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중국의 위험물 창고 보관사고 분석 및 안전관리방안에 관한 연구*

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Dangerous goods warehouse storage accident and safety management: evidence from Chinese data analysis

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Abstract

This paper aims to reduce the frequency of dangerous goods storage accidents in China. Advocating the managers of warehousing and logistics enterprises to pay attention to the operation process of dangerous goods warehousing business. Improving the safe storage and management capabilities of dangerous goods warehouses. This article first collects official data on dangerous goods storage accidents in China and conducts a general statistical analysis of the accidents. Based on the results of accident statistics and related literature research on dangerous goods storage management, establish a dangerous goods storage safety management factor system, use the analytic hierarchy process, establish a factor importance questionnaire and implement data collection. Through statistics, this paper finds that the storage accidents of dangerous goods in China in the past ten years mainly occurred in the inbound phase of dangerous goods and the storage phase of dangerous goods warehouses. Through the results of the analytic hierarchy process, it is found that the professionalism of the dangerous goods storage practitioners, the compliance of the practitioners with safety regulations, and the awareness of operational safety are the most important.

Keywords: Dangerous Goods, Warehouse Management, Storage Accidents, Safety Awareness, Port Logistics
JEL Classifications: M11, M14

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Ⅰ. Introduction

As the chemical industry has developed, there have been continual expansion in the production and trade of dangerous goods, and accidents caused by dangerous goods frequently occur in the supply chain, particularly in logistic and storages. Rigas and Sklavounos (2004) predicted that the storage of dangerous goods in densely populated areas could lead to catastrophic consequences in the event of an accident. On August 12, 2015, a series of explosions ripped through the warehouse of Ruihai Logistics in Tianjin Port, leaving 165 dead, eight missings, and 798 injured. The blast also damaged 304 buildings, 12,428 cars, and 7,533 containers, with total economic losses of 6.87 billion yuan ($1.01 billion). In addition, on August 4, 2020, a large amount of ammonium nitrate stored in the port of the city of Beirut, Lebanon, exploded, causing at least 137 deaths, 5,000 injuries, leaving an estimated 300,000 people homeless.

Accidents involving such dangerous goods cause relatively amounts of casualties and economic losses. However, in China, the study of safety management regarding the transportation and storage of dangerous goods is considerably less than in other developed countries. This study was conducted to propose a plan to improve plan the safety management of the storage of dangerous goods in Chinese warehouse logistics enterprises with the ultimate aim of reducing the occurrence of dangerous goods storage accidents in China's warehousing and logistics enterprises, reducing the numbers of casualties in such accidents, and minimizing financial losses.

This article presents the stage of occurrence of accidents in warehousing operations, establishing a ranking table of the importance of dangerous goods storage safety management factors. This study collected and studied storage accidents in China involving dangerous goods over a 10-year period (2010–2019) and summarized the characteristics of these accidents. Further, relevant research on storage was reviewed in telephone interviews, the business processes for the warehouse storage of dangerous goods were clarified, and important factors regarding the safety management in dangerous goods warehouse storage were clarified. A questionnaire survey was conducted of experts in the field of dangerous goods storage management in China and assessed with the analytic hierarchy process, the determine the relative importance of all factors in the safety management of dangerous goods storage.

Ⅱ. Literature Review

1. Dangerous goods accidents

First, the relevant research on dangerous goods accidents in logistics companies was reviewed. Chen et al. (2020) used a method of formal concept analysis to conduct statistical analyses of dangerous goods accidents in ports in China and elsewhere. Three key factors regarding accidents involving dangerous goods at Chinese ports were found: warehousing management, facilities and equipment, and goods registration. Ellis (2011) analyzed records of the release of dangerous goods releases in the US and UK over the 11-year period of 1998–2008 to identify and categorize the main factors that have contributed to dangerous goods accidents in container ships. In an analysis of the records of 2781 accidents, Rømer et al. (1995) found that the risk of accident in the transportation of dangerous goods at sea is extremely high, and accident losses are even more serious. Wu and Sun (2006), using a detailed analysis of 200 typical transportation accidents of hazardous chemicals, classified causes, characteristics, and types of accidents and proposed countermeasures and suggestions for safety management and supervision of road transportation of hazardous chemicals in China.

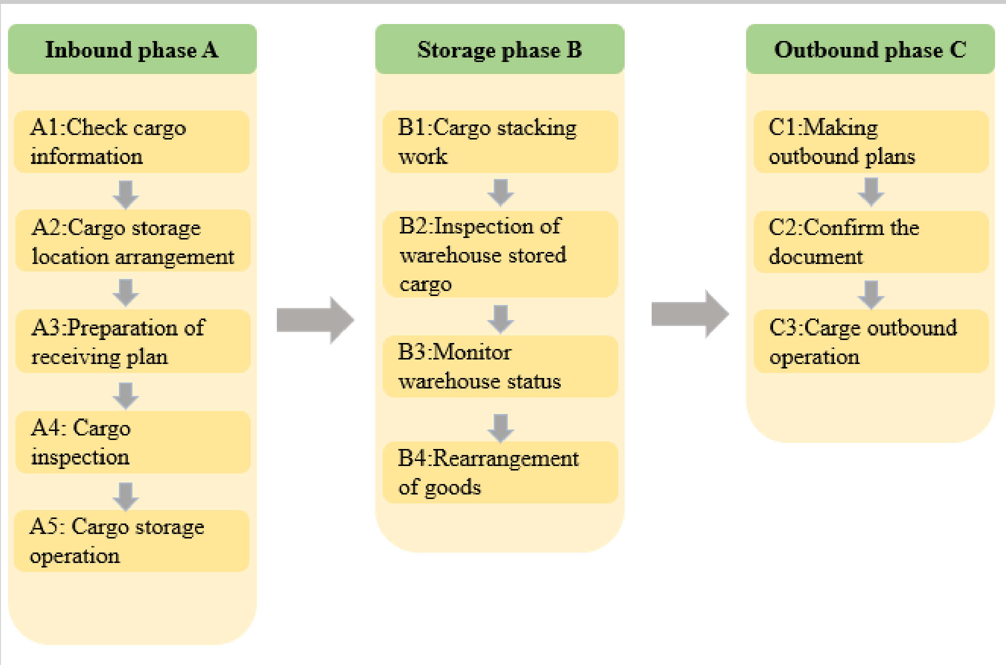
Christou (1999) described major accident hazards associated with the intermediate, temporary storage of dangerous substances in transportation-related activities. Bersani et al. (2010) presented statistics and analyses regarding accidents and their causes in the pipeline transportation of dangerous goods. Wang, Fu and Yan (2020) presented a detailed comparison of two warehouse storage accidents of major dangerous goods in China, highlighting their specific causes, along with detailed description of individual factors, organizational factors, and external regulatory factors. Cimer and Szakál (2015) analyzed the causes of accidents with dangerous goods in combined terminals and put forward suggestions for improvement.

2. Dangerous goods logistics management

Due to the large number of dangerous goods appearing at ports, the design of the inland wharves used for dangerous goods containers has received increasing attention. Hervás-Peralta et al. (2020) established a performance management evaluation system for dangerous goods container inland terminals and used analytic hierarchy processes to analyze the weighting for each indicator to help decision-makers improve the design of their inland terminals for dangerous goods containers. Hofstra et al. (2018) established a theoretical framework for warehouse security to allow for the evaluation and promotion of warehouse security to support warehouse storage logistics service providers to develop warehouse safety culture and improve the safety behavior of warehouse employees.

Zhou, Fu and Xue (2020) reported fire protection requirements for hazardous chemical warehouse storage in relation to different storage modes for hazardous chemical substances, using fuzzy comprehensive assessment to construct a secondary evaluation index group for fire resource requirements. Zhao, Zhang and Guan (2018) established a model for evaluating the safety of air carriers in the transportation of dangerous goods. The hybrid evaluation method of analytic hierarchy processes and entropy weighting was used to determine the importance of each factor. Meanwhile, Batarlienė and Jarašū nienė (2014) also put forward safety management recommendations for the railway transportation of dangerous goods. Tixier et al. (2002) described different types of dangerous goods and transportation accidents and created a risk simulation office to help decision-makers quickly analyze accident risks and increase the speed of accident handling. To improve the ability of emergency management for the storage area of dangerous chemicals, Liu, Li and Li (2017) proposed a framework of risk management technical system about the flammable and explosive dangerous chemicals

Fig. 1. Dangerous goods warehouse storage operation in China



Ⅲ. Materials and data sources

1. Dangerous goods warehouse storage process

To determine the storage processes used in dangerous goods warehouses for Chinese logistics companies, company practitioners, experts, and scholars in related fields were consulted. Typical dangerous goods warehouse storage operations in China can be divided into three main phases, as shown in Figure 1: the inbound, storage, and outbound phases.

1) Inbound stage

A simple summary of storage operations in Chinese dangerous goods warehouses. In the warehousing stage, the main task is to accept the order from the owner and confirm the relevant dangerous goods information. Once this information is received, the storage location of the dangerous goods is represented. Next, the warehousing is implemented. Then, regular inspections of the goods to be put in the warehouse are performed, followed by the final exit of the dangerous goods out of the warehouse

(1) Receiving cargo information

This operation confirms the information on the dangerous goods that the owner needs to store and confirms whether the goods can be stored in the warehouse. Some types of dangerous goods can be stored, and some cannot. Therefore, the confirmation of precise information on the hazardous materials is a very important stage of work.

(2) Storage location of dangerous goods warehouse

Each kind of dangerous goods has different characteristics. A safe interval should be kept between dangerous goods during the storage of dangerous goods warehouse. It should be noted that mixed storage of dangerous goods is more dangerous than storage of other ordinary dangerous goods stored separately. Fu, Wang and Yan (2016) believe that one of the reasons that the explosion in Tianjin Port was so dangerous was that goods that should not be mixed together were in the same warehouse. The mixed storage of dangerous goods should also be safely managed in accordance with relevant laws, and attention should be paid to the regulations regarding mixed storage of dangerous goods and storage safety intervals.

(3) Preparing a receiving plan

After checking the information on dangerous goods and arranging their storage location, it is necessary to arrange operators and prepare appropriate machinery for warehousing operations, and safe accident-prevention measures should always be followed.

(4) Inspection of cargo

This process has the main responsibility for the inspection of the storage of dangerous goods. The type and quantity of dangerous goods should be checked, along with whether the dangerous goods match the order. The correct packaging of the dangerous goods should be checked, as well as whether the marking of the dangerous goods meets requirements.

(5) Move dangerous goods to designated areas

After completing the inspection steps, the dangerous goods must be moved to the designated storage area. However, before any handling operations, the relevant dangerous goods must be unloaded from the delivery vehicle. When moving goods, regulations must be strictly followed.

2) Storage stage

In Figure 1, major storage tasks are shown, such as stacking cargo, inspecting cargo condition, monitoring and controlling the ventilation and moisture conditions of warehouses, and rearranging long-term cargo.

(1) Stacking of cargo

Dangerous goods should only be stacked to a limited height using specialized machines. Due to the limitations of human factors, safety awareness and professionalism of practitioners must be maintained. For example, when stacking dangerous goods, to avoid direct contact between them, plastic or cloth should be placed between the packaging of the goods. Most practitioners, however, ignore this process, which can lead to warehouse accident

(2) Warehouse inspection.

For dangerous goods already stored in the warehouse, relevant inspections should be carried out regularly, including on storage containers, storage status, etc.

(3) Warehouse status

The moisture and temperature conditions of the warehouse are of considerable

Table 1. Data survey details

Classification	Content
Time period of accident	2010–2019
Accident content	Accident in storage of dangerous goods warehouse
Analysis content	–Status by type of accident –Accident status by type of dangerous goods –Accident status by region –Accident status by storage process

Source: State Administration of Work Safety(2020) and China Chemical Safety Association(2020)

importance, in a warehouse storing dangerous cargo in particular. Humidity and temperature conditions may vary and cause variable dangers in stored materials.

3) Outbound operations

Outbound operations are not much different from receptive ones. It is only necessary to check the recipient of dangerous goods based on the recipient's certificate or bill of lading. Developing relevant personnel, machinery, and safety instructions are necessary to enable warehouse operations.

1. Accidents

1) Overall accident and data collection

To assess storage accidents in China’s dangerous goods warehouses, this study compiled statistics on 105 storage accidents in China’s dangerous goods warehouses that have occurred over 10 years by consulting the China General Administration of Work Safety, Chinese customs data, and literature data.

The specific contents of 105 dangerous goods warehouse storage accidents are shown in the appendix. Table 3 presents the overall description of the statistics on accidents and their source.

2) Dangerous goods accident Analyses

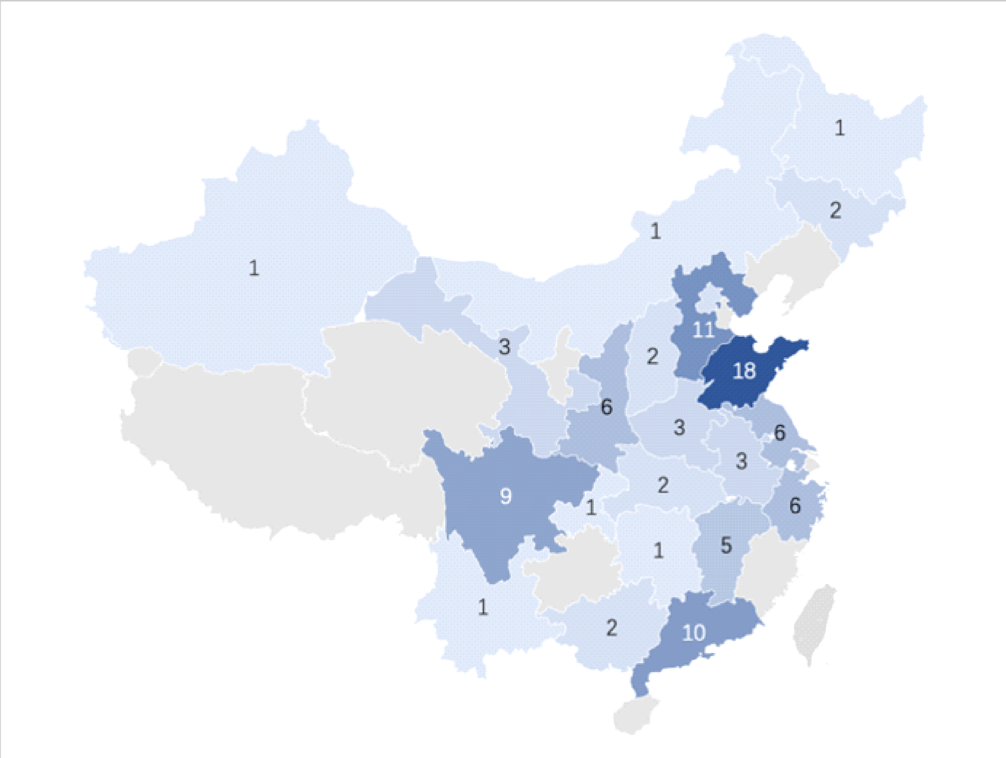
In all, 105 storage accidents regarding dangerous goods were divided into three types: explosions, fires, and leaks. The goods were divided into four types: solid, liquid, gas, and mixed. Further, the accidents were grouped according to China’s regions and provinces. Finally, the literature was investigated to analyze the stages of the warehouse storage for dangerous goods, and the accidents were grouped by stage in this process.

There were 30 cases of leaks, 35 of fires, and 40 of explosions identified. There was little difference in frequency by accident type.

There were 18 incidents involving solids, 51 involving liquids, 25 accidents involving gasses, and 11 involving mixes. Accidents with liquid dangerous goods are far more common than other types.

The safety management of such goods in warehouses in China is far from adequate, and a storage improvement must be put in effect. As shown in Figure 2, Shandong

Fig. 2. Statistics on the distribution of accidents by province



Source: State Administration of Work Safety(2020) and China Chemical Safety Association(2020)

Province has the highest rate of accidents in the study period, followed by Hebei Province and Guangdong Province. These all have a more highly developed chemical industry, so it is natural that more accidents would be seen. These provinces must focus on improving their safety management in warehousing.

This largest number of accidents occurred in stage B2, where the stored goods are checked. This indicates that on-site inspection and safety management in dangerous goods warehouses in China are obviously insufficient, and it is necessary to increase safety management controls at this stage and to strictly abide by safety management regulations for warehouse storage. The second-largest number of accidents was in B3, status inspection. Both of these stages require special attention.

Ⅳ. Research Methods

This study of 105 accidents at dangerous goods warehouses in China over 10 years, found that Chinese logistics companies continue to exhibit many shortcomings in their safety management. There is an urgent need for a plan to improve storage safety management in dangerous goods warehouses in Chinese logistics enterprises, strengthen safety management, and avoid safety accidents.

Table 2. Priority factors system of safety management for hazardous cargo storage warehouses

	Level1	Level2
Safety management of hazardous cargo storage	Human factors (Hf)	Professional quality of employees (Hf1)
		Working status of employees (Hf2)
		Safety awareness of employees (Hf3)
	Safety factor (Sf)	Compliance with safety rules (Sf1)
		Emergency safety training (Sf2)
		Monitoring of stored dangerous goods (Sf3)
	Facility factor (Df)	Main storage facility (Df1)
		Emergency storage facility (Df2)
		Cargo information supervision facility (Df3)
	Environmental factors (Ef)	Warehouse location (Ef1)
		Warehouse storage environment (Ef2)
		Natural state of the warehouse (Ef3)

1. Dangerous goods warehouse storage safety management index system

To improve the level of safety management of dangerous goods warehouse storage, the incidence of safety accidents in dangerous goods warehouse storage must be reduced. This produced a safety management index system for dangerous goods warehousing.

Chen et al. (2020) found that the main factors affecting dangerous goods accidents in ports were personnel professionalism, operational specifications, warehousing management, enterprise operations, supervision and management, facilities and equipment, emergency management, goods registration, and natural factors. Wang, Fu and Yan (2020) reported that the main deficiencies that caused the Tianjin Port accident and other major accidents involving dangerous goods in China were personnel management, workplace management, hazards management, and emergency management. In their analyses of chemical accidents in China. They also described three main categories of accident factors, namely, man-made, equipment, and natural factors. Zhao, Zhang and Guan (2018) showed that safety management factors for air transportation of dangerous goods could be grouped into five dimensions based on their properties and attributes: organizational/regulatory, equipment/facilities, operations, emergency, and training.

This article divides safety management factors for dangerous goods storage into four primary factors, namely, human factors, safety factors, facility factors, and environmental factors. The human factors are professional quality, working status, and safety awareness. The safety factors were degree of compliance with safety rules, emergency safety training, and monitoring of stored dangerous goods. The facility factors were the degree of infrastructural

Table 3. Scaling method of the judgment matrix elements

Factor i compared with factor j	Quantitative values
Equally important	1
Moderate important	3
Strong important	5
Very strong important	7
Extreme important	9
The middle value of two adjacent judgments	2,4,6,8

completion, alternative facilities after the accident, and information registration and transmission facilities. Finally, the environmental factors were warehouse location, ventilation and humidity in the warehouse, and warehouse status level. Table 4 presents the overall factors of the storage safety management of dangerous goods warehouses in China.

2. Questionnaire

To conduct an effective priority-level division for storage safety management factors at dangerous goods warehouses, this study conducted surveys conducted among experts in the field. The factors' importance was assessed using the analytic hierarchy process to analyze relative weighting to provide a scientific basis for dangerous goods warehouse management for use by decision makers at warehousing and logistics enterprises. The questionnaire used is given at the end of this article.

3. Analytic hierarchy process

1) Construct a judgment (pair comparison) matrix

The qualitative weighting between factors at various levels may not be easily accepted by all. Wind and Saaty (1980) proposed a consistent matrix method to compare factors. This relative scale can improve accuracy.

〈Table 5〉 lists the nine importance levels and their assessments. The matrix formed by the pairwise comparison results is called the judgment matrix. The judgment matrix has the following properties:

$$a_{ij} = \frac{1}{a_{ij}} \quad (1)$$

2) Hierarchical order and its consistency check

The feature vector corresponding to the largest feature root of the judgment matrix is normalized (to make the sum of the elements in the vector equal to 1) and then denoted as . The elements of are the ranking weights of the relative importance of the factors to the same level as the factors of the previous level. This process is called single-level ranking. The confirmation of the order of the level list requires a consistency test that etermines the allowable range of inconsistency for A. Here, the only non-zero characteristic root of the n-th order consistent matrix is the largest characteristic root of the , n-th order reciprocal matrix , and if and

Table 4. Questionnaire results

	Questionnaire content	Frequency	Proportion (%)
Working years	1-5 years	0	0
	6-10 years	6	31.61
	11-15 years	12	63.16
	〉15 years	1	5.32
Corporate scale	〈50 people	1	94.77
	50-100 people	16	5.32
	〉100 people	2	25
Dangerous goods storage site operation	yes	18	66.67
	no	1	8.33

only if is A a consistent matrix.

Since λ continuously depends on , the larger that λ is than , the more serious the inconsistency of A. The consistency index is calculated with . The smaller , the greater the consistency. The eigenvector corresponding to the largest eigenvalue is used as the weight vector of the degree of influence of the compared factor on a certain factor in the upper layer. The greater the degree of inconsistency, the greater the judgment error caused. Therefore, λ-n value can be used to measure the inconsistency of A. The consistency index was defined as:

$$CI=\frac{\lambda-n}{n-1} \quad (2)$$

where CI = 0 means complete consistency; CI near to 0 is satisfactory consistency; as CI increases, the more serious the inconsistency. To measure the size of CI, the random consistency index is introduced:

$$RI=\frac{C1_1+C_2+...+CI_N}{n}p \quad (3)$$

The random consistency index RI is related to the order of the judgment matrix. In general, the larger the order of the matrix, the greater the possibility of consistent random deviations.

Deviations in consistency may have random causes, so when testing whether the judgment matrix has satisfactory consistency, It is also necessary to compare CI and the random consistency index RI to obtain test coefficient CR. The formula is as follows:

$$CR=\frac{CI}{RI} \quad (4)$$

Generally, if CR 〈 0.1, the judgment matrix is considered to pass the consistency test. Otherwise, it does not have satisfactory consistency.

3) Level total ranking and its consistency check

Calculating the relative importance for all factors of a certain level to the highest level (total goal) is called the total ranking of levels. This is carried out sequentially from the highest to the lowest levels (Shubai, 1988).

Table 5. Level 2 overall factor priority

Level 1	Importance	Ranking	Level 2	Importance	Ranking	Composite weights	Ranking
Human factors	0.3455	1	Professional quality of employees (Hf1)	0.6013	1	0.21	1
			Working status of employees (Hf2)	0.0895	3	0.031	12
			Safety awareness of employees (Hf3)	0.3074	2	0.11	3
Safety factor	0.2527	3	Compliance with safety rules (Sf1)	0.4925	1	0.12	2
			Emergency safety training (Sf2)	0.1294	3	0.032	11
			Monitoring of stored dangerous goods (Sf3)	0.3781	2	0.095	5
Facility factor	0.2532	2	Degree of infrastructure completion (Df1)	0.3952	1	0.1	4
			Alternative facilities after the accident (Df2)	0.3542	2	0.09	6
			Cargo information registration and transmission facilities (Df3)	0.2507	3	0.0634	8
Environ mental factors	0.1486	4	Warehouse location (Ef1)	0.4281	1	0.0636	7
			Warehouse storage environment (Ef2)	0.3279	2	0.05	9
			Natural state of the warehouse (Ef3)	0.2440	3	0.04	10

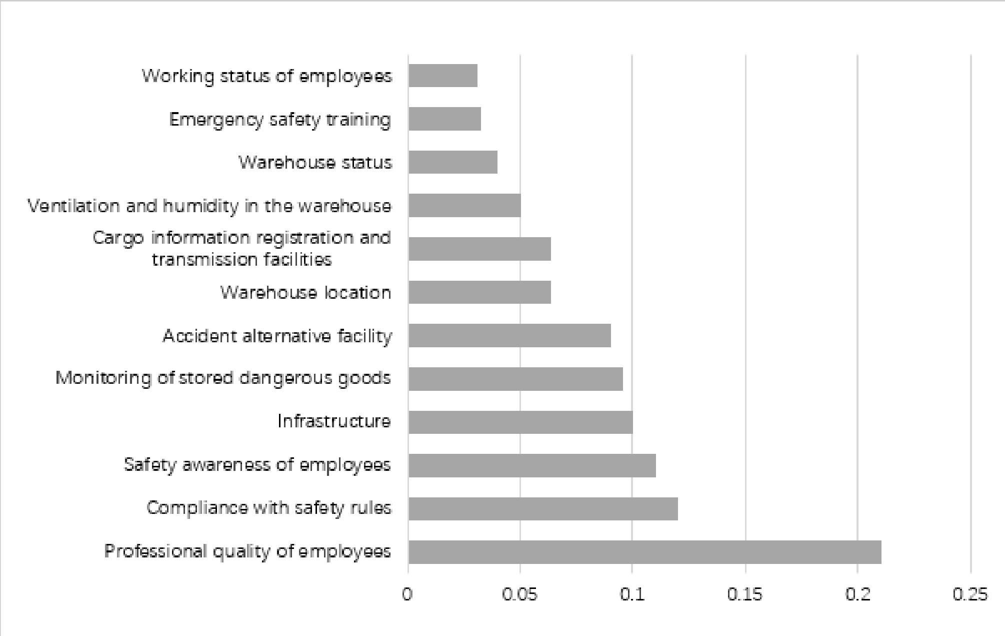
Ⅴ. Results

In this study, a total of 50 questionnaire surveys were conducted with logistics leaders at service companies that offer warehouse storage of dangerous goods and logistics associations experts as. The survey lasted from May 19 to May 30, 2019. In total, 23 questionnaires were returned, a recovery rate of approximately 46%. Among these 23, 4 questionnaires were questionable, so they were regarded as invalid. This study used 19 responses from experts, scholars, and relevant practitioners in dangerous goods warehouse storage as data for use in the analytic hierarchy process.

1. Empirical analysis

Matlab-R2020a software was used to conduct analytic hierarchy process (AHP).

Fig. 3. Overall factor weight ranking



1) Analysis of level 1 factors

The first-level factors in the safety management system drawn from the literature were Hf (human factor), Sf (safety factor), Df (facility factor), and Ef (environmental factor). In the data analysis of the responses of experts and scholars in related fields, Hf accounted for the highest rate overall, reaching 0.3455, and Df and Sf were not much different from each other, at 0.2532 and 0.2527, respectively. Ef had the lowest weight, at 0.1486.

2) Analysis of level 1 factors

In the empirical analysis of the secondary factors, the order of the weighting of the sub-factors in the human factors was Hf1 (0.6013), Hf3 (0.3074) and Hf2 (0.0895). In the empirical analysis of the secondary factors, the order of weighting of the sub-factors in the safety factors is Sf1 (0.4925), Sf3 (0.3781), and Sf2 (0.1294). In the empirical analysis of the secondary factors, the order of the weighting of the sub-factors in the facility factors was Df1 (0.3952), Df2 (0.3542), and Df3 (0.2507). In the empirical analysis of the secondary factors, the order of the weighting of the sub-factors in the facility factors was Ef1 (0.4281), Ef2 (0.3279), and Ef3 (0.2440).

3) Analysis of level 2 factors

The top three the overall safety management factors for dangerous goods warehousing were Hf1, Sf1, and Hf3, at weightings of 0.21, 0.12, and 0.11. Secondary sub-factors with higher weighting were mainly concentrated among the human factors and safety factors. The overall factor weight ranking is shown in the figure below.

Ⅵ. Discussion

1. Interpretation of results

1) First-level factors

The results of the analytic hierarchy process showed that the highest factor weight in the comparative analysis, namely the human factor, exceeded 0.34. In any dangerous goods storage operation, the most important role is played by the employees of the warehousing logistics enterprise, such that a small mistake by an employee can cause a catastrophic accident. Almost all storage accidents of this kind are related to human behavior. The employees working in important roles must have strong professionalism, high safety awareness, and good working conditions. The second-ranking factor was the facility factor, with a weight of 0.253. Dangerous goods are different from ordinary goods and require special storage facilities. If warehousing and logistics enterprises do not have special storage facilities for dangerous goods, the possibility of accidents will naturally increase. This has led warehousing and logistics companies to more highly value basic storage facilities.

In third place was the safety factor, with a weighting that is little different from the previous one. Safety runs through the entire operation in hazardous goods warehousing. Employees must abide by safety rules at all times, and warehousing and logistics companies should strengthen emergency safety training and constantly monitor the safety status of the stored goods. The final factor is environmental, but it is not unimportant. Due to the characteristics of dangerous goods, the storage environment of the warehouse is particularly important. Its location and its natural environment determine the types of dangerous goods that can be stored, so warehousing logistics has increased its consideration of this factor in recent years.

2) Overall weight explanation

The overall comparative analysis of the weighting of secondary factors shows that employee professionalism received the highest overall weighting, at 0.21. Human factors are the main cause of many accidents, and experts and scholars agree that professionalism should be given the highest attention. In second place is the safety rule compliance, with a weighting of 0.12. Experts and scholars reported that if employees at warehousing and logistics enterprises correctly abided by safety regulations, this will greatly reduce the probability of accidents. Warehousing and logistics companies must formulate comprehensive, detailed safety regulations for employee operations. The third place is employee safety awareness, with a weight of 0.11. Many storage accidents with dangerous goods are due to insufficient safety awareness of employees and a lack of a safety culture in warehouse logistics enterprises. An analysis of the overall factor weight ranking indicated that we must focus on improving issues related to the human factor in dangerous goods safety management systems.

2. Improvement plan

1) Corporate management

The previous analysis indicated that human factors are the foremost factor in safety accidents in the storage of dangerous goods. Employees are the foundation of the healthy development of a storage enterprise. Further, safety is the soul of its successful operation. To improve the storage safety management of dangerous goods warehouses in storage enterprises, it is necessary to improve the professionalism of employees in warehousing and logistics enterprises. To recruit personnel, human resources departments must focus on checking and selecting highly professional and dedicated employees. The physical condition of front-line operators should also be a consideration. Second, logistics companies should regularly conduct training on the safety of dangerous goods warehousing and constantly update training contents so that employee knowledge remains up-to-date with the current state of the market, including the relevant storage accidents that have occurred in recent years.

Warehousing and logistics companies should re-engineer all relevant operating procedures in detail. Everything from receiving to the warehouse to storage to exit from the warehouse should be given detailed operating instructions. Warehousing and logistics companies must establish a complete safety management code that covers all aspects of operations, is convenient for employees to refer to and study, and founds a corporate safety culture that encourages every employee to comply with relevant safety regulations and improve their safety awareness.

Enterprises must also carry out safety management reforms at the facility level to ensure that the main storage facilities are qualified and to regularly maintain and manage the warehouses. Second, they should establish emergency storage facilities and emergency refuge facilities. This study found that emergency storage facilities are conducive to the transfer of dangerous goods that are not affected by accidents and reduce the loss caused by accidents. Emergency refuge facilities can help protect the lives of frontline employees in accidents. At the same time, warehousing and logistics companies must always pay attention to advanced science and technology, including artificial intelligence, big data, and the Internet of Things in relation to the warehousing field to improve the accuracy of company operations and reduce accidents.

2) Government supervision

When a dangerous goods warehouse storage accident occurs, the enterprise is responsible, but the local government also bears some responsibility. China's laws on the storage of dangerous goods are not sound and lack the ability to guide construction. Therefore, the government should strengthen cooperation with enterprises and should increase the intensity and frequency of field investigations. The rapid establishment and development of relevant laws and regulations in the field of dangerous goods storage and storage can improve policy support for dangerous goods logistics and reduce accidents at the source. The government should also promote coordination and guidance and regularly inspect warehousing and logistics enterprises. Every company process must be assessed for compliance with laws and regulations, and every facility must comply with storage standards.

3) Social cooperation

To improve safety management in dangerous goods warehouse storage in Chinese warehousing and logistics enterprises, the joint efforts of experts and scholars in related fields are needed. Warehousing and logistics companies can conduct practical seminars with experts and scholars, such as the Warehousing Association and the Dangerous Goods Research Association, that bear on their current status. The problems faced by warehousing and logistics enterprises in their operations can be put before experts and scholars, who can seek solutions to pressing problems and work together improve safety management capabilities at enterprises. Companies must also cooperate with universities in related fields and adopt cooperative mechanisms of cooperative education and high-quality talent entering the company. Professionals should be trained in dangerous goods storage. In this way, the frequency of corporate accidents owing to the human factor can be reduced, and more profits can be obtained for the company.

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Appendix

Table A. Dangerous Goods Accidents List

Accident Happened: According to figure 1 of this paper, the author divided the stage of dangerous goods warehouse storage operation.

No.	Year	Province	Accident Type	Dangerous Cargo	Accident Happened
1	2019	Guangdong	Fire	Mixed storage	B3
2	2019	Guangdong	Fire	Mixed storage	B1
3	2019	Sichuan	Leakage	Liquid	A5
4	2019	Jiangsu	Explosion	Liquid	B3
5	2018	Hebei	Explosion	Gas	B2
6	2018	Shandong	Explosion	Gas	B3
7	2018	Shaanxi	Explosion	Liquid	B4
8	2018	Shandong	Fire	Solid	B3
9	2018	Henan	Leakage	Gas	B3
10	2018	Sichuan	Explosion	Gas	B2
11	2018	Sichuan	Explosion	Solid	A1
12	2018	Anhui	Fire	Solid	B3
13	2017	Hebei	Explosion	Liquid	B2
14	2017	Shandong	Fire	Liquid	B3
15	2017	Shaanxi	Fire	Liquid	B3
16	2017	Jiangxi	Fire	Solid	A4
17	2017	Shaanxi	Leakage	Gas	B2

18	2017	Shandong	Fire	Gas	B3
19	2017	Shanxi	Explosion	Liquid	B3
20	2017	Jiangxi	Fire	Liquid	B2
21	2017	Gansu	Fire	Solid	B2
22	2017	Shandong	Leakage	Liquid	B3
23	2017	Guangdong	Leakage	Liquid	B2
24	2017	Henan	Fire	Liquid	B2
25	2017	Shanxi)	Leakage	Liquid	B3
26	2017	Shandong	Explosion	Liquid	A5
27	2017	Sichuan	Fire	Liquid	B2
28	2017	Guangxi	Leakage	Liquid	B2
29	2017	Zhejiang	Leakage	Liquid	B2
30	2017	Anhui	Explosion	Liquid	B2
31	2017	Jiangxi	Leakage	Liquid	A5
32	2016	Shandong	Leakage	Solid	B2
33	2016	Beijing	Fire	Mixed storage	B3
34	2016	Hebei	Explosion	Liquid	A5
35	2016	Hebei	Leakage	Gas	B1
36	2016	Hebei	Explosion	Liquid	B2
37	2016	Jiangsu	Explosion	Solid	B2
38	2016	Jiangsu	Fire	Liquid	B3
39	2015	Guangdong	Leakage	Gas	B3
40	2015	Zhejiang	Explosion	Mixed storage	B2
41	2015	Henan	Fire	Mixed storage	B2
42	2015	Hebei	Leakage	Liquid	B2
43	2015	Shandong	Fire	Solid	B2
44	2015	Gansu	Fire	Liquid	B2
45	2015	Gansu	Explosion	Gas	B1
46	2015	Shandong	Explosion	Liquid	B1
47	2015	Jiangsu	Fire	Mixed storage	B2
48	2015	Shaanxi	Leakage	Liquid	B2
49	2015	Liaoning	Fire	Gas	A5
50	2015	Shandong	Explosion	Mixed storage	A5
51	2015	Shandong	Explosion	Liquid	B2
52	2015	Hubei	Explosion	Liquid	B2
53	2015	Shandong	Explosion	Mixed storage	B1
54	2015	Shandong	Leakage	Gas	B1
55	2015	Yunnan	Explosion	Solid	B3
56	2015	Guangdong	Leakage	Gas	B2
57	2015	Shandong	Explosion	Liquid	B3
58	2014	Zhejiang	Explosion	Gas	B1
59	2014	Hubei	Explosion	Liquid	B2
60	2014	Sichuan	Explosion	Liquid	B2
61	2014	Sichuan	Explosion	Gas	B2

62	2014	Shaanxi	Explosion	Gas	B2
63	2014	Liaoning	Leakage	Gas	B2
64	2014	Jiangsu	Fire	Solid	B1
65	2014	Neimenggu	Fire	Gas	B1
66	2014	Hebei	Fire	Gas	B2
67	2014	Sichuan	Leakage	Solid	B2
68	2014	Jilin	Explosion	Liquid	B2
69	2014	Anhui	Leakage	Mixed storage	B2
70	2014	Shandong	Leakage	Liquid	A5
71	2014	Liaoning	Leakage	Gas	B2
72	2014	Sichuan	Fire	Liquid	A2
73	2013	Hebei	Explosion	Liquid	A5
74	2013	Shandong	Leakage	Gas	B2
75	2013	Guangdong	Explosion	Solid	A2
76	2013	Zhejiang	Leakage	Liquid	B2
77	2013	Hebei	Leakage	Gas	B2
78	2013	Jilin	Explosion	Mixed storage	B2
79	2013	Liaoning	Explosion	Gas	B2
80	2013	Hebei	Leakage	Gas	B2
81	2013	Hebei	Leakage	Gas	B3
82	2013	Liaoning	Explosion	Liquid	B2
83	2012	Guangdong	Explosion	Liquid	A5
84	2012	Guangxi	Leakage	Solid	A5
85	2012	Shandong	Leakage	Liquid	A5
86	2012	Liaoning	Fire	Mixed storage	B3
87	2012	Chongqing	Leakage	Liquid	B2
88	2012	Guangdong	Fire	Liquid	B2
89	2012	Zhejiang	Leakage	Solid	B3
90	2012	Jiangxi	Fire	Liquid	B3
91	2012	Shaanxi	Fire	Liquid	B3
92	2011	Liaoning	Explosion	Liquid	A5
93	2011	Shandong	Fire	Solid	B2
94	2011	Hunan	Explosion	Liquid	B3
95	2011	Sichuan	Explosion	Liquid	A2
96	2011	Jiangxi	Explosion	Liquid	B1
97	2011	Xinjiang	Explosion	Solid	A2
98	2010	Zhejiang	Fire	Liquid	B1
99	2010	Beijing	Fire	Liquid	B3
100	2010	Guangdong	Fire	Solid	B1
101	2010	Liaoning	Fire	Liquid	A5
102	2010	Liaoning	Fire	Liquid	A5
103	2010	Heilongjiang	Fire	Solid	B1
104	2010	Guangdong	Fire	Liquid	B4
105	2010	Jiangsu	Explosion	Gas	B3