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Research Article

Research on the Coupled Relationship of Factors Influencing Construction Workers' Unsafe Behaviors: A Hybrid DEMATEL-ISM-MICMAC Approach

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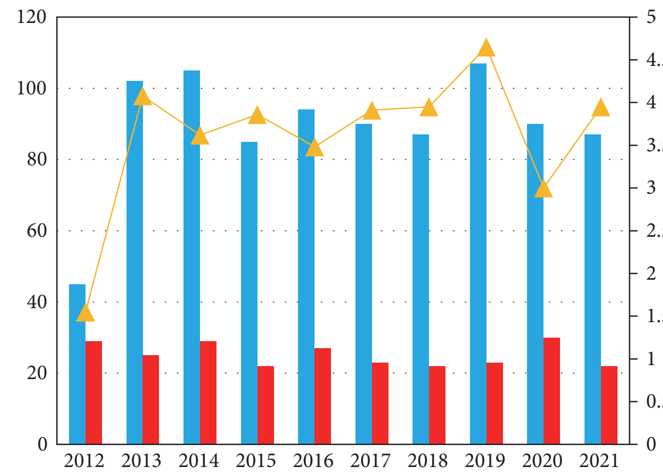
The unsafe behavior of construction workers is the most direct reason of frequent construction site accidents. In order to improve the safety management of construction sites and figure out the causal relationship among the influencing factors in the field of construction workers' unsafe behaviors, literature research, questionnaire survey, decision-making trial, and evaluation laboratory—interpretive structural modeling—crossimpact matrix multiplication applied to classification (DEMATEL-ISM-MICMAC) methods were used in combination in this thesis. The analysis of collected data was carried out in three dimensions: individual, organizational environment, and safety management. A framework about influencing factors of construction workers' unsafe behaviors was constructed. DEMATEL-ISM was used to construct the explanatory structural model, which to analyze the influence relationships and hierarchical relationships among factors. MICMAC method was used to analyze the driving dependency. ISM model consists of six parts, the bottom of which includes three influencing factors: work environment, safety supervision, and concernment of superior. With characteristics of high drive and low dependence, the bottom layer are the root causes of construction workers' unsafe behaviors. Work environment and concernment of superior are the core indicators of it. The intermediate layer with a low drive and low dependence covers six factors: psychological status, physical health, professional skills, organizational climate, work quota, and safety plan. It is the indirect factor to influence construction workers' unsafe behaviors. The top layer is composed of safety awareness, safety education, and technical delivery. Safety awareness is the core of individual dimension, showing the characteristics of low drive and high dependence, is the direct factor to influence construction workers' unsafe behaviors. Based on the DEMATEL-ISM-MICMAC method, the methodology to reduce construction workers' unsafe behaviors was proposed.

1. Introduction

With the continuous advancement of urban and rural infrastructure, the construction industry has also developed by leaps and bounds [1]. Nowadays, the trend of complexity in the construction industry is obvious, and construction workers need a more solid technical foundation [2]. The possibility of safety hazards at construction sites has also increased. The frequent accidents in construction site led to a reluctance for people to work in the construction industry, which is detrimental to the development of the construction industry [3]. In addition, China is a major country in infrastructure construction, and its production safety situation in the construction industry is still not optimistic [4]. According to the statistics, the average death toll of each accident is about four people since 2013. In 2019, this number reached 109 people, 23 accidents occurred, and the average death toll of no accident reached 4.62 people [5]. The situation is extremely serious. The number of production accidents of major or above housing and municipal engineering in our country and the average death toll per accident have not improved significantly from 2012 to 2021, as shown in Figure 1. The unsafe behavior of construction workers is the main cause of the accidents, accounted for



	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of deaths	45	102	105	85	94	90	87	107	90	87
Number of accidents	29	25	29	22	27	23	22	23	30	22
Average number of deaths per accident	1.55	4.08	3.62	3.86	3.48	3.91	3.95	4.65	3	3.95

Figure 1: Number of major production accidents of housing and municipal engineering in China and the average death toll per accident from 2012 to 2021.

88%. Based on the above, the unsafe behavior of construction workers is the initiator of the accident [6]. Construction workers are the ultimate performers of construction work and the main bearers of accidental injuries. Strengthening the system of management and supervision remains the top priority for future safety work [7]. Reducing safety hazards during construction and improving managers' management ability will be significant practically for the transformation and upgrading of the construction industry.

The safety production system of construction is a complex multidimensional system, including multifactor, multisubsystem, and multispace structure. It is a complex, dynamic, and nonlinear system. Security managers should understand these complex systems to identify risk factors and formulate risk management policies. Existed research mainly focuses on the construction of safety monitoring information platform and the role of unsafe behaviors in construction accidents. As construction is a complex process, it is also affected by factors such as human factors, organizational environment, and safety management, and its interaction is complex. However, the research about the key risk factors, interrelations, and the factor propagation chain of unsafe behavior of construction workers, have not been fully studied. A thorough understanding about the mechanism of unsafe behavior of construction workers is a prerequisite for improving the occurrence of accidents and carrying out risk management. If safety managers cannot systematically identify the diversity and interaction of causes of safety incidents, it will hinder the identification of weak links in safety incident analysis and the development of policies. The decision-making trial and evaluation laboratory (DEMATEL) method is an effective method to analyze the causal relationship among complex system factors and convert these relationships into visual structure models using graph theory. Interpretive structural modeling (ISM) builds visual structural maps by decomposing complex systems into various factors at the macro level, and had been used to describe the hierarchical structure and relationships between multiple factors. The crossimpact matrix multiplication applied to classification (MICMAC) method can classify the driving forces and dependence of different factors to get insight into the interrelations among these factors. The combination of DEMATEL-ISM-MICMAC methods is more suitable for analyzing the interaction between the factors affecting unsafe behavior of construction workers. This study aims to develop a system model that captures the factors affecting the occurrence of unsafe behaviors and their interrelations by adopting a combination of DEMATEL and ISM methods. On this basis, the MICMAC method is used to determine the driving and dependent values of the risk factors, and countermeasures are proposed for these risk factors and complex interrelations. Based on the results above, the precise and direct control methodology will be beneficial to improve the unsafe behaviors of construction workers and enhanced the safety of the construction operations, so as to solve the weak links of accidents in the construction process.

2. Literature Review

2.1. Construction Workers Unsafe Behavior. Recently, domestic and foreign research had been carried on unsafe behaviors affecting construction workers, these researches focused on individual, organizational environment, and safety management. The individual dimension had focused on analyzing construction workers' physical and psychological status. For example, Mohajeri et al. [8] recorded 1,347 attempted falls through camera system statistics and got the conclusion that the main factors of construction workers' unsafe behaviors consist of personal habits and motivation and the control of sensation. Chen et al. [9] studied the psychological status of construction workers and its structural relationship with unsafe behaviors through literature analysis, questionnaire, and AMOS software fitting model. Taking poor safety climate and unjustified safety motive as mediator, the hypothesis model of the structural relationship between paranoid psychological factor and unsafe behavior was proposed. The results showed that a good psychological status can improve safety awareness and reduce the probability of unsafe behavior and injury. The organizational environment dimension had been addressed for the specific environment in which workers live, for example, Aksorn and Hadikusumo [10] showed that the environment influences the occurrence of unsafe behaviors through the study on 214 workers in 20 construction projects in Thailand. Yao et al. [11] concluded that workload has the most significant effect on unsafe behaviors during construction by the model about the relationship between workload, job satisfaction, and other factors. Sun et al. [12] built a model to calculate the mean square error to construct an artificial neural network model by dividing the team safety climate into seven dimensions by literature research. The reliability of the model will be verified by real cases. The safety management dimensions were analyzed from the managerial perspective. For example, Choudhry and Fang [13] confirmed that safety management can greatly influence construction workers' unsafe behaviors by means of field interviews and grounded theory. Khosravi et al. [14] argued that the occurrence of construction workers' unsafe behaviors is related to social, project management, supervision, and contractor factors. He et al. [15] constructed and solved the safety benefit equation by taking two different perspectives about the project constructor and project manager. It proved that reducing the occurrence of construction workers' unsafe behaviors is crucial to the improvement of project safety performance. At present, researchers had done a lot of work on the formation process, influence mechanism, and structural relationship of a certain type of factors of construction workers, but have not formed a unified system, and the interaction relationships and attribute characteristics between the causes of accidents are not in-depth, the integrity, and systematization are lacking. In order to further explore the hierarchical structure and characteristics of each cause, this paper statistically analyzed the cause factors from literature, extracted the factors affecting the unsafe behavior of construction workers from three dimensions of individual, organizational environment, and safety management. The DEMATEL-ISM-MICMAC method was carried out to study the interaction and characteristics of them from a quantitative perspective to provide a theoretical basis for effectively preventing and reducing the occurrence of construction site accidents, and to provide a theoretical basis for construction managers to formulate management programs.

2.2. Hybrid Modeling Approach. With the development of the age of intelligence, hybrid modeling approaches had been studied. DEMATEL-ISM-MICMAC was first applied in the fields of healthcare and blockchains. Yang et al. [16] provided strong methodological guidance and recommendations for policymakers in industry associations such as government departments by using the DEMATEL-ISM-MICMAC method. Nagariya et al. [17] first used the model to identify the key enablers for achieving sustainability in service only supply chain and derived the enabler hierarchy levels. Finally, these enablers were divided into causal groups. Existed research about construction on hybrid modeling approaches focused on ISM-MICMA and DEMATEL-ISM hybrid modeling approaches. For the DEMATEL-ISM method, for example, Zhou et al. [18] used the DEMATEL-ISM method to clarify the structural hierarchy of 17 influencing factors affecting construction workers' unsafe behaviors, built an integrated influencing factor model, and finally proposed integrated facilitation measures for construction workers' safe behaviors. Shakeri and Khalilzadeh [19] used the DEMATEL-ISM method to analyze the factors affecting project communication. The factors affecting project communication, cluster order, and relationships were identified to enable managers to manage information flow in a better and more controlled manner. Xiahou et al. [20] identified 17 key factors of smart construction site development from managerial, technical, and perspectives through the DEMATEL-ISM method and divided them into seven levels to demonstrate the interrelationship between key factors in the development of the smart construction site. The DEMATEL-ISM method only perform the hierarchical division and cannot provide a more specific basis for the proposal of measures. For the ISM-MICMAC method, Prakash and Phadtare [21] adopted the ISM method to establish a structural relationship between the drivers of project marketing. In addition, high driving power and high dependency factors were established through MICMAC. Presenting these drivers as a logically consistent ISM model provided a theoretical basis for project marketing. Nagpal et al. [22] used the ISM-MICMAC method to help urban developers and planners to identify the relationship among barriers and to design strategic plans for the smarter cities. Bashir and Ojiako [23] used the ISM-MICMAC method to analyze the dependencies between engineering parameters in the early design phase. The ISM-MICMAC method relies more on expert experience and is more subjective. Therefore, the DEMATEL-ISM-MICMAC method is introduced into the field of unsafe behavior of construction workers in this paper, overcame the defects of the original methods, as detailed in Table 1. The DEMATEL-ISM-MICMAC model provided new ideas for the study of construction workers' unsafe behavior. The government departments, building construction site managers, and safety management formulators would get strong methodological guidance and decision-making suggestions.

3. Research Methods

3.1. Research Framework. The main purpose of this study is to determine the causal relationships of construction workers' unsafe behaviors from the perspective of complex systems analysis. Accordingly, the hierarchical structure of these factors was divided to obtain the final 12 influencing factors to be studied in this paper. Relevant data was collected for prescreening based on literature research and questionnaire survey. Then, the expert interview method was conducted and the DEMATEL-ISM-MICMAC model was analyzed by the obtained data. The DEMATEL method is used to analyze each factor in the system with uncertain relationships based

Table 1: Advantages and disadvantages of existed methods.

Method	Advantages	Disadvantages
PATTERN	The calculation is simple, the process is clear, and the relationship between subordinate and superior index can be discussed	Relationship of the indicators at the same level cannot be given
FA and PCA	The principal components of the original indicators can be extracted, and various influencing factors can be sorted and evaluated	FA and PCA are calculated considering variance and Pearson correlation or variance–covariance matrix, which are metric measures that make these techniques unsuitable for qualitative data
CFA and SEM	CFA is a method used in structural equation modeling (SEM) to determine the reliability of the model	The relationships were based on assumptions, it has problems in classifying the importance level and hierarchy of model factors
DEMATEL	Reflect the degree of mutual influence between various factors, understand the size of the degree of influence	Subjective factors have a great influence, it is difficult to analyze large and complex systems
ISM	The structural relationship between system factors can reflect intuitively and clearly	Only reflect the monomial relationship of factors
DEMATEL-ISM-MICMAC	Reflect the relationship between complex systems, accurately divide the structural level between the elements, which is conducive to identify the key influencing factors and the influence range among the factors, better judge the internal motivation of the research factors and determine the status and role of the influencing factors. It reduces the loss of information in the system, improves the operation efficiency, which is more comprehensive and detailed.	

on expert cognition, and serves to analyze the extents and relationships of the influencing factors. This method can make full use of expert knowledge and experience to deal with complex system problems, and translate them into concrete values to describe the relationship between the factors of the system [24]. The ISM method aims to decompose complex systems into different levels, so that it can reveal the internal structural relationships of the system. It can hierarchize and organize the intricate factor relationships and explain the influence path and scope of the hierarchical structure among factors [25]. MICMAC can construct a driver-dependency diagram of construction workers' unsafe behavior based on the specific values of driving force and dependencies [26]. The position and role of factors in the system were analyzed to better understand the driving and dependency relationships among factors. This paper combined three methods in a flexible way, including DEMATEL, ISM, and MICMAC, to study the factor system structure and the association among factors. Accordingly, an improved methodology of construction workers' unsafe behaviors was proposed in this paper, the relevant specific research process is shown in Figure 2.

3.2. DEMATEL-ISM-MICMAC Model. DEMATEL is a methodology proposed by American scholar Bottelle in 1971 has been widely used in education and management fields. This method is based on research and analysis, can makes full use of the empirical knowledge of experts and scholars. It is one of the best practical methods for evaluating the causal relationship of influencing factors, which had been proven to be effective in practice [27]. This paper used this method to identify the complex systemic issues of individual, organizational environment, and safety management dimensions that affect the occurrence of construction workers' unsafe behaviors by the knowledge from experts and scholars, so that to make a scientific study of the relationships of influencing factors that affect construction workers' unsafe behaviors.

ISM is a method of analysis based on directed graphical models and Boolean matrices. This method can divide the complex factors affecting the overall development of the system into several clear layers through people's knowledge and practical experience. It was proposed by American scholar Warfield [28] to solve complex problems. Later seven explanatory structural models GISM, FISM, DISM, VISM, FunISM, CIA-ISM, and AISM were deduced.

MICMAC is based on the principle of matrix multiplication. If a change in one factor causes a change in other factors, it is considered that there is an indirect influence relationship between the factors. The driving force indicates the amount of influence by other factors. Dependency indicates the amount of influence on other factors. Factors can be classified into the following four types: linkage factors, dependent factors, autonomous factors, and independent and dependent factors. The degree of interaction between the factors of the system can be expressed through the matrix of drivers and dependencies [29].

4. Experiment Analysis

4.1. Data Acquisition. Through literature research combined with accident causation theory, 15 initial influencing factors affecting construction workers' unsafe behaviors had been screened from three dimensions: individual, organizational environment, and safety management. The personal dimension

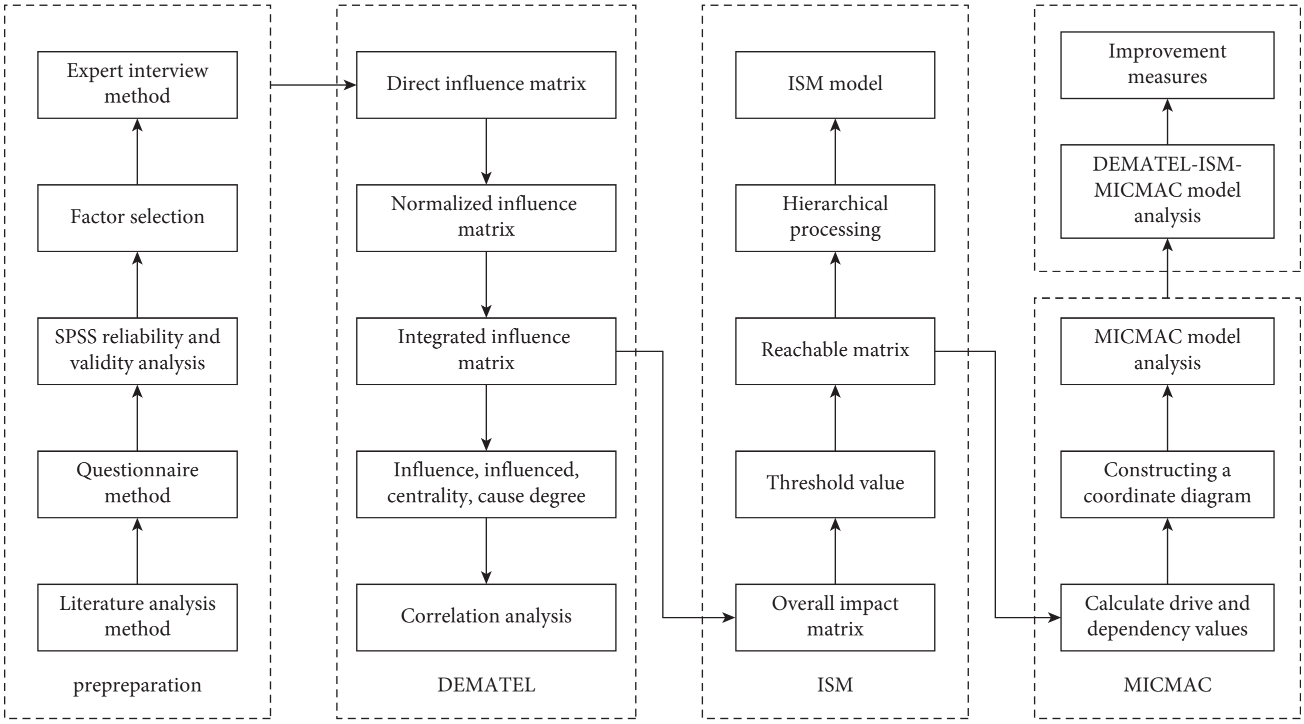


Figure 2: Framework for research on unsafe behaviors of construction workers.

included safety awareness, psychological status, safety attitude, physical health, and professional skills. The organizational environment dimension consists of safety equipment, work environment, organizational climate, work quota, and safety plan. Safety supervision, safety education, concernment of superior, technical delivery, and safety communication belongs to safety management dimension.

The questionnaire was set up by literature research method and field investigation method. After the questionnaire was initially settled, three experts and workers with rich experience in the field were invited to review the questionnaire, the first person was a senior researcher of university research project management, the second one was a construction site manager with many years of experience, and the last was an engineering contractor with many years of service. The questionnaire was further modified according to their suggestions. After the questionnaire was set up, the research was conducted through 408 construction workers as well as managers in 23 construction projects across China, including Jiangsu, Shanghai, Zhejiang, Yunnan, and Shaanxi. A combination of online and field research was used to carry out a survey on the factors influencing construction workers' unsafe behavior from April 5, 2022 to May 26, 2022. A total of 295 online questionnaires and 113 paper questionnaires were collected, totaling 408 questionnaires. A amount of 124 invalid questionnaires were excluded and 284 valid questionnaires were screened, with an efficiency rate of 69.61%. Using SPSS25.0 software to analyze the reliability and validity of 284 valid questionnaires, obtained Cronbach's $\alpha = 0.880 > 0.8$ and $KMO = 0.665 > 0.6$ for the total scale, with a very good reliability and qualified validity, which could be analyzed in the next step [30]. Finally, 12 deep influence factors in three dimensions were summarized. The expert interview method was used to ensure that the selected influencing factors are representative. Four experts with more than 5 years of work experience reviewed the research results obtained by the questionnaire survey method on site, including two construction site managers, two university engineering management researchers, so as to construct a deep influence factor system of construction workers' unsafe behaviors. The definitions of the influencing factors are shown in Table 2.

Questionnaires and expert interviews were used to investigate the impact degree of 12 deep impact factors. The questionnaire utilized 0–4 scoring method: no influence assigned 0, small influence assigned 1, general influence assigned 2, large influence assigned 3, large influence assigned 4, and the diagonal of the table is 0 [31]. The influence degree scale of the influence factors of unsafe behavior of construction workers is shown in Table 2. Eleven experts participated in the discussion on the relationship between the factors affecting the unsafe behavior of construction workers, in order to further achieve the expected goal of this paper to ensure the rationality of the data in this paper, the experts were required to determine the final size of the influencing factors by using expert interviews, expert judgments, and Delphi method. These experts come from research institutions in the construction field, construction management departments and universities engaged in engineering management researchers, and the specific information of 11 experts is shown in Table 3. Six representatives from the 11 experts were selected to participate in the data review, and the selection was based on: high education level and long working years. According to the research objectives and results of this paper, two experts are selected from research institutions, enterprise

Table 2: Influencing factor definition.

Dimension	Factors	Definition
Individual	Safety awareness (K_1)	Safety concepts built up by construction workers in the course of performing construction labor
	Psychological status (K_2)	Negative personality traits exhibited by construction workers in the course of their labor, such as hostility
	Physical health (K_3)	Construction workers exhibited physical functioning conditions such as fatigue, illness
	Professional skills (K_4)	Proficiency in operation skills of the construction workers in a certain process
Organizational environment	Work environment (K_5)	The physical environment around the work of construction workers, such as the placement of objects on the construction site, noise, and so forth
	Organizational climate (K_6)	Safety and communication atmosphere for construction workers' living environment
	Work quota (K_7)	The amount of work to be done by construction workers per unit of time
	Safety plan (K_8)	Measures and plans developed to ensure safety at building construction sites
Safety management	Safety supervision (K_9)	Supervision of unsafe worker behavior by building construction managers
	Safety education (K_{10})	The degree of education of staff safety knowledge by building construction managers
	Concernment of superior (K_{11})	Leaders' attention to construction safety on construction sites
	Technical delivery (K_{12})	Before the process is carried out, the responsible officer will train the relevant personnel on the operating procedures and precautions

Table 3: Basic information of experts.

Number	Name	Gender	Age	Education	Work organization	Work year	Whether to participate in the review
1	Qi**	Male	49	MA	Management departments	23	Yes
2	Liu**	Male	40	PhD	Research institutions	10	Yes
3	He**	Female	39	PhD	Research institutions	7	Yes
4	Xue**	Male	42	PhD	Management departments	17	No
5	Yang**	Female	36	PhD	University	6	No
6	Wang**	Male	41	PhD	Management departments	12	Yes
7	Liu**	Male	32	NA	Research institutions	6	No
8	Li**	Male	37	MA	Management departments	12	No
9	Hou**	Female	46	PhD	University	17	Yes
10	Pan**	Male	39	NA	Research institutions	13	No
11	Li**	Male	47	MA	University	21	Yes

management departments and researchers engaged in engineering management research in universities, respectively. These experts have been engaged in the research and work in the field of construction for more than 10 years. The judgment of experts is based on their professional knowledge, work experience, and field authority. These six experts reviewed and confirmed the rationality of the preliminary data. In addition, to ensure the usability of the research data, the Cronbach's α coefficient test was applied to the opinions of experts and scholars in the field using SPSS25.0 software, and $\alpha = 0.946 > 0.8$ was obtained, with excellent reliability.

4.2. Factor Attribute Analysis Based on DEMATEL. In this paper, MATLAB software was used to calculate the matrix.

Step 1: Calculate the direct influence matrix

First, determine the set of influence factors, K_i denotes the ith influence factor, so the set $K = \{K_1, K_2, \ldots, K_{12}\}$. Second, the average of 11 experts' scores for each influence factor is calculated to obtain the direct influence factor matrix O. When i and j are equal (i denotes the number of rows and j denotes the number of columns), O_{ij} is assigned to 0 [32].

Table 4: Influence degree, influenced degree, centrality degree, and cause degree.

	K_1	K_2	K_3	K_4	K_5	K_6	K_7	K_8	K_9	K_{10}	K_{11}	K_{12}
G_i	4.893	3.992	4.070	3.904	5.466	5.228	5.368	5.156	5.339	5.088	5.941	4.218
G_i'	5.946	3.933	3.028	3.342	4.012	5.508	5.216	5.391	5.476	5.668	5.500	5.641
P_i	10.839	7.926	7.098	7.246	9.478	10.736	10.584	10.547	10.816	10.757	11.441	9.858
Q_i	−1.053	0.059	1.042	0.562	1.453	−0.281	0.151	−0.235	−0.137	−0.580	0.441	−1.423

Step 2: Calculate the normalized direct influence matrix

From the direct influence matrix O, the normalized direct influence matrix was calculated based on Equation (1).

$$N = \frac{O}{\max \sum_j^n O_{ij,\, i=1,2,\ldots,n}}, \quad (1)$$

where N denotes the normalized direct influence matrix; n represents the matrix order; max is the maximum value of the matrix row sum of order n; and O_{ij} denotes the degree of influence of element K_i on K_j in matrix O.

Step 3: Calculate the comprehensive influence matrix

From the normalized direct influence matrix, the integrated influence matrix of factors influencing the unsafe behavior of construction workers was obtained based on Equation (2).

$$H = N(I - N)^{-1}, \quad (2)$$

where H is the integrated impact matrix and I denotes the unit matrix.

Step 4: Calculate the influence degree, influenced degree, centrality degree, and cause degree

The influence degree (G_i) was obtained by summing up the rows of the combined influence matrix. Summing up the columns to obtain influence degree (G_i'). The sum of the influence degree and influenced degree was the central degree (P_i), and the difference between them was the cause degree (Q_i) [32]. Influence degree: The influence degree of a factor is represented by G_i, the larger the value is, the greater the influence it has on other factors. The extent of the impact was influenced by other factors is represented by G_i', the larger the value is, the greater was influenced by other factors. The cause degree of a factor is represented by $G_i - G_i'$ and is denoted as P_i. The centrality is represented by $G_i + G_i'$ and is denoted as Q_i. Centrality indicates the degree of influence of a factor on other factors, and causation indicates the difference between the influence of the factor and the influence impacted by other factors [33]. A positive value of causation indicates that the factor is a causal factor, and the numerical value is proportional to the degree of its influence on other factors. If the cause degree is less than 0, the factor is the result factor. A smaller value indicates that the factor is more affected by other factors [34]. The specific values of influence degree, influenced degree, centrality degree, and cause degree affecting construction workers' unsafe behaviors were calculated and shown in Table 4. Based on the four values, the scatter diagram of factors influencing construction workers' unsafe behavior was obtained, as shown in Figure 3.

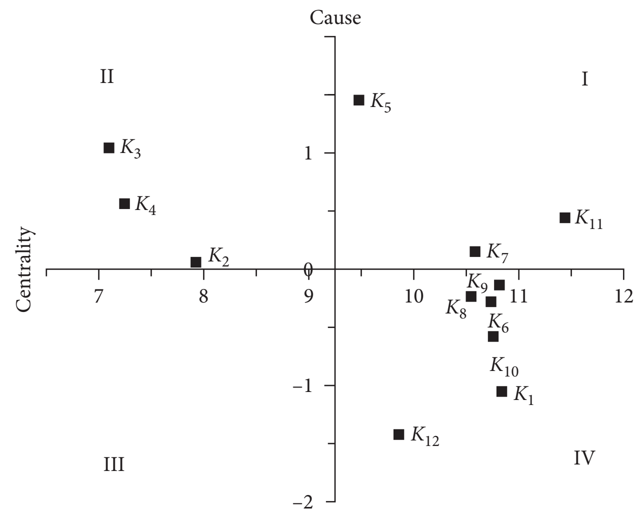


Figure 3: Scatter diagram of influencing factors.

4.3. Hierarchy of Factors Using ISM

Step 1: Overall influence matrix

Based on Equation (3), the overall influence matrix of factors influencing unsafe behavior of construction workers was calculated.

$$E = I + H, \quad (3)$$

where E represents the overall influence matrix.

Step 2: Reachable matrix

The refined simplification matrix was obtained by introducing a threshold μ to eliminate redundant values. The mean α and standard deviation β of the overall influence matrix was calculated to obtain the threshold μ, which was the sum of the mean α and standard deviation β. It was calculated that $\alpha = 0.407$ and $\beta = 0.101$, the threshold $\mu = 0.508$. If the value in the overall influence matrix is greater than or equal to μ, 1 will be displayed in the reachable matrix, otherwise 0 is displayed in the reachable matrix.

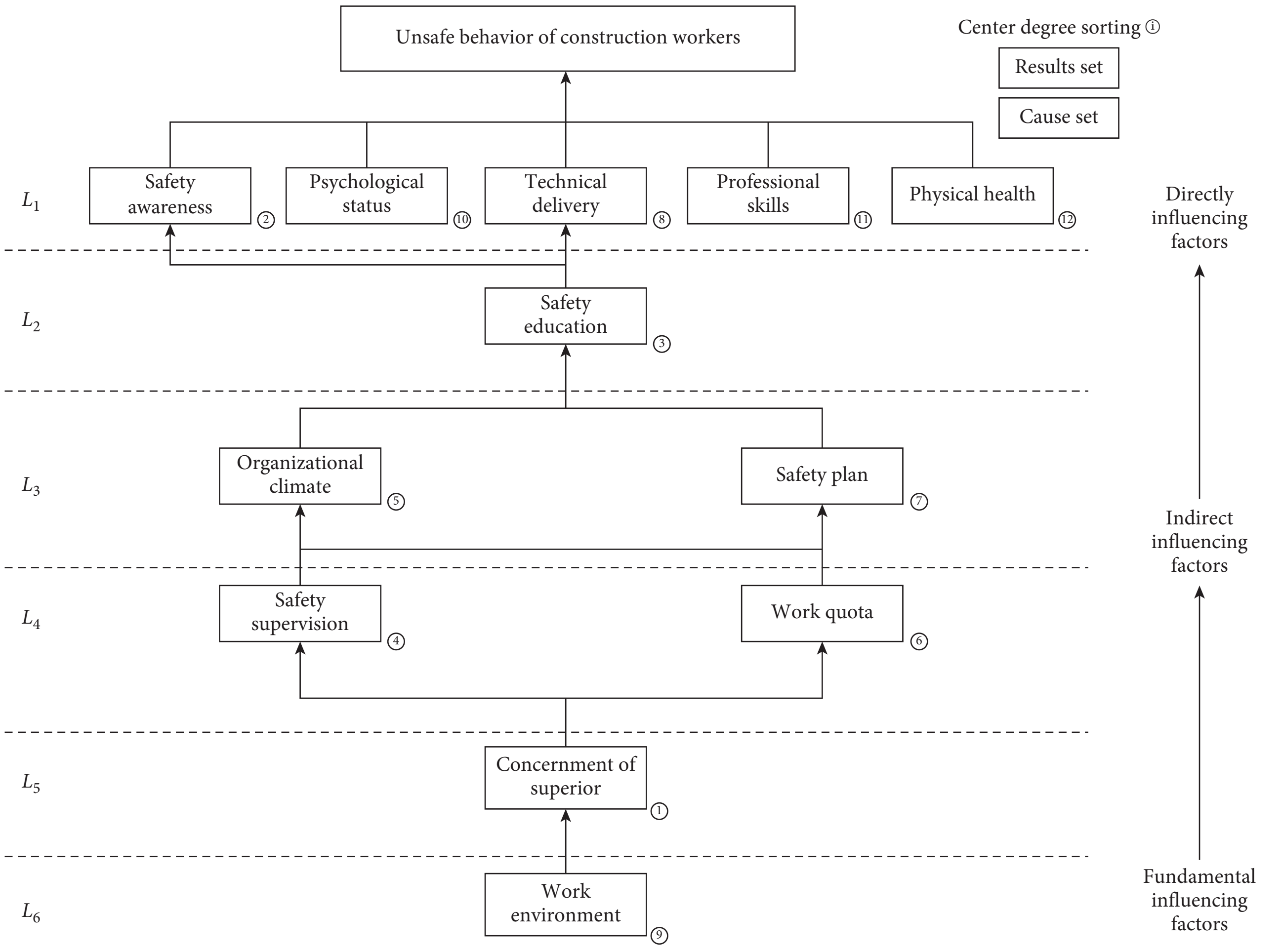


Figure 4: ISM model of influencing factors.

Step 3: Hierarchical processing

The reachable set $B(n_i)$, the prior set $Y(n_i)$, and the intersection set $T(n_i) = B(n_i) \cap Y(n_i)$ of the reachable and prior sets of the system factors were obtained after hierarchical processing. The rows and columns of the factor set mapping with the same reachable set $B(n_i)$ and intersection set $T(n_i)$ were crossed out until all factors were crossed out to obtain the set of factors A_q ($q = 1, 2, 3, 4, 5, 6$) for each level of factors affecting the unsafe behavior of construction workers [35]. The nodes of each level were calculated as follows: level 1 node $A_1 = \{1, 2, 3, 4, 12\}$; level 2 node $A_2 = \{10\}$; level 3 node $A_3 = \{6, 8\}$; level 4 node $A_4 = \{7, 9\}$; level 5 node $A_5 = \{11\}$; and level 6 node $A_6 = \{5\}$. According to above all, the ISM model was established, as shown in Figure 4.

4.4. Dependency and Drive Relationships. The MICMAC method was used to stratify among indicators by calculating the driving force and dependency of each indicator. The driving force refers to the degree of influence of other indicators on the indicator, and its numerical magnitude is the sum of the rows of the reachable matrix. Dependency is the degree of influence of the indicator on other indicators, and it is the sum of the elements of each column of the reachable matrix, as shown in Table 5. Based on the specific values of driving force and dependency, each indicator factor was divided into four categories in the form of two-dimensional axes, located in I, II, III, and IV four different quadrants, and represent linkage, dependent, autonomous, and independent factors, respectively. The driving force and dependency of the linkage factors are strong. Independent factor has a stronger driving force and weaker dependency. The autonomy factor is less driven and dependent. Dependent elements are more dependent and less driven [36]. The specific distribution is shown in Figure 5.

5. Results and Discussion

5.1. Research Findings

5.1.1. DEMATEL Results Analysis. From the analysis of individual dimension (K_1, K_2, K_3, K_4), considering Table 4 and Figure 3, in terms of centrality, the greatest influence on individual dimensions is safety awareness, followed by psychological status, and other indicators have relatively small influence. Meanwhile, safety awareness is in the first place in the whole index system, which indicates that safety awareness is in the core position in the index system. It is the most important indicator that affects construction workers' unsafe

Table 5: Drivers and dependencies of influencing factors.

Influence factors	Driving force value	Dependency value	Influence factors	Driving force value	Dependency value
K_1	1	8	K_7	3	2
K_2	1	1	K_8	4	4
K_3	1	1	K_9	7	3
K_4	1	1	K_{10}	3	6
K_5	6	1	K_{11}	8	3
K_6	4	3	K_{12}	1	7

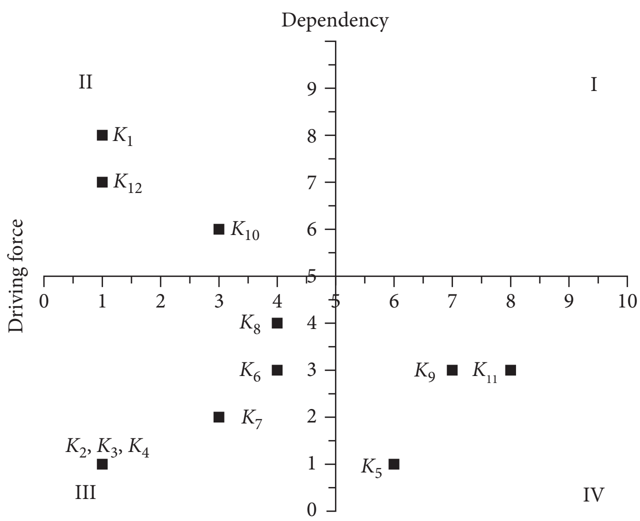


Figure 5: Analysis chart of MICMAC results of influencing factors.

behavior. As for the cause degree, among the four layers of the personal dimension, the cause group factors are psychological status, physical health, and professional skills. The result group factor is safety awareness, which is the result of the influence of cause elements. To comprehensively improve the unsafe behavior of construction workers caused by the personal dimension, it is necessary to start from psychological status, physical health, and professional skills. Safety consciousness, the factor with the smallest cause dimension, is the factor most easily influenced by other factors. Therefore, for the personal dimension, it is important to focus on the special contribution of safety awareness that can help reduce construction workers' unsafe behaviors [37].

From the analysis of organizational environment dimension (K_5, K_6, K_7, K_8), organizational climate, work quota, and safety plan are the three elements with relatively high centrality, which indicates that these three elements are closely related to the occurrence of unsafe behaviors of construction workers. The work environment with the highest cause degree is in the first place in the whole index system. The work environment has the greatest influence on other indicators hence it is in the core position in the indicator system. It is the most important core indicator affecting construction workers' unsafe behavior with the strong constraint and drive [38, 39].

The analysis of the safety management dimension (K_9, K_{10}, K_{11}, K_{12}) showed the concernment of superior has the highest centrality. It indicates that concernment of superior has the strongest strength of total influence relationship in construction workers' unsafe behaviors and is the key indicator in this dimension. Safety supervision and education place are in an inferior position, indicating that they are also factors that need to be valued. Among the four dimensions of the safety management dimension, the cause group has technical delivery, and the outcome group consists of safety supervision, safety education, and technical delivery. With the lowest cause degree, technical delivery is the most vulnerable to other factors in the whole system and need to be specificity needs attention. Under the safety management dimension, safety education and safety supervision are the more susceptible factors that need special attention in reducing construction workers' unsafe behaviors [1, 40, 41].

5.1.2. ISM Results Analysis. Figure 4 shows that the influencing factors show a multilevel distribution. The work environment (K_5) is the lowest level factor, has an effort on other factors, indicating that the work environment is the fundamental factors of construction workers' unsafe behavior. Concernment of superior (K_{11}), safety supervision (K_9), work quota (K_7), organizational climate (K_6), safety plan (K_8), and safety education (K_{10}) are located in the second to fifth strata. They influence and are influenced by other factors, and are indirect factors on construction workers' unsafe behavior. For example, concernment of superior is influenced by the harshness of the working environment, while concernment of superior also influences the regulation of safety supervision or not. Safety consciousness (K_1), psychological status (K_2), technical briefing (K_{12}), professional skills (K_4), and physical health (K_3) are in the first layer. All of these indicators directly act on the total evaluation index of construction workers' unsafe behaviors and are the direct influencing factors of construction workers' unsafe behaviors.

5.1.3. MICMAC Results Analysis. As shown in Figure 5, safety awareness (K_1), technical delivery (K_{12}), and safety education (K_{10}) are located in the second quadrant, characterized by high dependence and low driving force, and are dependent elements. They show strong dependency and can be influenced by all indicator factors. It is important to strengthen the monitoring of the whole indicator system to achieve effective management [42].

Psychological status quality (K_2), physical health (K_3), professional skills (K_4), organizational climate (K_6), work quota (K_7), and safety plan (K_8) are located in the third quadrant. This quadrant, characterized by low dependency, low driving force, is autonomous element. The six factors are divided into two parts, one is psychological status quality (K_2), physical health (K_3), and professional skills (K_4). The other is organizational climate (K_6), work quota (K_7), and safety plan (K_8). Comparing these two parts, it was found that the former is significantly less dependent and driven than the latter. It indicates that psychological status, physical health, and professional skills are hardly influenced by other factors. Therefore, these factors should be considered separately when analyzing the factors influencing construction workers' unsafe behaviors.

Work environment (K_5), safety supervision (K_9), and concernment of superior (K_{11}) are located in the fourth quadrant, and this quadrant is characterized by low dependence and high drive, which are independent elements. It indicates that these factors are weakly influenced by other factors, but have a strong driving effect on other factors. These factors have an important influence to the construction of workers' unsafe behaviors. Therefore, these factors need to be focused on when improving workers' unsafe behaviors. They have a greater influence on the whole evaluation system and should be listed as the primary research factors.

5.2. Improvement Measures. As for the construction worker dimension, a parallel approach of safety psychological status intervention and behavioral intervention is adopted at the construction site. The SCL-90 scale is regularly used to assess construction workers' psychology, detect and solve in a timely manner, in terms of work teams and project departments. Selecting teams with good safety habits and setting up benchmark awareness to enhance the safety awareness of construction workers from the psychological status level [43]. Standardization of safety awareness is an effective way to improve construction workers' unsafe behaviors in the short term. Professional skills are objectively uncontrollable factors determined by construction workers themselves. In order to improve the professional skills of construction workers, apprenticeship system can be carried out, and the system of taking the old with the new can be implemented. The "one with one" model can be adopted, and humanistic care should be emphasized to improve the treatment of frontline workers.

From the dimension of the organizational environment, a safety-oriented organizational atmosphere can be established by reasonably formulating safety plans and strengthening the implementation of main responsibilities. A good safety atmosphere can have an indirect influence on avoiding construction accidents [44]. Individual and group behavior complement each other, they are all the basis of the organization. In order to ensure the construction cycle, the construction workers can be trained in early stage, establishing the concept of "efficiency is the main focus, time is supplementary". On the one hand, construction workers can also be classified and assigned to their respective duties, and work can be reasonably distributed based on the principle of "matching ability with work." On the other hand, the working environment is the most important part of the model, a cluttered site, unsafe construction environment, will cause the occurrence of unsafe behavior. At present, the building construction field in China is mainly outdoor, with long project cycle, temperature factor, thunderstorm weather will cause construction workers body discomfort, affecting the site construction workers work state, these reasons will threaten the safety of construction workers. In addition, the "14th Five-Year Plan" for the development of the construction industry clearly put forward to improve the social insurance contribution mechanism for construction workers, to protect occupational safety and health rights. The basic configuration of construction site living environment, labor protection, and operating environment should be fully implemented. In addition, continuously improve the production and living environment of construction workers.

From the dimension of safety management, technical delivery belongs to the factors that are subjective and easy to control. The implement the technical delivery in the construction process of the project to help enhance the job competency of construction workers. At the same time, with characteristic of the long construction period, large scale, and costly human and financial resources, safety management must be guaranteed for construction projects. Therefore, attaching the importance of safety education and strengthening safety supervision is considered as an effective solution.

6. Conclusions

This paper reveals the mechanisms of unsafe behaviors by construction workers from personal, organizational context, and safety management. In theoretical perspective, the conclusions of this paper contribute to the current understanding of decision-making processes in organizational behavior. In practical point of view, this paper can reduce the occurrence of safety hazards in construction site and unsafe behavior of construction workers, improve the management ability of managers, and promote the transformation and upgrading of the construction industry and the healthy development of the national economy. From the perspective of methodology, this paper introduced the DEMATEL-ISM-MICMAC method into the field of unsafe behavior of construction workers to solve the problem of safety management and fill the gap in the academic community. From the content point of view, taking the unsafe behavior of construction workers as the background, the DEMATEL-ISM-MICMAC method is used to answer the influence relationship and interaction between the factors from both macro and micro aspects. Combining context, the background of the research about using the DEMATEL-ISM-MICMAC method is a gap in the field of construction workers and in the field of behavioral safety. According to the full text, the existed research content mainly analyzes one or a class of influencing factors, lacking the holistic view. The influence of individual, organizational climate, and safety management on construction workers' unsafe behavior is mainly reflected on the interrelationship between the influencing factors of each dimension. The DEMATEL method was used to microanalyze the intercorrelation of the factors and the importance of the factors. The most important indicator in the personal dimension, safety awareness ranks the first place among personal dimension. The work environment is in the first place in the whole index system, and it is also the most important core index affecting construction workers' unsafe behavior. About the whole index system, the centrality of leadership is in the first place, which is the key indicator in the safety management dimension. The lowest degree reason is technical delivery, which is vulnerable to other factors and needs to pay attention to its special characteristics.

The factors were analyzed hierarchically at the macro level by the ISM method, and the ISM multilevel recursive explanatory structure model was constructed. The model suggested that the work environment and concernment of superior were the most fundamental influencing factors, which ran through the whole model and needed extra attention. When managers are formulating management policies, this factor is a factor that cannot be ignored. The DEMATEL-ISM model results were further analyzed by the MICMAC method, which facilitated a deeper inquiry into the relationship between the factors. The specific values of drivers and dependencies obtained from this step were categorized into four quadrants. Psychological quality, physical quality, professional skills, organizational climate, workload, and safety plan are located in the third quadrant, which is characterized by low dependence and low driving force; safety awareness, technical delivery, and safety education are located in the second quadrant, which is characterized by high dependence and low driving force. Work environment, safety supervision, and concernment of superior were located in the fourth quadrant, which was characterized by low dependence and high driving force. Further validation of the conclusions obtained from the MICMAC and ISM methods was consistent, enhancing the validity, accuracy, and persuasiveness of the model.

The system of influencing factors about unsafe behavior of construction workers contains six layers. Combined with the driving dependency matrix, the fourth to sixth layers are work environment, concernment of superior, and safety supervision. These three influencing factors have the highest driving power and are independent factors, which are the most important influencing factors of the whole system. Next, the autonomy factor is divided into two parts. One is organizational climate, work quota, and safety plan, which belong to the second to fourth layer, the other is psychological status, physical health, and professional skills, which belong to the first level. The second part is weakly dependent and needs to be considered separately when reducing unsafe behavior of construction workers. The dependent factors are safety awareness, safety education, and technical briefing, which are in the first two layers, they are dependent and need to be strengthened to pay attention to the factors.

The results of the study provided rationalized recommendations for construction site managers. The formation of the unsafe behavior management system depends on the comprehensive investment of all departments in people, materials, information technology, and policies. The government should increase the support of information technology in the construction field, strengthen the integration of various professions, and deepen the development of information technology in the knowledge of the construction industry, which is mainly reflected in the formulation and inclination of policies. Construction site managers are the actual formulators and direct beneficiaries of the management policy, so the management policy should be combined with the latest research results and keep pace with the times. The proposal of management policy should be supported by enough latest theories. At the same time, on-site construction personnel need to comply with construction site regulations and listen to the policies of each department to minimize the dangers. Work environment and leadership emphasis affect the whole model. It is necessary to establish a management system centered on them. According to the research results of this paper, the main measures to improve unsafe behavior are as follows. First, safety awareness and humanistic care should be established, combining with safety psychological intervention and behavioral intervention. What's more, the competency of construction workers is supposed to be stressed. In addition, the technical disclosure, safety plans, and strengthen the implementation of main responsibilities in the project construction process should be formulated. As for the administrator, establish an organizational atmosphere about security; attach importance to safety education, strengthen safety supervision, improve the employment system of enterprises, and standardize the management of construction safety data is necessary. Finally, the frontline working environment of construction, reasonable arrangement of work plan, and skills training need more attention.

This paper constructed a system about factors influencing unsafe behavior of construction workers. The data analysis was carried out by the DEMATEL-ISM-MICMAC hybrid method, enriched the model quantification tools about construction safety. It provided a scientific research model for the study of construction workers' unsafe behaviors. But there are still some limitations in this paper. Such as the subjectivity of 12 factors in this paper. Although these determined factors were obtained by literature review and expert ratings, some factors that affect the unsafe behavior may be ignored. In order to make the research more authoritative, the diversity of samples needs to be strengthened. In addition, this paper does not clarify whether the factors are positively or negatively correlated with each other and some efforts should to be done in the future.

Data Availability

The data used to support the findings of this study are included within the article.

Consent

Informed consent was obtained from all subjects involved in the study.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to have influenced the work reported in this paper.

Authors' Contributions

Qing Liu contributed in the methodology and writing review—funding acquisition; Yanxiang Liang contributed in the writing—original draft preparation; Hui Jiang contributed in the policy analysis—funding acquisition; Tao Gao contributed in the resources and data curation. All authors have read and agreed to the published version of the manuscript.

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