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An evaluation of the information literacy of safety professionals

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ABSTRACT

Information literacy has gradually become one of the necessary qualities in current and future safety practices. The calculation and assessment of information literacy of safety professionals is an effective way to understand their information literacy level. This paper, therefore, aims to evaluate the information literacy level of safety management personnel, for improving their ability to comprehend safety language/technology/information. Based on the theory of safety information systems and the characteristics of safety professionals, this study develops an index system to assess the information literacy level of safety professionals. The index system consists of five indexes: safety information demand consciousness, safety information acquisition ability, safety information evaluation ability, safety information utilization ability, and information ethics. According to the analytic hierarchy process method, the weight of the index can be determined. This developed method was implemented to evaluate the safety information literacy level of 40 safety professionals from four different corporations. The quantitative results of the fuzzy evaluation are in good agreement with the qualitative analysis results, indicating that the index system has excellent applicability and can be applied to the evaluation of the information literacy level of safety professionals. Besides, recommendations are put forward to improve the information literacy of safety professionals.

1. Introduction

It is well known that the present society is surrounded by large amounts of information. The rapid development of information technology results in data generation at an unprecedented rate and makes us enter the Big Data era (García-Gil et al., 2019). In this society where information is everywhere, accidents can be redefined from the viewpoint of information. The causes of the major accidents(Chen et al., 2020) refer to information loss, incorrect information, fake news, and an abnormal flow of information (Luo and Wu, 2019). Wu and Huang (2019) presented a new accident causation model based on the information flow, highlighting that the causes of accidents can be attributed to the failures of safety information acquisition, analysis, and utilization. Hughes et al. (2015) indicated that the lack of safety information is a common cause of human-caused accidents. The fundamental cause of the lack of safety information can be attributed to the lack of information literacy.

The big data era also provides many promising opportunities for companies to take full advantage of social media data in safety management. Data-driven safety decision-making was proposed to obtain smart safety management (Wang et al., 2019; Huang et al., 2018). However, a great deal of false and disloyal information significantly influences the safety of big data, which is complex, emergent, and uncertain. Therefore, it is difficult to deal with safety problems effectively (Ouyang et al., 2018). To facilitate safety decision-making and management, organizations or professionals should carry out efficient measures to process various assorted data on safety into meaningful 'safety information'. Moreover, professionals ought to have the ability to understand, evaluate, and apply safety information, also called information literacy.

In general, Information literacy (IL) is the ability to use critical thinking to identify, evaluate, and apply information. It is associated with long-term learning (Wadson and Phillips, 2018; Brettle and Raynor, 2013; Saranto and Hovenga, 2004). IL is regarded as a study object in

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different contexts, including educational sectors, various workplaces, or safety management. The concept of IL has gained increasing attention in education research. Many studies on the level of IL among students were conducted. For example, Woitte and McCay (2019) explored using cyclical assessment to guide IL instruction for first-year undergraduate students. Kirker and Stonebraker (2019) used cognitive dissonance theory to examine first-year students' IL changes. The relationship between IL and college students' motivation & academic performance was investigated (Flierl et al., 2018). Bartol et al. (2018) compared the IL of first- and second-year undergraduates at the Faculty of Agriculture. A multiple linear regression method was applied to explore differences in IL among students with different native languages (Zhao et al., 2021). Besides, some studies were conducted on faculty's IL teaching practices. Purnell et al. (2020) found that library instruction and cross-grade training improve IL among nursing students. Statistical analysis methods were used to evaluate the teaching effect of IL for international engineering graduate students (Liu, 2021). By interviewing teachers from thousands of primary and secondary schools, Wu et al. (2022) identified the impact of the school environment on teachers' ability to cultivate students' IL. Furthermore, the outbreak of COVID-19 has brought enormous challenges to IL education. Scholars have been exploring ways to promote IL education during the pandemic. Shiwei (2020) argued that avoiding disseminating misinformation is the focus of IL education nowadays. Taking 42 university libraries in China as an example, Guo and Huang (2021) analyzed the characteristics and problems of IL education during the pandemic and proposed countermeasures. The above studies have significant guidance for improving IL teaching methods, cultivating students' IL skills in future research.

However, IL should not be exclusively related to education since it is related to a given social setting (Woitte and McCay, 2019). Compared with IL in education, IL in the workplace requires individuals to practice in a broader social setting and deal with more complex and variable information sources (Lawal et al., 2014). Head et al. (2013) revealed the differences between graduates' information competencies and the requirements of employers. These information competencies include teamwork skills, information seeking skills, information comprehension skills, and personal patience. In another study, Inskip (2014) identified the concepts, practices and policies of IL in the workplace, and noted the gaps between IL in the workplace and IL in the education setting. Moreover, several scholars researched IL in different workplaces. Bruce (1999) summarized seven aspects of IL required in the university as a workplace. Further, a survey was carried out to identify the level of IL among university library employees (Ali and Richardson, 2018). Through the qualitative study on firefighters, Lloyd (2007) found that the development of IL in the workplace required practical experience and the establishment of social relationships. Based on a phenomenological approach, Abdi et al. (2016) noted four ways for web workers to improve IL. Besides, Jinadu and Kaur (2014) proposed a model for evidence-based research on IL in the workplace. The model could be used to assess employees' IL. Such studies have contributed to the emergence of enterprise information literacy and the development of information management within enterprise organizations. However, only a few scholars studied the application of IL in safety management. Yang (2012) proposed the definition and determinants of safety managers' IL. The IL of safety managers is determined by various factors. The IL of safety managers is the ability to recognize information on safety needs and collect, analyze, assess, organize and synthesize information to solve safety problems in safety management.

There is no denying that the findings promote in-depth comprehensions of IL in different contexts. However, there is less emphasis on safety professionals' IL, especially the lack of research on the evaluation of IL. In the present studies, there is neither a widely applicable evaluation index nor a valid evaluation method for the IL level of safety managers. With the promotion of information theory and evidence-based concepts (Wang et al., 2017a), the IL of safety personnel has become a fundamental component of theoretical research and practical exploration in the field of safety engineering. As a significant role in the human–machine-environment-management system, safety professionals must identify and collect information from various resources to meet safety goals. It also places a high demand on the IL skills of safety professionals. Therefore, there is a need to understand the safety professionals' IL skills. Furthermore, It is efficient to understand the safety professionals' IL competencies by evaluating IL.

IL evaluation refers to surveys, tests, questionnaires, and relevant appraise tools (Bartol et al., 2018). For example, the student nurses and recent nurse graduates were required to finish online surveys to evaluate their information-seeking behaviors within clinical practice. An IL test on students in Agricultural Sciences was conducted using the Association of College & Research Libraries standards (Bartol et al., 2018). The pre-test was applied to evaluate first-year college students' IL skills. (Lanning and Mallek, 2017). Therefore, the IL assessment of safety professionals refers to scientific and reasonable evaluation methods being used to carry out a qualitative or quantitative evaluation of the safety information literacy of safety experts. And the IL evaluation scores of safety professionals are determined. This way, possible problems with the IL of safety professionals can be identified, and corresponding measures can be proposed subsequently.

The selection of a reasonable evaluation method is the crucial step in IL evaluation. "Fuzzy" means the non-deterministic relationship between two things, similar to a fuzzy state. A fuzzy comprehensive evaluation is an evaluation method based on fuzzy mathematics, which could analyze systems with multiple uncertain factors. According to the membership theory of fuzzy mathematics, this method transforms qualitative evaluation into quantitative evaluation, which can better solve fuzzy and difficult to quantify problems (Cheng and Tao, 2010). And it is suitable for solving various non-deterministic problems. The IL evaluation indicators of safety professionals are complex, and the correlation between the indicators is uncertain. The fuzzy comprehensive evaluation could determine classification boundaries through the relative degree of membership and objectively reflects safety professionals' IL level.

In conclusion, there is a need to evaluate the IL of safety professionals and establish an effective evaluation index system and evaluation method. Besides, the fuzzy comprehensive evaluation method may be applied to evaluate the IL competencies of safety professionals. This study, therefore, intends to develop an IL evaluation system for safety personnel, conduct a qualitative and quantitative evaluation using the fuzzy comprehensive evaluation method, and calculate safety professionals' IL levels. Furthermore, guiding measures would be proposed to promote the development of IL of safety professionals in the future.

In this paper, a survey was conducted within the oil and gas industry, the construction industry, the manufacturing industry, and the warehousing & postal industry. In total, 40 safety officers were selected from four representative companies in these industries, and their IL levels were evaluated based on the Analytic Hierarchical Process (AHP) and fuzzy comprehensive evaluation. And the IL evaluation index system for safety professionals has been validated by comparing the correlation between the results of qualitative and quantitative analyses. Some suggestions have been put forward to continuously improve the IL skills of safety professionals. Meanwhile, the enterprise managers can find defects and take remedial measures.

2. Four-step approach

To understand the IL level of safety experts and enhance their IL skills, a four-step systematic approach was proposed, as shown in Fig. 1.

According to the approach, the first step is to establish a multi-level evaluation indicator system for safety professionals. Before establishing the indicator system, we need to fully understand the concepts and applications related to IL, the principles of selecting evaluation indicators, and the Association of College and Research Libraries (ACRL) standards through literature reading. Meanwhile, we must master the analytic

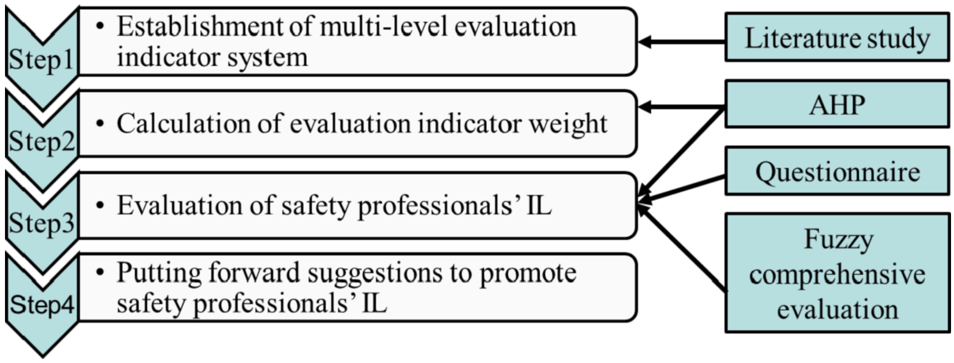

Fig. 1. A systematic approach to evaluate safety experts' IL.

hierarchy process to establish a multi-level indicator system. More details are illustrated in Section 2.1.

Step 2 of the approach is to calculate the weight of evaluation indicators. This study determines the indicator weight by the analytic hierarchy process combined with the experts' authority level. The specific calculation steps are described in Section 2.1. The results are presented in Section 3.2.

Step 3 of this approach is to evaluate safety professionals' IL. The fuzzy method is used to evaluate the safety professionals' IL. Interviews were conducted in four companies to obtain accurate fuzzy membership matrices. More details are shown in Section 2.3. The evaluation steps are illustrated in Section 2.2; an example application is provided in Section 3, and the evaluation results are presented in Section 4.1.

Finally, some suggestions were put forward to improve safety professionals' IL based on analysis results in Steps 1–3. The experience gained in this study can provide theoretical guidance for improving safety personnel's professionalism.

2.1. Analytic Hierarchical process (AHP)

The analytic hierarchy process (AHP)(Chen et al., 2021) is a qualitative and quantitative decision analysis method proposed by Saaty (1977). It employs pairwise comparisons to obtain priority scales. (Şahin et al., 2019). It makes complex decision-making activities systematic, thereby using a simple structure, which is easy to understand (Chang et al., 2015). It has been successfully applied in numerous fields, such as agriculture, education, resources planning, and risk assessment (Yang et al., 2019; Şahin et al., 2019; Opitz et al., 2019; Eskander, 2018). Applying the analytic hierarchy process to decision-making can be divided into two steps. First, the various factors involved in decision-making problems are divided into multiple levels to make them organized. Second, mathematical methods are used to determine the weights of indicators.

To obtain objective evaluation results, the evaluation indicators should adhere to the scientific, systematic, representative, and independent principles (Maclaren, 1996). The Association of College & Research Libraries (ACRL), which is a division of the American Library Association (ALA), and other library associations have established the method for evaluating IL, namely ACRL standards (ACRL, 2000). According to the ACRL standards, the evaluation of information literacy can be divided into five aspects: information need identification, information access, information evaluation, information use, and legal & ethical issues (Bartol et al., 2018). Based on the ACRL standards, previous research (Yang, 2012; Wang et al., 2019), and expert consultation, a two-layer comprehensive evaluation index system of safety professionals' IL is presented in Table 1. The index system consists of five main (first-level) criteria: recognizing safety information need (L_1), location and access to safety information (L_2), evaluation of safety information (L_3), applying safety information (L_4), ethical and legal use of safety information (L_5). Each of the first-level criteria is composed of several independent indexes. A total of 25 s-level indicators such as "understand the need for safety information" have been identified.

Table 1
Primary evaluation indicator (Bartol et al., 2018; Wang et al., 2019; Yang, 2012; ACRL, 2000).

No.	Factor category	Category code	Factors
1	Recognizing safety information need L_1	L_{11}	Understand the need for safety information
		L_{12}	Express the need for safety information
		L_{13}	Identify safety information
		L_{14}	Keep a positive attitude on safety information
2	Location and access to Safety information L_2	L_{21}	Choose effective ways to locate safety information
		L_{22}	Distinguish different information sources
		L_{23}	Know some well-known safety information internet
		L_{24}	Grasp some information retrieval strategies
		L_{25}	Acquire safety information with various methods
		L_{26}	Manage safety information
3	Evaluation of safety information L_3	L_{31}	Understand the quality and extent of safety information
		L_{32}	Understand the content of safety information
		L_{33}	Evaluate the value of safety information
		L_{34}	Measure the cost of safety information
		L_{35}	Evaluate the source of safety information
4	Applying safety information L_4	L_{41}	Summarize key points of safety information
		L_{42}	Record safety information for future reference
		L_{43}	Utilize safety information to prevent accidents
		L_{44}	Apply safety information to improve safety management
		L_{45}	Integrate information into daily safety management
		L_{46}	Screen safety information
		L_{47}	Share safety information
5	Ethical and legal use of safety information L_5	L_{51}	Understand information ethics and laws
		L_{52}	Comply with information regulations in the organization
		L_{53}	Refer to information in a correct way

The steps using AHP to calculate the index weights are as follows (Baffoe, 2019; Zhang et al., 2019; Salvia et al., 2019; Şahin et al., 2019; Kheybari et al., 2019; Wang et al., 2018):.

(1) Each expert assigns the weight of each indicator based on a 9-points scale to form (n × n) -sized judgment matrices, where n is the number of indicators being compared.

(2) The maximum eigenvalues λ_{max} and eigenvector $\boldsymbol{W}$ of each judgment matrix are determined, and a consistency check is carried out according to Eqs. (1) and (2), in which RI is the average random consistency index (which is related to the value of n). When $CR < 0.1$, the judgment matrix's consistency is good; otherwise, the judgment matrix needs to be adjusted.

$$CI = (\lambda_{max} - n)/(n - 1) \tag{1}$$

$$CR = CI/RI \tag{2}$$

(3) The weights of each evaluation indicator are aggregated and normalized to obtain the integrated weight vector.

2.2. Fuzzy comprehensive evaluation

Fuzzy sets theory was put forward by (Zadeh, 1965), and it plays a significant role in depicting the quantifiable level of uncertainty for people's estimations (Wang et al., 2018). Accordingly, the fuzzy comprehensive evaluation method is widely utilized to deal with vague decision-making issues (Li et al., 2015; Wang et al., 2017a,b; Yang and Mak, 2017; Wang et al., 2018). The whole evaluation process contains five steps (Li et al., 2015; Xie et al., 2017; Yang and Mak, 2017), as follows:.

Step1: Build up the factor set $\boldsymbol{U}$ shown in Eq. (3). The factor in $\boldsymbol{U}$ influences safety professionals' IL evaluation objective.

$$U = \{u_1, u_2, u_3, \cdots, u_n\} \tag{3}$$

in which u_i (i = 1, 2, 3,…, n) represents indicators, the first-level or second-level indicators, etc. n is the number of evaluation indicators.

Step2: Determine the factor weight set $\boldsymbol{W}$ given in Eq. (4). The weight represents the relative importance of a factor u_i in $\boldsymbol{U}$. $\boldsymbol{W}$ consists of all weights of the factors in $\boldsymbol{U}$.

$$W = \{w_1, w_2, w_3, \cdots w_n\} \tag{4}$$

where w_i (i = 1, 2, 3, …, n) is the weight of factors in $\boldsymbol{W}$.

Step3: Establish the evaluation set $\boldsymbol{V}$. As shown in Eq. (5), $\boldsymbol{V}$ comprises several comment results conveyed by fuzzy language.

$$V = \{v_1, v_2, v_3, \ \ldots., v_m\} \tag{5}$$

where v_1, v_2, v_3, ……. v_m represent different evaluation grades, such as "Excellent", "good", "acceptable", and "Unacceptable", m represents the number of judgments.

Step4: Establish the comprehensive membership matrix $\boldsymbol{R}$ as Eq. (6).

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2j} & \cdots & r_{2m} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} & \cdots & r_{im} \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nj} & \cdots & r_{nm} \end{bmatrix} \tag{6}$$

where r_{ij} represents the membership; i = 1, 2, ⋯, n; j = 1, 2, ⋯, m.

Step5: Determine the fuzzy comprehensive evaluation result. Based on evaluation matrix $\boldsymbol{R}$ and factor weight set $\boldsymbol{W}$, the comprehensive evaluation results can be obtained by Eq. (7).

$$B = W \cdot R = \{b_1, b_2, \cdots, b_i, \cdots, b_m\} \tag{7}$$

where b_i represents the membership degree of evaluation grade v_i. The symbol "·" represents fuzzy composition between weighted fuzzy matrix $\boldsymbol{W}$ and factor evaluation matrix $\boldsymbol{R}$.

2.3. Questionnaire

The determination of the fuzzy membership matrix is an essential aspect of the fuzzy comprehensive evaluation. The method of determining the fuzzy membership matrix includes the fuzzy statistical method and distribution function method. The fuzzy statistical method refers to the researcher designing, distributing, and recycling questionnaires, and determining the membership degree by counting the evaluation results of research objects. The distribution function method calculates the membership degree by selecting a specific fuzzy distribution function depending on the nature of the evaluation indicator. The distribution function method is more subjective than the fuzzy statistical method. To reduce subjectivity and ensure the accuracy of the evaluation results, a questionnaire was used to determine the membership degree of each evaluation indicator. The interviews were conducted within four companies.

Company I belongs to the warehousing, postal, and transportation industries. The company's core business is producing, handling, storing, and transporting liquid chemical materials, such as toluene, acetic acid, and ethylene glycol. The company's board of directors unifies the leadership and coordinates various safety tasks. A safe production committee is responsible for the specific implementation of safety tasks. It includes 17 safety professionals. Most of the employees have a bachelor's degree or below.

Company II belongs to the manufacturing industry. The company is a modern enterprise engaged in high-precision aluminum sheet and strip processing controlled by Aluminum Corporation of China. The safety and environmental management department includes 10 safety professionals such as safety and environmental technicians and occupational health sponsors. About 80% of the employees have a bachelor's degree, and about 20% have a master's degree or above. Besides, all employees have worked for the company for more than 3 years.

Company III belongs to the construction industry. The company is mainly responsible for installing structures, decoration, electrical, and equipment for numerous industrial and civil construction projects. The safety management department mainly conducts on-site inspections of the hidden dangers and collation and summary of various safety data. The department includes 25 safety professionals. All workers have a bachelor's degree or below. The average working life of workers is 13 years.

Company IV belongs to the oil and gas industry. The company's business scope includes the sales of gasoline, kerosene, diesel, and natural gas, and the operation of convenience stores at subordinate gas stations. The company has a safety management department in charge of safety hazard investigation. The department includes 13 safety professionals. All employees have a bachelor's degree or above, and half of them have a master's degree.

10 workers were selected from each company to participate in the IL evaluation. Safety professionals from Company I were numbered S_{10}, S_{11}, S_{12}, S_{13}, S_{14}, S_{15}, S_{16}, S_{17}, S_{18}, S_{19}; Safety professionals from Company II were numbered S_{20}, S_{21}, S_{22}, S_{23}, S_{24}, S_{25}, S_{26}, S_{27}, S_{28}, S_{29}; Safety professionals from Company III were numbered S_{30}, S_{31}, S_{32}, S_{33}, S_{34}, S_{35}, S_{36}, S_{37}, S_{38}, S_{39}; Safety professionals from Company IV were numbered S_{40}, S_{41}, S_{42}, S_{43}, S_{44}, S_{45}, S_{46}, S_{47}, S_{48}, S_{49}.

The questionnaire was developed based on the primary evaluation indicators in Table 1. It consists of 5 first-level evaluation indicators and 25 s-level evaluation indicators. Four evaluation grades, A, B, C, and D, were established to represent the highest to the lowest degree of compliance. The researchers retrieved and checked the questionnaires, and recorded the score for each participant.

3. Fuzzy comprehensive evaluation of safety professionals' IL

3.1. Establishment of fuzzy sets

3.1.1. Establishment of factor sets

Based on the evaluation index system of IL for safety professionals, key factors affecting the level of IL are identified. First, establish the upper-level factor set. Then, based on the structural characteristics of each factor, the corresponding underlying factor set is determined. Finally, a set of two-layer factor sets that can reflect the IL skills of enterprise safety management personnel from all aspects is formed, as shown in Eqs. (8) and (9).

$$U = \{u_1, u_2, u_3, u_4, u_5\} = \{L_1, L_2, L_3, L_4, L_5\} \tag{8}$$

$$\begin{aligned} u_1 &= \{L_{11}, L_{12}, L_{13}, L_{14}\} \\ u_2 &= \{L_{21}, L_{22}, L_{23}, L_{24}, L_{25}, L_{26}\} \\ u_3 &= \{L_{31}, L_{32}, L_{33}, L_{34}, L_{35}\} \\ u_4 &= \{L_{41}, L_{42}, L_{43}, L_{44}, L_{45}, L_{46}, L_{47}\} \\ u_5 &= \{L_{51}, L_{52}, L_{53}\} \end{aligned} \tag{9}$$

3.1.2. Calculation of the membership degree

In this study, the judgments are divided into four levels, represented by the evaluation standard set $\boldsymbol{V}$, namely.

$$V = \{v_1, v_2, v_3, v_4\} = \{A, B, C, D\} \tag{10}$$

An evaluation was conducted on the IL performance of 40 safety professionals. Each employee invited to the survey was required to self-assess and evaluate the other members of the same company. Finally, the membership frequency was used to define the membership degree. Due to space reasons, only the membership degree of safety officer S_{10} is chosen as an example shown in Table 2.

3.2. Determination of evaluation weights

According to the steps of using AHP to determine the indicator weight described in Section 2.1, the weights of first-level evaluation indicators and second-level evaluation indicators are calculated. Five experts engaged in safety management and information technology were selected to determine judgment matrices based on the positional titles, work age, and education background. The basic information of the selected experts is shown in Table 3. Taking the first-level indicator L_1 as an example, the steps for calculating the weights of the second-level indicators L_{11}, L_{12}, L_{13}, and L_{14} using AHP are as follows:.

(1) After integrating the evaluation results of five experts, a judgment matrix is obtained, as shown in Table 4.
(2) Normalizing the matrix to get the eigenvector $\boldsymbol{W} = [0.2320 \quad 0.2770 \quad 0.2473 \quad 0.2437]$. And the maximum eigenvalues $\lambda_{max} = 4.2689$.
(3) The consistency test was carried out following Eq. (1) - (2). $CI = \frac{\lambda_{max}-n}{n-1} = 0.0896$, $CR = \frac{CI}{RI} = 0.0996 < 0.1$. Therefore, the consistency of the judgment matrix is good. And the weights of the second-level indicators L_{11}, L_{12}, L_{13}, and L_{14} can be expressed as $\boldsymbol{W} = [0.2320 \quad 0.2770 \quad 0.2373 \quad 0.2473]$.

The weights of other evaluation indicators were calculated based on the above steps, as presented in Table 5.

3.3. Fuzzy comprehensive evaluation

Due to space limitations, the safety professional S_{10} of Company I was selected as an example for fuzzy comprehensive evaluation. The evaluation process is as follows:.

(1) Determination of indicator sets: $u_1 = \{L_{11}, L_{12}, L_{13}, L_{14}\}$.

Table 2
The membership degree of safety professional S_{10}.

First-level	Second-level	Membership degree A	B	C	D
L_1 Recognizing safety information need	L_{11}: Understand the need for safety information	0.4	0.4	0.2	0
	L_{12}: Express the need for safety information	0.2	0.4	0.4	0
	L_{13}: Identify safety information	0.4	0.6	0	0
	L_{14}: Keep a positive attitude on safety information	0.6	0.2	0.2	0
L_2 Location and access to Safety information	L_{21}: Choose effective ways to locate safety information	0.2	0.6	0.2	0
	L_{22}: Distinguish different information sources	0	0.2	0.6	0.2
	L_{23}: Know some well-known safety information internet	0	0.4	0.4	0.2
	L_{24}: Grasp some information retrieval strategies	0	0.2	0.6	0.2
	L_{25}: Acquire safety information with various methods	0.6	0.4	0	0
	L_{26}: Manage safety information	0.4	0.4	0.2	0
L_3 Evaluation of safety information	L_{31}: Understand the quality and extent of safety information	0	0.4	0.6	0
	L_{32}: Understand the content of safety information	0.4	0.4	0.2	0
	L_{33}: Evaluate the value of safety information	0.2	0.6	0.2	0
	L_{34}: Measure the cost of safety information	0	0.2	0.6	0.2
	L_{35}: Evaluate the source of safety information	0	0.4	0.4	0.2
L_4 Applying safety information	L_{41}: Summarize key points of safety information	0.8	0.2	0	0
	L_{42}: Record safety information for future reference	0.2	0.4	0.4	0
	L_{43}: Utilize safety information to prevent accidents	0.4	0.2	0.4	0
	L_{44}: Apply safety information to improve safety management	0.2	0.4	0.4	0
	L_{45}: Integrate information into daily safety management	0.6	0.2	0.2	0
	L_{46}: Screen safety information	0	0.4	0.6	0
	L_{47}: Share safety information	0.4	0.2	0.4	0
L_5 Ethical and legal use of safety information	L_{51}: Understand information ethics and laws	0.2	0.6	0.2	0
	L_{52}: Comply with information regulations in the organization	0.4	0.2	0.4	0
	L_{53}: Refer to information in a correct way	0	0.2	0.8	0

Table 3
Basic information of five experts.

NO.	Job title	Length of service	Academic qualifications
1	Professor	31	PhD
2	Senior engineer	32	Master
3	Associate Professor	21	PhD
4	Associate Professor	13	PhD
5	Lecturer	8	PhD

(2) The first-level indicator "L_1: Recognizing safety information need" is selected as a calculation example for evaluation. L_{11} is "Understand the need of safety information", L_{12} is "Express the need of safety information", L_{13} is "Identify safety information", L_{14} is "Keep a positive attitude on safety information".
(3) Formulation of evaluation set: $V = \{v_1, v_2, v_3, v_4\} = \{A,B,C,D\}$.

Table 4
Judgment matrix of first-level indicator L_1.

	L_{11}	L_{12}	L_{13}	L_{14}
L_{11}	1.00	1.50	0.50	0.90
L_{12}	0.67	1.00	1.85	1.20
L_{13}	2.00	0.54	1.00	0.80
L_{14}	1.11	0.83	1.25	1.00

(4) (3)Calculating weight vector of second-level indicators: W_1=(0.2320,0.2770,0.2473,0.2437).

(5) Based on the survey results of safety professional S_{10}, the membership degree matrix($\boldsymbol{R_1}$) is obtained, and the fuzzy comprehensive evaluation vector of indicator L_1 is calculated.

$$R_1 = \begin{bmatrix} 0.4 & 0.4 & 0.2 & 0 \\ 0.2 & 0.4 & 0.4 & 0 \\ 0.4 & 0.6 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 \end{bmatrix}$$

$$B_1 = W_1 \cdot R_1 = (0.2320, 0.2770, 0.2473, 0.2437) \cdot \begin{bmatrix} 0.4 & 0.4 & 0.2 & 0 \\ 0.2 & 0.4 & 0.4 & 0 \\ 0.4 & 0.6 & 0 & 0 \\ 0.6 & 0.2 & 0.2 & 0 \end{bmatrix}$$

$$= (0.393, 0.401, 0.206, 0)$$

(6) Following steps (1) -(4) to calculate the evaluation vector of the remaining first-level indicators, and the evaluation results of safety professional S_{10}'s IL first-level indicators are obtained, as shown in Table 6.

(7) The second evaluation.

Repeat step (4) to get the final IL evaluation results of safety professional S_{10}: $B = W \cdot R = (0.1115,\ 0.3039,\ 0.2026,\ 0.3068,\ 0.0752) \cdot$

$$\begin{bmatrix} 0.393 & 0.401 & 0.206 & 0 \\ 0.168 & 0.369 & 0.354 & 0.109 \\ 0.162 & 0.422 & 0.364 & 0.052 \\ 0.378 & 0.286 & 0.336 & 0 \\ 0.179 & 0.353 & 0.468 & 0 \end{bmatrix} = (0.257,\quad 0.357,\quad 0.342,\quad 0.044)$$

According to steps (1) -(6), the fuzzy comprehensive results of safety professionals can be calculated, as shown in Fig. 2.

4. Results and discussion

4.1. Evaluation results

4.1.1. Qualitative analysis

Based on the maximum subordination principle, if $b_{i0} = \max\{b_i\}$, the evaluation result is the i_0th grade, so the IL evaluation levels of 40 safety professionals are obtained, as shown in Tables 7–10.

According to the results of the fuzzy analysis in Tables 7–10, part of the safety professionals has the same Level of IL. Therefore, the department manager is invited to carry out further qualitative analysis by combining the evaluation results, the questionnaire, and employees' daily performance. Finally, the IL level of safety professionals is ranked, as shown in Table 11.

4.1.2. Quantitative analysis

To quantitatively evaluate the IL of safety professionals and make full use of various information and weights, the IL score S* of safety professionals was obtained based on the weighted average method (Zheng et al., 2019).

Table 5
Weights of IL evaluation indicators for safety professionals.

First-level indicator	Weight	Second-level indicator	Weight	Comprehensive weight
L_1: Recognizing safety information need	0.1115	L_{11}: Understand the need for safety information	0.2320	0.026
		L_{12}: Express the need for safety information	0.2770	0.031
		L_{13}: Identify safety information	0.2473	0.028
		L_{14}: Keep a positive attitude on safety information	0.2437	0.027
L_2: Location and access to Safety information	0.3039	L_{21}: Choose effective ways to locate safety information	0.2162	0.066
		L_{22}: Distinguish different information sources	0.1128	0.034
		L_{23}: Know some well-known safety information internet	0.1746	0.053
		L_{24}: Grasp some information retrieval strategies	0.2564	0.078
		L_{25}: Acquire safety information with various methods	0.1424	0.043
		L_{26}: Manage safety information	0.0976	0.030
L_3: Evaluation of safety information	0.2026	L_{31}: Understand the quality and extent of safety information	0.2114	0.043
		L_{32}: Understand the content of safety information	0.2800	0.057
		L_{33}: Evaluate the value of safety information	0.2477	0.050
		L_{34}: Measure the cost of safety information	0.1381	0.028
		L_{35}: Evaluate the source of safety information	0.1228	0.025
L_4: Applying safety information	0.3068	L_{41}: Summarize key points of safety information	0.1936	0.059
		L_{42}: Record safety information for future reference	0.1332	0.041
		L_{43}: Utilize safety information to prevent accidents	0.1134	0.035
		L_{44}: Apply safety information to improve safety management	0.1178	0.036
		L_{45}: Integrate information into daily safety management	0.1075	0.033
		L_{46}: Screen safety information	0.1763	0.054
		L_{47}: Share safety information	0.1582	0.049
L_5: Ethical and legal use of safety information	0.0752	L_{51}: Understand information ethics and laws	0.3823	0.029
		L_{52}: Comply with information regulations in the organization	0.2561	0.019
		L_{53}: Refer to information in a correct way	0.3616	0.027

Table 6
The first evaluation of safety professional S_{10}'s IL.

First-level		Evaluation grade			
Index	Weight	A	B	C	D
L_1: Recognizing safety information need	0.1115	0.393	0.401	0.206	0
L_2: Location and access to Safety information	0.3039	0.168	0.369	0.354	0.109
L_3: Evaluation of safety information	0.2026	0.162	0.422	0.364	0.052
L_4: Applying safety information	0.3068	0.378	0.286	0.336	0
L_5: Ethical and legal use of safety information	0.0752	0.179	0.353	0.468	0

$$S^{*} = \frac{\sum_{i=1}^{m} v_i \cdot b_i}{\sum_{i=1}^{m} b_i} \tag{11}$$

where v_i is the evaluation grade, $i = 1,2,\cdots m$, $m = 4$; $\{v_1, v_2, v_3, v_4\} = \{A,B,C,D\}$; The evaluation grade A represents j equal to 4, B represents j equal to 3, C represents j equal to 2, D represents j equal to 1; b_i represents the membership degree of evaluation grade. The IL score S^* is in the range (1,4). The IL level of safety professionals increases with increasing the S^*. Based on Eq.(11), the S^* values of 10 safety professionals are calculated, as shown in Table 12.

According to Table 12, the average IL scores of safety professionals of Company I, Company II, Company III, Company IV, are 3.076, 3.248, 3.037, 3.375, respectively. The average IL score of safety professionals of Company IV (the oil and gas industry) is the highest, and the average IL score of safety professionals of Company III (the construction industry) is the lowest. The main reason is the difference in the safety knowledge reserve of safety professionals in diverse industries. Half of

Table 7
Fuzzy analysis results of safety professionals' IL of Company I.

Safety professional	Evaluation grade	Safety professional	Evaluation grade
S_{10}	B	S_{15}	B
S_{11}	B	S_{16}	A
S_{12}	B	S_{17}	A
S_{13}	B	S_{18}	A
S_{14}	C	S_{19}	B

Table 8
Fuzzy analysis results of safety professionals' IL of Company II.

Safety professional	Evaluation grade	Safety professional	Evaluation grade
S_{20}	A	S_{25}	B
S_{21}	B	S_{26}	B
S_{22}	B	S_{27}	B
S_{23}	A	S_{28}	B
S_{24}	A	S_{29}	B

Table 9
Fuzzy analysis results of safety professionals' IL of Company III.

Safety professional	Evaluation grade	Safety professional	Evaluation grade
S_{30}	B	S_{35}	B
S_{31}	B	S_{36}	B
S_{32}	B	S_{37}	B
S_{33}	B	S_{38}	B
S_{34}	B	S_{39}	B

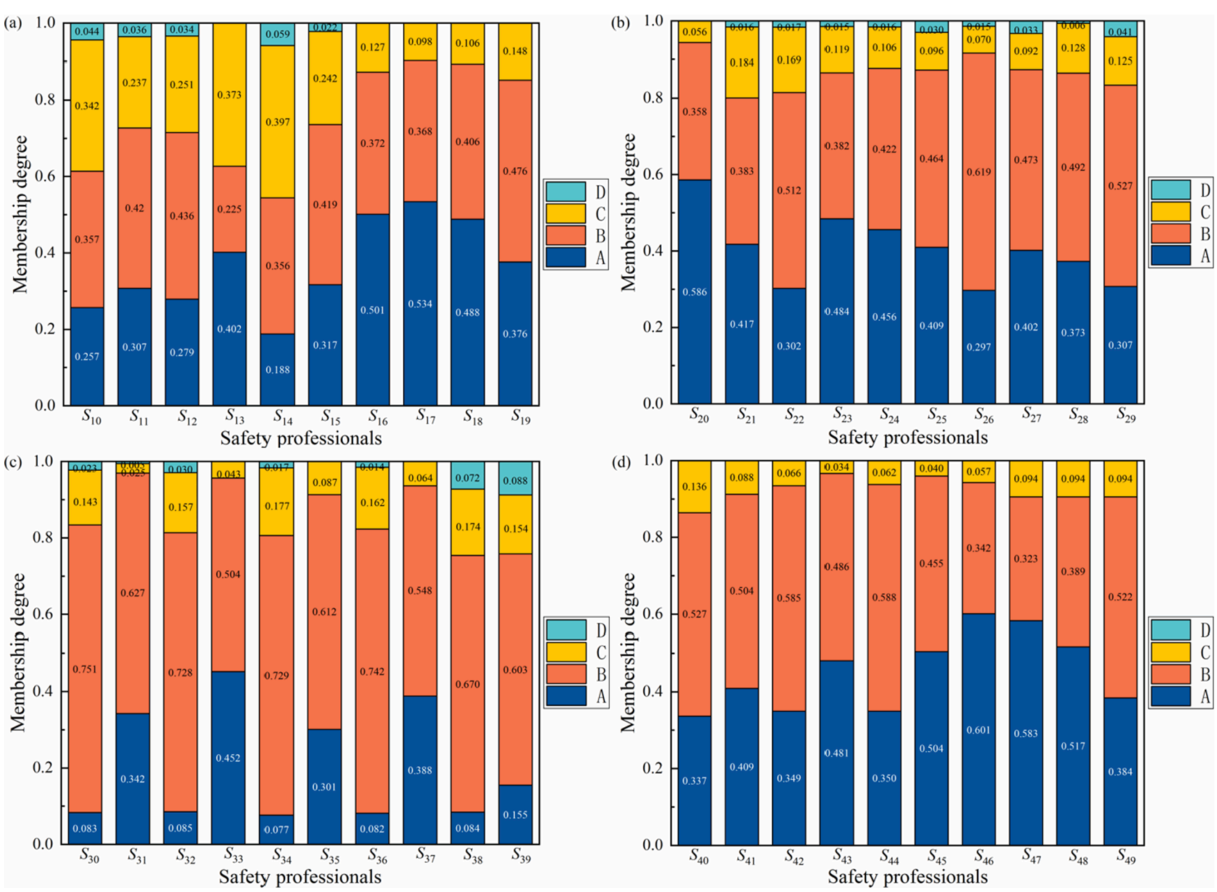

Fig. 2. The second evaluation results of safety professionals' IL (a): Company I (b): Company II (c): Company III (d): Company IV.

Table 10
Fuzzy analysis results of safety professionals' IL of Company IV.

Safety professional	Evaluation grade	Safety professional	Evaluation grade
S_{40}	B	S_{45}	A
S_{41}	B	S_{46}	A
S_{42}	B	S_{47}	A
S_{43}	A	S_{48}	A
S_{44}	B	S_{49}	B

Table 11
Qualitative analysis results of safety professionals' IL.

NO.	Company I	Company II	Company III	Company IV
1	S_{17}	S_{20}	S_{33}	S_{46}
2	S_{18}	S_{23}	S_{37}	S_{47}
3	S_{16}	S_{24}	S_{31}	S_{45}
4	S_{19}	S_{25}	S_{35}	S_{43}
5	S_{15}	S_{27}	S_{30}	S_{43}
6	S_{13}	S_{28}	S_{36}	S_{48}
7	S_{11}	S_{26}	S_{32}	S_{41}
8	S_{12}	S_{21}	S_{34}	S_{49}
9	S_{10}	S_{22}	S_{39}	S_{42}
10	S_{14}	S_{29}	S_{38}	S_{40}

the safety professionals of Company IV have a master's degree. They have a solid reserve of safety knowledge systems and are more capable of identifying, processing, and applying complex safety information. However, safety professionals of Company III have a bachelor's degree or below. They lack thorough understanding and research on safety theory. It is also related to the low requirements of the construction industry on the safety literacy of safety professionals. Therefore, the safety information literacy of Company III is the lowest among the four companies. Moreover, the education level of the safety professionals of Company I (the warehousing, postal, and transportation industries) is similar to that of the safety professionals of Company III. Thus, the information literacy level of the safety professionals of the two companies is relatively close. All safety professionals of Company II (the manufacturing industry) have a bachelor's degree, and a few have a master's degree. Overall, they have a solid foundation of safety knowledge and can efficiently deal with changing safety information.

Besides, the qualitative and quantitative evaluation results of enterprise safety professionals' IL are consistent, indicating that the IL evaluation index constructed in this paper is reasonable.

4.2. Discussion

According to the IL evaluation index weights for safety professionals obtained in Section 3, ten factors with the most significant impact on the IL of safety professionals can be identified, i.e., the ten indicators with the top ranking of comprehensive weights in the system (see Table 13). The factors of "location and access to safety information" (L_2) and "applying safety information" (L_4) are most critical to the IL of safety professionals in enterprises.

To enhance the IL of safety professionals, it is imperative to understand the determinants of IL. Yang (2012) suggested that the IL of safety professionals is influenced by safety climate and culture, safety information sources, IT human resources, production technology, management, managers' attitudes towards IL, and many other factors.

Therefore, a cultivation path to promote the IL of safety professionals is proposed, as shown in Fig. 3. The improvement of safety professionals' IL requires the cooperation of five departments: the human resource department, the health and safety department, the IT department, the finance department, and the communication department. They evaluate the IL level of safety professionals according to the AHP and fuzzy comprehensive evaluation method, identify, summarize and analyze the weaknesses of the safety IL of employees, and propose corrective measures. Thus, the IL of safety professionals is continuously promoted through a positive feedback system.

Safety professionals need to identify, process, and apply a vast amount of information for making good safety decisions. Safety managers should master information technology, have excellent professional skills, possess good professional ethics, etc. Gyekye and Salminen (2009) discovered that workers who had received formal occupational safety education and training demonstrated a higher level of safety perceptions. Therefore, the human resources sector should do a multi-level screening and multi-faceted assessment when recruiting. Safety managers should also be trained and educated to use a range of business software packages. At the same time, safety managers are encouraged to improve their English proficiency to learn more advanced information.

Safety climate relates to the perceptions held across the workforce at a given minute about how things are done. Taking advantage of the group effect of human beings to create a good enterprise safety climate can enhance safety professionals' perception. The Health and Safety department in the enterprise could establish a strong safety climate by the following measures:.

(1) Conducting cross-cutting discussions in various departments.

Table 13
Ten factors with the most significant impact on the IL of safety professionals.

NO.	Factors	NO.	Factors
1	L_{41}: Summarize key points of safety information	6	L_{46}: Screen safety information
2	L_{42}: Record safety information for future reference	7	L_{47}: Share safety information
3	L_{43}: Utilize safety information to prevent accidents	8	L_{21}: Choose effective ways to locate safety information
4	L_{44}: Apply safety information to improve safety management	9	L_{22}: Distinguish different information sources
5	L_{45}: Integrate information into daily safety management	10	L_{23}: Know some well-known safety information internet

Table 12
Quantitative evaluation results of safety professionals' IL.

NO.	Company I	S*	Company II	S*	Company III	S*	Company IV	S*
1	S_{17}	3.436	S_{20}	3.529	S_{33}	3.409	S_{46}	3.544
2	S_{18}	3.382	S_{23}	3.335	S_{37}	3.324	S_{47}	3.489
3	S_{16}	3.374	S_{24}	3.318	S_{31}	3.306	S_{45}	3.464
4	S_{19}	3.228	S_{25}	3.253	S_{35}	3.214	S_{43}	3.452
5	S_{15}	3.031	S_{27}	3.244	S_{30}	2.895	S_{43}	3.422
6	S_{13}	2.852	S_{28}	3.232	S_{36}	2.891	S_{48}	3.321
7	S_{11}	2.998	S_{26}	3.198	S_{32}	2.869	S_{41}	3.290
8	S_{12}	2.960	S_{21}	3.168	S_{34}	2.866	S_{49}	3.288
9	S_{10}	2.827	S_{22}	3.100	S_{39}	2.826	S_{42}	3.283
10	S_{14}	2.673	S_{29}	3.099	S_{38}	2.767	S_{40}	3.201
Average		3.076		3.248		3.037		3.375

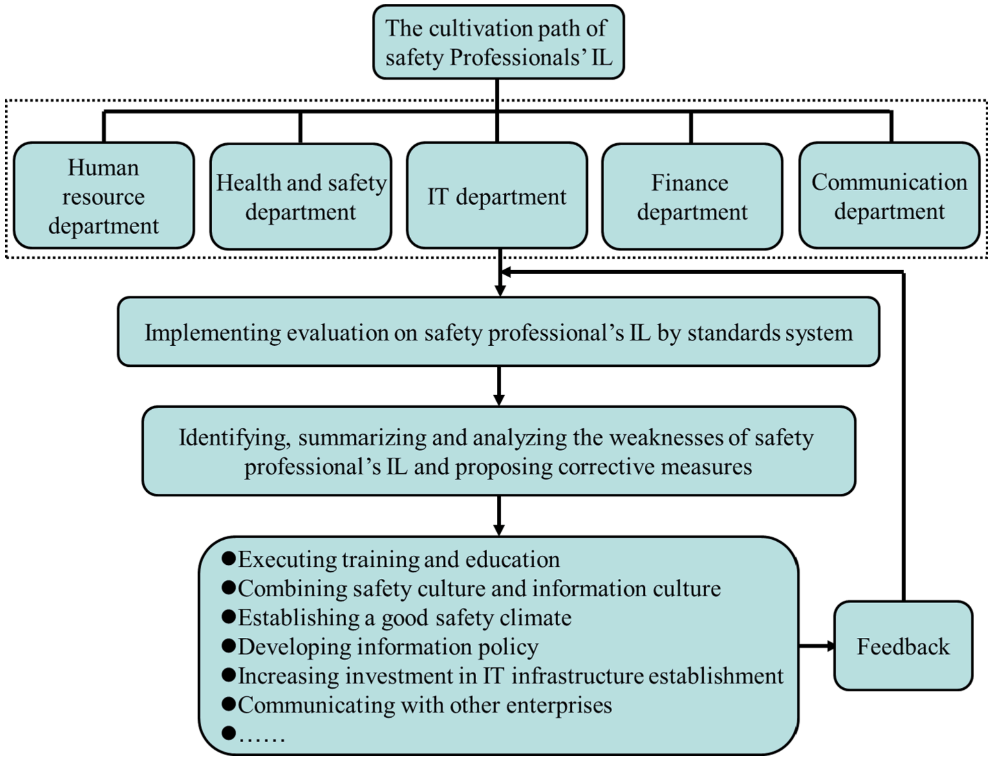

Fig. 3. The cultivation path of safety Professionals' IL.

(2) Engaging in inter-enterprise safety management communications.
(3) Organizing publicity activities for Safety Production Month.

Safety culture is the underlying shared values, beliefs, and habitual working practices that influence health and safety performance. Safety culture construction is an effective way to improve safety management and realize the essential safety of enterprises. It is a project that benefits the health and safety of workers. An enterprise with an influential safety culture has a safety information system that analyzes and summarizes previous accidents/errors, encourages employees to provide safety information. It is flexible enough to cope with demanding task environments, thus ensuring safe production in the enterprise (Parker et al., 2006). The health and safety department in an enterprise can establish a positive safety culture by the following:.

(1) Strengthening the implementation and enforcement of safety concepts to form the core driving force of safety culture construction.
(2) Implementing the intangible safety culture into the tangible corporate logo to enhance cohesiveness.
(3) Continuously promote the safety perception of employees through training and education.
(4) Forming participatory management of all employees to enhance the cohesiveness of safety culture construction.

In the wave of globalization, information has become a valuable resource that countries worldwide are competing. To exploit information resources, coordinate information utilization, and ensure the efficiency of IT applications, most countries have formulated information policies (Hassanlou et al., 2009). The enterprise shall establish appropriate information policies to discipline employees' behavior. When handling safety information, safety managers need to be aware of the ethical, legal, and moral norms related to safety information and information technology.

To get access to, analyze and address large amounts of safety information, the enterprise has to use a variety of information infrastructures, including computers, databases, internal corporate LANs, office automation management systems, etc. Moreover, IT professionals are to manage and repair the information infrastructure daily. To some extent, the knowledge level of IT professionals has an indirect impact on the IL of safety professionals (Yang, 2012). The IT department has to build an information management system in line with the actual situation of the enterprise. Computer system security and the confidentiality of documents and files are also supposed to be strengthened. Besides, the training and education of IT professionals in computer knowledge and application software need to be proactively executed. Moreover, the finance department increases the investment in IT infrastructure and adjusts it depending on the actual situation.

In addition, the transmission and exchange of information are also quite significant. The communication department must do well in installing, maintaining, debugging, upgrading, and improving the enterprise communication system and communication equipment, thus ensuring the smooth flow of information.

5. Conclusions

With the rapid development of information technology, IL has gradually become a vital ability required by people in modern society. IL has been viewed as a research object in different contexts, including education and the workplace. However, there is a lack of research in the domain of safety science. Based on the safety information system, combined with the characteristics of safety managers and related literature, an IL evaluation index system of safety professionals is proposed. The system includes 5 first-level indicators and 25 s-level indicators such as recognizing safety information need, location and access to safety information, evaluation of safety information, applying safety information, ethical and legal use of safety information. Furthermore, theoretical support for evaluating the IL level of enterprise safety professionals is provided.

The weights of enterprise safety professionals' IL evaluation indicators are calculated with AHP. 40 safety professionals from four different industries were selected as the survey subjects. The fuzzy comprehensive evaluation method is used to evaluate their IL levels. The quantitative results of the fuzzy evaluation are consistent with the qualitative analysis results, indicating the rationality of the index system. Moreover, a way found for enterprise safety professionals' IL is proposed according to the evaluation results. The improvement of safety professionals' IL requires the cooperation, timely feedback, and continuous refinement of five departments: The human resource department, the health and safety department, the IT department, the finance department, and the communication department.

In sum, this study developed an IL evaluation index system of safety professionals and adopted it to evaluate the IL skills of safety personnel in different enterprises. Besides, suggestions were put forward to improve the ability of safety personnel to identify, collect, process, and apply safety information. This study enriches the theoretical and practical exploration of safety information literacy research. It is conducive to improving the information literacy capabilities of safety personnel and contributes to promoting enterprise safety management levels. Furthermore, this study provides a basis for the evaluation of information literacy in other occupational groups. Despite the contributions of this study to safety information literacy, there are still disadvantages: the establishment of a multi-level evaluation indicator system may be improved with an expert view, and the evaluation methods may be refined to reduce subjectivity.

CRediT authorship contribution statement

Yong Guo: Writing – original draft. **Jing Tao:** Data curation. **Fuqiang Yang:** Writing – review & editing, Supervision, Resources, Methodology, Conceptualization. **Chao Chen:** Writing – review & editing, Supervision, Methodology. **Genserik Reniers:** Data curation, Supervision, Validation, Writing – review & editing.

Declaration of Competing Interest

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

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