

Analysis of Key Elements of Emergency Response Ability of Hazardous Chemicals Based on AHP Method

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Abstract: A evaluation system was constructed and each weight of the indexes was calculated based on the principle of AHP (Analytic Hierarchy Process), which were benefit of safety and sustainable development of chemical enterprise, emergency response capacity, accidents numbers and property losses The results show that emergency prevention capability and emergency preparedness capability are the key elements in the first-level indicator system. The plan initiation, drill, hazard source control and monitoring and early warning, emergency command, coordination and rapid response capability are the key elements in the secondary indicators.

0 Introductions

With the rapid development of our country's economy and society, chemical accidents happen constantly, and the situation of safe production is very serious. For example, Tianjiayi's "3 · 21" explosion caused 78 deaths and 566 injuries. Jiangsu Shurangama Chemical Company's "4 · 16" deflagration accident killed 8 people and injured 9 people. There are many enterprises in the chemical industry park, and the dangerous chemicals produced, stored and transported are of great risk, variety and quantity. Once a chemical accident occurs, it may not be dealt with timely and effectively due to insufficient emergency response capacity, resulting in serious accident consequences^[1].

In recent years, chemical safety production has become the focus of national attention. The number of accidents has increased and the damage has increased. It is particularly necessary to evaluate and construct the emergency response capability of hazardous chemicals enterprises.

Yang Jixing^[2] constructed an evaluation system of five first-level indicators and 23 second-level indicators, including risk identification and control, prevention and preparation, disposal and rescue, post-recovery and reconstruction, and emergency response capacity guarantee. Yang zhenhong^[3] established an evaluation system of 4 first-level indicators, 9 second-level indicators and 31 third-level indicators. Chen Wentao^[4] evaluated the triangle rescue mathematics theory and the fuzzy comprehensive evaluation team's emergency rescue capability. Zhang Shaogang^[5] established a three-level emergency capability evaluation model and applied it with AHP-fuzzy comprehensive method. Based on the emergency management process, this paper analyses the key elements of the emergency

capability improvement process by establishing the index system that affects the emergency capability of hazardous chemicals enterprises, and promotes the emergency response capability of hazardous chemicals accidents.

1 Emergency capability evaluation model for hazardous chemicals accidents

According to the various factors affecting emergency response capability, the AHP method is used to establish a multi-level structure index system, and the emergency response capability is quantitatively studied to find out the key elements in the emergency capability improvement process to achieve the purpose of optimization decision-making.

Table 1 Hierarchical model of emergency management capability evaluation of hazardous chemicals enterprises

Target layer	Criteria layer	Indicator layer
Emergency apability evaluation	Emergency prevention capability (B_1)	Monitoring and warning (C_1)
		Hazard control (C_2)
		Disaster insurance (C_3)
		Management ability (C_4)
	Emergency preparedness (B_2)	Perfection of system (C_5)
		Emergency resource protection (C_6)
		Emergency team (C_7)
		Preplan rehearsal (C_8)
	Emergency response capability (B_3)	Plan start (C_9)
		Rapid response capability (C_{10})
		Emergency experts and

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		technical support (C_{11})
		Emergency command and coordination (C_{12})
	Emergency recovery capability (B_4)	Return to normal production order (C_{13})
		Loss assessment (C_{14})
		Aftercare (C_{15})
		Post hoc summary (C_{16})

According to the principle and analysis process of AHP, the emergency capability evaluation is taken as the target layer, and the prevention, preparation, response and recovery in the emergency management process are taken as the criterion layer, and the index layer composed of 16 secondary indicators is determined. The final evaluation model of emergency management capability of hazardous enterprises is shown in Table 1.

2 Weight calculations of evaluation indexes

2.1 Determination of judgment criteria

As a systematic evaluation method, the AHP method must be evaluated by language description based on the unified comparison benchmark in the element pairing comparison. Through experiments, Satty^[6] found that the scale of Numbers 1-9 reflected the judgment ability of the majority, so the scale of 1-9 was adopted and the specific detail was shown in table 2.

Table 2 Meaning of 1-9 scale

Scaling	Meaning
1	C_i has the same effect as C_j
3	C_i is slightly more influential than C_j
5	C_i has a stronger influence than C_j
7	C_i is significantly stronger than C_j
9	C_i is definitely stronger than C_j
2, 4, 6, 8	The intermediate value of the above two adjacent judgment levels
1, 1/2, ..., 1/9	The factors i and j are compared as C_{ij} , then the factor j is compared with i , $C_{ji}=1/C_{ij}$

2.2 Construct a pairwise judgment matrix

According to the calculation principle of the analytic hierarchy process, the importance relationship between each element is determined, and the judgment matrix is constructed by using the 1-9 scale method. According to the score results, the comparison results of the relative importance of each indicator are shown in Table 3.

Table 3 Comparison of the importance of emergency prevention capabilities

B_1	C_1	C_2	C_3	C_4	W_{A_i}
C_1	1	1/2	3	2	0.29
C_2	2	1	3	2	0.41
C_3	1/3	1/3	1	1/2	0.11

C_4	1/2	1/3	2	1	0.19
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Table 4 Comparison of the importance of emergency preparedness

B_2	C_5	C_6	C_7	C_8	W_{A_i}
C_5	1	2	2	1/2	0.26
C_6	1/2	1	3	1/2	0.21
C_7	1/2	1/3	1	1/3	0.11
C_8	2	2	3	1	0.42

Table 5 Comparison of the importance of emergency response capabilities

B_3	C_9	C_{10}	C_{11}	C_{12}	W_{A_i}
C_9	1	2	3	2	0.4
C_{10}	1/2	1	2	1/3	0.17
C_{11}	1/3	1/2	1	1/3	0.11
C_{12}	1/2	3	3	1	0.32

Table 6 Comparison of the importance of emergency recovery capabilities

B_4	C_{13}	C_{14}	C_{15}	C_{16}	W_{A_i}
C_{13}	1	2	1/3	2	0.24
C_{14}	1/2	1	1/2	2	0.19
C_{15}	3	2	1	3	0.46
C_{16}	1/2	1/2	1/3	1	0.11

Table 7 Comparison of the importance of emergency management capabilities of hazardous chemicals enterprises

A	B_1	B_2	B_3	B_4	W_{A_i}
B_1	1	2	1/2	2	0.27
B_2	1/2	1	1/2	2	0.19
B_3	2	2	1	3	0.42
B_4	1/2	1/2	1/3	1	0.12

2.3 Consensus test of the criterion layer

According to the judgment matrix relationship and the calculated weight vector, the consistency test is performed, and the test results are shown in Table 8.

Table 8 Consistency test results

Indicator layer	λ_{max}	CI	RI	CR
$A-B$	4.08	0.03	0.9	0.03
B_1-C_{1-4}	4.14	0.05	0.9	0.06
B_2-C_{5-8}	4.14	0.05	0.9	0.06
B_3-C_{9-12}	4.15	0.05	0.9	0.06
B_4-C_{13-16}	4.08	0.03	0.9	0.03

As can be seen from Table 8, all judgment matrices $CR < 0.1$, all met the conformance test criteria.

2.4 Hierarchical total ordering

The above is the weight vector of a group of elements to an element in the previous layer. Total ranking is the ranking weight of the relative importance of all factors in the same level to the target level. The overall ranking of all factors of emergency response capacity

of hazardous chemical enterprises was conducted, and the results are shown in 9.

Table 9 Level total ordering and each indicator weight result

Criterion layer indicators	Index layer index	Index layer weight	The sorting	Criterion layer weight
Emergency prevention capability (B_1)	C_1	0.0783	5	0.27
	C_2	0.1107	3	
	C_3	0.0297	12	
	C_4	0.0513	8	
Emergency preparedness (B_2)	C_5	0.0494	9	0.19
	C_6	0.0399	11	
	C_7	0.0209	15	
	C_8	0.0798	4	
Emergency response capability (B_3)	C_9	0.1680	1	0.42
	C_{10}	0.0714	6	
	C_{11}	0.0462	10	
	C_{12}	0.1344	2	
Emergency recovery capability (B_4)	C_{13}	0.0288	13	0.12
	C_{14}	0.0228	14	
	C_{15}	0.0552	7	
	C_{16}	0.0132	16	

2.5 Level total order consistency test

Index of overall ranking of hierarchical structure relative to hierarchical structure consistency:

$$CI_G = \sum_{i=1}^m a_i CI_i = 0.27 \times 0.03 + 0.19 \times 0.06 + 0.42 \times 0.06 + 0.12 \times 0.03 = 0.0483$$

The total average random consistency index of the total ranking of the hierarchical structure relative to the hierarchical structure:

$$RI_G = \sum_{i=1}^m a_i RI_i = 0.27 \times 0.9 + 0.19 \times 0.9 + 0.42 \times 0.9 + 0.12 \times 0.9 = 0.988$$

Index of overall relative consistency of hierarchical structure:

$$CR_G = \frac{CI_G}{RI_G} = \frac{0.0483}{0.988} = 0.0489$$

The results of the hierarchical sorting consistency check are shown in Table 10.

Table 10 Total ranking consistency test results

Indicator layer	CI_G	RI_G	CR_G
A	0.0483	0.988	0.0489

It can be seen from Table 10 that $CR_G < 0.1$, it shows that the judgment matrix of the indicator system passes the consistency test.

3 Results analysis

According to the above weight calculation results and overall hierarchical ranking results, it can be seen that the index weight of the criterion layer for the evaluation of emergency response capability of hazardous chemical enterprises is ranked from the largest to the smallest in order of emergency response capability (0.42), emergency prevention capability (0.27), emergency preparation capability (0.19) and emergency recovery capability (0.12). Therefore, in the emergency management process, hazardous chemicals enterprises should focus on strengthening the emergency response capability and emergency prevention capability of hazardous chemicals enterprises.

According to the weight results of each index, the indicators such as pre-plan initiation (0.1680), emergency command and coordination (0.1344), hazard source control (0.1107), monitoring and early warning (0.0783), pre-plan exercise (0.0798) and emergency quick response capability (0.0714) account for a larger weight. The ability of emergency team construction, post-event summary and evaluation is very low, which needs to be paid attention to in the process of emergency management capacity construction of hazardous chemical enterprises.

4 Conclusions

The emergency response evaluation system of chemical enterprises was constructed, including four first-level indicators and 16 second-level indicators, and the two-two judgment matrix was constructed to obtain the weight of each indicator. All indicators and the overall ranking passed the consistency test. It is considered that emergency prevention and response capability are the key elements of first-level indicators, and emergency quick response capability, emergency command and coordination, plan initiation, hazard source control, monitoring and early warning and plan exercise are the key elements of second-level indicators.

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