

Safety Evaluation Index System for Dangerous Goods Transportation by Water in Weihai City

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Abstract

With the development of China's shipping industry, the maritime cargo transportation industry chain is becoming more and more complete, resulting in more and more problems. Among them, the transportation of dangerous goods by waterway is also receiving more and more attention. As an important method of transporting dangerous goods, the safety of waterway transportation is particularly important. In order to ensure the safety of waterway dangerous goods transportation, it is necessary to establish a scientific and reasonable safety evaluation index system, and conduct a comprehensive and systematic safety evaluation of waterway dangerous goods transportation. Firstly, this paper takes the transportation of dangerous goods by waterway in Weihai City as an example, and selects five primary evaluation indicators, including environment, personnel, ships, goods, and management, as well as their secondary and tertiary evaluation indicators, based on the actual situation; secondly, a safety index system for the transportation of dangerous goods by water in Weihai City has been constructed, and an example analysis has been conducted on it; finally, safety management measures for the transportation of dangerous goods by waterway in Weihai City were proposed.

Keywords

Dangerous Goods; Waterway Transportation; Safety Evaluation Index System.

1. Introduction

With the continuous development of the economy and the acceleration of industrialization, the position of dangerous goods transportation in social and economic development has become increasingly important. According to statistics, the annual transportation volume of dangerous goods worldwide reaches 4 billion tons, and China has an annual transportation volume of approximately 400 million tons. In China's total freight volume, the proportion of water transportation is second only to railways and highways. Therefore, the safety of dangerous goods transportation by waterway is particularly important.

The safety indicator evaluation system selects safety evaluation indicators based on features, which helps to strengthen the safety management system and protect the safety of personal and property. The safety indicator system has been applied in various industries [2-4], and this is also true in the field of transportation. In terms of road transportation, Zhao Yongchen combined the current situation of dangerous goods road transportation in China and used the Analytic Hierarchy Process to comprehensively analyze the influencing factors, constructing a safety evaluation index system for dangerous goods road transportation [5]; Chen Lijie et al. comprehensively considered the five main influencing factors of dangerous goods, drivers, vehicles, environment, management, and rescue measures, and established a safety evaluation index system for road transportation of dangerous goods [6]. In terms of railway transportation, Liu Jinfang et al. started from the theory of safety system engineering and used the fishbone diagram method to analyze from five aspects: human, machine, material, environment, and

management, constructing a 4-level railway dangerous goods transportation system safety evaluation system ; In terms of waterway transportation, Du Yaxiong has put forward several suggestions for the transportation of dangerous goods by waterway. Although there are many applications of safety evaluation index systems at present, there is still relatively little research on the safety evaluation index system for waterway dangerous goods transportation, and there is a lack of comprehensiveness. Based on the current situation of dangerous goods transportation by waterway in Weihai City, this article proposes an evaluation system for the indicators of dangerous goods transportation by waterway in Weihai City.

2. Transportation of Dangerous Goods

Dangerous goods transportation is a type of special transportation. Generally, only after strict review by relevant national functional departments and possessing corresponding facilities and equipment that can ensure the safe transportation of dangerous goods, can one be qualified to carry out dangerous goods transportation.[9-14] Dangerous goods are flammable, explosive, and highly corrosive, so their transportation poses great risks. Improper transportation of hazardous chemicals or accidents during transportation may cause serious consequences to surrounding personnel and the environment[15-17].

2.1. Dangerous Goods

2.1.1. Definition of Hazardous Materials

Hazardous materials are items or substances that can pose a threat to health, safety, property, or the environment, especially when handled improperly. Dangerous goods or materials can be solids, liquids, or gases, as well as pure chemicals, mixtures of substances, finished products, or individual items.[18-21] Due to their special physical and chemical properties, they are prone to accidents and disasters during contact and handling. Due to its flammability and explosiveness, its transportation process requires professional expertise.

2.1.2. Characteristics of Hazardous Materials

Dangerous goods have characteristics such as flammability, explosiveness, toxicity, corrosiveness, radioactivity, and contamination. Therefore, when dealing with dangerous goods, it is necessary to pay attention to the following points: first, the physical, chemical, radioactive or biological characteristics are relatively special and can easily cause harm; Secondly, once an accident occurs, the scope of harm is large and the impact is severe, which may lead to consequences such as casualties and environmental pollution; Thirdly, professional knowledge and skills are required to handle and manage correctly; Fourthly, special safety and protective measures need to be taken during production, storage, transportation, use or processing; Fifthly, there may be provisions related to laws, regulations, and standards that need to be followed.

Due to the particularity of hazardous materials, their management and handling requirements are very strict, requiring professional personnel and equipment to manage and handle them, comply with relevant regulations and standards, and ensure that hazardous materials do not cause harm to people, objects, and the environment. At the same time, it is necessary to strengthen publicity and education, raise public safety awareness, and reduce the occurrence of dangerous goods accidents.

2.1.3. Classification of Dangerous Goods

Dangerous goods can be classified based on their hazardous characteristics and properties. The following are common hazardous material classification systems:

(1) Classification based on hazard characteristics:

① Explosives ② Gas ③ Flammable liquids ④ Flammable solids, self igniting substances, flammable gas substances released when in contact with water ⑤ Oxidants and organic peroxides ⑥ Toxic and infectious substances ⑦ Radioactive substances ⑧ Corrosive substances ⑨ Miscellaneous substances.

(2) Classification based on transportation mode:

① Highway transportation of dangerous goods ② Railway transportation of dangerous goods ③ Air transportation of dangerous goods ④ Sea transportation of dangerous goods.

(3) Classification based on the use and handling of hazardous materials:

① Industrial products ② Pharmaceutical products ③ Pesticides and fertilizers ④ Firefighting supplies ⑤ Other dangerous goods.

The above is only a common classification of hazardous materials. In fact, the classification of hazardous materials may vary depending on different countries, industries, and application fields.

2.2. Current Situation of Dangerous Goods Transportation in Weihai City

Weihai City is a port city in Shandong Province, China, with multiple ports and waterways. In 2021, Weihai City strengthened the management of water transportation of dangerous goods, strengthened supervision and law enforcement efforts, and ensured the safe transportation of dangerous goods.

According to data released by the Weihai Transportation Bureau, in the first half of 2021, there were a total of 125 dangerous goods ships entering and exiting ports in the city, with a total transportation volume of 1.454 million tons of dangerous goods. Among them, hazardous materials such as chemicals, petroleum products, and hydrogen chloride are transported in large quantities.

In order to ensure the safe transportation of dangerous goods, Weihai City has strengthened the supervision of dangerous goods transportation enterprises and investigated and punished illegal enterprises. In addition, Weihai City has strengthened the management of ports and waterways, and strictly supervised and managed the loading, unloading, storage, and transportation processes of dangerous goods transportation to ensure the safety and controllability of dangerous goods transportation.

According to public information, Weihai City has established a comprehensive safety management system for dangerous goods transportation, including strengthening the approval and supervision of dangerous goods transportation enterprises, conducting regular inspections and maintenance of dangerous goods transportation vehicles, and strengthening the control and safety evaluation of dangerous goods transportation routes. In addition, Weihai City has strengthened its emergency management capabilities, developed detailed emergency plans, and regularly conducted emergency drills.

Overall, the safety management of dangerous goods transportation in Weihai City has been well guaranteed, but there is still a need to further strengthen the supervision and emergency management capabilities of dangerous goods transportation to ensure the safety of people's lives and property.

3. Safety Indicators for Water Transportation of Dangerous Goods

3.1. Principles for Selecting Safety Indicators for the Transportation of Dangerous Goods by Waterway

The selection of evaluation indicators for the transportation of dangerous goods by waterway should consider the following principles:

- (1) Safety principle: Evaluation indicators should mainly focus on the safety of dangerous goods transportation by waterway, including risks during transportation, accident probability, and potential hazards.
- (2) Comprehensive principle: The evaluation indicators should consider all aspects of the transportation of dangerous goods by waterway, including loading and unloading, transportation, storage, etc., and comprehensively consider the overall role of the evaluation indicators.
- (3) Principle of operability: Evaluation indicators should have operability, which is convenient for practical operation and management.
- (4) Comparability principle: Evaluation indicators should be comparable and can be used for comparison between different transportation companies and different waterway transportation methods.
- (5) Transparency principle: Evaluation indicators should be transparent and fair, making it easier for relevant stakeholders to understand the evaluation results and helping to improve the safety level of dangerous goods transportation by waterway.
- (6) Sustainability principle: Evaluation indicators should consider the sustainability of waterway transportation of dangerous goods, including considerations of environmental impact, social responsibility, and economic feasibility.

Taking into account the above principles, the following indicators can be selected as evaluation indicators for waterway dangerous goods transportation: transportation risk assessment, accident statistical analysis, safety management system evaluation, emergency response capability evaluation, loading and unloading equipment and site safety evaluation, employee training and quality evaluation, transportation safety equipment evaluation, waterway transportation safety planning evaluation, waterway siltation, accumulation, port management, and other aspects of evaluation indicators.

3.2. Safety Indicators for Dangerous Goods Transportation by Waterway

According to the theory of safety systems engineering, there are four factors that affect whether accidents occur: human, material, environment, and management, namely the 4M (Man, Machine, Media, Management) factor. According to the characteristics of dangerous goods and the characteristics of dangerous goods waterway transportation, we divide the 4M factors of waterway dangerous transportation into five categories: environment, personnel, ships, goods, and management. The selection of indicators is shown in Fig. 1.

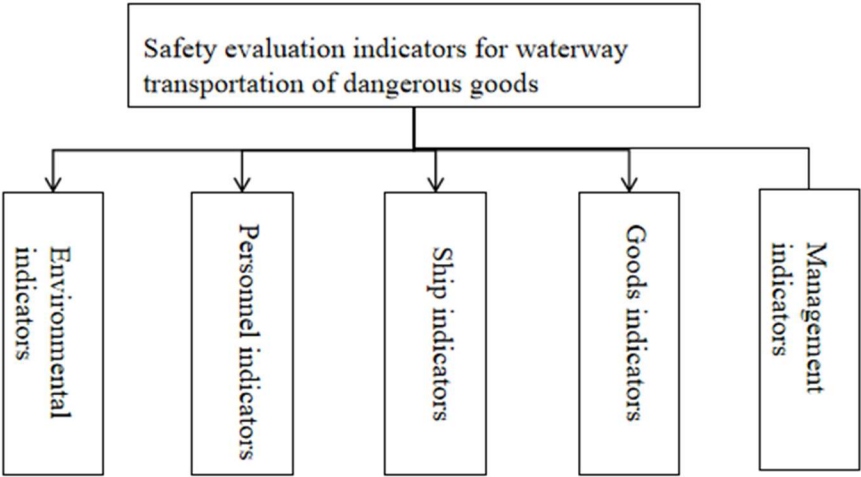


Fig. 1 Safety evaluation indicators for waterway transportation of dangerous goods

3.2.1. Environmental Indicators

The environmental indicators are divided into three secondary indicators: navigation environment, waterway conditions, and port conditions.

(1) Navigation environment

Navigation environment refers to various natural, cultural, technological and other factors that affect the safety and smoothness of waterway transportation. The evaluation indicators for safety in navigation environment are mainly divided into the following three points: first, meteorological conditions, such as wind, fog, rain, etc; Secondly, water conditions, such as water flow, depth, etc; Thirdly, transportation conditions, such as congestion and collisions.

(2) Navigation conditions

The waterway conditions have a significant impact on the safety of dangerous goods transportation by waterway, as they directly affect the stability and safety of ships. Its subordinate evaluation indicators include the width, depth, and crossing conditions of the waterway.

(3) Port conditions

Port conditions have a significant impact on the safety of dangerous goods transportation by waterway. Its subordinate indicators are as follows: water conditions, land conditions.

In summary, environmental indicators have a significant impact on the safety of waterway dangerous goods transportation, and corresponding safety and preventive measures must be taken based on environmental factors to ensure the safety and environmental protection of waterway dangerous goods transportation. The detailed sub indicators of environmental indicators are shown in Fig. 2.

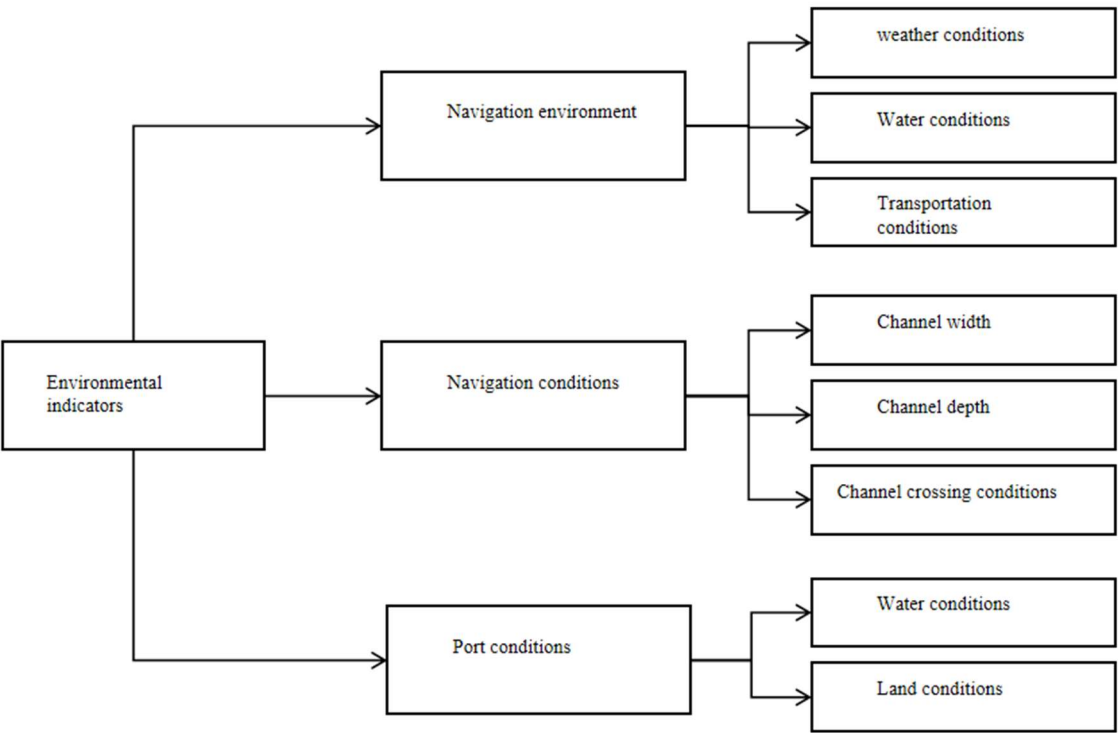


Fig. 2 Subordinate evaluation indicators of environmental indicators

3.2.2. Personnel Indicators

The personnel indicator is a key indicator related to the safety of waterway dangerous goods transportation, which can be evaluated from the following two secondary indicators:

(1) Leaders and safety management personnel
Leaders and safety management personnel play a decisive role in decision-making, therefore the four three-level indicators of subordinates: management ability, psychological quality, safety awareness, and legal awareness all play a role in influencing decision-making.

(2) Transportation and cargo operation personnel
Transportation and cargo operators often work on the front line, and as close contacts of dangerous goods, their business ability, psychological quality, safety awareness, and legal awareness play an important role in the evaluation indicators.

In summary, personnel indicators have a very important impact on the transportation of dangerous goods by waterway. If personnel are not properly equipped, it may lead to increased safety risks. Therefore, it is necessary to allocate and manage them reasonably. The subordinate evaluation indicators of personnel indicators are shown in Fig. 3.

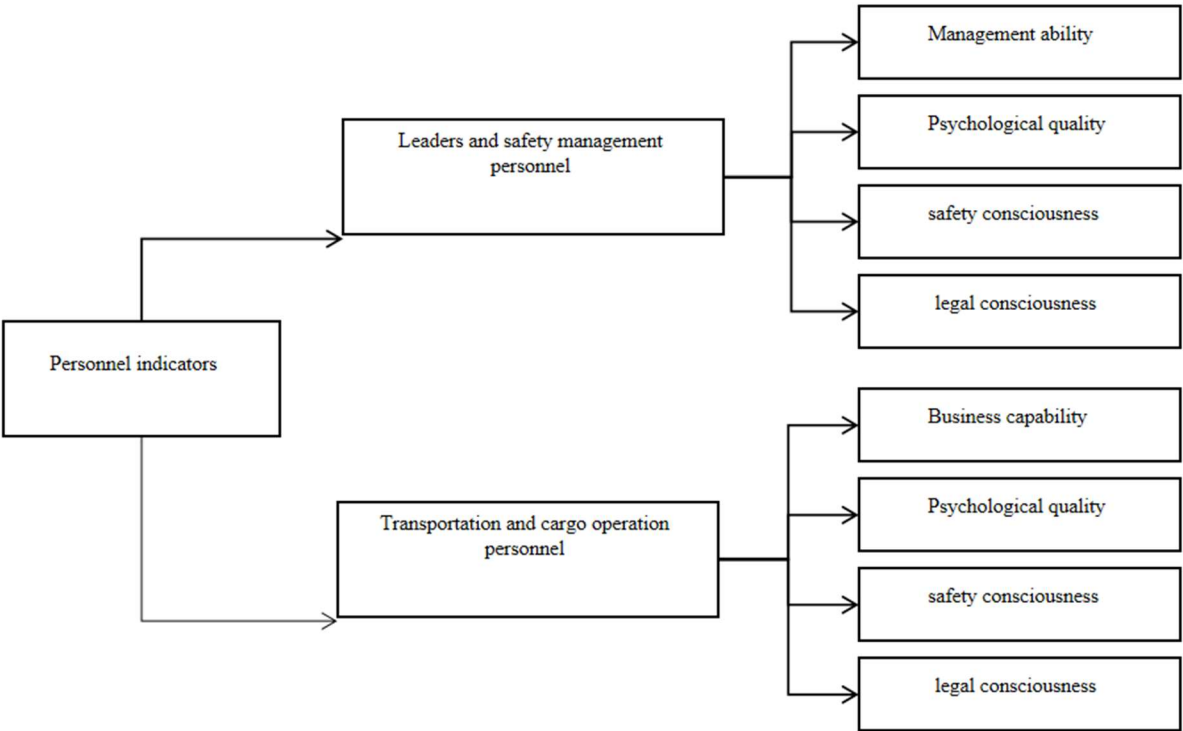


Fig. 3 Personnel indicators and subordinate evaluation indicators

3.2.3. Ship Indicators

The self-management and maintenance of ships, as well as the maintenance and upkeep of their equipment, are crucial for ensuring the safety of dangerous goods transportation. Therefore, the sub indicators of ship indicators are divided into two categories:

(1) Transport vessel
The three sub indicators of transportation vessels are: ship age, ship type, and hull structure. The age and age of a ship, as well as its structural wear and aging, pose a potential threat to the safety and reliability of the ship.

(2) Loading and unloading equipment
The two sub indicators of ship loading and unloading equipment are: technical condition and protective devices. The specificity and danger of hazardous materials, as well as the level of

technology and protective devices, are important indicators that affect the safety of water transportation of hazardous materials.

In short, the impact of ships on the safety of dangerous goods transportation by waterway is very important. Only by formulating and implementing appropriate safety measures can we ensure that hazardous materials do not have catastrophic impacts on the environment and humans during transportation. The subordinate evaluation indicators of ship indicators are shown in Fig. 4.

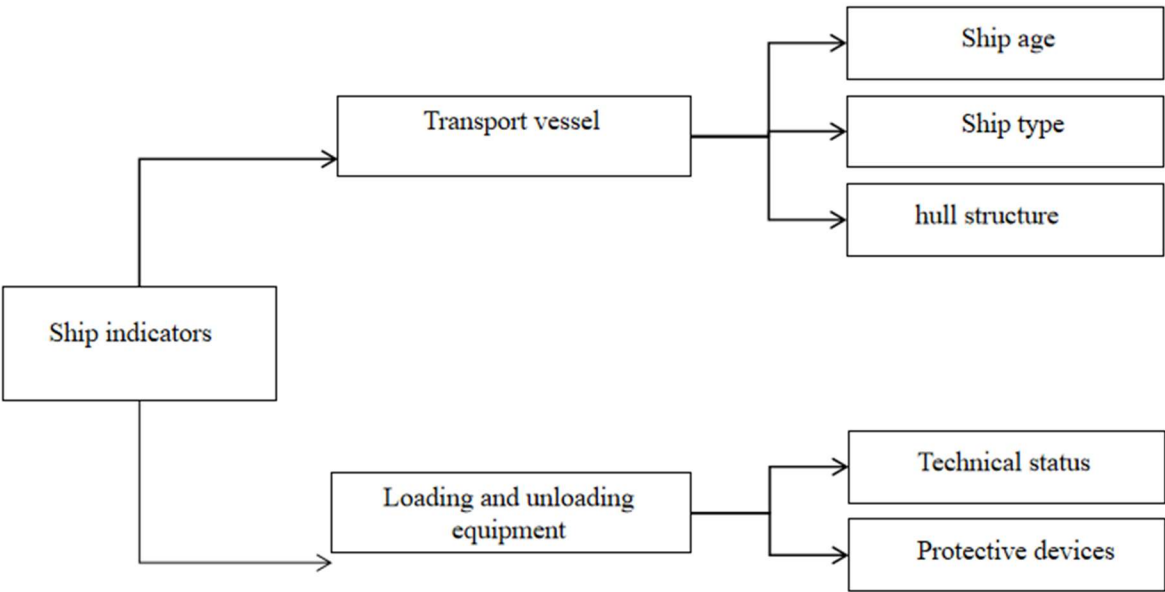


Fig. 4 Subordinate evaluation indicators for ship indicators

3.2.4. Goods Indicators

Due to the characteristics of dangerous goods, their danger and environmental hazards are considered as secondary indicators of cargo indicators.

(1) Danger

There are two sub level three indicators of cargo danger: cargo characteristics and cargo packaging quality. Due to the special nature of hazardous materials, special safety measures need to be taken during transportation, and whether the packaging of goods is in place is a factor that affects safety.

(2) Environmental hazards

The environmental hazards are considered from two aspects: the impact of hazardous materials on the ecological environment and human activities. Its subordinate three-level indicators are: ecological environment and human activities.

The transportation of dangerous goods by waterway, due to its special nature of goods, once a safety issue occurs, it is an irreversible accident. Therefore, it is crucial to consider its nature and its impact on the ecological environment and human production activities. The subordinate evaluation indicators of the goods index are shown in Fig. 5.

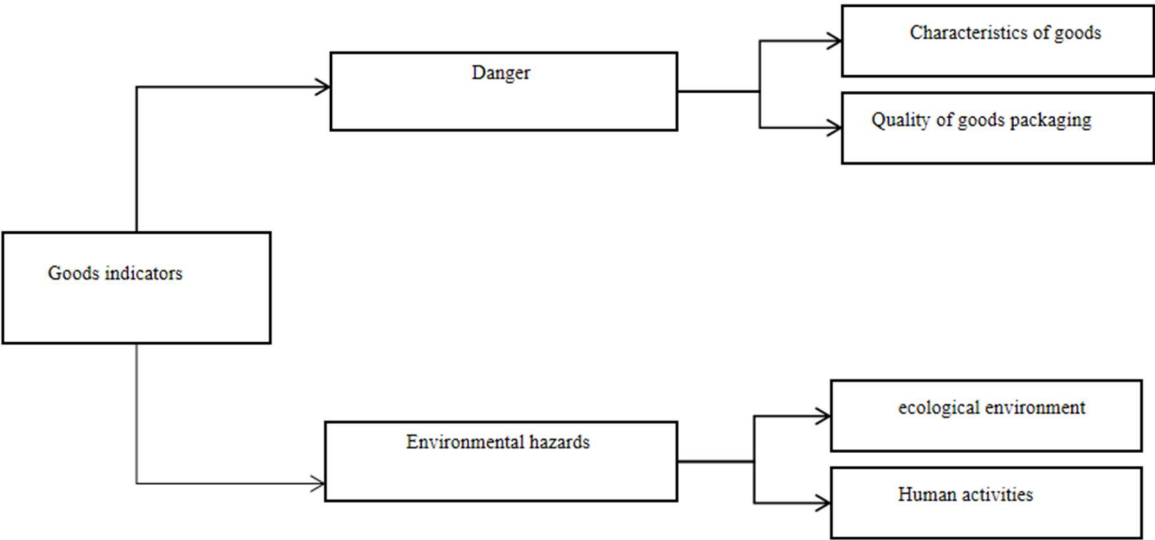


Fig. 5 Subordinate evaluation indicators for goods indicators

3.2.5. Management Indicators

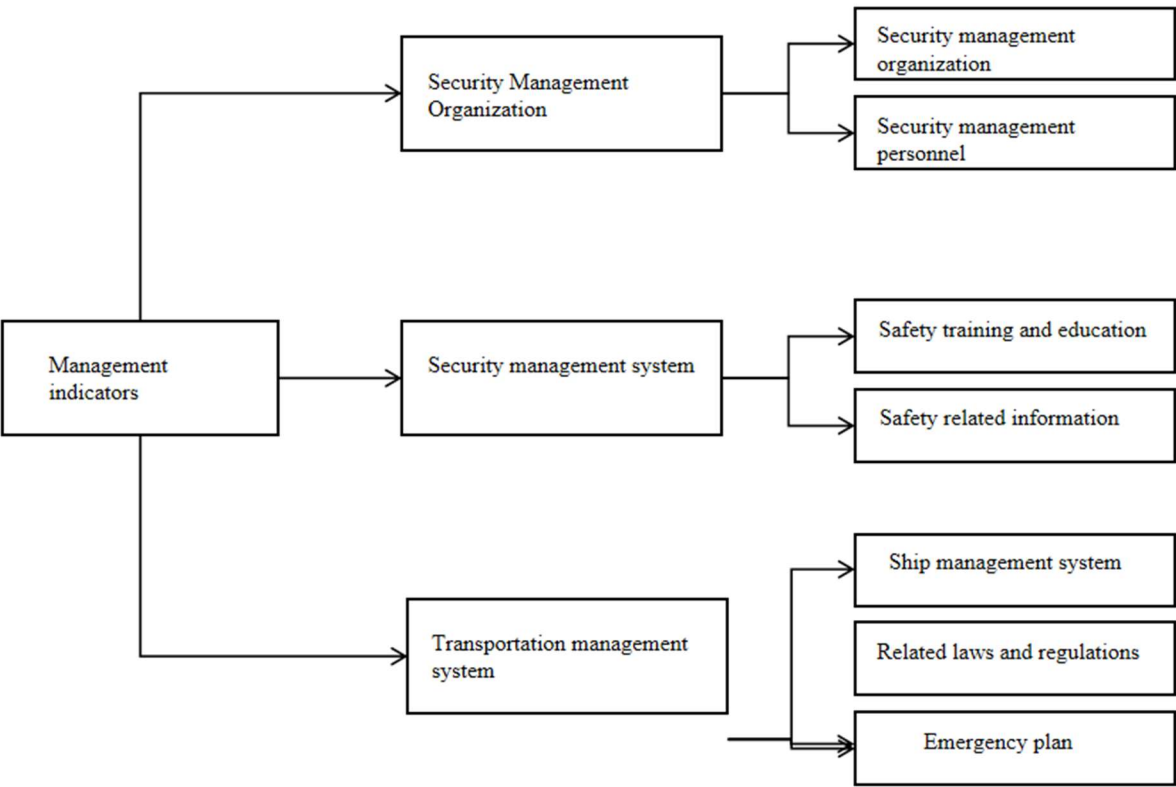


Fig. 6 Management indicators and subordinate evaluation indicators

Management plays a very important role in the transportation of dangerous goods by waterway. Due to the special nature of the transported goods, if not properly managed, waterway dangerous goods transportation packages may cause serious accidents and disasters. The following are three subordinate evaluation indicators for management:

(1) Security Management Organization

The reasonable allocation of safety management organization is the first line of defense for safety management: its two subordinate three-level indicators are: safety management organization and safety management personnel.

(2) Security management system

The safety management system refers to a series of rules, regulations, and standards established to ensure safety. A qualified safety management system can ensure personnel safety, prevent accidents, and enhance safety awareness. Its two subordinate three-level indicators are: safety training and education, and safety related materials.

(3) Transportation management system

The transportation management system formulates and implements relevant laws, regulations, standards, and norms to regulate and constrain the transportation of dangerous goods, prevent dangerous goods safety accidents during transportation, and ensure human life safety through emergency plans in the event of accidents. Its three subordinate tertiary indicators are: ship management system, relevant laws and regulations, and emergency plans.

4. Safety Index System for Waterway Transportation of Dangerous Goods

Establishing a hazardous material transportation indicator system can monitor, evaluate, and manage the safety, efficiency, and environmental aspects of hazardous material transportation.

4.1. Principles for Establishing a Safety Evaluation Index System

The principles for establishing an evaluation index system for the transportation of dangerous goods by waterway are as follows:

(1) The principle of scientificity: The indicator system must meet the requirements of scientificity, standardization, accuracy, and reliability, reflect the actual situation of dangerous goods transportation by waterway, and have scientificity.

(2) Objectivity principle: The indicator system should be objective, fair, and neutral, unaffected by subjective factors, and able to reflect the true situation of dangerous goods transportation by waterway.

(3) Principle of practicality: The indicator system should be practical, able to guide practical work and provide useful information for the safety management of dangerous goods transportation by waterway.

(4) The principle of comprehensiveness: The indicator system should comprehensively consider various factors related to the transportation of dangerous goods by waterway, such as ships, goods, environment, etc., and can comprehensively reflect the safety status of the transportation of dangerous goods by waterway.

4.2. Safety Index System for Waterway Transportation of Dangerous Goods

Based on the preliminary work of the safety evaluation index system for waterway dangerous goods transportation, firstly, determine the selection principles of each index and form the logical relationship and expression structure of each index; Then, based on the current situation and relevant laws and regulations, determine the principles for constructing a safety evaluation index system; Finally, establish a safety evaluation index system for the transportation of dangerous goods by waterway, as shown in Table 1.

Table 1. Safety evaluation index system for waterway transportation of dangerous goods

First indicator	Second indicator	Third indicator
Environmental indicators	Navigation environment	weather conditions
		Water conditions
		Transportation conditions
	Navigation conditions	Channel width
		Channel depth
		Channel crossing condition
	Port conditions	Water conditions
		Land conditions
Personnel indicators	Leaders and safety management personnel	Management ability
		Psychological quality
		safety consciousness
		legal consciousness
	Transportation and cargo operation personnel	Business capability
		Psychological quality
		safety consciousness
		legal consciousness
Ship indicators	Transport vessel	Ship age
		Ship type
		hull structure
	Loading and unloading equipment	Technical status
		Protective devices
Goods indicators	Danger	Characteristics of goods
		Quality of goods packaging
	Environmental hazards	ecological environment
		Human activities
Management indicators	Security Management Organization	Security management organization
		Security management personnel
	Security management system	Safety training and education
		Safety related information
	Transportation management system	Ship management system
		Related laws and regulations
		Emergency plan

5. Analysis of Dangerous Goods Transportation by Waterway in Weihai City

Weihai City is a port city located on the eastern coast of Shandong Province, China, with multiple ports and sea areas. Among them, Weihai Port is the largest port in Weihai City and one of the important comprehensive ports in China. It is located on the southeast coastline of Weihai City and is the easternmost port on the Shandong Peninsula. The main port areas of Weihai Port include Nanbao Port Area, Binhai Port Area, Rongcheng Port Area, and Huancui Port Area. Nanbao Port Area is the main port area of Weihai Port, as well as the main commercial and freight port of Weihai City. The cargo throughput of Weihai Port ranks among the top in the country's ports. In addition, there are other ports and sea areas in Weihai, such as Shidao Port, Rushan Port, and Beihai Sea. According to the analysis of the safety index system for the transportation of dangerous goods by waterway, the following are:

(1) Environment

Taking Weihai Port as an example, it is located in Weihai City, Shandong Province, China and is a natural and excellent port. Weihai Port is located in the central part of the Yellow Sea and is a transportation hub connecting the Bohai Bay and the Bohai Strait, with unique geographical advantages. The maximum depth in the North Port area of Weihai Port can reach 19.5 meters, and the maximum depth in the South Port area can reach 17.5 meters. Overall, Weihai Port has good water depth conditions and modern loading and unloading equipment, with the ability to undertake various types of goods, and obvious geographical advantages.

(2) Personnel

Weihai City is a port city in Shandong Province, China. The maritime department is one of the important government departments responsible for managing the navigation safety and maritime traffic order of Weihai Port. The relevant maritime departments include: Maritime Affairs Department of Weihai Transportation Bureau; Weihai Maritime Safety Administration; Weihai Ocean and Fisheries Bureau; Maritime Brigade of Weihai Border Defense Detachment, etc.

Weihai Port is a state-owned port managed and operated by Weihai Port Group Co., Ltd. The personnel composition of Weihai Port Group Co., Ltd. involves multiple departments and functions, including administrative management, port operation, logistics, shipping, finance, etc. The company has different levels of management positions and professional technical positions in different functional departments, with well-equipped personnel.

(3) Ships

The situation of ships in Weihai City is relatively diverse, covering multiple fields such as commercial ships, fishing boats, and warships. Among them, commercial ships include various types such as bulk carriers, oil tankers, container ships, etc; In terms of fishing vessels, there are multiple types such as trawlers and gillnet fishing vessels; There are various types of warships, including frigates, destroyers, submarines, etc.

Weihai City also has multiple shipbuilding enterprises, such as Weihai Square Shipbuilding Co., Ltd., Weihai Aerospace Industry Group Co., Ltd., etc. They have strong technical strength and rich experience in shipbuilding, ship repair, and ship modification fields. It can bring great help to ship maintenance.

(4) Goods

As a port city, the transportation of dangerous goods by ships in Weihai is one of its important economic activities. As an important port city, Weihai Port has a relatively large volume of dangerous goods transported by ships, involving many types of dangerous goods, mainly including chemicals, petroleum, and liquefied gas.

(5) Management

Weihai City attaches great importance to the safety management and supervision of ship dangerous goods transportation, strengthens the qualification approval and safety inspection of dangerous goods transportation enterprises, and improves the safety level of dangerous goods transportation. At the same time, a complete safety management system for dangerous goods transportation on ships has been established, which comprehensively manages and controls the links and processes of dangerous goods transportation, ensuring the safety and reliability of dangerous goods transportation on ships.

6. Safety Management Measures for Water Transport of Dangerous Goods in Weihai City

Weihai City is a coastal city, and safety management measures for waterway transportation of dangerous goods are crucial. Here are a few suggestions:

- (1) Establish a sound hazardous material transportation management system: Develop a hazardous material transportation management system, clarify the safety requirements for the classification, packaging, labeling, loading and unloading, and transportation of hazardous materials, and strictly implement them to ensure the safety of hazardous material transportation.
- (2) Strengthen the supervision of hazardous material transportation enterprises: Strictly supervise and manage hazardous material transportation enterprises, including qualification review, safety production management, inspection of equipment and facilities, monitoring of transportation vehicles, etc., to ensure that hazardous material transportation enterprises meet the requirements of laws and regulations and ensure the safety of hazardous material transportation.
- (3) Strengthen safety training for dangerous goods transportation: Targeting personnel engaged in dangerous goods transportation and relevant departments, strengthen the promotion and education of safety knowledge and skill training, improve their safety awareness and emergency response capabilities, and reduce the incidence of dangerous goods transportation accidents.
- (4) Carry out emergency response for dangerous goods transportation accidents: establish a comprehensive emergency plan for dangerous goods transportation accidents, strengthen emergency drills for dangerous goods transportation accidents, improve emergency response capabilities and levels, ensure rapid and effective emergency response in the event of dangerous goods transportation accidents, and reduce accident losses.
- (5) Strengthen information construction: Establish an information system for dangerous goods transportation, achieve real-time monitoring and management of the entire process of dangerous goods transportation, timely discover and handle safety hazards, and ensure the safety of dangerous goods transportation.

7. Conclusion

At present, research on the safety evaluation index system in the field of dangerous goods transportation is mostly focused on road transportation, and there is relatively little research on the safety evaluation system for waterway dangerous goods transportation. This article focuses on the current situation of Weihai City, selects appropriate evaluation indicators, constructs a safety evaluation system based on this, and proposes safety management measures for dangerous goods transportation by waterway in Weihai City. This has played an important role in the safety management of dangerous goods transportation by waterway in Weihai City.

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