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Research on risk identification, evaluation and countermeasures of liquid dangerous cargo ships in Yangpu Waters

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Research on Risk Identification, Evaluation and Countermeasures of Liquid Dangerous Cargo Ships in Yangpu Waters

By

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The People's Republic of China

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DECLARATION

I certify that all the material in this research paper that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this research paper reflect my own personal views, and are not necessarily endorsed by the university.

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Assessor: _____

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ABSTRACT

Title of Dissertation: **Research on Risk Identification, Evaluation and Countermeasures of Liquid Dangerous Cargo Ships in Yangpu Waters**

Degree: **MSc**

With the in-depth development of the Hainan Free Trade Port and the new land-sea channel construction strategy in western China, the number of liquid dangerous cargo transported by ships at Yangpu Port is increasing year by year, and the possibility of accidents during transportation also gradually increasing. However, the relevant supervision and management administrations have relatively weak research on the risks of such liquid dangerous cargo ships, and the accident emergency management system is not yet perfect. Therefore, exploring and studying the risks and countermeasures of liquid dangerous cargo ships in Yangpu Port is of great significance for preventing accidents.

In this paper, through investigation and data analysis, four aspects of risk, including cargo, ship, management, and navigation process, are selected as the research object, and the fault tree analysis (FTA) method is used to identify sub-factors of each risk factor to determine specific risk factors that affect the safety of liquid dangerous cargo ships in Yangpu waters. The risk matrix method of formal safety analysis (FSA) is used to quantitatively evaluate the above-mentioned transportation risk factors. Finally the problems and causes of the liquid dangerous cargo ships in Yangpu port are analyzed, and management countermeasures are provided from five aspects.

Key words: liquid dangerous cargo ships, risk factor identification, risk factor evaluation, management countermeasures

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LIST OF ABBREVIATIONS

AIS	Automatic identification System
ALARP	As Low As Reasonably Practicable
CCTV	Closed-Circuit Television
DWT	Deadweight tonnage
CIC	Concentrated Inspection Campaign
FSA	Formal safety Assessment
FTA	Fault Tree Analysis
IMO	International Maritime Organization
JSA	Job Safety Analysis
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MSA	Maritime Safety Administration
PDCA	Plan Do Check Action
PX	P-Xylene
SMS	Safety Management System
VHF	Very High Frequency
VLCC	Very Large Crude Carrier
VTS	Vessel Traffic Service

Chapter 1 Introduction

1.1 Research background

Yangpu Port is located in the western part of Hainan Province, the central area of the Pan-Beibu Gulf. It faces Guangxi in the north and Vietnam across the sea. It is the oil and gas reserve bases and the first node for Middle East and African oil and gas to enter China. On April 13, 2018, China decided to support the construction of a pilot free trade port on the entire island of Hainan Province. Hainan Free Trade Port positions Yangpu as a new shipping hub for international land-sea trade, an international energy trading center, a bulk commodity distribution center for Southeast Asia, an international offshore trade pilot zone, and a major national strategic service guarantee zone. It can be seen that with the deepening of the construction of Hainan Free Trade Port, oil tankers, chemical tankers, liquefied gas tankers and other bulk liquid dangerous cargo ships entering and leaving Yangpu port will gradually show an upward trend. Liquid dangerous cargo ships are prone to collisions, groundings, explosions or fires in the process of navigation, cargo handling operations, fuel loading, and tank washing, etc., which can lead to serious casualties and maritime pollution. Therefore, to strengthen the management of liquid dangerous cargo ships, it must work hard on prevention. This requires an in-depth assessment of the risk factors of these ships, grasping the weak links of risk, and exploring the rules.

1.2 Research purpose and main content

1.2.1 The purpose of the research

According to the actual situation of management of liquid dangerous cargo in Yangpu waters, relevant information of liquid dangerous cargo ships is collected. Through investigation and research, the production and circulation demand of liquid dangerous cargo as well as the distribution, characteristics, emergency measures, emergency capacity and other information will be mastered. Through risk identification, the risk sources of liquid dangerous cargo ships in Yangpu port are analyzed comprehensively. Through the assessment, the the risk level are obtained. Based on the above information and combined with the actual management needs, management countermeasure are put forward, so as to realize the scientific and efficient management of liquid dangerous cargo ships.

1.2.2 The main content of the research

The main contents of the research are the analysis of the current management situation of liquid dangerous cargo ships in Yangpu waters, the investigation and analysis of the enterprises related to the transportation of liquid dangerous goods in Yangpu port, the identification of risk sources of liquid dangerous cargo, risk assessment and management countermeasures.

1.3 Research methods

This research adopts a combination of literature research, field investigation, and data comparative analysis. The main theoretical models are the fault tree analysis method and the risk matrix evaluation method of formal safety analysis.

The main literature work involved in this paper is to collect relevant information on

the management of liquid dangerous cargo ship, combined with the author's daily work experience and consulting colleagues, to study the knowledge of the management of liquid dangerous cargo ship and emergency countermeasures, and lay the foundation for the writing of this article basis. The on-site investigation stage is mainly to conduct data collection and interviews with the Yangpu Maritime Safety Administration, the liquid dangerous cargo transportation and storage enterprises , and the emergency security agencies. Finally, organize and analyze the collected data, summarize the rules, and make suggestions.

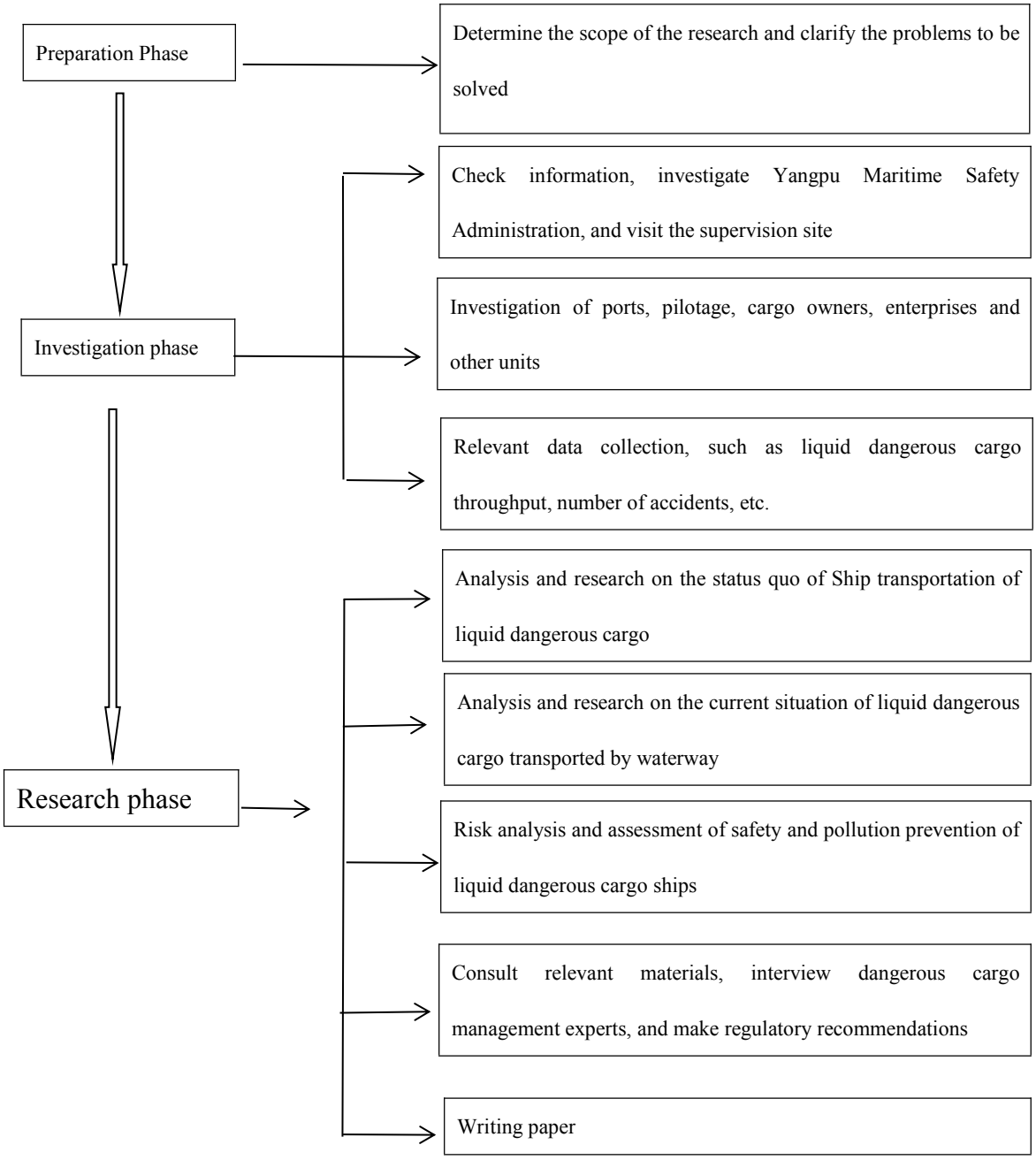

Figure 1: Paper writing process

(Source: Compiled by author)

1.4 Paper structure

This paper is divided into six chapters. Chapter 2 is the current status and analysis of liquid dangerous cargo ships in Yangpu Port. Chapter 3 is the risks analysis of liquid dangerous cargo ships. Chapter 4 is the risk assessment of liquid dangerous cargo ships. Chapter 5 is the liquid dangerous cargo ship management countermeasures. Chapter 6 is the conclusion and outlook.

Chapter 2 Current Status and Analysis of Liquid Dangerous Cargo Ships in Yangpu Port

2.1 Status of the port

2.1.1 Natural environmental conditions

(1) Meteorology

① Wind

Yangpu Port is located in the Yangpu Economic Development Zone of Hainan Province. It has a special geographical location and the wind has a significant impact. Especially when a typhoon makes landfall near Hainan Province, the shape of the mouth of Yangpu Port will aggravate the impact of wind and waves on the port. The annually normal wind direction in Yangpu is ENE with a frequency of 16.70%, the second normal wind direction is NE, with a frequency of 15.66%. Strong wind directions are ENE, NNE, and the frequency which greater than force seven is 0.01%.

② Fog condition

Compared with other port of China, the impact of fog on Yangpu Port is relatively small. Fog in this area most of the year occurs from November to April of the following year, with the most foggy days in January and March, and seldom from May to September. The appearance duration of moderate fog is 3-4 hours, and the

longest duration is 9 hours. The number of foggy days throughout the year is 34 days.

③Tropical cyclone

The influence of tropical cyclones usually occurs from July to October. The earliest can occur in early and middle of June, the latest can occur in mid-to-late of November. According to statistical data, tropical cyclones along the Qiongzhou Strait westward into the Beibu Gulf have relatively greater impact onYangpu port. Tropical cyclones on this type of path from the southern part of Hainan Island northward into the Beibu Gulf also have a relatively large impact.

(2) Hydrology

According to the analysis of the measured ocean current data, the ocean current in this sea area is affected by the offshore topography and flows back and forth. The direction of the rising tide is NNE, and the direction of the ebb tide is SSW. The maximum flow velocity on the surface is 87 cm/s and the flow direction is 010°. The maximum residual flow velocity (surface layer) is 18 cm/s and the flow direction is 010°. This sea area is an irregular daily current.

2.1.2 Status quo of port conditions

(1) Overview of the jurisdiction

Yangpu port is close to the west mouth of the Qiongzhou Strait, and adjacent to Houshui Bay. Known as "long line and good natural deep-water port", it is an

important port of the industrial corridor in the northwest of Hainan Province and a first-class open port in China. With the deepening of the construction of the Hainan Free Trade Port, it can be predicted that in the next few years, the number of ships entering and leaving Yangpu Port, especially those ships carrying liquid dangerous cargo, will increase substantially.

From north to south, there are five liquid dangerous cargo wharves inYangpu port, including SDIC Vopak, Hainan Yisheng, Hong Kong Petrochemical, Hainan LNG, Hainan Refining and Chemical. There are totally seventeen dangerous cargo berths for these five liquid dangerous cargo wharves. The loading and unloading of cargo involves crude oil, refined oil, LPG, and LNG. , PX and other liquid dangerous cargo.

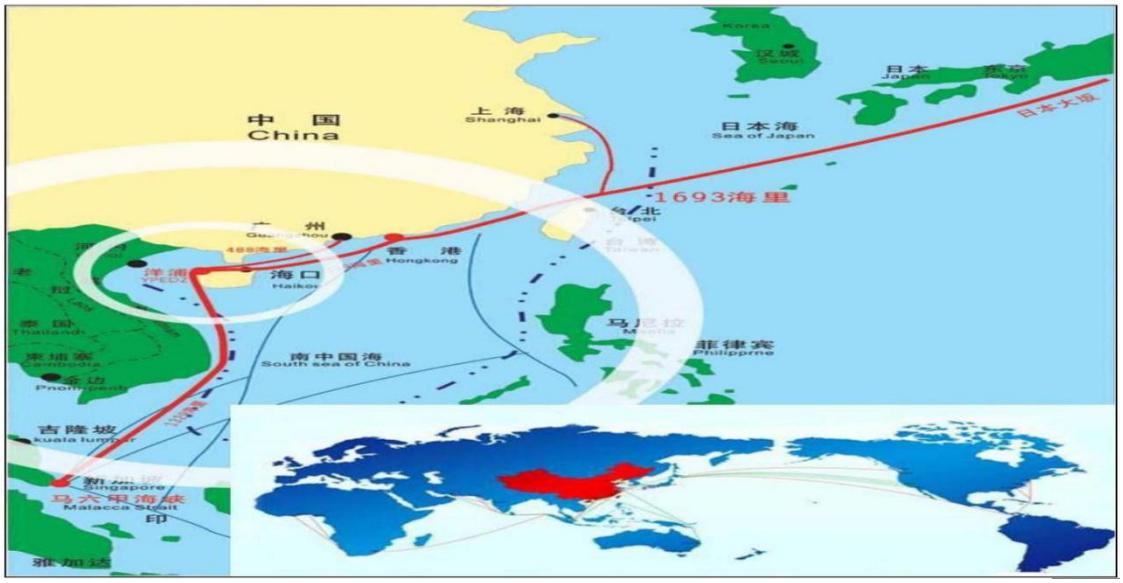

Figure 2: Location map of Yangpu Port

(Source:Yangpu MSA,2019)

(2) Channel

There are eight special channel for liquid dangerous cargo in Yangpu waters. The specific distribution and detailed information are as follows:

Channel name	length	width	water depth
Hainan Refinery Chemical 1 # Berth	2000m	300m	-22.6m
Hainan Refining Chemical 2 # Berth	1060m	300m	-14.6m
Hainan Refinery 3 # -8 # Berth Channel	435m	100m	-9.4m
Terminal Channel of Sinopec Hong Kong Branch	1800m	260m	-15.0m
Hainan LNG terminal channel	1000m	312m	-14.3m
Hainan Yisheng Petrochemical Terminal Channel	4520m	266m	-11.1m
SDIC Fubao Crude Oil Terminal Channel	1000m	390m	-21.6m
SDIC Fubao Product Oil Terminal Channel	600m	230m	-11.8m

Figure 3: General situation of the channel of the dangerous cargo wharf in Yangpu waters

(Source: Statistic of Yangpu MSA, 2019)

(3) Anchorage

There are currently sixteen anchorages in the Yangpu waters, including eleven anchorages for dangerous cargo ships, which are mainly used for the anchoring of crude oil ships, LNG ships, and product oil tankers. The natural water depth is from -6 meters to -34 meters. The specific situation is shown in the figure:

Anchorage name	Type of anchorage	Maximum depth	Type of ship
1# anchorage	Anchorage for ships carrying dangerous cargo	-34.00 m	Large crude oil ship
2# anchorage	Anchorage for ships carrying dangerous cargo	-32.00 m	Large crude oil ship
3# anchorage	Anchorage for ships carrying dangerous cargo	-30.00 m	Large crude oil ship
4# anchorage	Anchorage for ships carrying dangerous cargo	-23.00 m	LNG ship
5# anchorage	Anchorage for ships carrying dangerous cargo	-24.00 m	LNG ship
6# anchorage	Anchorage for quarantine and fumigation	-23.00 m	
7# anchorage	Anchorage for ships carrying dangerous cargo	-24.00 m	Medium and large dangerous cargo ship
10# anchorage	Anchorage for ships carrying dangerous cargo	-10.00 m	Medium and large dangerous cargo ship
12# anchorage	Anchorage for ships carrying dangerous cargo	-6.00 m	Small dangerous cargo ship
14# anchorage	Anchorage for ships carrying dangerous cargo	-25.00 m	Large dangerous cargo ship
15# anchorage	Anchorage for ships carrying dangerous cargo	-25.00 m	Medium and small dangerous cargo ship

Figure 4: List of anchorages for ships carrying dangerous cargo in Yangpu waters

(Source:Statistic of Yangpu MSA, 2019)

(4) wharf

Yangpu Port has five liquid dangerous cargo wharves and seventeen berths. The specific information of wharves and berths are shown in the figure below:

Terminal name	Berth number	Type of cargoes	Maximum berthing capacity
Hainan Refinery Terminal	1# berth	Crude oil	300000 tons crude oil tanker
	2# berth	Gasoline, diesel, etc.	100000-ton product oil tanker
	3# berth	Gasoline, diesel, etc.	5000-ton product oil tanker
	4# berth	Gasoline, diesel, etc.	5000-ton product oil tanker
	5# berth	Toluene, styrene, etc.	5000-ton chemical tanker
	6# berth	Toluene, gasoline, etc.	5000-ton chemical tanker
	7# berth	Gasoline, diesel, toluene, etc.	10000-ton chemical tanker
	8# berth	Gasoline, diesel, aviation kerosene, etc.	10000-ton product oil tanker
Hainan LNG terminal	LNG berth	Liquid nature gas	267000 cubic meters of liquefied gas tanker
China Petrochemical Hong Kong Branch Terminal	1# berth	Gasoline, diesel	100000-ton product oil tanker
	2# berth	Gasoline, diesel	50000-ton product oil tanker
	3# berth	Gasoline, diesel	50000-ton product oil tanker
	4# berth	Gasoline, diesel	50000-ton product oil tanker
Hainan Yisheng Petrochemical terminal	1# berth	Toluene	20000-ton chemical tanker
	2# berth	Toluene	10000-ton chemical tanker
SDIC Fubao Terminal	Crude oil berth	Crude oil	300,000 tons crude oil tanker
	Product oil berth	Product oil	50000-ton product oil tanker

Figure 5: The liquid dangerous cargo wharf and berth situation in Yangpu waters

(Source:Statistic of Yangpu MSA, 2019)

2.2 Transportation of liquid dangerous cargo

2.2.1 Overview of liquid dangerous cargo

According to the definition in the "Regulations on the Safety Supervision and Administration of Ships Carrying Dangerous cargo", the so-called dangerous cargo refer to the characteristics of explosion, flammability, poisoning, corrosion, radioactivity, pollution risks, etc., which are likely to cause personal injury during the navigation of ships, items that require special protection due to property damage

or environmental pollution (China Ministry of Transport, 2018). Dangerous cargo can be divided into two categories: packaged dangerous cargo and bulk dangerous cargo according to different transportation modes. Among them, bulk dangerous cargo can be subdivided into solid bulk dangerous cargo, bulk oil, bulk liquid chemicals, and bulk liquefied gas. The liquid dangerous cargo transported by ships in Yangpu waters are all in bulk, including crude oil, refined oil, liquefied petroleum gas (LPG), liquefied natural gas (LNG), xylene (PX), etc.

2.2.2 Ships entering and leaving the port

It mainly refers to the arrival and departure times of liquid dangerous cargo ships in the past four years, as shown in the following figure:

Year	Crude oil ships (times)	Product oil ships (times)	LNG ships (times)	LPG ships (times)	PX ships(times)	Total (times)
2016	117	2082	2	213	282	2696
2017	114	1391	6	152	248	1911
2018	93	3181	11	107	436	3828
2019	91	3924	31	36	547	4629

Figure 6: The number of liquid dangerous cargo ships entering and leaving port from 2016 to 2019 in Yangpu waters

(Source:Statistic of Yangpu MSA, 2019)

2.2.3 Throughput of liquid dangerous cargo

On the whole, the throughput of liquid dangerous cargo in the waters of Yangpu is gradually increasing. From the statistical data, the liquid dangerous cargo in Yangpu waters are mainly product oil and crude oil, followed by LNG and PX, and the least is LPG. The detailed information is shown in the following figure:

Year	Crude oil (tons)	Product oil (tons)	LPG (tones)	PX (tones)	LNG(cubic meters)	Total (tons)
2016	13525842.9	9192027.6	338501	1203450.2	156981.9	24416803.6
2017	10460152.6	8377426.1	249250	1384958	425601	20897387.7
2018	9658834.2	10927155.2	158623	1617740	608190.1	22970542.5
2019	9266092.6	11746792.6	49540	2110923.4	1033230.3	24206578.9

Figure 7: Yangpu Waters liquid dangerous cargo through put by category from 2016 to 2019 (Source:Statistic of Yangpu MSA, 2019)

2.2.4 Statistics and analysis of accidents of liquid dangerous cargo ships

(1) Statistics on accidents of liquid dangerous cargo ships in the past five years

According to statistics from the Yangpu Maritime Safety Administration, from 2015 to 2019, there were four accidents involving liquid dangerous cargo ships in Yangpu waters, causing economic losses of 1.2058 million yuan RMB and one minor injury. The number of accidents in each year is shown in the following table:

Year	2015	2016	2017	2018	2019
Number of accident	0	1	1	1	1

Figure 8: Statistics on accidents of liquid dangerous cargo ships in Yangpu waters from 2015 to 2019

(Source:Statistic of Yangpu MSA, 2019)

(2) Analysis of accidents of liquid dangerous cargo ships

The four accidents that occurred from 2015 to 2019 were all minor accidents, and the types were two operational oil spills, one fire explosion, and one collision. According to the accident location of liquid dangerous cargo ships in Yangpu waters from 2015 to 2019, the author made a spatial distribution map of the accident. Details are as follows:

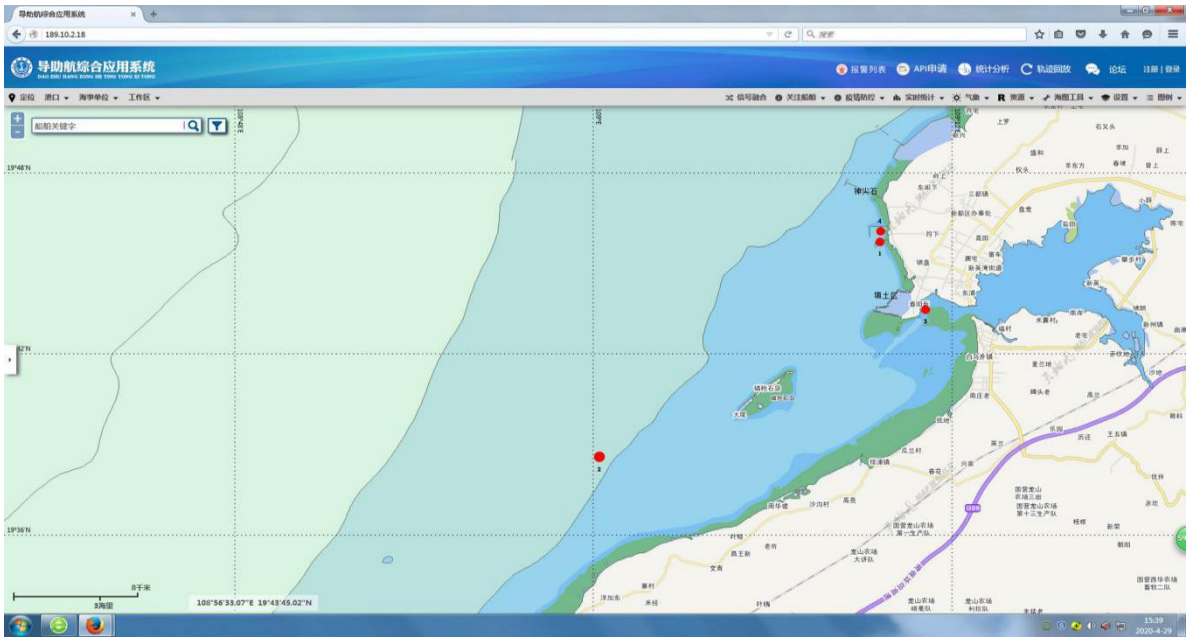

Figure 9: Spatial distribution map of accidents involving liquid dangerous cargo ships in Yangpu waters from 2015 to 2019

(Source:Compiled by author)

It can be seen from the figure that the accidents of liquid dangerous cargo ships are mainly concentrated near the port waters. According to the investigation results of the accident, combined with the accident types of liquid dangerous cargo ships in Yangpu waters in the past 10 years, the main factors causing the accident are cargo factors, environmental factors and personnel factors. The specific analysis is as follows:

① Cargo factors

All kinds of liquid dangerous cargo entering and leaving Yangpu Port, including oil cargo, bulk chemicals and liquefied gas, are all bulk liquid dangerous cargo. These liquid dangerous cargo will cause serious loss of life and property and environmental pollution if leakage or accident occurs due to their own dangerous characteristics.

② Environmental factors

One is that the ship deviates from the channel due to factors such as poor visibility, wind and current conditions, navigation capacity of the channel, etc., causing the ship to collide, run aground or get damaged. Second, because of the dense traffic, the dangerous situation formed under the influence of natural conditions such as fog, wind, tidal current, etc., which in turn caused ships to collide. Third, due to the influence of wind and current pressure, the ship's operation is restricted that causing the ship to collide, run aground or get damaged.

③ Personnel factors

Due to the human factors such as improper operation, failure to maintain a regular lookout, lack of responsibility on duty, faulty ship speed control, faulty navigational position control, improper emergency actions, negligence of navigational alert, and faulty communication with other ships (Ellis, 2011), which are easy to cause oil spills, collision, grounding and other accidents.

2.3 Management of liquid dangerous cargo ships

2.3.1 Management organization

Yangpu Maritime Safety Administration is the authority in charge of the unified management of water traffic safety and environmental pollution prevention from ships in Yangpu Waters , and is responsible for the daily management of liquid dangerous cargo and their transportation ships.

2.3.2 Management facilities

The VTS center of Yangpu Maritime Safety Administration is responsible for duty and maritime search and rescue. Now it adopts the operation mode of "three stations and one center". The central system is the STYRIS system imported from France AIRBUS. The installation and use of this system is of great significance to ship traffic management and emergency response in Yangpu waters. The monitoring equipment of Yangpu VTS center includes radar system, VHF communication system, information processing and display system, information transmission system, recording/replaying system and weather sensing system. The functions that can be

realized are: data collection, data evaluation and processing, information provision, traffic organization, navigation assistance services, support for joint operations, etc. In addition, the maritime patrol boats, law enforcement vehicles, and dangerous cargo detection equipment owned by the Yangpu Maritime Safety Administration are also effective management facilities.

2.3.3 Management status

As a new shipping hub for international land-sea trade, the number of liquid dangerous cargo ships arriving at the port has gradually increased at Yangpu, and maritime regulatory pressure has increased day by day. In order to meet new challenges and ensure the stability of water safety and order, Yangpu Maritime Safety Administration continues to carry out research on the supervision of liquid dangerous cargo ships. First, the supervision of liquid dangerous cargo ships has gradually formed a three-tier supervision model of "access barriers, hierarchical management, and joint inspection". In terms of ships eligible for inspection, the implementation of a joint security inspection model of "maritime administration + classification of society + company" has achieved the goal of reducing overall safety risks and improving the intrinsic safety of ships. The second is to establish a key supervision list for the management of liquid dangerous cargo ships. As soon as the ships that belonging to the key supervision list appear in Yangpu waters, the Yangpu Maritime Safety Administration will immediately receive a message.

2.4 Emergency situation

2.4.1 Emergency plan and emergency equipment

In recent years, the emergency rescue capability of Yangpu has been greatly improved. Specifically, it is manifested in two aspects: First, in terms of institutional mechanism, the government currently has the "Emergency Rescue Plan for Hazardous Chemical Accidents in Yangpu Economic Development Zone", and "Emergency Plan for Maritime Search and Rescue in Yangpu Economic Development Zone". According to the emergency plans such as the emergency plan for Ships Carrying Hazardous Chemicals, the government actively carries out comprehensive emergency drills. Secondly, in terms of infrastructure and equipment, the land and sea fire station, the "integrated" emergency platform and the fire command center have been built, the largest coastal firefighting ship in Asia has been built, and the 3D fire-fighting decision-making auxiliary system has been developed. A batch of fire-fighting equipment was purchased in accordance with the ability to extinguish fire accidents of 100,000 tons of crude oil storage tanks, which effectively guarantees fire emergency response to ship-borne dangerous cargo accidents in the jurisdiction.

2.4.2 Emergency supplies

The following figure shows the anti-pollution facilities and equipment . It can be seen that the basic materials and facilities such as oil booms, oil-absorbing felts, and oil recovery ships in the jurisdiction can cope with large-scale oil pollution accidents. However, there are still shortcomings in some equipment such as oil skimmers, unloading pumps and high-pressure washers.

Category	Name	Unit	Number		
			MSA	port&terminal	Sewage cleaning company
Oil spill pollution removal materials	Oil boom	metre	3200	23112	9280
	Oil absorbent felt	ton	1.5	40.14	17.4
	Oil Suction bar	metre	700	1000	8860
	Other oil-absorbing materials	ton	2	0	0
	Degreaser	ton	2	28	13.3
	Skimmer	set	3	14	6
	Unloading pump	set	0	4	2
	Pressure washer	set	0	0	13
	Spraying device	set	1	13	26
	Oil recovery ship		0	10	0
	Oil boom deployment boat		0	17	0
Hazardous chemical pollutant removal materials	Leak monitoring / detection equipment	set	0	8	0
	Fire pump	set	0	0	0
	Neutralizing substances	ton	0	0	0
	Inert substance	ton	0	0	0
	Adsorption material	ton	0	0	0
	Personal protective equipment	set	2	0	0

Figure 10: Statistics of anti-pollution equipment and equipment in Yangpu area

(Source: Statistic of Yangpu MSA, 2019)

2.4.3 The emergency response capability against pollution

Each wharf in the jurisdiction is basically equipped with corresponding anti-pollution equipment in accordance with the requirements of the risk assessment report of the maritime environment pollution caused by ships, and the emergency response capability can basically meet the pollution prevention needs of the area.

Chapter 3 Risks Analysis of Dangerous Liquid Ships

3.1 Risks of liquid dangerous cargo ships

To obtain the risk of liquid dangerous cargo ship, the type of risk must be analyzed before the specific risk can be determined.

3.1.1 Risk types of liquid dangerous cargo ships

Due to the complexity of the environment and the influence of factors such as ships, cargo, and management, liquid dangerous cargo ships are prone to collisions, grounding, fires, explosions, and pollution. Once such an accident occurs, it may cause serious casualties, property losses and maritime environmental pollution (Ditta et al., 2018). Therefore, it is necessary to analyze and identify the risks type of liquid dangerous cargo ships.

(1) Cargo risk

The cargo risks of liquid dangerous cargo carried by ships in Yangpu waters mainly fall into the following categories:

① Risks caused by the physical and chemical properties of liquid dangerous cargo.

Due to its physical and chemical properties, ship-borne liquid dangerous cargoes generally have the characteristics of explosion, flammability, poisoning, corrosion,

and radioactivity. They themselves are the risk source of ship accidents and are potentially dangerous and polluting.

② Leakage risk

The pollution accident caused by the leakage of liquid dangerous cargo ships refers to the maritime environment pollution accidents caused by the leakage of oil, oily mixtures and other toxic and hazardous substances from ships and related operations. According to the cause of pollution accidents, ship pollution accidents can be divided into accidental ship pollution accidents and operational ship pollution accidents. According to statistics, operational accidents account for a large proportion of maritime environmental pollution.

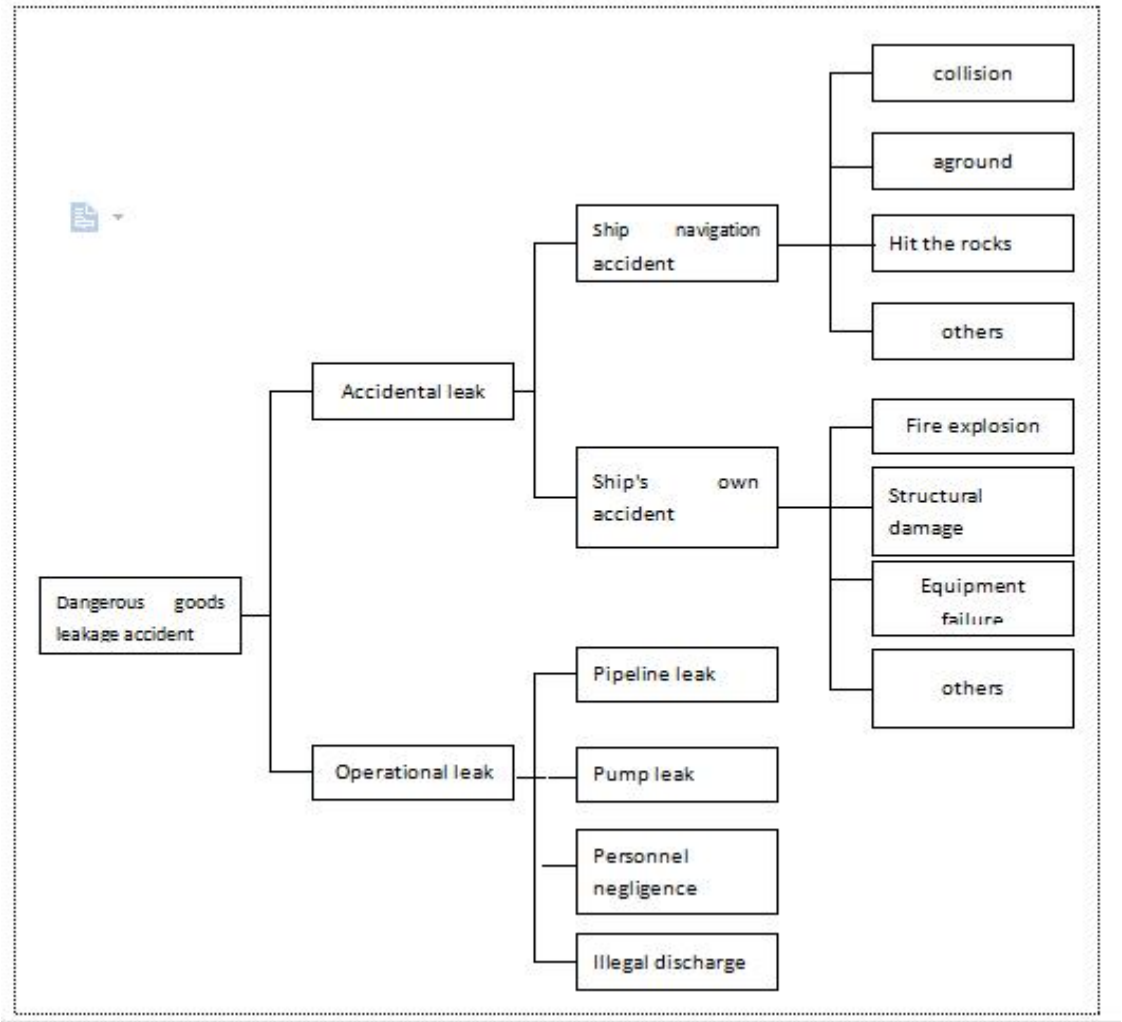

Figure 11: Classification of liquid dangerous cargo leakage accidents

(Source:Compiled by author)

(2) Ship risk

As the carrier for the transportation of liquid dangerous cargo, the safety of ships directly affects the safety of related personnel, the safety of the maritime environment and the safety of cargo. The risks of liquid dangerous cargo ships mainly include the influence of factors such as the age of the ship, the type of the

ship, the size of the ship, the structure of the ship, the ship equipment, the ship safety system, and the ship's history record.

(3) Safety management responsibility risk

The management parties related to liquid dangerous cargo ships are mainly maritime safety administrations, port enterprises, and ship management companies. Among them, the management risks from the maritime safety administrations are mainly the risks of inadequate on-site supervision, unreasonable emergency plan formulation, insufficient maritime regulatory personnel, and insufficient supervision methods (Li and Jiang, 2005). The management risks of port enterprises are mainly in the following aspects: not in place the regulations such as the formulation of emergency plans, insufficient safety equipment, low quality of wharf staff, and insufficient construction of wharf. The management risks of ship management companies are mainly the inadequate management rules and regulations, inadequate crew training, and inadequate ship management.

(4) Risks during navigation process

Navigation process risk refers to the risks faced by liquid dangerous cargo ships during navigation, berthing, and operations, which mainly include accidents during navigation, berthing and unberthing at wharves, loading and unloading or transfer operations, and anchoring that may occur. Ships may have different risks in each process. This paper mainly analyzes and identifies the risks of liquid dangerous cargo ships in the port area, such as navigation, anchoring, loading and unloading operations, transfer operations, and berthing and unberthing. The main risk during the voyage is the risk of collision and grounding, which will cause the burning,

explosion and pollution of liquid dangerous cargo. The main risks in the process of anchoring are accidents such as collisions with illegally crossing boats, and accidents such as anchor removal caused by strong winds and other weather. The loading and unloading operations are mainly liquid dangerous cargo leakage and pollution accidents caused by dangerous operations or improper protection. The main risk in the process of transfer operations and berthing is the leakage or combustion explosion of liquid dangerous cargo caused by the collision between the ship and the wharf or other ships caused by natural or human factors. The risk in the navigation process is closely related to factors such as the channel conditions, traffic conditions, wharf conditions and natural conditions at the time in the jurisdiction.

3.1.2 Risk factors of liquid dangerous cargo ships

(1) Determination of risk factors for liquid dangerous cargo ships

The risk factors of liquid dangerous cargo ships in Yangpu waters present complex characteristics. Based on the current status of maritime safety administration's management and the risk types of liquid dangerous cargo ships analyzed in the previous section, the following will mainly focus on cargo factors, ship factors, related management parties factors and navigation process factors to analyze the risks of liquid dangerous cargo ships.

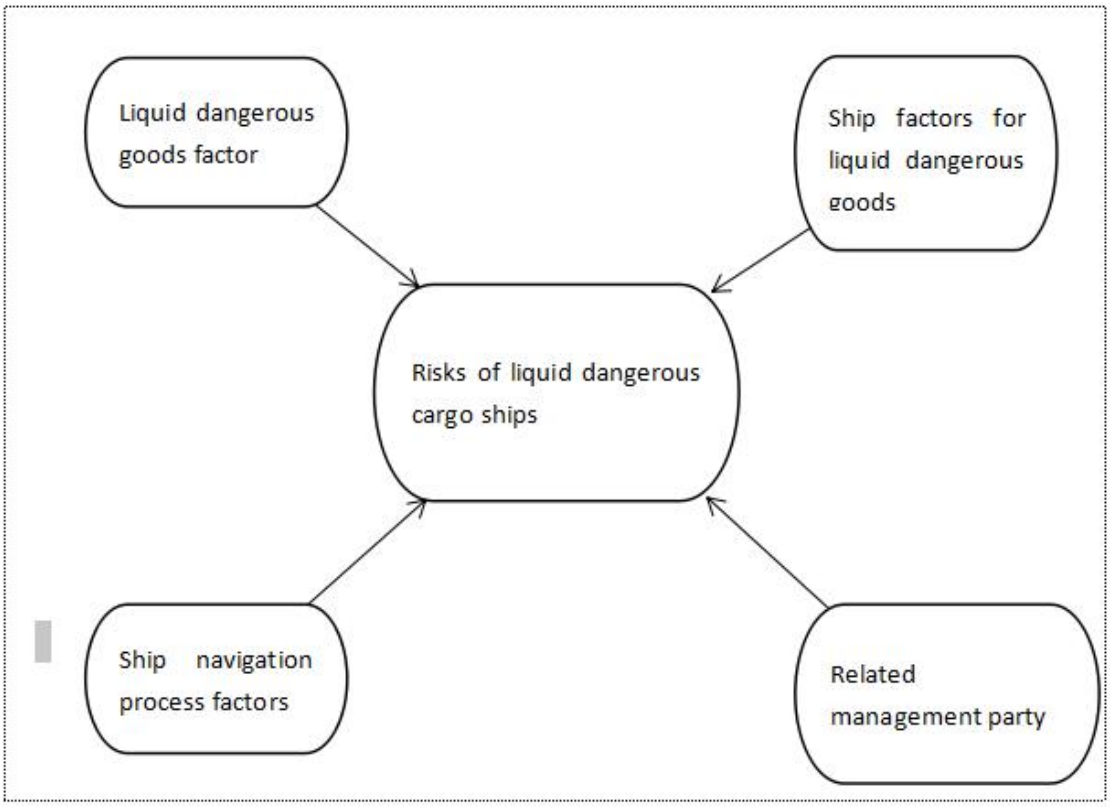

Figure 12: Risk factors of liquid dangerous cargo ships

(Source:Compiled by author)

(2) The impact of liquid dangerous cargo on other factors

The risk of liquid dangerous cargo ships comes from the process of ship transport, in which the risk factors influence each other. Therefore, the mutual influence of various factors, especially the influence of the liquid dangerous cargo on other factors, should be considered in the identification of the risks of the transport of liquid dangerous cargo. The relationship between the risk factors is obtained mainly through the investigation and data analysis of Yangpu Maritime Safety Administration.

① The impact of liquid dangerous cargo on ships

According to the "International Convention for the Safety of Life at Sea" and "International Maritime Dangerous cargo Code", special requirements are put forward for ships transporting liquid dangerous cargo. Seafarers must undergo special training and obtain qualification certificates, and adopt safe practices . It is also equipped with corresponding safety devices to ensure the safety of liquid dangerous cargo transportation (Clark and Besterfield-Sacre, 2010). The requirements for safety devices of liquid dangerous cargo ships vary with the types of cargo to be transported. In general, they mainly include: compartment separation, lightning protection measures, and cable penetration requirements, power distribution system insulation requirements, electrical explosion-proof, prevention of static sparks, enhanced ventilation, sprinkling cooling devices, fire alarm and combustible gas detection devices, fire extinguishing systems, firefighter equipment, dangerous cargo carrying warning lights and other special requirements.

If the liquid dangerous cargo are improperly stowed or kept, unsafe conditions will easily occur as the ship bumps during the voyage, and even accidents that threaten the safety of human life and the safety of the ship may occur. Therefore, while the liquid dangerous cargo increase the possibility of ship accidents, the requirements on the structure, equipment and personnel of the ship will also increase.

② The impact of liquid dangerous cargo on port safety

The import and export liquid dangerous cargo in the Yangpu Port Area include various liquid chemicals such as bulk oil, liquefied natural gas, liquefied petroleum

gas and xy-lene. The port wharves are widely distributed, involving many industries and enterprises, including chemical, petrochemical, electric power, light industry, civil fuels and other industries. It involves operations of all kinds of dangerous cargo except for the seventh class of radioactive dangerous cargo. There are many types of hidden dangers caused by liquid dangerous cargo. Therefore, dangerous cargo have a great impact on the wharf and waters, especially when the size of ships is large, and an accident will have a major impact.

The potential risks of liquid dangerous cargo to the port area are shown in: a. The pollution of the sea, land and atmosphere caused by the leakage of dangerous cargo. b. The explosion, fire and other accidents of dangerous cargo threat the safety of port facilities, life and property. c. Various toxic substances cause a fatal blow to fishery and other aquatic resources in the port area.

In short, all kinds of liquid dangerous cargo pose a great threat to the safety of the port area, especially sudden major accidents, which not only pose a threat to the port area's property, life and environment, but also cause major adverse social influences.

(3) The impact of liquid dangerous cargo on maritime supervision

Due to its special dangerous properties,liquid dangerous cargo need more supervision to be strengthened by maritime safety administrations. The impact of liquid dangerous cargo on maritime supervision is mainly reflected in the following points: First, it is necessary to strengthen the approval of liquid dangerous cargo ships, as well as the escort and dynamic monitoring of entering voyages, assess the risks such as leakage, and conduct hierarchical management. Second, it is necessary to strengthen the supervision of liquid dangerous cargo wharves and the supervision of

loading and unloading between ships and shores, and to build modern information monitoring methods. third, it is necessary to strengthen the construction of emergency response capabilities, including the construction of emergency teams, emergency equipment and materials, and emergency plan systems. The liquid dangerous cargo ship is also need other agencies to do some work to maintain safety.

3.2 Identification of risk factors of liquid dangerous cargo ships

After the above analysis on the risk factors of liquid dangerous cargo transported by ships, the fault tree analysis method (FTA) is used to analyze the sub-factors of each risk factor of liquid dangerous cargo, liquid dangerous ships, related management parties and navigation process.

3.2.1 Methods of identifying risk factors

The fault tree analysis method is one of the important analysis methods of safety system engineering. It can identify and evaluate the dangers of various systems. It can not only analyze the direct cause of the accident, but also reveal the potential cause of the accident in depth. Using it to describe the cause-and-effect relationship of accidents is intuitive and clear, which can be analyzed both qualitatively and quantitatively. In the analysis of the cause of the accident, we must first determine the possible cause. There are quite a lot of consequences or causes of accidents. According to the existing knowledge, it is necessary to determine which phenomena are related to the accidents being studied and determine the possible causes of the objects being studied (COSTIND, 1998). For this reason, the risk analysis of liquid dangerous cargo ships is planned to be carried out by using fault tree analysis. The purpose is to identify the real cause from the possible causes. It is necessary to

compare the various situations of the phenomenon under study in order to eliminate the reasons that are not the real cause, so as to identify the real cause.

This method targets large events (top events) that the system does not want to occur. Through the layer by layer analysis of its occurrence of various possible causes, until the cause of the event can no longer be decomposed. Generally, a logical gate symbol is used to connect a specific accident and each level of cause (hazard factor) to obtain a logical graphic that expresses its logical relationship (or causality) vividly and concisely, which is called an fault tree. After the fault tree is initially formed, the purpose of accident analysis and evaluation is achieved by simplifying and calculating the fault tree. Through this analysis, accident prevention methods can be found economically and conveniently, which can not only achieve the micro-guidance of safety evaluation, but also check whether the system has reliable preventive protection measures (COSTIND, 1998; Zhou et al., 2020).

Fault tree analysis can generally has the following process:

(1) Select a reasonable top event, systematically analyze the boundary and define the scope, and determine the criteria for success and failure.

It was described in the Guide to Fault Tree Analysis (COSTIND, 1998) that: through the analysis of the collected technical data, with the help of design and operation managers, build a fault tree. Supposing there are several basic events, Ci is a collection of some basic events. When all the basic events in Ci occur, the top event must occur, then Ci is a cut set of the fault tree. If Ci is a cut set, and Ci is not a cut set after removing a basic event arbitrarily, Ci is called a minimum cut set. The minimum cut set can indicate the danger of the system. Because each minimum cut

set is a possibility for the occurrence of the top event, the minimum cut set of each group is obtained, and all possible ways for the top event to occur are clarified, which provides a basis for accident prediction, prevention, and investigation. The more the minimum cut set group number of the fault tree, the greater the risk of the system. The minimum cut set with few basic events is more dangerous than the minimum cut set with many basic events.

(2) Qualitative analysis: The fault tree is simplified by Boolean Algebra, the minimum cut set is obtained, and the structural importance degree of the basic events is analyzed (Zhou et al., 1998). The conclusion is given: according to the different importance degree of the basic events, the basic events are arranged according to their structural importance degree, which is conducive to the qualitative analysis of the system security. This arrangement can be implemented by the comparison method, that is, by the minimum cut set arrangement, which is not precise, but it is simple and common.

(3) Quantitative analysis, including calculation of the occurrence probability of top events, and significance analysis.

In this paper, the risk factors of liquid dangerous cargo ships are analyzed qualitatively, not quantitatively.

3.2.2 FTA analysis of risk factors of liquid dangerous cargo ships

In the traditional production practice, the management of liquid dangerous cargo ship mainly stays in the single and relatively shallow application in accordance with the requirements of the International Maritime Dangerous cargo Codes and other

relevant regulations. Operators make qualitative evaluations of the status of cargo, storage equipment, environment, personnel, management, etc., based on their own experience and judgment ability. The advantage is that it is easy to operate, the evaluation process and the results are intuitive. The disadvantage is that the knowledge of the risk of liquid dangerous cargo ship obtained through this method is not systematic, and the work efficiency is often low. Therefore, more scientific and effective analysis and evaluation methods are needed to identify risks. Firstly, collect as widely as possible the past cases of liquid dangerous cargo ship accidents, and investigate all relevant causes. Secondly, it is necessary to clearly understand the system of the liquid dangerous cargo ship, Including all kinds of important information such as transportation process, characteristics of dangerous cargo, status of employees, time and place of operation, working environment and relevant laws and regulations, and then determine the top events. The so-called top event is the target event we want to analyze---the accidents of liquid dangerous cargo ships. Finally, determine the relevant risk factors of liquid dangerous cargo ship.

After compiling the fault tree of liquid dangerous cargo ships, the logical relations are listed and the logical operation is carried out to obtain the minimum cut set. Through the qualitative analysis of the fault tree structure, and the calculation of the structural importance and system weakness of each basic event, we can identify the risk factors of the liquid dangerous cargo ships and then evaluate the safety system, so as to obtain the corresponding safety countermeasures (Emre, 2020). After analysis, an fault tree for liquid dangerous cargo ships is established. For the smallest cut set, it is connected with the “or gate” on the top event. Obviously, the smaller the number of minimum cut sets the safer, the more the more dangerous.

Through the classification of the risk sources of liquid dangerous cargo ships, the

risk event tree is sorted out, which are the factors related to liquid dangerous cargo, the factors related to ships, the factors related to management and navigation process, and then the four risk factors are analyzed in detail to obtain a comprehensive composition of risk factors.

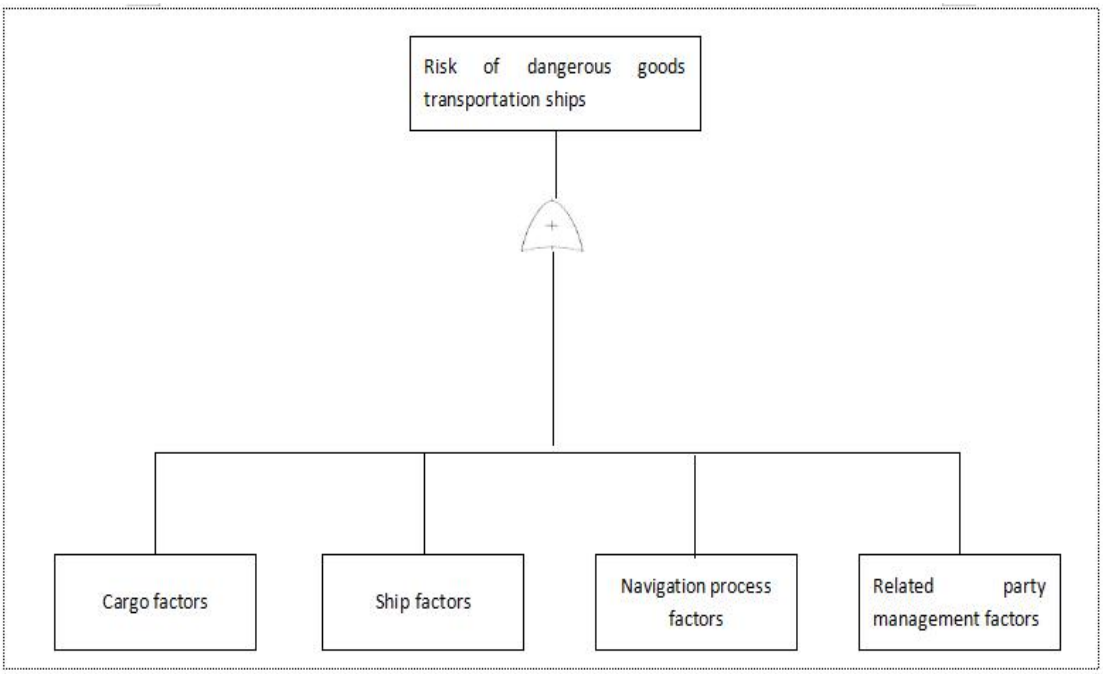

Figure 13: FTA analysis of risks of liquid dangerous cargo ships

(Source:Compiled by author)

(1) Risk factors related to liquid dangerous cargo

Ships transporting liquid dangerous cargo in Yangpu waters are mainly in bulk form, including various oil products such as crude oil, diesel and gasoline, liquid chemicals such as xy-lene, benzene, and glycol, as well as LNG and LPG. According to the analysis of the FTA, based on the risk of leakage, flammability and explosion, the risk factors of liquid dangerous cargo mainly include: cargo dangerous attribute,

cargo carrying volume, cargo loading situation, improper operation, intentional violation, navigation accident and own accident, etc. Among them, the inherent risks of liquid dangerous cargo constituted by the loading conditions, dangerous attributes and transportation volume of liquid dangerous cargo belong to the first category of hazard sources, which determine the magnitude of the consequences of a ship accident. The operation factors and accident factors that cause the leakage of liquid dangerous cargo belong to the second category. These factors play a decisive role in the probability of accidents on liquid dangerous cargo ships.

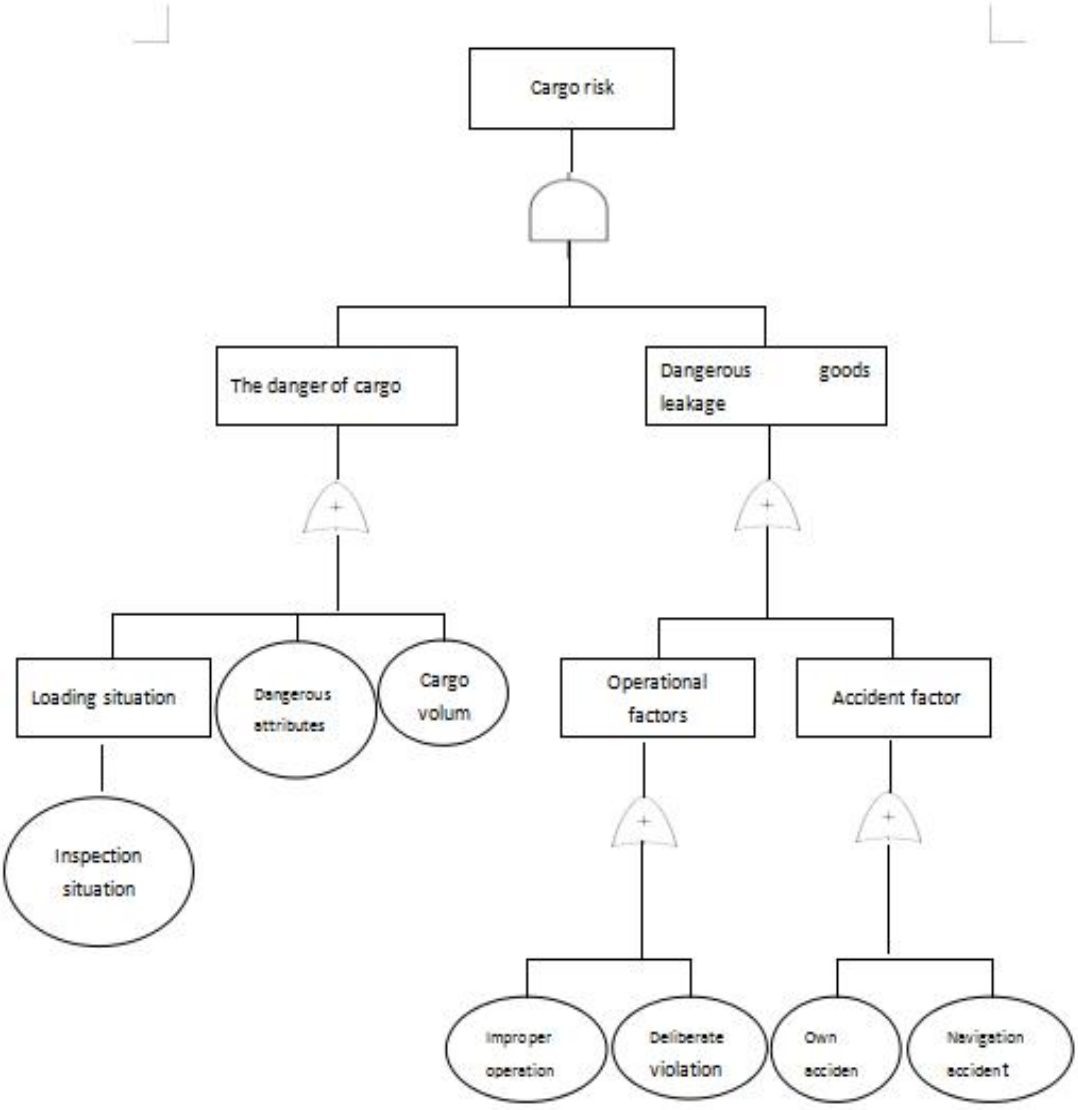

Figure 14: FTA analysis of liquid dangerous cargo ships from the perspective of cargo risk

(Source:Compiled by author)

① Dangerous attributes of cargo

According to the International Maritime Dangerous cargo Code , the dangerous cargo carried by ships can be divided into nine categories, namely: explosives, gases, flammable liquids, flammable solids, pyrophoric substances, substances that emit flammable gases in contact with water, oxidizing substances and Organic peroxides, toxic and infectious substances, radioactive materials, corrosive substances, miscellaneous dangerous substances and articles(IMO, 2018). Different types of dangerous cargo have different accident risks and impacts due to their different physical and chemical properties, so it is necessary to treat them differently in risk identification and assessment, and analyze the combustibility, explosiveness, toxicity, corrosiveness and contamination of different types of cargo, so as to identify their risks.

② Ship carrying capacity

The carrying capacity of liquid dangerous cargo ships has a greater impact on transportation risks and will directly affect the consequences of accidents. With the vigorous development and construction of various liquid dangerous cargo wharves in Yangpu waters, two crude oil wharves of 300,000 DWT, three product oil wharves of 100,000 DWT, and one large LNG wharf have been built. The tonnage of entering

and leaving of the liquid dangerous cargo ships is increasing. Once an accident occurs, the consequences will be disastrous. Therefore, when analyzing the risks of liquid dangerous cargo ships in Yangpu waters, the carrying capacity of liquid dangerous cargo ships should be fully considered.

③ Cargo loading protection

Judging from the actual production situation of Yangpu Port, most of the import and export cargo are liquid dangerous cargo. For bulk liquid dangerous cargo, the implementation of cargo loading protection measures is mainly considered.

④ Improper loading and unloading operations

It mainly refers to the leakage accident of liquid dangerous cargo caused by personnel's failure to operate correctly according to the relevant rules and regulations, or low operational skills, improper loading of cargo and lack of sense of responsibility during the daily operation and loading and unloading of liquid dangerous cargo, including improper operation of seafarers and wharf staffs (Senol, 2015). Therefore, it is important to strengthen process supervision during loading and unloading to prevent illegal operation, so as to prevent the leakage of liquid dangerous cargo caused by improper operation.

⑤ Deliberate violation

The crew of some liquid dangerous cargo ships have low awareness of pollution prevention. In order to save the cost of pollutant treatment, they often use various methods to secretly discharge pollutants containing dangerous substances. Such

pollution in general is not big, however, because the crew often takes some cover-up measures before and after the sneaking, such as sneaking outside the port or at night, making false records in the "Oil Record Book" or "Garbage Record Book", etc., and generally would not actively cooperate with maritime investigations and even false testimony, increasing the difficulty of investigation and handling (Shao, 2015). If this kind of pollution is not investigated and stopped effectively, the liquid dangerous cargo ships will cause environmental damage accidents.

⑥ Ship accident

This type of risk refers to the risk of leakage of liquid dangerous cargo caused by ship collision, grounding, hitting on the rock, and explosion, which cause damage to the hull. The leakage of liquid dangerous cargo caused by such accidents is often serious.

⑦ Own accident

Due to equipment failure and other reasons, accidental pollution accidents of liquid dangerous cargo will occur on ships, mainly including oil spill caused by internal oil transfer, leakage caused by pipeline rupture or damage, pollution accident caused by malfunction of liquid level indicating equipment of sewage water tank, etc.

(2) Related risk factors of ships

There are many various liquid dangerous cargo ships entering and leaving the port, mainly oil tankers, chemical tankers, LNG ships and LPG ships. The risk identification of liquid dangerous cargo ships is mainly considered from the static

and dynamic factors of the ship. The static factors of the ship mainly include the type and size of the ship, and the dynamic factors of the ship mainly include the technical condition, age of the ship and the history record.

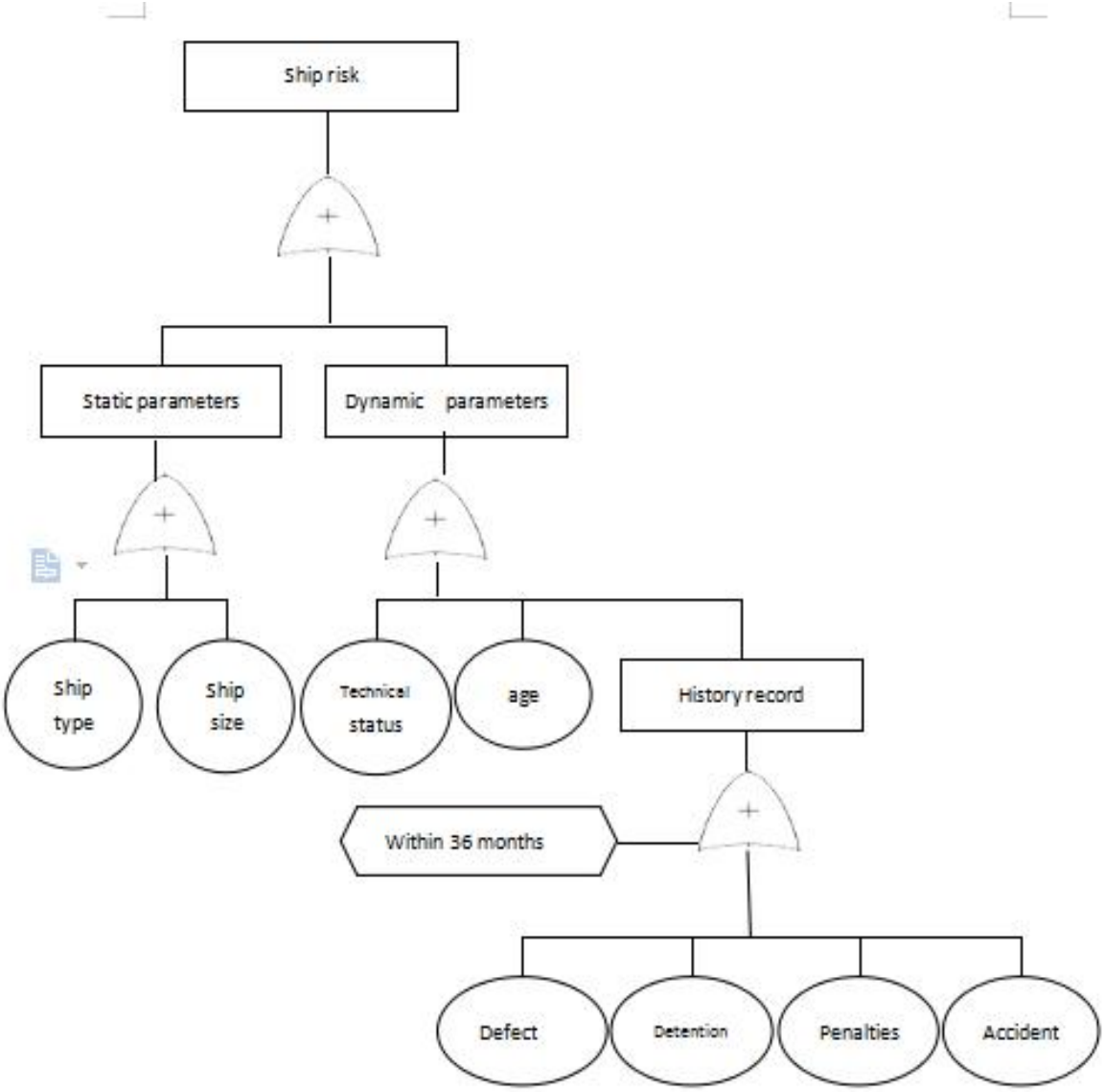

Figure 15: FTA analysis of liquid dangerous cargo ships from the perspective of ship risk

(Source:Compiled by author)

①Ship type

Different types of ships have different effects on safety due to the different physical and chemical properties of the cargo and the different safety performance of the ships. Therefore, the types of ships are one of the factors to be considered in the risk assessment of the ships carrying dangerous cargo.

②Ship age

The age of a ship indicates the existing condition and performance of the ship to a certain extent. With the increase of the service life of a ship, the aging of the hull structure and various equipment on the ship (including electronic equipment, mechanical equipment, cargo carrying equipment, etc.) will occur to different degrees. All these will affect the ship's overall performance and transport safety, especially for the liquid dangerous ship, the fault of the ship's structure and equipment is more likely to cause ship pollution accident. According to statistical analysis, there are a large number of liquid dangerous cargo transport ships, especially oil transport ships in Yangpu Port, among which the domestic trade ships are older and in relatively poor technical condition, while the foreign trade ships are younger and in relatively good technical condition.

③Ship size

Generally, the larger the tonnage is, the larger the size is. Large size ships carry more liquid dangerous cargo, once the accident happen, the loss and impact is also greater. In Shentou area of Yangpu Port, there are 300,000DWT crude oil wharves, 100,000DWT product oil wharves and one large LNG wharf. Other large wharves

are also under construction. The size and tonnage of ships arriving at the port are increasing, especially the increasing number of large vessels such as VLCC, brings more risks.

④Ship technical status

The technical status of ships mainly includes factors such as ship structure and technical status of various equipment. The hull structure affects the safety of ship transportation. Many ship accidents are caused by hull structure problems. For liquid dangerous cargo ships, the requirement of integrity and strength of the hull structure are relatively higher. Ship equipment includes power equipment such as main and auxiliary engines on board, steering gear and anchor equipment and other control equipment, various electronic communication equipment, etc., whether these equipment can operate efficiently and normally directly affects the navigation safety of ships.

⑤ Historical records

The historical record of a ship can also reflect its current safety status to a large extent, mainly considering the defect inspection of the ship in the past three years, the detention of the ship, the occurrence of accidents, administrative penalties, and the operation of the ship's safety management system.

（3）Risk factors of relevant management parties

Although the management of related parties in the transportation of liquid dangerous cargo has an indirect impact on its risks, it plays an important role in the formation

and control of risks. It mainly includes the management of maritime safety administrations, the management of port enterprises, and the management of shipping companies etc.

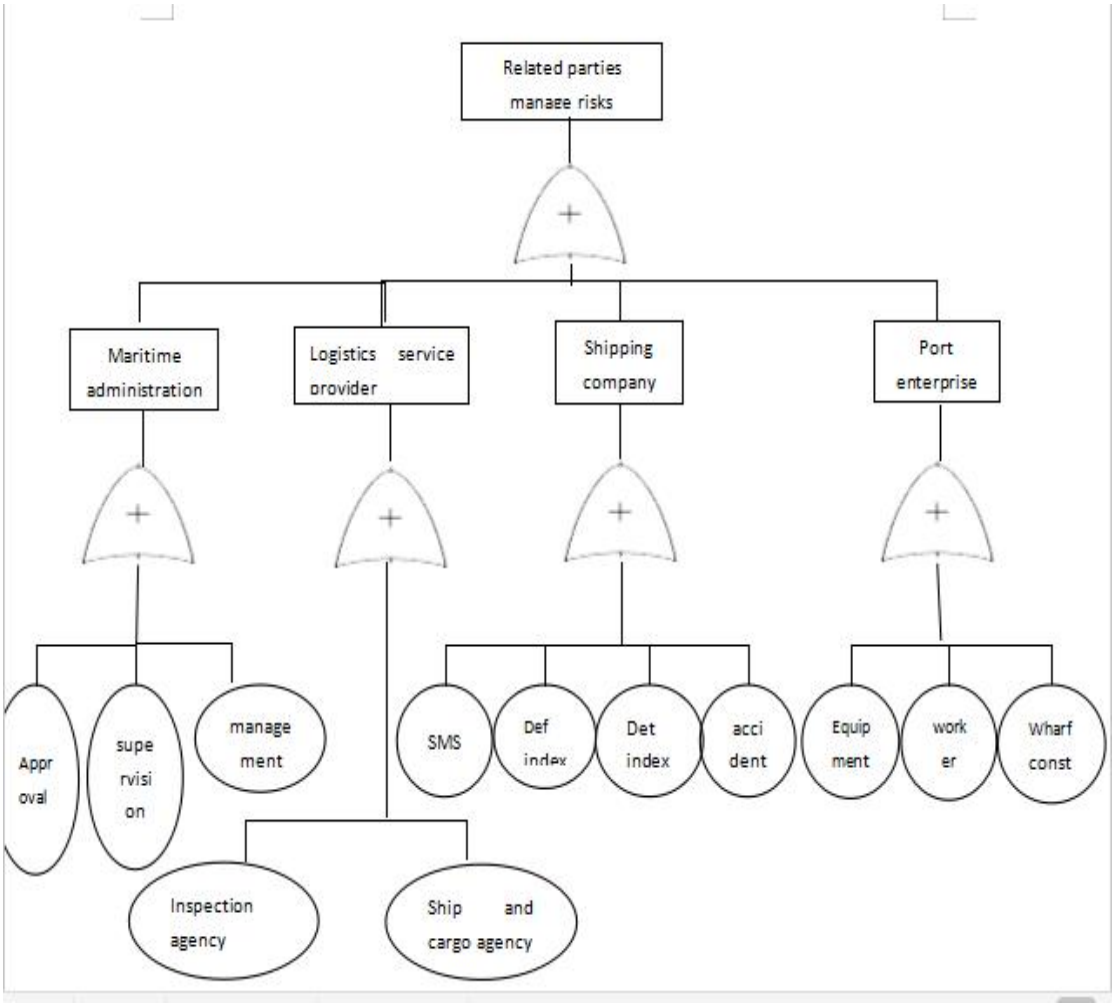

Figure 16: FTA analysis of liquid dangerous cargo ships from the perspective of related management parties risk

(Source:Compiled by author)

①Management of maritime safety administration

In terms of risks, the following factors should be considered, such as maritime approval and issuance, maritime on-site supervision, and maritime emergency management. Maritime approval refers to the strict implementation of the liquid dangerous cargo declaration and verification system. According to the certificate materials provided by the ship and its historical records, the risk of the ship shall be carefully checked, and the ship carrying liquid dangerous cargo that do not meet the requirements shall be prohibited from entering the port. Maritime on-site supervision refers to the maritime safety administration monitors the dynamics of incoming ships, conducts safety inspections of liquid dangerous cargo ships and inspections of port safety facilities, and focuses on checking the structural stability of ships and related equipment, as well as the use of life-saving, fire-fighting, and anti-pollution equipment. Maritime emergency management refers to the emergency response system and pollution prevention emergency equipment prepared by the maritime safety administration and its joint government. Due to the shortage of manpower and equipment, the maritime on-site supervision force may not be able to meet the above requirements.

②Management of port enterprises

It mainly includes wharf personnel management, wharf construction management and port emergency management. The safety quality of wharf staff, including operational skills, physical and mental state, and sense of responsibility are essential to the safe operation of the wharf. Port enterprises must formulate strict rules and regulations and do a good job in daily supervision and management, urge the staff to strictly implement the safety operation regulations. Wharf construction management includes wharf breakwater construction, wharf safety facilities construction,

management of engineering vessels and other management related to wharf construction, which are also crucial to ensure the safety of wharf. Port emergency management means that port enterprises should establish their own emergency plans, emergency forces and emergency equipment.

③Management of shipping company

The following factors should be considered: the defect index, detention index, safety management system situation and accident situation of the shipping company. The defect index is the ratio of the number of defect of all ships in the fleet managed by the company in the last 36 months to the total number of inspections of all ships in the fleet managed by the ship management company during the calculation period. Detention index is the ratio of the number of detentions of all ships in the fleet managed by the company in the last 36 months to the total number of inspections of all ships in the fleet managed by the ship management company during the calculation period. The status of the safety management system refers to the development and implementation of the safety management system documents. The accident situation refers to the situation of all the company's ships in the last 36 months.

④ Management of third-party logistics service companies

It mainly includes inspection institutions and agencies. Their management level has a greater impact on the safety of liquid dangerous cargo ships. The inspection institution factors include the inspection before the shipment of the cargo and the inspection after the shipment. The agency is divided into two types: shipping agency and cargo agency, and the risk factors they bring are different.

(4) Risk factors during navigation process

The navigable risks of liquid dangerous cargo ships mainly include their risk factors during navigation, anchoring, berthing and unberthing, loading and unloading, and transfer operations. According to the results of FTA analysis, they are mainly related to the following relevant factors: natural conditions, channel conditions, traffic conditions, wharf conditions, loading and unloading conditions, the quality of the operators and emergency conditions, etc.

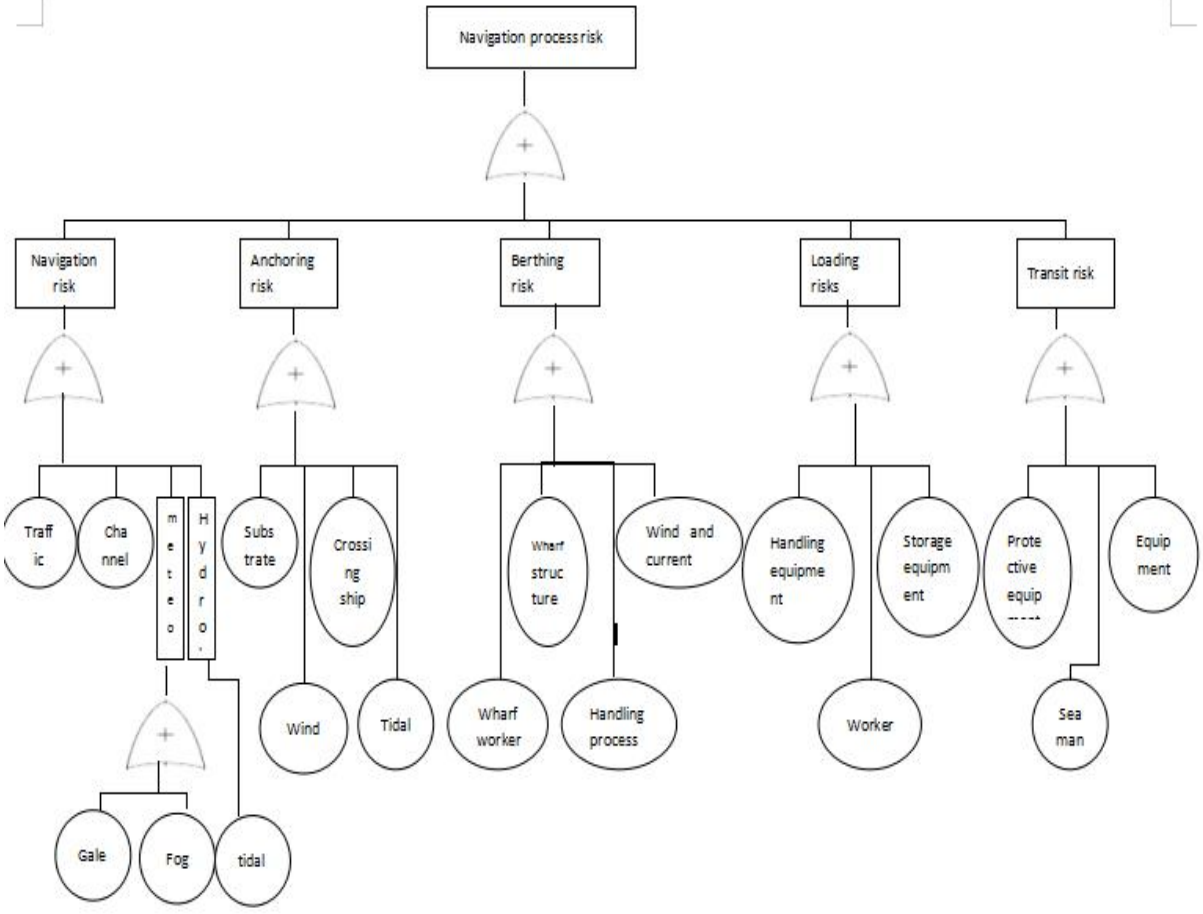

Figure 17- FTA analysis of angerous liquid cargo ships from the perspective of navigation process risk

(Source:Compiled by author)

①Traffic conditions

With the rapid growth of cargo especially the liquid dangerous cargo, throughput of Yangpu Port, the density of ships is increasing, and the risks of ships continue to increase. The traffic conditions mainly include the density of ships, traffic management conditions and other factors. In 2019, the average number of liquid dangerous cargo ships at the port is about 12.6 times/day. The traffic density of dangerous cargo ships is increasing, and the number of ships encounters increases, accidents risk also increase. In addition, the coupling of traffic conditions and other conditions must be considered. For example, due to dense traffic, the dangerous situation is easy to form under the influence of fog, wind, tidal current and other natural conditions. If situations are not properly handled, collision between ships will occur. The anchoring fishing boats and crossing boats in the main channel are also potential risks to the navigation safety of large ships in the channel.

② Channel conditions

Channel conditions mainly include the length, width, curvature, water depth, navigation aid signs and other conditions of the channel. Obstructions in the waters near the channel will also affect the navigation safety of ships.

③ Natural conditions

Natural conditions include the influence of hydrological and meteorological factors such as strong wind, fog and tidal current. In addition, the navigation safety of liquid dangerous cargo ships under poor visibility should also be given sufficient attention. Due to the influence of strong wind and current pressure, the ship's operation is restricted and the ship is displaced in the course of navigation, which may easily lead to collision, grounding or contact damage. Extreme weather such as typhoons, strong winds and dense fog are major risks factor for the navigation safety of ships, strict and effective supervision methods should be implemented.

④ Anchorage conditions

Anchorage conditions include factors such as anchorage bottom quality, illegal crossing of ordinary ships, etc. Different bottom quality will cause the anchor to have different holding power. If the holding power is small, it is easy to dragging under the action of strong wind and strong current. The anchorages in Yangpu waters with good wind-shielding conditions are insufficient. In typhoon weather, the ship in anchorages are denser, and accidents may occur. In 2014, under the influence of strong typhoons "Ramason" and "Seagull", six ships had accidents during the anti-typhoon protection period at anchorage. In addition, accidents may also occur if ordinary ships crossing the anchorage of dangerous cargo ships, supervision and management should be strengthened.

⑤ wharf conditions

wharf conditions include factors such as wharf structure, wharf worker skills, and handling techniques. Collision accidents between ships of liquid dangerous cargo and the wharf during berthing, unberthing and operations may occur. wharf conditions

mainly consider factors such as the structure of the wharf (including the breakwater), the professional quality and sense of responsibility of the wharf workers, and the safety of the loading and unloading process of the wharf.

⑥ Loading, unloading and transfer conditions

There are also accident risks during the loading and unloading and transfer operations of ships, which mainly depend on the loading and unloading and transfer conditions at the time, including the hardware equipment and personnel. The equipment mainly includes loading and unloading equipment, storage equipment, emergency protection equipment, transfer equipment, etc.

⑦ Personnel factors

The personnel related to the safety of loading and unloading and transshipment of liquid dangerous cargo ships mainly involve crew members and wharf personnel, among which the quality and behavior of crew members play a major role in the safety of ships. Crew error, neglect of management and lack of skills are the three main factors that lead to the accident (Ung and Shuen-Tai, 2018). During the loading and unloading of ships at the wharf and the transshipment at sea, there are many irregularities in the operation of crew and wharf workers, which cause potential accidents.

Chapter 4 Liquid Dangerous Cargo Ships Risk Assessment

4.1 The concept of risk

In the "Formal Guidelines for FSA Application" adopted by the IMO at the MSC74 meeting, risk is defined as the combination of frequency and severity of consequences. (IMO, 2013).

The risk in this paper specifically refers to the objective quantity of the accidental event that describes the damage to the analysis object. The main considerations are: (1) The risk is regarded as the accidental event or the possibility of the occurrence of the damage consequence in the system. (2) The risk is viewed as the degree to which an accident occurs or an accident causes damage. Risk is a combination of the possibility of an accident and the consequences of damage (Bai and Jin, 2016).

4.2 The nature of risk

Risk is the result of the interrelation of three major elements: risk factors, risk events and risk consequences (Chen and Lin, 2001), as shown in the figure.

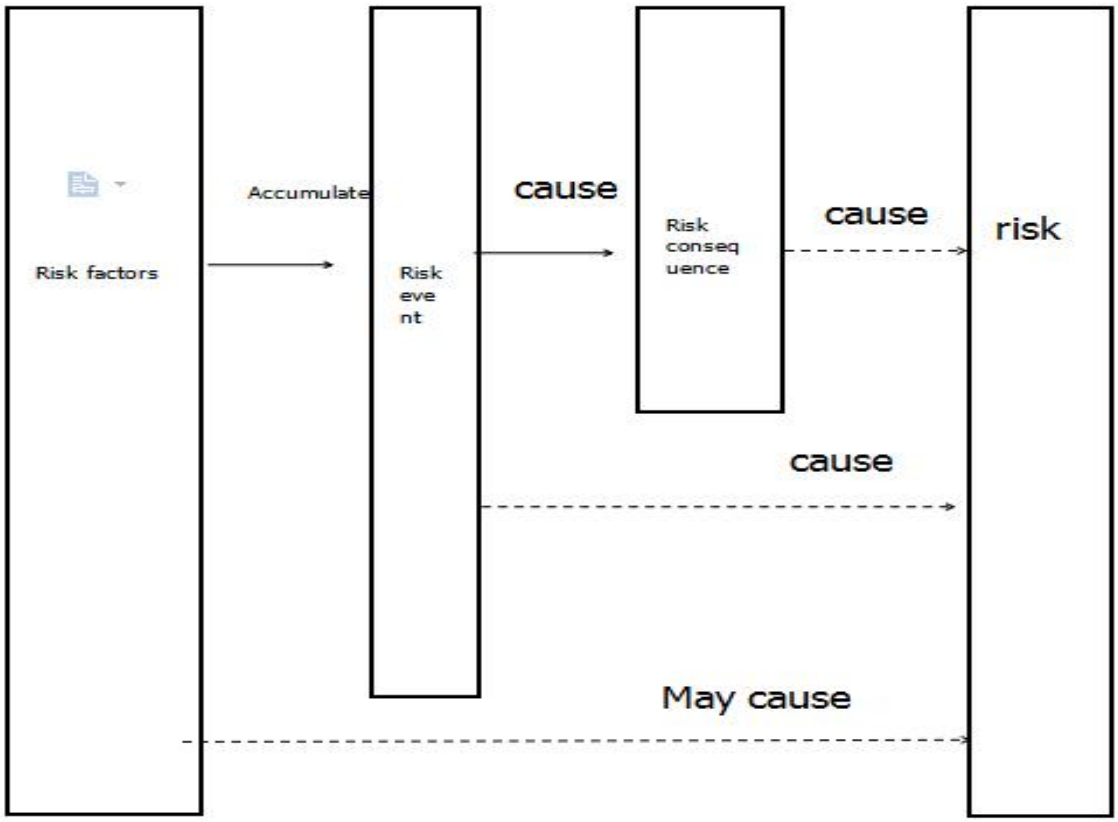

Figure 18: Schematic diagram of risk generation process

(Source:Compiled by author,based on Chen and Lin, 2001)

Risk factor: A condition or factor that causes the occurrence of a risk event, increases the probability of its occurrence, or affects the severity of a loss. Risk factors are the potential causes of risk accidents and the indirect or intrinsic causes of losses (AQSIQ and SAC, 2011).

Risk event: refers to an accidental event that directly leads to loss (adverse results or consequences), also known as a risk accident. Risk events make the possibility of risk become reality, so that the occurrence of losses, it is the direct cause of losses or

external causes and the loss of intermediaries. That is, risk can only cause losses through the occurrence of risk event (AQSIQ and SAC, 2011).

Risk consequences: refers to the unintended and unplanned adverse consequences or negative effects caused by risk events, also known as dangerous consequences. Consequences relate not only to the degree of the damage, but also to the extent of the damage (AQSIQ and SAC, 2011).

The risk is also a measure to describe the relationship between the danger and the safe state. As mentioned earlier, the definition of risk is not yet complete, but the definition of safety and danger is basically mature. "Safety" refers to a state in which the life, health, property, or environment of objective things are harmed to a generally accepted state. "Danger" refers to a state in which the life, health, property, or environment of objective things is not generally accepted by people. Danger is that objective things are in unsafe state (Tian and Jing, 2009). Therefore, as far as the state of the event is concerned, safety and danger are a set of relative concepts, as shown in the figure.

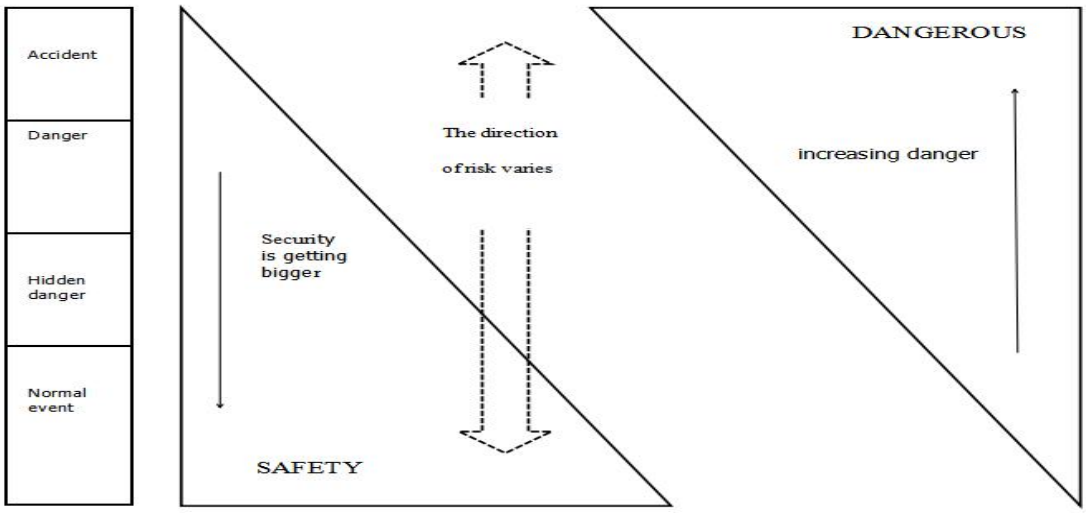

Figure 19: The relationship between risk safety and danger

(Source:Compiled by author,based on Tian and Jing, 2009)

Risk is the link between the dynamic connection and transformation of safety and danger of an event, and the relative existence of safety and danger. When the risk is large to a certain level (usually reaching an unacceptable range), we consider it dangerous. Conversely, when the risk is small to a certain level (usually within an acceptable range), we consider it safe. Therefore, safety can be understood as the danger of not exceeding the allowable limit, and danger can be understood as the safety of exceeding the allowable limit. In fact, risk can not only express the state, but also describe the possibility of the state (Tian and Jing, 2009).

4.3 Risk Matrix

In the definition of risk, regardless of loss or consequence, it is defined for accidents, including accidents that have occurred and accidents that will occur. Since risk is a measure of the danger of the system, it is not sufficient to measure the risk of the system only by accident, unless all possible accident forms can be identified. This section will introduce the concept of risk matrix to make every risk of the liquid dangerous cargo ship visible in a classification form.

4.3.1 Risk frequency

Risk frequency is used to describe the possibility of harmful events or abnormal events, and is a common measure of probability events. For ship navigation, frequency is the ratio of the number of incidents per unit time to the amount of ship

activity. In the FSA analysis process, qualitative division of the quantitative value of frequency is required. Generally, the description of frequency is: frequently, very likely, occasionally, very rarely (Fang and Hu, 2006, pp330). This article suggests that the description of frequency can refer to the criteria in figure 20.

Frequency	frequently	Very likely	Occasionally	Very rarely
FI	F4	F3	F2	F1
Data	0.001(0.1%)	0.0001(0.01%)	0.00001(0.001%)	0.000001(0.00001%)
Description	May occur frequently during the work cycle	May occur during the work cycle	It may not happen frequently during the operation cycle, but it may happen several times	Impossible to happen during the work cycle, but there is such a possibility

Figure 20: Frequency Criteria in Ship Navigation

Source: Hu et al., (2005) Standardized safety assessment technology and relative risk assessment model for ship navigation

4.3.2 Risk consequences

The risk consequence is to describe the degree of damage caused by the occurrence of a harmful event or an abnormal event. The quantification of consequences is a more complicated issue in safety assessment. Depending on the perspective of research and analysis, the scope of quantitative analysis of consequences is different (Mentes, 2015). For ships sailing, the consequences involved are divided into three categories: (1) From the perspective of safety, it refers to the loss of human life caused by harmful or abnormal events, including the injury or death of human life. (2) From the perspective of business loss, it refers to the direct economic loss caused by the occurrence of harmful or abnormal events, including the loss of shipwreck. (3)

From the perspective of environmental pollution, it refers to the environmental pollution loss caused by harmful or abnormal events (Hu et al., 2005, pp19).

In the analysis of the consequences of an actual accident, various risks need to be considered, such as the risk to personnel or the risk to economic loss. Since the risk to the environment is a joint risk of ship navigation, or a secondary risk, more attention should be paid to the risk of traffic safety in the risk analysis. Because of the consequences of accidents often involve the above two categories (1) and (2), the criterion of the consequences is described by "accident equivalent consequences". For example, the consequences of the loss of one seriously injured person is equivalent to the direct economic loss of 300,000 yuan RMB (Fang and Hu, 2006).

In view of the actual situation of the ship's voyage, this paper recommends the use of the criteria in figure 21 for the description of consequences. When determining the consequences of the accident, the direct consequences of the accident including casualties and property losses should be calculated in detail, and the numerical value of the consequences of the accident should be established and graded. For example, if one person is slightly injured in an accident and property loss is 10,000 yuan RMB, the consequence value of the accident can be determined as S =1+1/3 =1.33. In general, the description of the consequences is used as very serious, serious, general, slight (Fang and Hu, 2006,).

Degree	Very serious		Serious		General		Slight
SI	S7	S6	S5	S4	S3	S2	S1
Data	100		10		1		0.1
Description	One person died, or direct economic loss of more than RMB 3 million		One person was seriously injured, or a direct economic loss of more than 300,000 yuan RMB.		One minor injury, or direct economic loss of more than 30,000 yuan RMB.		Did not meet the above standards

Figure 21: Absolute Criteria for Consequences During Ship Navigation

Source: Fang, Q.G. , & Hu, S.P. (2006). The application of FSA in ship pilotage risk assessment: Journal of Harbin Engineering University

The risk level obtained by the analysis should be discriminated by comparison to determine whether the risk is within the tolerable range. Appropriate and reasonable risk standards should be selected as the discriminant criteria. Generally, the decision should not be made according to a single acceptable risk standard, but the criteria of risk range division should be used.

4.3.3 Classification matrix of ship navigation risk levels

In order to comprehensively consider the frequency of accidents and the degree of consequences, the risk matrix is used in the FSA analysis. The risk matrix is an effective classification and identification method for risk analysis. The risk matrix can comprehensively represent the two elements of risk: the frequency of accidents

and the severity of consequences. As shown in Figure 22, the numerical value of risk (R) is established according to the calculated results by classifying the accident frequency (F) and consequence (S). According to the calculated results, the risk of analysis is classified, and three different risk categories and areas are obtained, namely "negligible risk area", "as low as reasonably practicable area (ALA RP)" and "intolerable high risk area". In the figure, the red area (R9-R11) is the "intolerable high risk area", the yellow area (R5-R8) is the "ALARP area", and the green area (R2-R4) is the "negligible risk area".

Very serious	F_1S_7 (R_8)	F_2S_7 (R_9)	F_3S_7 (R_{10})	F_4S_7 (R_{11})
	F_1S_6 (R_7)	F_2S_6 (R_8)	F_3S_6 (R_9)	F_4S_6 (R_{10})
Serious	F_1S_5 (R_6)	F_2S_5 (R_7)	F_3S_5 (R_8)	F_4S_6 (R_9)
	F_1S_4 (R_5)	F_2S_4 (R_6)	F_3S_4 (R_7)	F_4S_4 (R_8)
General	F_1S_3 (R_4)	F_2S_3 (R_5)	F_3S_3 (R_6)	F_4S_3 (R_7)
	F_1S_2 (R_3)	F_2S_2 (R_4)	F_3S_2 (R_5)	F_4S_2 (R_6)
Slight	F_1S_1 (R_2)	F_2S_1 (R_3)	F_3S_1 ($R4_2$)	F_4S_1 (R_5)
S / F	Very rarely	Occasionally	Very likely	Frequently

Figure 22: Ranking of risk for ship navigation

(Source: Compiled by author based on Fang& Hu, 2006)

4.3.4 Risk assessment of liquid dangerous cargo ships in Yangpu waters

After sorting out the risk sources of liquid dangerous cargo ships, sixty-five risk events are identified, including forty-six bottom events, which are related to dangerous cargo, ships, related party management factors, and navigation process.

The specific distribution of risk factors is as follows:

(1) Cargo-related factors, including the dangerous attributes of the cargo, loading conditions, cargo capacity, improper operation, deliberate violation of regulations, own equipment accidents, and traffic accidents.

(2) Ship-related factors, including ship type, ship size, ship age, historical records, and technical status.

(3) Related party management factors, including the supervision of maritime safety administration, shipping company management, port cargo management, and cargo logistics management.

(4) The navigation process factors, including traffic conditions, channel conditions, natural conditions, anchorage conditions, wharf conditions, and loading and unloading conditions.

In view of the above risk factors, combined with the actual situation of liquid dangerous cargo ships entering and leaving Yangpu waters, the risk level of important risk factor is analyzed as follows:

Table 1: Risk factor rating table for liquid dangerous cargo ships in Yangpu waters

Serial number	Risk factor	Situation in Yangpu waters	Risk manifestation		Risk level
			Probability of occurrence	Result	
	（1）Cargo-related factors				
1	Type of cargo	Wide variety of liquid dangerous cargo	F2	S7	R9
2	Loading situation	Large volume of liquid dangerous cargo handling	F2	S7	R9
3	The quantity of cargo	Large throughput of liquid dangerous cargo	F2	S7	R9
4	Improper operation	Crews and stevedores have varying levels of service	F3	S7	R10
5	Deliberate violation	Often found in supervision and inspection	F4	S6	R10
6	Own equipment failure	Uneven ship suitability	F3	S7	R10
7	Navigation traffic accident	There are not many traffic accidents on liquid dangerous cargo ships	F2	S7	R9

Serial number	Risk factor	Situation in Yangpu waters	Risk manifestation		Risk level
			Probability of occurrence	Result	
	（2）Ship related factors				
1	Ship type	Mainly liquid bulk dangerous cargo ships	F3	S7	R10
2	Ship size	Mainly small and medium-sized ships, but ships of more than 100,000 tons operate frequently	F2	S7	R9
3	Technical status	There are many inspection defects (in the past 36 months), but not many detained ships	F2	S7	R9
4	Ship age	Very different, more old ships	F4	S7	R11
5	history record	There are many administrative penalties for ships, the number of defects in on-site inspections is large, and the number of focused tracking ships is small	F4	S7	R11

Serial number	Risk factor	Situation in Yangpu waters	Risk manifestation		Risk level
			Probability of occurrence	Result	
	（3）Related management factors				
1	Supervision by Maritime Safety Administration	Insufficient number of personnel makes supervision difficult	F3	S6	R9
2	Shipping company management	The management level varies greatly	F4	S7	R10
3	Port cargo management	Big difference	F4	S6	R10
4	Cargo logistics management	Big difference	F4	S6	R10
5	Ship inspection	Ship inspection defects occasionally occur	F2	S7	R9

Serial number	Risk factor	Situation in Yangpu waters	Risk manifestation		Risk level
			Probability of occurrence	Result	
	（4）Navigation process factors				
1	Natural conditions	Wind, currents, waves, and visibility have a great impact	F2	S7	R9
2	Channel conditions	Ships are mostly one-way navigation, and occasional two-way navigation increases the risk	F2	S7	R9
3	Traffic condition	Many intersections	F3	S7	R10
4	wharf conditions	Very different, insufficient protection	F3	S7	R10
5	Loading and unloading conditions	Very different, insufficient protection	F3	S7	R10
6	Emergency conditions (including anchorage)	Very different, insufficient protection	F3	S7	R10

(Source:Compiled by author)

4.3.5 Basic risk characteristics of liquid dangerous cargo ships in Yangpu waters

Through the assessment of risk factors, the risk characteristics of liquid dangerous ships in Yangpu waters can be summarized as below:

(1) Operational risks of liquid dangerous cargo ships are relatively prominent

By analyzing the operation of liquid dangerous cargo ships in Yangpu waters and previous accident cases, it is concluded that the operational risks of liquid dangerous cargo ships have the following characteristics:

① The crew failure to inspect related facilities and equipment in accordance with relevant regulations (MOT, 2017). Before loading and unloading operations, the crew fails to inspect relevant facilities and equipment in accordance with relevant regulations or the company's SMS requirements, the working conditions of key equipment can not meet the requirements of safe operation requirement, and then the cargo leakage occurs.

② The crew are not familiar with the loading and unloading plan. Before loading and unloading operations, the relevant crew members do not know the loading and unloading plan (Woodward, 1995). For example, the loading and unloading operation plan formulated by the chief officer has not been approved by the captain, the ship has not organized the crew to learn the loading and unloading operation plan, and the crew is not familiar with the loading and unloading operation plan, resulting in valve switching errors during the operation. These situations may cause cargo leakage to pollute the maritime environment.

③ The ship's emergency preparations are insufficient. It is mainly manifested in that the deployment of emergency towlines does not meet the requirements of the "Oil Tanker and Oil wharf Safety Operation Regulations" (Chen, 2016), the poor working condition of the fire-fighting hose, and the lower water hole of the deck leading to the outboard is not smooth, etc., resulting in the failure of timely disposal in case of dangerous cargo leakage (AQSIQ, 2001).

(2) The number of arriving ships increases, and old ships and sub-standard ships bring risks

① The number of liquid dangerous cargo ships will gradually increase. With the construction of the free trade port, Yangpu's position in Southeast Asian ports will become higher and higher, and the throughput of liquid dangerous cargo, especially crude oil, will also increase. In addition, the berths of Yangpu Port are undergoing transformation towards large-scale development. It can be predicted that the scale of liquid dangerous cargo ships entering and leaving Yangpu port will also tend to be larger overall in the future.

② Old ships and sub-standard ships will exist in Yangpu Port for a long time. Affected by Covid-19, there will be great uncertainties in the shipping economy for a long period of time in the future. Shipowners dare not rush to invest too much capital in new shipbuilding (https://xw.qq.com). In addition, driven by profits, many shippers tend to choose old ships and sub-standard ships to save logistics costs. This will cause some old ships and sub-standard ships to appear in Yangpu Port, which will bring risks to Yangpu's maritime safety and environment.

(3) The management risks related to the transportation of liquid dangerous cargo are high

The lessons of accidents in recent years show that the possibility of regulators being held accountable is increasingly high, the degree of accountability is increasingly heavy, and the legal responsibility is increasingly heavy, which leads to the huge psychological pressure on front-line law enforcement personnel, and subjectively weakens the enthusiasm of embarkation inspection. The big challenge is how to improve the system, standardize the embarkation inspection law enforcement behavior, reduce the psychological pressure of front-line personnel. At the same time, how to really improve the quality of inspection and eliminate ship safety hidden dangers are also the difficulty. Besides, how to improve the management level of ship management companies, port enterprises and third-party logistics enterprises through the implementation of supervision and management of Maritime Safety Administration is also an issue that needs to be considered.

(4) The dynamic risks in the process of navigation of liquid dangerous cargo ships exist for a long time

① Some liquid dangerous cargo berths in the jurisdiction are open berths, which are greatly affected by wind and waves. The southwest wind prevails in the Yangpu area in summer, and strong convection is prone to sudden weather. The northeast wind prevails in winter, and it is easy to encounter cold waves and strong winds. Ships have poor stability in open berths, and there is a risk of collision with the dock under the action of wind and waves.

② From north to south, the jurisdiction has five dangerous cargo wharves including SDIC Vopak, Hainan Yisheng, Sinopec Hong Kong Branch, Hainan LNG, and Hainan Refining and Chemical. There are seventeen dangerous cargo berths. According to statistics, the average number of liquid dangerous cargo vessels operating in the port in 2019 is about 12.6 times/day. The frequent entry and berthing operations of liquid dangerous cargo ships increase safety risks.

③ Most of the large liquid dangerous cargo ships, such as VLCC and LNG ships, in the jurisdiction are foreign ships, which require pilots to navigate during the process of entering, berthing and unberthing. There are certain risks in the piloting process of ships: First, the port area of has changed in recent years, and some new berths have been added. However, the current pilot embarkation and departure points were announced in 2015. These embarkation and departure points are far away from the wharf, wind and waves have a greater impact and are not conducive to pilots boarding and leaving the ship. Second, due to their own characteristics, large liquid dangerous cargo ships often have a long stroke, large windage area, and are not easy to handle, so there are safety risks in the piloting process (Shao, 2019).

④ Ships will encounter many situations. The routeing system has not yet been implemented in Yangpu waters. Ships sail more casually after leaving the wharf. In addition, there are a large number of fishing vessels in the jurisdiction, resulting in the irregular flow of ship traffic in Yangpu waters, and liquid dangerous cargo ships will encounter many situations during navigation. There is a risk of collision with other ships.

⑤ Due to the lack of typhoon-prevention anchorages with better shelter conditions in

Hainan Province, when a typhoon comes, a large number of ships choose to use the typhoon-prevention anchorages in Hou shuiwan and Da chan reefs in the Yangpu area. The distance between ships is small. Due to the influence of typhoons and strong waves, liquid dangerous cargo ships are likely to collide with other ships during anchoring, which can lead to vicious accidents such as fire and explosion.

Chapter 5 Management Countermeasures for Liquid Dangerous Cargo Ships in Yangpu Waters

Based on the analysis and assessment of the risks on liquid dangerous cargo ships in the waters of Yangpu previously, and combines with the management status of liquid dangerous cargo ship, management countermeasures to control the specific risk factors of liquid dangerous cargo ships are put forward from five aspects.

5.1 Cargo management

In accordance with the requirements of relevant laws and regulations, maritime safety administration shall strengthen the check of materials submitted by liquid dangerous cargo operations units, establish a linkage mechanism for static supervision and dynamic supervision of relevant maritime departments. If the approval department has doubts about the liquid dangerous cargo declaration materials provided by the ship or agent, it should promptly notify the on-site inspection department to board the ship for verification. If the on-site inspection department finds that the actual operation of the ship is inconsistent with the declaration, it should also verify with the approval department in time (Wang, 2015; Chen et al., 2019). In addition, the maritime safety administration can also encourage personnel to report the actions of misreporting and concealment of liquid dangerous cargo and intentional violations of regulations by means of material rewards and spiritual rewards, so as to severely crack down on such violations (Huang, 2016).

5.2 Ship management

5.2.1 Establishment of a scientific ship selection mechanism to prevent sub-standard ships from entering

A ship selection scoring standard shall be established by the enterprise in collaboration with the maritime safety administration, which is carried out by the cargo owner, shipper or wharf enterprise independently. It is mainly divided into two major modules: The first module is the direct elimination project, which includes incomplete certificates, insufficient manning and the ship does not meet the requirements of regulations. The cargo owner, wharf enterprise or shipper can refuse the ship's consignment task and directly eliminate these ships. After passing the screening of the first module, enter the second module. In the second module, the cargo owner, the wharf enterprise, the shipper and maritime safety administration will score the ship's equipment maintenance, personnel operation ability, safety management system operation, ship defect correction, etc., and the scoring data will be aggregated to the cargo owner, the wharf enterprise, the shipper, with a full score of 100 grades. Vessels with a total score of ≥80 grades are recommended to use. Vessels Vessels with 70 grades ≤ total score < 80 grades must formulate and implement safety measures and make safety commitments before they can be used. Vessels with 60 grades ≤ total score < 70 grades shall formulate and implement safety measures and rectify critical defects before use. Vessels with a total score of less than 60 grades are not recommended. In this way, we can prevent the low standard dangerous liquid cargo ships from entering the waters of Yangpu to ensure water traffic safety from the source.

5.2.2 The inspection of ships arriving at the port

A liquid dangerous cargo ship has a lot of equipment and operation procedures, and the risks are different. Through the inspection and accident assessment and data analysis in previous years, the three sections of high, medium and low risk points are sorted out, and the supervision efforts are focused on the programme with high risks for the same ship. For example, in view of the high proportion of cargo pump room defects in the safety inspection of liquid dangerous cargo ships in Yangpu Port, combined with cases of accidents occurring in liquid dangerous cargo ships on a global scale, special inspection activities for cargo pump rooms will be carried out. Cargo pump room inspection is a mandatory item of on-site inspection. At the same time, a special activity for centralized inspection of liquid dangerous cargo ships is implemented every year, similar to the "CIC" special item in the port state control, and gradually realizes a good situation of effective management of ship risks.

5.3 Related management parties

5.3.1 Maritime Safety Administration

(1) The emergency response mechanism for liquid dangerous cargo accidents will be improved by Yangpu maritime administration. Although the number of accidents involving liquid dangerous cargo ships in Yangpu waters has been small in recent years, and they have not caused serious consequences. However,with the deepening of free trade port and the construction of new land-sea channels in western China, the number of liquid dangerous cargo ships will increase substantially, and the risks will also increase substantially. Although the Yangpu Economic Development Zone

Management Committee has established relevant emergency plans, there are still problems such as imperfect emergency response mechanisms and poorly targeted emergency response measures. The Yangpu maritime safety administration should suggest the Yangpu Economic Development Zone Management Committee to improve the emergency response plans based on the current situation of liquid dangerous cargo ships to make them more targeted, maneuverable and forward-looking, and revise each plan in time. In this way, quick and effective rescue measures can be taken after the accident, timely rescue can be realized to prevent the accident from expanding, casualties, economic losses, and environmental pollution can be reduced.

(2) Coordination and communication between relevant departments should be further strengthened (Guo, 2015). It is recommended that the maritime safety administration take the lead to establish a unified supervision platform so that all relevant departments can conduct joint supervision of liquid dangerous cargo. Such a platform can realize cross-departmental information sharing and communication, and realize "transparent" management of all links that can be checked, visible and controllable at any time (Wang, 2016). An emergency linkage mechanism between member units will be developed to establish a joint unit meeting system, and to organize joint meetings every year to discuss emergency work in the jurisdiction.

(3) Education and training are strengthened to improve the professional level of employees. The maritime safety administration can carry out measures as below: First, strengthen the publicity, training, inspection and pollution prevention management knowledge of relevant operating units. Second, regularly or irregularly organize the management personnel, declaration personnel and crew members of

relevant operating units to learn the knowledge of new laws and regulations, improve their level of safety and pollution prevention management, so as to ensure the navigation and operation safety of liquid dangerous cargo ships (Li, 2017). Third, urge port enterprises to conduct regular training to improve the operational skills of wharf workers. In view of the weakened enthusiasm of maritime inspectors for boarding and inspection, maritime safety administration should introduce corresponding fault-tolerant mechanisms and reward mechanisms, strengthen the training of inspectors' professional capabilities, and increase their enthusiasm for ship inspection.

(4) Emergency drills need to be Strengthened to improve the level of maritime emergency response. It is recommended that maritime safety administration regularly organize comprehensive maritime emergency drills in multiple subjects such as "ship oil spill", "dangerous chemical leakage", "liquid dangerous cargo ship collision", etc., referring to the content of the emergency response action guide for ship pollution accidents and starting from accident reports, accident early warning, accident assessment, emergency command, emergency response and other aspects to carry out emergency drills to find out the shortcomings in the emergency response work and to correct them (Han, 2017). Maritime enforcement officers should check the emergency drills for ships with liquid dangerous cargo arriving in the port, provide guidance on deficiencies found, and effectively improve the crew’s emergency response capabilities (Yang et al., 2013).

5.3.2 Port enterprises

(1) Port enterprises should actively explore modern ship-borne liquid dangerous

cargo emergency disposal structures, focus on strengthening the construction of maritime pollution emergency equipment warehouses, emergency rescue ships, etc., and gradually establish an emergency disposal work pattern based on the emergency response forces of ships and wharves, combining professional rescue with social rescue forces. In response to the actual pollution risks in the Yangpu waters, an emergency equipment warehouse with comprehensive removal and control capabilities for oil spills and dangerous cargo accidents should be built, and the construction of pollutant reception and treatment facilities will be strengthened. Liquid dangerous cargo wharves should be equipped with a certain number of oil booms, oil dispersants and other anti-pollution equipment according to the level of risk and scale.

(2) The ship pollution emergency joint prevention system need to be established. It is very important for the emergency response to ship pollution accidents to be fast and to ensure that as many emergency resources as possible are invested in the shortest time to ensure the control of the spread of pollutants (Jing, 2018). Although each wharf of Yangpu Port is equipped with corresponding emergency equipment in accordance with relevant requirements, it is impossible to quickly and effectively deal with the accident with the emergency equipment provided by itself. On the one hand, the establishment of the ship pollution emergency joint prevention system can invigorate the existing emergency resources, establish the cooperation mechanism through joint prevention and construction, optimize the resource allocation, reduce the economic burden of enterprises, jointly prevent and control regional ship pollution, and effectively maintain the water environment clean. On the other hand, it can improve the equipment management level, greatly improve the emergency response capacity of oil spill, and reduce the possible risks caused by the leakage of

dangerous liquid cargo from ships in the Waters of Yangpu.

5.3.3 Ship management company

In accordance with the SMS, the ship management company focuses on personnel training, learning, assessment, emergency drills, ship-to-shore communication equipment, and other self-inspections, timely check the hidden danger of safety management, and send special personnel to track and guide rectification of the problems detected, so as to ensure the safety of liquid dangerous cargo ships at the source (Ye, 2017). In addition, regular training on the latest knowledge of laws and regulations and operational skills should be carried out for the crew, so that the crew can enhance their self-discipline while constantly improving their operational skills.

5.4 Navigation process

5.4.1 Optimization of the navigation environment on the water and improvement of the safety of dangerous liquid cargo ships

The Yangpu maritime safety administration shall put forward professional maritime opinions on the existing navigable environment and anchorage in the waters of Yangpu, further optimize the establishment of maritime navigation environment and anchorage, and meet the requirements of liquid dangerous cargo ships to anchor and evade typhoons. If necessary, ,traffic separation schemes can be implemented to avoid the crossing of liquid dangerous ships with other ships, so as to ensure the navigation safety of ships in Yangpu waters.

5.4.2 Standardization of ship on-site operations by modern maritime information methods

At present, the Yangpu Maritime Safety Administration has established a ship traffic service system and is in trial operation. The high-definition video surveillance system (CCTV), AIS, RADAR, etc., in the system can be applied to the navigation reminder and operation supervision of liquid dangerous cargo ships. Information services to sailing ships should be provided so that the seafarers can fully understand the surrounding navigation environment and take corresponding avoidance measures in advance (Ying, 2009). The implementation of video surveillance on ships in operation is conducive to urging seafarers and wharf operators to implement the requirements of on-site operations and comply with the safety standards for dangerous cargo ships.

5.4.3 Implementation of the ship leaving berth and avoiding wind mechanism under severe weather conditions

The level of weather information forecasting can be improved through liaison with meteorological information services. In advance of typhoons and other inclement weather, maritime safety administration should allow liquid dangerous cargo ships to leave port for shelter to avoid accidents caused by high winds.

5.5 Working mechanism

From the perspective of the supervision system and mechanism and the overall level, China's liquid dangerous cargo transportation safety supervision methods are now

relatively complete. However, with the transformation of China's ruling philosophy from a "regulatory government" to a "service-oriented government", while optimizing the structure, it faces the task of fine-tuning management quality and increasing the structure of the transportation industry. From the perspective of the overall supervision network, the imperfection of the legal system has led to problems such as poor supervision, prevarication of supervisory responsibilities, and inadequate implementation of responsibilities and powers.

5.5.1 The supervision system optimization

(1) The government could recall or update the old laws, regulations and documents, and do a good job of coherent connection between the upper and lower laws. It is necessary to sort out the revocation documents in a comprehensive way, avoid inconsistencies and irregularities in the implementation of standards, further improve the legal efficiency of industry regulations, avoid the risk of lower-level regulations without the legal support of higher-level laws, and promote the closeness of regulatory laws and regulations to actual regulatory needs.

(2) With the general requirements of "assigning responsibilities in accordance with the law", the authorities and responsibilities of supervisory departments and posts should be fully clarified, and corresponding lists of powers and responsibilities should be sorted out and formulated (Tang, 2014).The responsibility of safety supervision should be implemented to specific nodes, and the awareness of responsibility of safety supervision should be enhanced to avoid regulatory risks caused by unclear demarcation of rights and responsibilities.

(3) The government also needs to improve work service guidelines, optimize law enforcement procedures and deepen regulatory processes (Yu and Ren, 2011). According to work safety analysis (JSA), relevant work is taken as the main node, work guidelines established, safety standard operation is taken as the quality control point, law enforcement process is optimized, and PDCA cycle is taken as the quality control ring to deepen the supervision process and comprehensively improve the efficiency of supervision.

5.5.2 Targeted supervision

Targeted regulation is a standardized management mode established by taking safety responsibility as the primary responsibility to meet the requirements of precise positioning of regulatory measures. It can make regulatory matters detailed, standardized and procedural. It has the characteristics of reproducibility of management mode, controllability of process and targetability of work direction. It can be divided into three stages: first, formulate corresponding numerical evaluation indicators. Second, the construction and improvement of digital standardized content. Third, the sustainable innovation of the system.

(1) The Yangpu Maritime Safety Administration should grasp the key points and establish the appraisal mechanism. According to the classification of supervision objects and the characteristics of actual supervision, a set of evaluation mechanism and management scheme for supervisors based on safety responsibility performance evaluation should be established. The implementation of safety supervision responsibility should be digitized to form a one-to-one correspondence relationship on responsibility. and be evaluated through the inspection of indicators. In this way,

the completed evaluation plan can be formed.

(2) Law enforcement resources need to be integrated in order to improve the on-site inspection mechanism. On the one hand, Yangpu maritime safety administration should improve the routine supervision, analyze and summarize the key points of supervision, and lay a solid foundation for supervision. On the other hand, it should make full use of non-routine inspection and invigoration mechanisms, such as integrating front-line law enforcement resources to carry out key on-site checks or inspections in important waters, important periods and key ships, or by not sending notice, not accompanying, not receiving, not listening to reports, not greeting, directly cutting into the scene, straight to the grass-roots level, and according to the circumstances appropriate to expand the subject of inspection.

(3) Newly discovered problems need to be analyzed in order to achieve the goal of optimizing regulatory effectiveness (Shao, 2015). This requires a unified grouping of unsafe transportation problems that have been checked or discovered, analyze their causes, and their characteristics and the possibility of evolution, expand the data sample space, analyze the data foundation and diffusion direction in the evolution process, and carry out real-time dynamic analysis to adjust the supervision strategy in time.

Chapter 6 Conclusion and Prospects

With the deepening of the construction of the Hainan Free Trade Port, the number of liquid dangerous cargo ships entering and leaving Yangpu Port will increase significantly, which will also lead to an increase in maritime risks in the Yangpu waters. It is necessary to analyze the risk of liquid dangerous cargo ships in Yangpu waters, find risk points, and propose countermeasures based on the risk points, so as to improve the level of risk prevention and control in Yangpu waters and improve the safety of water traffic.

6.1 Research conclusion

Based on the risk and emergency management of liquid dangerous cargo carried by ships in Yangpu waters, this paper analyzes the current situation of dangerous cargo ship in the jurisdiction, and uses the FTA to construct a risk analysis model for liquid dangerous cargo ships. The risk matrix method is used to classify the specific risk factors of liquid dangerous cargo ships in Yangpu waters. Finally, management countermeasures are put forward from five aspects. The main research conclusions are：

.1 The present situation of liquid dangerous cargo ships transportation and emergency management in Yangpu waters are analyzed comprehensively.

.2 Through reading relevant literature, visiting maritime dangerous cargo management experts and wharf cargo managers, etc., the specific risk factors of

liquid dangerous cargo ships have been determined from four aspects: cargo factors, ship factors, management factors and navigation process factors, and then carry out risk evaluation based on the risk evaluation model of the risk matrix.

.3 Based on the risk factor evaluation results of liquid dangerous cargo ships, this paper analyzes the problems existing in cargo management, ship management, management of related parties and navigation process management. In the aspect of cargo management, countermeasures are put forward from the perspective of strengthening the daily management of liquid dangerous cargo operation declaration. In terms of ship management, countermeasures are put forward from the perspective of ship safety inspection. In terms of the management of the relevant management parties, suggestions are made to maritime safety administration, port enterprises and ship management companies respectively. In terms of navigation process, some suggestions are put forward from the perspective of optimizing navigation environment, using modern information means and implementing ship leaving berth and avoiding wind mechanism. In terms of working mechanism, countermeasures are put forward from the perspective of supervision system and targeted supervision.

6.2 Research Outlook

Taking the liquid dangerous goods ships risk management in Yangpu waters as the main research goal, together with the present situation of ship navigation environment, management situation of liquid dangerous cargo transportation and the rescue and emergency equipment. Risk factors of liquid dangerous goods transport ships are studied. Based on this, some corresponding suggestions are given. However, due to the author’s theory and work experience are limited, there are many

shortcomings in the paper. The research content of this paper still needs further research and improvement:

.1 This paper has insufficient consideration and insufficient selection of risk factors in the analysis of the risk factors of liquid dangerous cargo ships. Moreover, only the analysis of liquid dangerous cargo ships in Yangpu waters has certain limitations. Future research should increase data samples and expand the scope of ports to provide more basis for policy choices.

.2 Only the FTA method is used to analyze the main risk factors in the construction of the risk evaluation system for liquid dangerous cargo ships. The risk matrix method is used to divide the risk levels, and other models are not used for evaluation. The risk level accuracy needs to further improvement. In future research, more accurate analysis models should be adopted, and even mathematical modeling methods can be used for risk analysis, so as to improve the accuracy of analysis and provide more accurate data basis for policy making.

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