledge S6; Inappropriate human resource management S11 → Poor safety awareness S7 → Insufficient safety knowledge S6 (Unsound safety production management system S13); etc.

4. Conclusions

Scholars both at home and abroad have fully studied the causes of unsafe behaviors by construction workers; now, in the literature [14,44], there is a lack of research on the mechanisms of action between the main factors influencing these unsafe behaviors. This study provides valuable and comprehensive insights into the impacts of unsafe behaviors by construction workers, emphasizing the hierarchical relationships between the factors influencing unsafe behaviors by construction workers and their impacts on unsafe behavior. The results show that the relative importance of the interactions between different unsafe behaviors varies, as do their degrees of influence on the unsafe behavior. Skill error S1, Changes in process equipment S2, and Adverse mental factors S9 were found to be the underlying influencing factors; therefore, in the actual long-term safety management process, it is necessary to address these root factors for targeted management. In the short term, construction enterprises should pay attention to the importance of Technological environment S4, Insufficient safety knowledge S6, Good corporate safety culture S14, Poor safety awareness S7, and Unsound safety production management system S13 in order to prevent workers' safety-related accidents, as well as administer daily construction accident safety education and training. In addition, this study presents a certain reference from which to further explore the key factors influencing unsafe behavior by construction workers and the interactions and hierarchical relationships between influencing factors. From the influence path analysis, Changes in process equipment S2, to Skill error S1, to Violation of operating procedures S3, to Poor safety awareness S7, to Insufficient safety knowledge S6 formed the main action path of unsafe behavior by construction workers. Construction enterprises should improve the ability of workers to adapt to new equipment through safety training in order to reduce the incidence of skill errors by construction workers, so as to reduce workers' violations of operation procedures, improve workers' safety awareness, enrich workers' safety knowledge, and finally, effectively prevent construction workers' unsafe behaviors. In general, the factors influencing unsafe behavior by construction workers are systematic and interrelated, and previous studies have also shown this [8]. The research results outlined in this paper can provide some reference for construction enterprises to comprehensively control the interactions between the factors influencing unsafe behavior, according to the actual situation, so as to improve the efficiency of safety management, help them understand the main factors in workers' unsafe behaviors, and clarify the relationships between the factors.

However, this study still has some limitations. First of all, the research objects of this work were the factors influencing construction workers' unsafe behaviors. There are many influencing factors that were finally determined; their pertinence is not strong, and the related research is not deep enough. In the future, we can study certain types of factors, such as unsafe action and unsafe state. The relevant conclusions obtained in this way would be more valuable for reference. Secondly, the experts' scores were based on the questionnaire. Although we adopted the fuzzy set theory for the scoring results in order to

make them more reliable, potential deviation in the expert judgment is still unavoidable. In follow-up work, various statistical methods can be used to score and screen. Thirdly, in the process of data collection, there was a lack of international data. In addition, the members of the expert group comprised Chinese enterprise managers, relevant scholars in universities, and government staff, and there is a lack of research on the factors influencing unsafe behaviors in international building construction. Therefore, it is expected that, in a follow-up study, we will further improve the index of influencing factors constructed for this paper and conduct in-depth analysis through the collection and supplementation of international data.

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