Factors analysis and safety risk assessment of port dangerous cargo container yard location

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Abstract. Due to the inflammable, explosive and toxic characteristics of the goods stored in the container yard of dangerous goods, its operation risk once out of control is likely to lead to serious production safety accidents, causing huge losses to personnel, property and society, and emergency handling of accidents is also very difficult. This paper systematically analyzes the index elements in the site selection process of dangerous cargo container yard, and establishes a multi-level and multi-dimensional risk assessment index system. Ahp is adopted to assign the weights of the evaluation index system, fuzzy comprehensive evaluation rules are finally proposed, fuzzy mapping relationship is established, fuzzy matrix and weight vector are used to calculate the evaluation vector to achieve the quantitative evaluation conclusion, and a risk assessment method combining AHP and fuzzy comprehensive evaluation is formed for the port dangerous cargo container yard. The effectiveness of the technique is verified by an example of the site selection of a port loading and storage yard for dangerous goods.

Keywords: Port container yard for dangerous goods; Analytic hierarchy process; Fuzzy evaluation; Fishbone diagram method; Risk assessment

1 Introduction

Port dangerous goods container yard is a special place for storing dangerous goods containers in the open air in the port area [1]. As "a container storage buffer factor in the entire port operation chain", the efficient and safe operation of the container yard will increase the relative capacity of the port and improve the operation efficiency of the port. In recent years, the scale of port operation of dangerous goods has expanded rapidly, showing the characteristics of increasing types and quantities of shipments, coupled with the dangerous goods themselves are mostly flammable, explosive, toxic and other dangerous and harmful characteristics, which have led to the increasing risk of port security. In 2015, a major fire and explosion at Ruihai's dangerous goods warehouse in Tianjin Port on August 12 killed 165 people, left 8 missing and injured 798. 304 buildings, 12,428 commercial vehicles and 7,533 containers were damaged, resulting in a direct economic loss of 6.866 billion yuan. In 2020, the explosion in the port area of Beirut, the capital of Lebanon, caused serious damage to facilities within 5 kilometers of the explosion center, and buildings within 10 kilometers were

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damaged to varying degrees, resulting in 177 deaths, more than 6,000 injuries, and about dozens of missing people. It can be seen that once a production safety accident occurs during the storage of dangerous goods, its social and economic impact will be extremely bad.

Dangerous goods container piles in major coastal ports in China are located in designated areas behind the docks, with the stock ranging from 400 to 600TEU, and the number of dedicated dangerous goods container yards is not large. The situation of dangerous goods container yards in major coastal ports in China is shown in Table 1.

Table 1. Situation of dangerous goods container yard in Chinese port

Serial number	Port name	Dangerous goods container yard
1	Port of Shanghai	There are 8 operators of dangerous goods container yards in the port of Shanghai, mainly distributed in Waigaoqiao Port area and Yangshan Port area, among which 7 port operators have built supporting dangerous goods container yards behind the container loading terminals for decentralized management, and dangerous goods container yards have limited time and limited storage management, covering an area of $5000m^2$~$10000m^2$. At the same time, Shanghai Port City Dangerous Goods Logistics Co., Ltd. is specialized in dangerous goods container transportation, loading and unloading, warehousing, unpacking, packing site, the yard covers an area of about 200,000 m^2, all kinds of dangerous goods are also limited storage
2	Port of Ningbo	There are 7 operators of dangerous goods container yards in Ningbo port area, and the types of dangerous goods stored are class 1, 2, 3, 4, 5, 6, 8 and 9 (some dangerous goods are limited in time, and heavy drugs and ammonium nitrate substances are prohibited to be stored). One of the 7 dangerous goods container yards is a professional dangerous goods yard set up in a centralized way. The other 6 are storage yards supporting container terminals
3	Port of Qingdao	There are three dangerous goods container yards in Qingdao Port, which are located at the rear of the port and store all kinds of dangerous goods in limited quantity and limited time
4	Port of Tianjin	There is a logistics company in Tianjin Port that has the port operation qualification for storing category 8 and 9 dangerous goods. There is no supporting container yard for dangerous goods behind the container terminals under construction or already in operation

In the current study, researchers have used BP (Back Propagation) neural network, Bayesian network, multi-evaluation, fire identification and accident tree analysis to analyze and evaluate the location of dangerous cargo container yard [1-3], focusing on the evaluation method based on the basic theory construction based on model. All of the above methods need to collect a large number of sample data and repeated simulation calculations, which is more suitable for the field with relatively single impact indicators. Social impact should be fully considered in the site selection process of dangerous goods container yard. There are multi-dimensional influences such as concentration of operation volume, diversification of cargo types, scale of cargo quantity and significant impact of accident consequences. The application of the above methods requires a relatively long period. The analytic Hierarchy Process (AHP) and fuzzy comprehensive judgment (FCE) have been widely used in the field of port operation risk assessment [4-5], which can carry out quantitative analysis of complex and fuzzy problems more conveniently. In summary, AHP and FCE will be applied in this paper to put forward a comprehensive assessment method based on the probability and severity of risk influencing factors. The model quantifies the risk level based on the influence factors existing in the operation process, so as to determine the risk degree of the site selection of dangerous cargo container yard.

2 Technical method

Based on the existing risk control theory, this paper puts forward a comprehensive risk assessment method based on AHP and FCE for dangerous cargo container port operation. On the basis of expert investigation, the method uses fishbone diagram to reflect the key influencing factors in the site selection process of dangerous cargo container yard, so as to build the index set of evaluation model, and uses AHP to solve the hierarchical structure and weight distribution of evaluation indicators to achieve quantitative evaluation of the model. Finally, FCE evaluation rules are set for application verification and analysis of evaluation conclusions. This method can be used to solve a series of complex process and uncertain factors of location model analysis. The proposed technical route is shown in Figure 1.

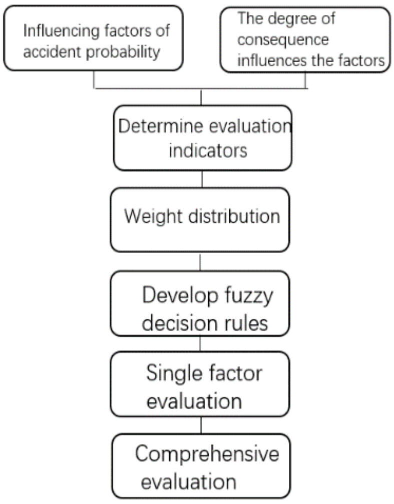

Figure 1 The analytic hierarchy process (AHP) and fuzzy decision principle are used for risk assessment Technology roadmap

2.1 Screening methods for evaluation indicators

According to the safety engineering theory, danger is a potential state opposite to safety, and risk considers the possibility of accident more, and accident is the state of dangerous events. Affected by particularly serious production safety accidents, more consideration is given to the risk and its inherent risks in the selection process of port dangerous cargo container yard. Through the inquiry of industry experts, the fishbone chart is used to find the factors that have a greater impact on the location of container yards, and a multi-level risk assessment index system is established.

2.2 Analytic hierarchy process

The analytic hierarchy process (AHP) is a simple method that combines qualitative and quantitative analysis to make decisions on fuzzy or complex decision-making problems. In particular, it quantifies the experience judgment of decision makers. By hierarchizing people's thinking process, it compares relevant factors layer by layer, and tests the rationality of comparison results layer by layer, thus providing a more convincing basis. It is usually used to solve the ranking problem among multiple groups of schemes [6-7]. This method is used in this paper to assign the weights of evaluation indicators at all levels.

In this paper, the analytic hierarchy process is used to calculate the weight of evaluation indicators. The target layer is the target of model evaluation, and the target layer is usually composed of several factors affecting the target layer, which can be divided into several levels, such as first, second and third. The evaluation matrix A=(aij)n×n was established by pairwise comparison among the n evaluation factors of the index layer based on their influence on the upper factors, and the consistency test was carried out by the following formula

$$\mathrm{CI} = \frac{\lambda\mathrm{max} - \mathrm{n}}{\mathrm{n} - 1} \quad (1)$$

$$\mathrm{CR} = \frac{\mathrm{CI}}{\mathrm{RI}} \quad (2)$$

Where: is the maximum eigenvalue of the judgment matrix A; n is the order of the judgment matrix A; RI is a random consistency indicator. For details about its values, see Table 1.

When judging that the order of matrix A is 1 and 2, the positive reciprocal matrix of order 1 and 2 is always the consistency matrix, so RI=0, at this time, CR=0 is defined. When the order of the judgment matrix A is ≥3, if CR<0.10, the judgment matrix A can pass the consistency test, and the judgment matrix A should be modified.

After the judgment matrix A passes the consistency judgment, the weight vector of A is calculated and the overall consistency test is carried out using the following formula

$$\sum_{\mathrm{j}=1}^{\mathrm{n}} \omega_{\mathrm{j}} = 1 \quad (3)$$

$$\mathrm{A}\omega = \mathrm{n}\omega \quad (4)$$

Where: ω is the normalized vector, that is, ω is the eigenvector of the eigenvalue n of the matrix A.

$$CR^{(k)} = \frac{\sum_{j=1}^{t} a_j CI_j^{(k)}}{\sum_{j=1}^{t} a_j RI_j^{(k)}}, k = 3, 4, \cdots, s \quad (5)$$

Where: $CR^{(1)} = 0, CR^{(k)}$ is the consistency ratio of the judgment matrix of each index layer, and the condition for the k index layer to pass the combination consistency test is generally $CR^{(k)}$<0.1.

$$CR^{*} = \sum_{K=2}^{S} CR^{(k)} \tag{6}$$

Major decision-making problems should be controlled CR^{*} by appropriate elimination, in order to be considered as a whole to pass the consistency test

2.3 Fuzzy comprehensive evaluation

Fuzzy comprehensive evaluation means that the evaluation results of various factors related to the evaluation object are used to form a corresponding evaluation matrix, and the weight factors that determine the importance of each factor are used to make fuzzy transformation, and the evaluation results of the evaluation object are finally obtained. This paper uses this method to evaluate the location indicators of the port dangerous cargo container yard, so as to obtain quantitative conclusions.

In the research, the influencing factors of the evaluation object, that is, the evaluation indicators, are usually set as the set U={u1, u2, u3... The number of.um},m is determined by specific evaluation indicators. In order to facilitate weight allocation and calculation, evaluation indicators are usually divided into several classes and multi-levels according to the attributes of evaluation indicators, and the expected evaluation results in n of evaluation objects are usually set as the set V={v1, v2, v3... vn}. Using analytic hierarchy process, the weight vector set ω={a1, a2, a3... am}, and on this basis set a fuzzy mapping of the set U to V: f: U→V, and set the fuzzy matrix R to express the fuzzy mapping relationship. On this basis, the fuzzy synthetic vector B of the evaluation object can be obtained by synthesizing the weight vector set ω and the fuzzy matrix R. On this basis, the evaluation results are qualitatively processed by combining the evaluation object comment set and using the following publicity

$$R=\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} \tag{7}$$

$$B = \omega R = (a_1,\ a_2, \cdots,\ a_m)\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{23} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix} = (b_1,\ b_2, \cdots,\ b_n) \tag{8}$$

Where: bj represents the degree of membership of the evaluation object to the review set vj as a whole.

3 Construction of location index system of dangerous cargo container yard

3.1 Risk identification based on fishbone maps

The fishbone chart was proposed by Japanese researchers in the 1960s, and was originally used in the process quality management of shipyards, named for its graphic shape, and has been widely used in process safety analysis because of its intuitive and easy to use characteristics. Combined with the statistical analysis in the following table, the fishbone diagram should take "compliance of planning policy", "surrounding environment", "transportation cost" and "emergency resources" as the main bones. Usually, in the siting process of port dangerous cargo containers, The influencing factors of "planning policy compliance" are mainly determined by planning compliance, development boundary verification, permanent ecological protection area verification and industrial policy compliance. The influencing factors of "surrounding environment" are mainly determined by key protection targets, collection and distribution, supporting facilities, and the number of hazardous enterprises. "Transportation cost" mainly considers three factors: transportation distance, transportation path and transportation environment[10-11]. The influencing factors of "emergency resources" are mainly emergency materials, emergency linkage and social emergency forces. In addition, combined with the main characteristics and risk rules of the operation process of the port dangerous cargo container yard, "operating conditions" and "accident statistics" are also the core elements[8-9]. Therefore, the final fishbone diagram has six bones, and the contents below each bone represent the specific factors contained in the causes of this type of site selection. Theoretically, each factor can independently affect the results of container yard location, as shown in Figure 2.

To sum up, an index set of influencing factors of location selection of dangerous cargo container yard in common use is constructed by using each factor in fishbone diagram. The index system consists of 6 primary indexes and 19 secondary indexes.

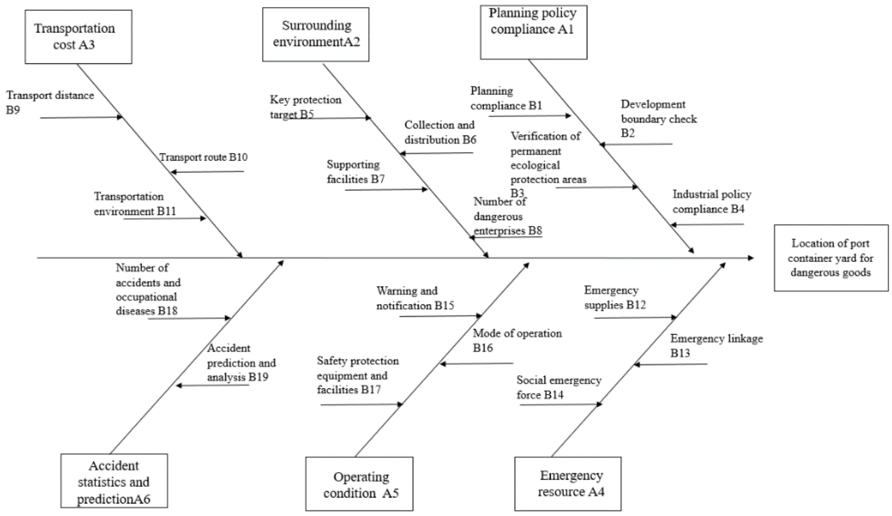

Fig 2 Factor analysis of port dangerous cargo container yard location based on fishbone diagram method

3.2 Weight distribution

100 experts in port dangerous goods safety management were invited to participate in this study. 57% of the experts were between 30 and 40 years old and 43% were between 40 and 70 years old. 62% of those with a bachelor's degree and 38% with a master's degree or above; The research direction focused on port safety management was 82%, and the research direction focused on mathematical statistics was 18%. By issuing questionnaires, experts judge and compare the pairwise importance of indicators at each level, construct a judgment matrix by pairwise comparison of the same indicator, and carry out consistency test until "pass" determines the weight in the hierarchical indicator system.

Among them, the judgment matrix constructed by the first-level evaluation index system and the conclusion of consistency test are shown in Table 4 to Table 6. Similarly, the judgment matrix of the second-level evaluation index system can be obtained and passed the consistency test. The weight vector and consistency test results of the evaluation fuzzy index set are shown in Table 6.

Similarly, the judgment matrix of each index system at the second level can be obtained and passed the consistency test. The index set and weight vector of the evaluation model and the consistency test results are shown in Table 2.

Table 2 Index set of port dangerous goods container yard location index system

Target layer	Index level		
	Primary index	Secondary index	Index evaluation content
Factors influencing site selection of port dangerous cargo container yard	Planning policy complianceA1	Planning complianceB1	Compliance with port master planning and detailed control line planning
		Development boundary checkB2	In accordance with the "three districts and three lines" control and urban construction land use control requirements, check the development boundary
		Verification of permanent ecological protection areasB3	Whether the site is located in a permanent ecological protection area
		Industrial policy complianceB4	Is it consistent with local industrial policy
	Surrounding environmentA2	Key protection targetB5	GB36984 in the clear types of protection objectives
		Collection and distributionB6	Collection and distribution routes, volume, etc
		Supporting facilitiesB7	Supply of coal, water and electricity
		Number of dangerous enterprisesB8	Number of hazardous chemicals production and storage enterprises
	Transportation costA3	Transport distanceB9	Transport distance condition
		Transport routeB10	Transport route
		Transportation environmentB11	Transport route surrounding information

Target layer	Index level		
	Primary index	Secondary index	Index evaluation content
	Emergency resourceA4	Emergency resourceB12	Emergency materials allocation
		Emergency linkageB13	The linkage with the surrounding units
		Social emergency forceB14	Social emergency resources
	Mode of operationA5	Warning and notificationB15	Setting of warning and notification on site of dangerous goods container yard
		Mode of operationB16	Including container stacking and unpacking operations
		Safety protection equipment and facilitiesB17	The configuration of safety protection equipment and facilities for site operation
	Accident statistics and predictionA6	Number of accidents and occupational diseasesB18	Statistics on the occurrence of serious injuries and occupational diseases
		Accident prediction and analysisB19	The cause of the accident is analyzed systematically and the safety situation is predicted

3.3 Risk assessment of container yard location

3.3.1 Evaluate object situation

The evaluation object of this study is the proposed site selection scheme of a new dangerous goods container yard in a certain area, which covers an area of 99,000 square meters, the surrounding environment is relatively empty, and no production and storage units of inflammable and explosive dangerous chemicals are involved within 3 kilometers. The types of dangerous goods involved in the operation include category 2 (gases), Category 3 (flammable liquids), Category 4 (flammable solids, substances prone to spontaneous combustion), Category 5 (oxidizing substances and organic peroxides), Category 6.1 (toxic substances), category 8 (corrosive substances), and category 9 (miscellaneous dangerous substances and articles, including substances hazardous to the environment). The operation process adopted by the company is "collection and distribution operation, unpacking operation, inspection operation", etc. The site selection of the storage yard is located within the overall planning boundary of the port, the nature of the land is consistent with the detailed control plan, and it is near the ecological protection area. The gathering and transportation route is long, about 10km, and the transportation route passes through villages, tourist areas, expressways, etc. There are more than 100 on-site workers, with a relatively complete safety facilities, auxiliary production system safety facilities, fire facilities and safety signs.

3.3.2 Paste evaluation process

A set of comments was set. 100 experts invited in this study evaluated 19 second-level evaluation indicators according $V=\{\text{good, preferably, intermediate, range, nonacceptance}\}$ to the site selection of the above companies, and used the number of comments obtained by each indicator to form a fuzzy mapping relationship and a fuzzy matrix,table 3 shows the assignment table of the judgment matrix of the first-level evaluation index system

Table 3 Assignment table of early judgment matrix of first-level evaluation index system

	A1	A2	A3	A4	A5	A6
A1	1	1	1/2	1/3	1/3	1/2
A2	1	1	1/3	1/2	1/4	1/4
A3	2	3	1	1/3	2	1
A4	3	2	3	1	1/2	1/2
A5	3	4	1/2	2	1	1
A6	2	4	1	2	1	1

Table 4 Consistency test of judgement matrix of first-level evaluation indicators

	W^T	λ_{max}	Consistency check			
			CI	RI	CR	Pass or not
A1	0.083					
A2	0.070					
A3	0.189					
A4	0.193	6.484	0.097	1.240	0.078	Pass
A5	0.227					
A6	0.238					
B19	0.667					

$$R_1 = \begin{bmatrix} 0.1 & 0.7 & 0.2 & 0.0 & 0.0 \\ 0.0 & 0.1 & 0.5 & 0.4 & 0.0 \\ 0.0 & 0.1 & 0.3 & 0.5 & 0.1 \\ 0.1 & 0.1 & 0.4 & 0.4 & 0.0 \end{bmatrix} \quad R2 = \begin{bmatrix} 0.1 & 0.7 & 0.2 & 0.0 & 0.0 \\ 0.1 & 0.2 & 0.5 & 0.2 & 0.0 \\ 0.1 & 0.3 & 0.4 & 0.2 & 0.0 \\ 0.1 & 0.4 & 0.3 & 0.2 & 0.0 \end{bmatrix}$$

$$R3 = \begin{bmatrix} 0.1 & 0.6 & 0.3 & 0.0 & 0.0 \\ 0.2 & 0.4 & 0.4 & 0.0 & 0.0 \\ 0.2 & 0.4 & 0.4 & 0.0 & 0.0 \end{bmatrix} \quad R4 = \begin{bmatrix} 0.1 & 0.6 & 0.3 & 0.0 & 0.0 \\ 0.2 & 0.4 & 0.4 & 0.0 & 0.0 \\ 0.0 & 0.1 & 0.5 & 0.4 & 0.0 \end{bmatrix}$$

$$R5 = \begin{bmatrix} 0.0 & 0.0 & 0.3 & 0.6 & 0.1 \\ 0.0 & 0.2 & 0.6 & 0.2 & 0.0 \\ 0.0 & 0.1 & 0.1 & 0.2 & 0.6 \end{bmatrix} \quad R6 = \begin{bmatrix} 0.8 & 0.1 & 0.1 & 0.0 & 0.0 \\ 0.1 & 0.7 & 0.2 & 0.0 & 0.0 \end{bmatrix}$$

By using the fuzzy matrix and the comprehensive weight vector in Table 6, the fuzzy comprehensive evaluation vector for the location selection of the dangerous cargo container yard can be calculated as

$$R = (0.14, 0.295, 0.338, 0.185, 0.042)$$

$$B = \omega R = (0.134, 0.283, 0.323, 0.176, 0.04)$$

Table 5 List of overall consistency tests for the index set of the evaluation model

level	A1	A2	A3	A4	A5	A6	Comprehensive weight	Global consistency CI	Population random consistency	Global consistency	Pass or not
	0.083	0.070	0.189	0.193	0.227	0.238			indexRI		
B1	0.168						0.014				
B2	0.180						0.015				
B3	0.282						0.023				
B4	0.371						0.031				
B5		0.120					0.008				
B6		0.187					0.013				
B7		0.247					0.017				
B8		0.446					0.031				
B9			0.143				0.027				
B10			0.286				0.054	0.040	0.491	0.081	通过
B11			0.571				0.108				
B12				0.143			0.028				
B13				0.286			0.055				
B14				0.571			0.110				
B15					0.493		0.112				
B16					0.311		0.071				
B17					0.196		0.044				
B18						0.333	0.079				
B19						0.667	0.159				

Note: In the process of calculating the weight of the above weight indicators, because some data cannot be evenly divided, in order to ensure accuracy, the sum of weights is not equal to 1 because of rounding and retaining 3 decimal places. So the last number takes the reciprocal.

3.3.3 Quantitative manifestation and analysis of evaluation results

In order to better quantitatively reflect the correlation degree of indicators in the selection process of dangerous goods container yard, a clear score set C is set for the evaluation set, and a set of safety risk degree assessment set interval is designed, as shown in Table 6. The degree of representation risk can be determined by the mapping relationship of fuzzy comprehensive evaluation vector to the review set.

By combining the setting results in Table 6, the location of the dangerous goods container yard can be calculated. Vector B is normalized to obtain

$$B' = \left\{ \frac{0.134}{0.956}, \frac{0.283}{0.956}, \frac{0.323}{0.956}, \frac{0.176}{0.956}, \frac{0.04}{0.956} \right\} =$$

（0. 14，0. 295, 0. 338, 0. 185, 0. 042）

The evaluation quantification score is: $F = B' \times C = 77.0$ (Take one decimal place)

Table 6 Comprehensive risk degree registration form

Collection of commentaries	good	preferably	intermediate	range	unacceptability
Fuzzy mapping score	95	85	75	65	30
C security risk degree evaluation set score interval	[100,90]	(90,80]	[80,70]	(70,60]	(60,0]

Comparing the mapping relationship in Table 7, it can be concluded that the degree of security risk is moderate. The evaluation quantification scores of the first level and the second level can also be obtained.

Table 7 Evaluation quantification scores of the second-level index layer

Target layer	Quantitative scoreF	Evaluation result	Secondary index	Quantitative scoreF	Evaluation result
Planning policy complianceA1	73.3	intermediate	Planning complianceB1	84	preferably
			Development boundary checkB2	72	intermediate
			Verification of permanent ecological protection areasB3	66.5	range
			Industrial policy complianceB4	74	intermediate
Surrounding environmentA2	79	intermediate	Key protection targetB5	84	preferably
			Collection and distributionB6	77	intermediate
			Supporting facilitiesB7	78	intermediate
			Number of dangerous enterprisesB8	79	intermediate

Transportation costA3	82.1	preferably	Transport distanceB9	83	preferably
			Transport routeB10	80	preferably
			Transportation environmentB11	83	preferably
Emergency resourceA4	76.7	intermediate	Emergency resourceB12	83	preferably
			Emergency linkageB13	83	preferably
			Social emergency forceB14	72	intermediate
Mode of operationA5	64.3	range	Warning and notificationB15	64.5	range
			Mode of operationB16	75	intermediate
			Safety protection equipment and facilitiesB17	47	unacceptability
Accident statistics and predictionA6	86.7	preferably	Number of accidents and occupational diseasesB18	92	good
			Accident prediction and analysisB19	84	preferably

Through the quantitative score of the evaluation results, it can be intuitively concluded that the site selection of the company's dangerous cargo container yard is medium. From the evaluation results of the first-level indicators, 2 of the 6 first-level indicators are "good", 3 are "medium" and 1 is "poor". According to the evaluation results of the second-level indicators, special attention should be paid to "safety protection equipment and facilities" and "verification of permanent ecological protection areas" to further improve the risk situation of "the location of dangerous cargo container yard".

4 Conclusion

This paper puts forward a set of risk assessment methods for the location of port dangerous cargo container yard, and draws the following conclusions:

(1) Using the fishbone diagram method to analyze the port container yard for dangerous goods is helpful to systematically identify the key elements and objective laws in the selection process of the container yard, and establish a systematic evaluation index set.

(2) The comprehensive application of analytic hierarchy process (AHP) and fuzzy comprehensive evaluation method can solve the operation risk assessment with complex processes and many uncertain factors, simplify the amount of data acquisition and calculation scale, and determine the guidance of each index with analytic hierarchy process. This research

establishes a set of risk assessment index system with 2 levels, 6 categories and 19 indicators. The analytic hierarchy process is used to determine the impact weight of each indicator, and the fuzzy comprehensive evaluation method is used to establish a fuzzy mapping relationship between evaluation indicators and evaluation results, so as to realize the quantitative reflection of evaluation results and provide multi-layer and multi-dimensional conclusions to reflect the risk degree of the assessed object.

(3) Through the study on the site selection of a new container yard in northern China, it is found that the timely method proposed in this study can be better applied to the risk identification and assessment of the site selection of a port container yard for dangerous goods. Based on the evaluation results, targeted risk control measures are proposed, so as to effectively reduce the risks in the operation process.

(4) There is too subjective uncertainty of fuzzy evaluation in the current evaluation process. Subsequent studies can further focus on the formulation of fuzzy evaluation rules for indicators to make the evaluation results more accurate.

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