SAFETY CULTURE SYSTEM ELEMENTS OF SMALL AND MEDIUM-SIZED CONSTRUCTION ENTERPRISES AND ITS EVALUATION METHOD

Jia HONGMEI[1], Wang JIANWEI[2], Liu SUXIA[3], Li LIXIA[4]

[1]School of ART, Jiangsu University, Zhenjiang Jiangsu 212013, China

[2,3,4]School of Environment and Safety Engineering, Jiangsu University, Zhenjiang Jiangsu 212013, China

Corresponding author: Li Lixia

Email: jiamei@ujs.edu.cn

Abstract:

While the construction industry has contributed significantly to the construction of national infrastructure and the enhancement of residents' living quality, many small and medium-sized construction industries have still been troubled by frequent accidents. Safety accidents have become an essential factor affecting their development of them. The construction of a safety culture is a critical way to solve this kind of problem and enhance the essential safety of these enterprises. Here, adopting the expert survey method, integrating the construction of safety culture with the existing system and work content, an element system of safety culture construction that contains eight primary elements and 32 secondary elements was developed, which could provide a practical and theoretical reference for the construction of safety culture in small and medium-sized construction enterprises. Through the expert survey method and hierarchical analysis method, the weights and sorting of each element were determined, which could guide the construction of enterprise safety culture efficiently. Next, a quantitative evaluation based on a fuzzy comprehensive evaluation of the overall effect of the construction of safety culture was proposed. It could support small and medium-sized construction enterprises to discover the short boards of construction, formulate strategies for continual improvement, and assess the safety culture of construction. Meanwhile, this safety culture system and evaluation method could be a reference for management departments or third-party organizations to manage and evaluate this type of enterprise.

Keywords: Construction Enterprise, Safety Culture, Safety Culture Elements, Analytic Hierarchy Process

INTRODUCTION

According to the investigation and statistical analysis of the national casualty accidents, the construction industry has a high incidence of safety production accidents. Therefore, it is urgent to reduce construction safety accidents in construction enterprises and improve the essential safety of construction enterprises (Li et al., 2023; Zhou. et al., 2023). Carrying out cultural construction is an effective way to enhance the essential safety of construction enterprises. Construction enterprise safety culture is usually defined as a unity composed of values, attitudes, morals, and behavioral norms recognized by staff at all levels, which emerge during the long-term development of

construction enterprises (Li & Wang, 2009). Business leaders, managers, and employees all play a pivotal role in the construction of safety culture in construction enterprises, and their safety quality directly affects construction safety and efficiency. At present, safety values, safety awareness, safety attitudes, abilities, and behaviors have gradually become the main factors restricting the essential safety of construction enterprises. Promoting all practitioners' awareness of safety responsibility and enhancing their safety skills while actively engaging them in developing a safety culture holds significant importance in enhancing the core competitiveness of construction companies (Han et al., 2018; Fu et al., 2013; Jeff. 2022). The construction of construction enterprise safety culture in China began in the 1980s (Dai, 2017). It was in 2008 that the Chinese government promulgated the <Guidelines for the Construction of Enterprise Safety Culture> (AQ/T9004-2008), which has provided theoretical support for the construction of enterprise safety culture. Till now, most large-scale construction enterprises in China have established a relatively perfect safety management system, carrying out safety standardization and dual prevention mechanism construction. However, it cannot be directly applied to guide small and medium-sized construction enterprises because it is inconsistent with the actual construction enterprise management mode. At the same time, the relevant management departments still need a comprehensive evaluation system targeted at the safety culture in construction enterprises. These small and medium-sized construction enterprises have weak cultural foundations, small scale, and limited economic strength, so it is also difficult to directly apply the experience of safety culture construction of large enterprises. Therefore, studying safety culture system elements of small and medium-sized construction enterprises and its evaluation method has excellent practical significance. Nantong, the famous hometown of construction, is known as the 'Iron Army of Construction.'. The Nantong area's small and medium-sized construction enterprises were selected as this research object. A safety culture framework was developed for a construction company through the expert survey method. The framework includes specific content and implementation suggestions for each element based on an in-depth understanding of the company's safety status. With the expert survey method and hierarchical analysis method, the weight and sorting of each element are determined. Then, using the weights of each element, a quantitative evaluation based on a fuzzy comprehensive evaluation for the overall effect of the construction of safety culture was proposed. It could support the continuous improvement of the safety culture construction in small and medium-sized construction enterprises. Also, it could provide a reference for relevant management departments and third parties to manage and evaluate the construction culture of small and medium-sized construction enterprises.

Safety Culture System Elements of Small and Medium-Sized Construction Enterprises, Safety Culture System Elements. According to the specific requirements of AQ/T 9004-2008, the content of safety construction norms such as <Technical Specification for Safety Preventive Engineering> GB50348-2018, as well as the characteristics of the small and medium-sized construction enterprise management, the element system of the safety culture of small and medium-sized construction enterprises was preliminarily drawn up and form the questionnaire, see questionnaire1 in Supporting information. Through the expert survey method, questionnaires and interviews were conducted with safety officers, safety managers, and supervisors, and evaluations were made to obtain opinions on the modification and improvement of the element system. It was finally determined that the construction element system for the safety culture of small and medium-sized construction enterprises included eight primary elements and 32 secondary elements, referring to Table S3 in Supporting Information.

Specific Contents and Implementation Suggestions for Safety Culture Elements. (1) Safety culture construction system. The 'safety culture construction system' element can rely on the existing safety management institution of the enterprise to determine the personnel and responsibilities of

safety culture construction. The element of 'safety culture construction leadership system' requires the establishment of a leadership mechanism for leaders to organize, participate in, and supervise the entire process of safety culture construction, regularly organize relevant training and meetings, deploy and promote the work of enterprise safety culture construction, and safeguard the capital investment for enterprise safety culture construction. The 'safety culture construction planning' element makes it clear for enterprises to define safety culture construction tasks, methods, measures, labor division, time limit, and assessment requirements. Construction capital planning' means that the capital investment in safety culture is clearly defined and included in the estimated safety investment budget based on the construction plan (Fernando & Carlos. 2022).

(2) Safety culture concept. The most basic core of safety culture is 'people,' who form the understanding and awareness of safety. In contrast, the enterprise safety culture consciousness is a whole with effectiveness depending on each enterprise staff. 'Safety policy' is a programmatic document for the safety culture construction in enterprises, which can reflect the overall safety values of the enterprise. The enterprise can refer to the national safety production policy and learn from large-scale construction enterprises. 'Safety targets' serve as the final result of enterprise safety construction, and different levels of general targets, sub-targets, and personal targets are set up. The 'Leader's Safety Commitment' element requires the leader to pay attention to, personally carry out, and practice the safety commitment, set an example for the staff, and fulfill their responsibilities in the work safety accountability system. The 'Safety Commitment of Employees and Related Parties' element requires all employees and related parties to make a safety commitment and consciously carry it out to fulfill their responsibilities in the work safety accountability system.

(3) Safety code of conduct. The element of a 'safety management system' requires enterprises to improve the existing safety management system and add systems related to the process of building a safety culture, such as safety inputs, observation and improvement of safety behaviors, safety role models, safety activities, and evaluation and improvement of safety culture construction; it is recommended that top, middle, and bottom leaders and grassroots employees all participate in the development of the system. The 'job operation rules and regulations' are the operation rules and regulations for the original jobs in the enterprise, which contain the safety requirements for the job, aiming at standardizing the operation conduct of the employees and preventing and safeguarding against insecurity; the middle leaders and the front-line employees should work together to formulate the rules. The enterprise routinely engages in 'Safety risk classification and control and hidden risk detection mechanism.' Employees are strongly advised to identify, assess, manage, and discover hidden risks associated with their respective roles, equipment utilization, operational tasks, and processes. 'Contractor safety management' also refers to the original work of the enterprise, aiming at regulating the safety conduct of contractors and strengthening safety awareness. The element of 'safety behavior observation and improvement' can be established to set up observer positions to understand the work of construction personnel's thinking and behavioral habits at any time, find undesirable phenomena, and improve promptly. The stop card or BBS can be adopted to encourage employees to carry out safety discussions. With their remarks and safety behavior observed, the establishment of enterprise employee safety conduct can thus be improved (Osei-Asibey et al., 2021).

(4) Safety education and training. 'Safety knowledge and skills' refers to the training on the job operating procedures, job risks, and hidden risk investigation ability. The main content of 'typical cases' focuses on attempted accidents as well as cases of accidents and improvements within the enterprise or similar jobs in other enterprises; 'Safety laws and regulations' enables leaders and employees to understand their obligations and powers in safety; the above elements, as well as

'three-level education' and 'emergency response capability,' are part of the work of most construction companies and need to be maintained.

(5) Safety behavior incentives. The 'evaluation of leaders' safety targets and commitments' requires enterprises to assess their leaders regularly and expects them to set a tangible example and provide data for the higher management to monitor. It is also required by the element of 'evaluation of employees' safety targets and commitments' to regularly evaluate their employees to ensure that safety targets are accomplished, and employee responsibilities are fulfilled. "Employee safety performance and job performance assessment" necessitates that enterprises evaluate both employee safety performance and job performance. This evaluation aims to identify areas of concern, allowing for the provision of rewards (with an emphasis on rewards) or penalties. It is also a valuable data source to effectively tailor safety education and training initiatives. The above elements can be combined in the original work content of the enterprise. The 'safety role model' element requires enterprises to reward employees or groups that have made safety commitments, accomplished safety goals well, and behaved safely, and set them up as safety role models to motivate employees to learn and improve independently.

(6) Safety environment culture. The element of 'visualization management' requires enterprises to post safety signs, warning signs for significant safety risk areas or safety risks, signs informing of more significant safety risks, signs displaying the wearing of PPE, signs displaying entry safety instructions, and public notices of safety production, which can be implemented based on the original work of the enterprise. The 'emergency facilities' element requires enterprises to configure appropriate equipment and perform maintenance. The element of 'on-site safety inspection' requires enterprises to develop all-weather and all-round job, departmental, and professional safety inspections with the participation of all staff. Most enterprises have already carried out the first two elements, while on-site safety inspection needs to be strengthened.

(7) Safety information dissemination. The 'safety information dissemination system' element requires enterprises to establish hardware platforms or networks for safety information dissemination, such as telephone, SMS, e-mail, information platforms, and conference rooms, to provide hardware protection for safety information dissemination. The 'safety risk hidden accidents reporting and alarm' element requires enterprises to formulate safety risk and hidden danger accident reporting and accident alarm processes and establish emergency plans. It is set clear by the element of 'safety publicity' that enterprises should publicize internal safety role models, safety accidents, industry-related safety events, the latest safety technologies, safety policies, standards, and severe accidents using circulars, paper posters, and new media. The 'safety day activities' element means enterprises should organize regular safety construction activities by departmental groups to learn safety knowledge and exchange safety experience.

(8) Review and evaluation. 'Regular review and evaluation' require enterprises to review the construction of safety culture regularly; the combination of quantitative evaluation of secondary elements and overall fuzzy comprehensive evaluation of the effect of safety culture construction can be considered, and the evaluation frequency can be once a year. The 'safety culture construction report' requires that the evaluation process and results be organized into a safety culture construction report to facilitate inspection and preparation for the next stage of work. The element of 'continuous improvement measures" requires enterprises to put forward improvement measures for the insufficient, unreasonable, and imperfect places in the process of safety culture construction and then make improvements in the following year.

METHODS

The Weights of the Elements of Safety Culture System. Enterprises can construct a safety culture based on the contents and suggestions of Section 1.2 and following the actual situation of enterprises. Due to the complexity of enterprise safety work, the construction of safety culture needs to grasp the main contradictions and critical issues in the process of practice, which necessitates analyzing the importance of 32 elements to the construction of enterprise safety culture. Determining the importance of each element requires analyzing, comparing, judging, and evaluating each element, and finally making a judgment of importance, in which the human subjective elements occupy a large proportion and must be solved using statistical mathematical tools. Moreover, the analytic hierarchical process is a hierarchical, weighted decision analysis method proposed by American mathematician Saaty around 1970, which can effectively deal with this kind of problem (Ge et al., 2023; Huang et al., 2020).

Hierarchical Structure Model of Safety Culture Elements System. With the level of safety culture construction of construction enterprises set as the target level, eight primary elements as the criterion level, and 32 secondary elements as the program level, the hierarchical structure model of safety culture construction of construction enterprises was thus established, which was an entirely independent hierarchical structure model as shown in Figure 1.
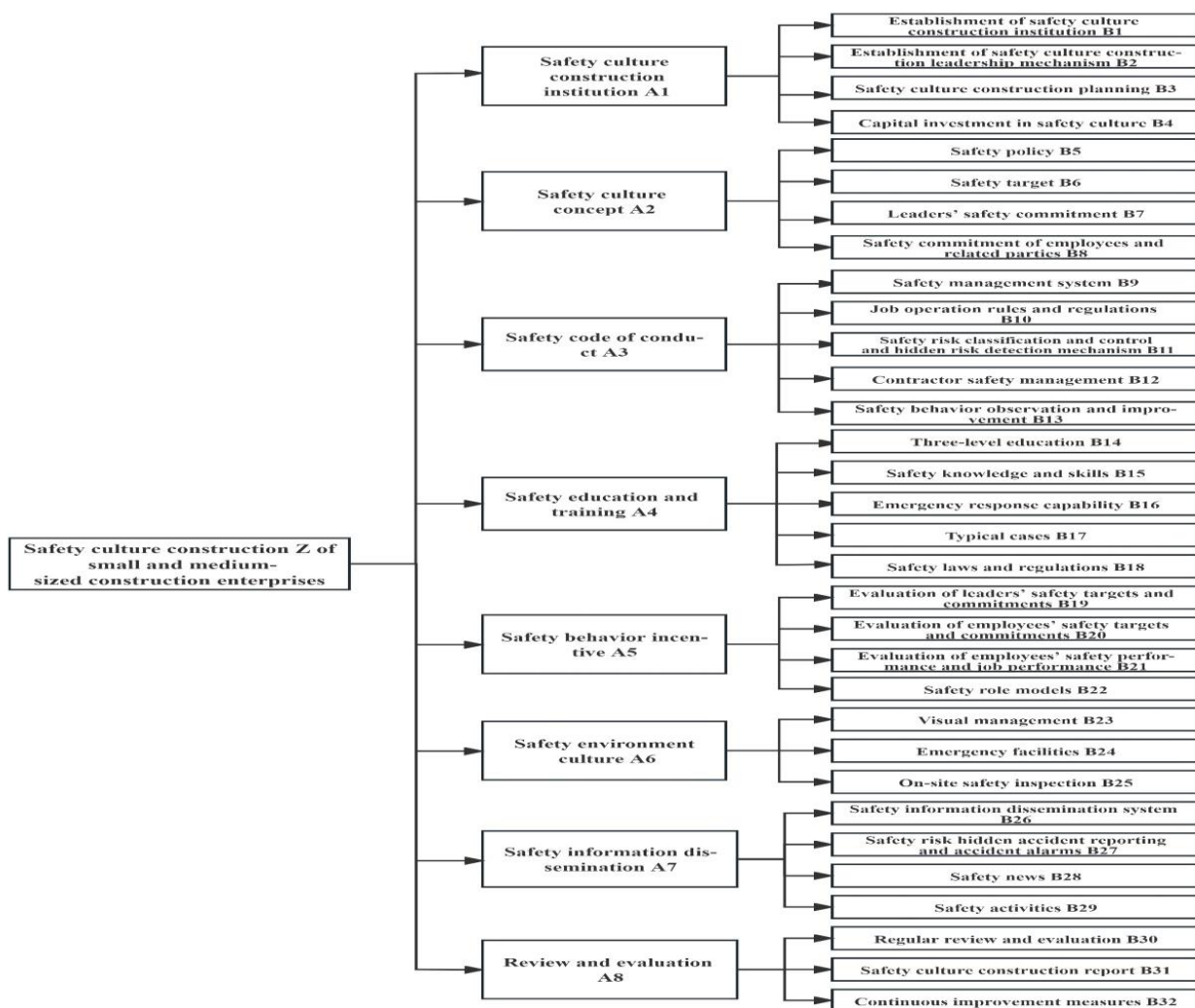
Figure 1. Hierarchical structure model of safety culture construction elements in small and medium-sized construction enterprises

The Construction of a Judgment Matrix. The judgment matrix is the basic information for the weighting analysis of each element, and here, the judgment matrix refers to the judgment value of the importance of each element of each level concerning the importance of an element of the previous level, written as a result in the form of a matrix. The usual practice is to determine the importance of the element of a level relative to the previous criterion level by comparing the n elements of that level two by two; the experts score the weights by the 1-9 scale method, and the judgment matrix is constructed by using aij to indicate the comparison results of each element in the ith row relative to the element in the jth column. Here, the expert survey method was used for consultation and scoring, and the questionnaire was drawn up, see Questionnaire 2 in Supporting Information. According to the scoring results, one 8×8 judgment matrix, two 5×5 judgment matrices, four 4×4 judgment matrices, and two 3×3 judgment matrices, a total of nine matrices, were obtained as follows.

(1) Judgment matrix of safety culture construction in construction enterprises.

$$
A = \begin{bmatrix}
1 & 5 & 1 & 5 & 1 & 5 & 5 & 1 \\
\frac{1}{5} & 1 & \frac{1}{5} & 1 & \frac{1}{5} & 1 & 5 & \frac{1}{5} \\
1 & 5 & 1 & 5 & 3 & 5 & 5 & 1 \\
\frac{1}{5} & 1 & \frac{1}{5} & 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} \\
1 & 5 & \frac{1}{3} & 3 & 1 & 5 & 3 & 1 \\
\frac{1}{5} & 1 & \frac{1}{5} & 3 & \frac{1}{5} & 1 & 1 & \frac{1}{5} \\
\frac{1}{5} & \frac{1}{5} & \frac{1}{5} & 3 & \frac{1}{3} & 1 & 1 & \frac{1}{5} \\
1 & 5 & 1 & 5 & 1 & 5 & 5 & 1
\end{bmatrix}
$$

(2) Judgment matrix of safety culture construction institutions

$$
B_1 = \begin{bmatrix}
1 & \frac{1}{5} & \frac{1}{3} & \frac{1}{5} \\
5 & 1 & 3 & 1 \\
3 & \frac{1}{3} & 1 & 3 \\
5 & 1 & 3 & 1
\end{bmatrix}
$$

(3) Judgment matrix of safety culture concept

$$
B_2 = \begin{bmatrix}
1 & \frac{1}{3} & \frac{1}{5} & \frac{1}{5} \\
3 & 1 & \frac{1}{5} & \frac{1}{5} \\
5 & 5 & 1 & 1 \\
5 & 5 & 1 & 1
\end{bmatrix}
$$

(4) Judgment matrix of safety Code of conduct

$$B_3 = \begin{bmatrix} 1 & 1 & \dfrac{1}{5} & 1 & \dfrac{1}{3} \\ 1 & 1 & \dfrac{1}{5} & 1 & \dfrac{1}{3} \\ 5 & 5 & 1 & 5 & 3 \\ 1 & 1 & \dfrac{1}{5} & 1 & \dfrac{1}{3} \\ 3 & 3 & \dfrac{1}{3} & 3 & 1 \end{bmatrix}$$

(5) Judgment matrix of safety education and training

$$B_4 = \begin{bmatrix} 1 & \dfrac{1}{5} & 1 & 3 & 3 \\ 5 & 1 & 5 & 3 & 3 \\ 1 & \dfrac{1}{5} & 1 & 3 & 3 \\ \dfrac{1}{3} & \dfrac{1}{3} & \dfrac{1}{3} & 1 & 1 \\ \dfrac{1}{3} & \dfrac{1}{3} & \dfrac{1}{3} & 1 & 1 \end{bmatrix}$$

(6) Judgment matrix of safety behavior incentives

$$B_5 = \begin{bmatrix} 1 & 1 & \dfrac{1}{3} & 1 \\ 1 & 1 & \dfrac{1}{3} & 1 \\ 3 & 3 & 1 & 3 \\ 1 & 1 & \dfrac{1}{3} & 1 \end{bmatrix}$$

(7) Judgment matrix of safety environment culture

$$B_6 = \begin{bmatrix} 1 & 3 & \dfrac{1}{3} \\ \dfrac{1}{3} & 1 & \dfrac{1}{5} \\ 3 & 5 & 1 \end{bmatrix}$$

(8) Judgment matrix of safety information dissemination

$$B_7 = \begin{bmatrix} 1 & \dfrac{1}{5} & 1 & 1 \\ 5 & 1 & 5 & 5 \\ 1 & \dfrac{1}{5} & 1 & 1 \\ 1 & \dfrac{1}{5} & 1 & 1 \end{bmatrix}$$

(9) Judgment matrix of review and evaluation

$$B_8 = \begin{bmatrix} 1 & 5 & 1 \\ \dfrac{1}{5} & 1 & \dfrac{1}{5} \\ 1 & 5 & 1 \end{bmatrix}$$

Calculation of the Weight of Each Element. Its calculation method is detailed in the literature (Liu et al., 2020), and the statistics were calculated using its programmed SPSSAU online analysis software, the results of which are shown in Table 1.

Table 1. List of Weighting Results

Goal level	Criterion level (primary element)	Weight of element A to Z	Program level (secondary element)	Weight of element B to element A	Weight of element B to Z	Total sorting
Safety culture Construction Z of small and medium-sized construction enterprises	A1	0.21051	B1	0.06748	0.01421	21
			B2	0.39081	0.08227	4
			B3	0.15089	0.03176	8
			B4	0.39081	0.08227	4
	A2	0.05148	B5	0.06292	0.00324	30
			B6	0.10898	0.00561	25
			B7	0.41405	0.02132	17
			B8	0.41405	0.02132	17
	A3	0.24150	B9	0.08857	0.02139	14
			B10	0.08857	0.02139	14
			B11	0.49807	0.12028	1
			B12	0.08857	0.02139	14
			B13	0.23623	0.05705	7
	A4	0.03410	B14	0.18030	0.00615	23
			B15	0.47356	0.01615	20
			B16	0.18030	0.00615	23
			B17	0.08292	0.00283	31
			B18	0.08292	0.00283	31
	A5	0.16150	B19	0.16667	0.02692	10
			B20	0.16667	0.02692	10
			B21	0.50000	0.08075	6
			B22	0.16667	0.02692	10
	A6	0.04830	B23	0.25828	0.01248	22
			B24	0.10473	0.00506	29
			B25	0.63699	0.03077	9
	A7	0.04210	B26	0.12500	0.00526	26
			B27	0.62500	0.02631	13
			B28	0.12500	0.00526	26
			B29	0.12500	0.00526	26
	A8	0.21051	B30	0.45455	0.09569	2
			B31	0.09091	0.01914	19
			B32	0.45455	0.09569	2

The consistency testing data of the weights of each element are shown in Table 2. As all elements have passed the consistency testing, the above data encompassing weights and importance sorting have been proven valid.

Table 2. Consistency Checking Table for Each Judgment Matrix

The construction of a judgment matrix	λ_{max}	n	CI	RI	CR	Consistency testing
Judgment Matrix of Safety Culture Construction in Small and medium-sized Construction Enterprises	8.70695	8	0.10099	1.41	0.07163	Pass
Judgment Matrix of Safety Culture Construction institutions	4.04338	4	0.01446	0.89	0.01625	Pass
Judgment matrix of safety culture concept	4.15326	4	0.05109	0.89	0.05740	Pass
Judgment matrix of safety Code of conduct	5.04174	5	0.01043	1.12	0.00932	Pass
Judgment matrix of safety education and training	5.42678	5	0.10669	1.12	0.09526	Pass
Judgment matrix of safety behavior incentives	4	4	0	0.89	0	Pass
Judgment matrix of safety environment culture	3.03851	3	0.01926	0.52	0.03703	Pass
Judgment matrix of safety information dissemination	4	4	0	0.89	0	Pass
Judgment matrix of review and evaluation	3	3	0	0.52	0	Pass
Consistency testing of total sorting			0.01276	0.85763	0.01488	Pass

As can be seen from Table 1, the weights of A1 (safety culture construction institution), A2 (safety culture concept), A3 (safety code of conduct), A4 (safety education and training), A5 (safety behavior incentives), A6 (safety environment culture), A7 (safety information dissemination), and A8 (review and evaluation) to the target level of 'safety culture construction of construction enterprises' are 0.21051, 0.05148, 0.24150, 0.03410, 0.16150, 0.04830, 0.04210 and 0.04210, respectively. The weights can be ranked as follows: A3＞A1=A8＞A5＞A2＞A6＞A7＞A4. Therefore, special attention should be paid to the construction of a safety code of conduct for enterprise employees, followed by the construction of safety culture construction institutions and timely review and evaluation.

Among secondary elements, the weights of B1 (establishment of safety culture construction institution), B2 (establishment of safety culture construction leadership mechanism), B3 (safety culture construction planning), B4 (capital investment in safety culture construction) to the criterion level A1 (safety culture construction institution) are 0.01421, 0.08227, 0.03176, 0.08227, respectively. The weights can be obtained in the following order: B2 = B4 > B3 > B1. The importance of the secondary elements of criterion level A2 (safety culture concept) relative to A2 are B7 (leaders' safety commitment) = B8 (safety commitment of employees and related parties) > B6 (safety targets) > B5 (safety policy). The importance of the secondary elements of criterion level A3 (safety code of conduct) relative to A3 are B11 (safety risk classification and control and hidden risk detection mechanism) > B13 (safety behavior observation and improvement) > B9 (safety management system) = B10 (job operating procedures) = B12 (contractor safety management). The importance of the secondary elements of criterion level A4 (safety education and training) relative to A4 is B15 (safety knowledge and skills) > B14 (three-level education) = B16 (emergency response capability) > B17 (typical cases) = B18 (safety laws and regulations). The importance of the secondary elements of criterion level A5 (safety behavior incentives) relative to A5 is B21 (evaluation of employees' safety performance and job performance) ＞ B19 (evaluation of leaders' safety targets and commitments) = B20 (evaluation of employees' safety targets and commitments) = B22 (safety role models), respectively. The importance of the secondary elements of criterion level A6 (safety environment culture) relative to A6 is B25 (on-site safety inspection) > B23 (visual management) > B24 (emergency

facilities), respectively. The importance of the secondary elements of criterion level A7 (safety information dissemination) concerning A7 is B27 (safety risk hidden accident reporting and accident alarms) > B26 (safety information dissemination system) = B28 (safety news) = B29 (safety activities). The importance of the secondary elements of criterion level A8 (review and evaluation) relative to A8 is B30 (regular review and evaluation) = B32 (continuous improvement measures) > B31 (safety culture construction report).

As seen from the data in the sixth and seventh columns of Table 2, the importance of each secondary element for the construction of enterprise safety culture varies. However, its essential sorting is a more realistic response to the key to enhancing the essentiality of safety, for example, the element with the most significant weight of the safety risk classification and control and hidden risk detection mechanism (0.12028), which has been the focus of the enterprise's safety work for the last few years, and also an essential hand of the governments at all levels in the supervision of the enterprise. The construction of such a mechanism can significantly reduce accidents and attempted accidents. Regular review and evaluation (0.45455) and continuous improvement measures (0.45455), which are the second most important in terms of weight, are the front-loading of safety work. Through regular review and evaluation, risks and hidden dangers can be discovered, and appropriate improvement measures can be taken to prevent them from occurring before too late, thus significantly reducing the losses of the enterprise. In general, the weighting analysis of the elements of the safety culture construction system of small and medium-sized construction enterprises can provide a practical reference for the efficient development of enterprise safety culture construction and provide essential data for evaluating the effect of enterprise safety culture construction.

RESULT AND DISCUSSION

Evaluation Methods for the Effectiveness of Safety Culture Construction. For the evaluation of the primary elements and the overall effect of the construction of enterprise safety culture, they belong to a fuzzy phenomenon. For example, in the element of safety culture concept, which included four secondary elements, the construction effect of each secondary element was not the same, and each secondary element was not the same as the importance of the concept of safety culture, so how to evaluated the construction effect of the element of safety culture concept? The same was true for evaluating the overall effect of enterprise safety culture construction. For this kind of problem, the fuzzy comprehensive evaluation method can be applied (Hing & Xiao, 2013). After the bottom elements are evaluated, the bottom-level evaluation results are used to conduct a comprehensive evaluation of the high level, evaluating step by step (Manickam et al., 2023).

(1) Establish a multilevel (multilevel) fuzzy comprehensive evaluation model, i.e., divide the element domain U into several subsets, i.e., U= {U1, U2,..., Up}

Referring to Table 1 here, the safety culture construction system of small and medium-sized construction enterprises includes nine fuzzy sets, namely one right-element set and eight subsets. Element domain U= {u1, u2, u3, u4, u5, u6, u7, u8} = {Safety culture construction institution, safety culture concept, safety code of conduct, safety education and training, safety behavior incentives, safety environment culture, safety information dissemination, review and evaluation}. Eight subsets u1= {u11, u12, u13, u14} = {establishment of safety culture construction institution, establishment of safety culture construction leadership mechanism, safety culture construction planning, capital investment in safety culture}; similarly, the other elements in the subsets of u2, u3, u4, u5, u6, u7, u8 exist as their secondary elements.

(2) Determine the rubric level domain V, V= {v1, v2, …, vn}

Here, to determine the rubric level domain V = {excellent, good, medium, pass, poor}, a value can be assigned as follows: excellent = 95, good = 85, medium = 75, pass = 65, poor = 55.

(3) Set the weight coefficients of each element (or subset) separately by level

As can be seen from Table 1, the weight coefficients of each subset of the element domain U={u1, u2, u3, u4, u5, u6, u7, u8}are a={0.21051, 0.05148, 0.24150, 0.03410, 0.16150, 0.04830, 0.04210, 0.21051}; the subset u1={u11, u12, u13, u14}, the set of weight coefficients of each element in subset b1={0.06748, 0.39081, 0.15089, 0.39081}; similarly, the set of weight coefficients of each element in the other subsets can be obtained from the fifth column of Table 2.

(4) Evaluate all the underlying elements of each subset and establish the fuzzy relationship matrix of each subset

The scoring method is used to evaluate each element in the subset concerning the rubric level thesis domain V. Take the u6 subset as an example; set 10 people for scoring, of which six people think that enterprise visual management u61 is excellent, two people rate good, two people rate medium, no one rates fail and poor, then the rubric affiliation of u61 is as follows in the first row of the table. The same method of assigning values to u62 and u63 is shown in Table 3.

Table 3. Table for u6 Subset Rubric Level Ass

Element	Excellent	Good	Moderate	Pass
u_{61}	0.6	0.2	0.2	0
u_{62}	0.5	0.3	0.1	0.1
u_{63}	0.2	0.4	0.2	0.1

From this, the fuzzy relationship matrix of the u6 subset can be obtained as follows: u6.

(5) Comprehensive evaluation of each subset with synthetic operators. Take the subset u6 as an example. The element weights in the subset U6 = {u61, u62, u63} are b6 = {0.25828, 0.10473, 0.63699}, and using the synthesis operator b6 ⋅u6 =, which yields:

b6 ⋅u6= {0.25828, 0.4, 0.2, 0.1, 0.1} = (normalized)

From the above fuzzy vectors of comments, it can be seen that the construction effect of 'safety environment culture' for the {Excellent, Good, Medium, Pass, Poor} has a degree of affiliation of {0.244, 0.378, 0.189, 0.0945, 0.0945}, and the degree of affiliation to Good is the highest, so it can be concluded that the construction effect of 'safety environment culture' is good. According to the assigned value, the evaluation score of the construction effect of the enterprise's 'safety environment culture' is 8.83 points.

(6) After each subset is calculated, high-level operators are synthesized until the highest level.

Here, the fuzzy relationship matrix of the U set, U=, can be obtained. The overall effect of enterprise safety culture construction for {excellent, good, medium, pass, poor} has the affiliation degree of {x1, x2, x3, x4, x5}, the overall evaluation of the effect of safety culture construction refers to the evaluation of the highest degree of affiliation, or the value assigned to the effect of the enterprise's safety culture construction. In this way, the evaluation of the primary elements or the overall construction effect of the enterprise's safety culture construction from internal employees or external experts can be reached, thus providing a reference for continuous improvement.

CONCLUSION

This study aims to enhance the level of safety in small and medium-sized construction enterprises by providing a reference method for assessing the quality of their safety culture system. The research focuses on small and medium-sized construction companies in Nantong, Jiangsu Province. The study investigates the elements of the corporate safety culture system and develops

an evaluation method for it. A system of safety culture construction elements for small and medium-sized construction enterprises was constructed by using literature research method, theoretical analysis method, and expert survey method, specifically including safety culture construction institution, safety culture concept, safety code of conduct, safety education and training, safety behavior incentives, safety environment culture, safety information dissemination, and review and evaluation eight primary elements, as well as thirty-two secondary elements. With all the elements analyzed in-depth, specific work contents and implementation suggestions were put forward to provide practical and theoretical references for constructing enterprise safety culture. The weights and sorting of the elements at all levels with the help of SPSSAU online analysis software were determined using the expert survey method and analytic hierarchical process, which provided a theoretical basis for the efficient and smooth development of enterprise safety culture construction. A quantitative fuzzy comprehensive evaluation based on the weights of the elements for the effect of whole safety culture construction was proposed, which could provide support for assessing the effect of enterprise safety culture construction, the search for weaknesses, and continuous improvement. The connotation of elements needs further improvement in the practice process, and its practicability and effectiveness must be further verified.

REFERENCES

Dai G.J. (2017). Research on Safety Culture Construction of Construction Enterprises [D]. Southwest Jiaotong University, Master's thesis.

Fernando Acabado Romana, Carlos Guillen Gestoso. (2022). Adopting a New Leadership Style for the Current Context.*American Journal of Industrial and Business Management, 12,* 894-918. https://doi.org/10.4236/ajibm.2022.125046

Fu G., He D.Y. (2013). Rediscussion on the Definition of Safety Culture and Evaluation Index of Construction Level[J]. *China Safety Science Journal,23*(4), 140–145. https://doi.org/10.16265/j.cnki.issn1003-3033.2013.04.026https://doi.org/10.16265/j.cnki.issn1003-3033.2013.04.026

Ge Rui, Deng Bingbing,Yao Wui Hua, Xu Ya Bo. (2023). Prediction of Industrial Enterprise Safety Production Accidents Based on Uncertainty Theory. *Safe, 44*(08), 17-22. https://doi.org/10.19737/j.cnki.issn1002-3631.2023.08.003

Han S.M., Lee S.M., Yim H.B., Seong P.H. (2018). Development of Nuclear Safety Culture Evaluation Method for an Operation Team based on the Probabilistic Approach. *Annals of Nuclear Energy, pp. 111,* 317–328. https://doi.org/10.1016/j.anucene.2017.07.018doi.org/10.1016/j.anucene.2017.07.018

Hing Kai Chan, Xiao jun Wang. (2013). Fuzzy-ANP Approach for Environmental Risk Assessment of Product Designs.Engineering (R0), 135–153 https://doi.org/10.1007/978-1-4471-5043-5_8doi.org/10.1007/978-1-4471-5043-5_8

Huang Z.A., Zhao W., Zhang Y.H. (2020). Safety Assessment of Emergency Training for Industrial Accident Scenarios based on Analytic Hierarchy Process and Gray-Fuzzy Comprehensive Assessment. IEEE Access, p. 8, 147776–147789. https://doi.org/10.1109/ACCESS.2020.3013671

Jeff Brown. (2022). Safety Culture and Communication in a Fulfillment Center: A Case Study. *Open Journal of Leadership, p. 2,* 13421. https://doi.org/10.4236/ojl.20:.112009

Karoline, R., Sunarto, S., Jamalullail, J., & Ariani, N. (2023). Elaboration Likelihood Model (Elm) as Interpersonal Communication in Persuading Consumers in the Era of Disruption. *International Journal of Environmental, Sustainability, and Social Sciences, 4*(4), 1048–1054.

Li F. (2023). Effect Evaluation and Countermeasure Analysis of Project Safety Management in Construction Enterprises. *Journal of Engineering Construction and Design, pp. 16*, 215–217. https://doi.org/10.13616/j.cnki.gcjsysj.2023.08.270

Li G.Z., Wang F.B. (2009). Analysis of Construction Accidents and the Construction of Safety Culture in Construction Enterprises. *Building Science, 12*,71-72. https://doi.org/10.16661/j.cnki.1672-3791.2009.12.068

Liu Y., Eckert Claudia, Earl Christopher. (2020). A review of Fuzzy AHP Methods for Decision-making with Subjective Judgements. *Expert Systems with Applications,161*,113738. https://doi.org/10.1016/j.eswa.2020.113738

Manickam Bhuvanesh Kumar, Rathinasamy Parameshwaran, Jiju Antony, Elizabeth Cudney. (2023). Framework for Lean Implementation Through Fuzzy AHP-COPRAS Integrated Approach. *IEEE Transactions on Engineering Management, 70* (11）, 3836–3848. https://doi.org/10.1109/TEM.2021.3089691

Osei-Asibey, D., Ayarkwa, J., Adinyira, E., Acheampong, A. and Amoah, P. (2021). Roles and Responsibilities of Stakeholders towards Ensuring Health and Safety at Construction Site. *Journal of Building Construction and Planning Research, 9,* 90-114. https://doi.org/10.4236/jbcpr.2021.91008

Setiawati, A., Ronda, M., & Seran, A. (2023). Individual Freedom and Netizen Presence as Others in Tiktok Social Media Creator Content Message Delivery. *International Journal of Environmental, Sustainability, and Social Science, 4*(4), 1027–1035.

State Administration of Work Safety. AQ/T 9004-2008 Guidelines for Enterprise Safety Culture Construction[S].

Zhou Peng, Zhang Ting Ting, Wang Yu. (2023). Study on the practice of corporate safety culture construction in Daqing Field.*Chinese Journal of Safety Science, 33*(S1), pp. 20–24. https://doi.org/10.16265/j.cnki.issn1003-3033.2023.S1.0328