8-23-2015

Risk assessment of water area covered by Tianjin VTS

Tong Gu

WORLD MARITIME UNIVERSITY

Dalian, China

RISK ASSESSMENT OF WATER AREA COVERED BY TIANJIN VTS

By

GU TONG

The People's Republic of China

A research paper submitted to the World Maritime University in partial fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2015

DECLARATION

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

The content of this research paper reflects my own personal views, and are not necessarily endorsed by the University.

(Signature): Gu Tong

(Date): July 2, 2015

Supervised by:

Shi Guoyou

Professor

Dalian Maritime University

Assessor:

Co-assessor:

ACKNOWLEDGEMENTS

This paper is developed as part of my studies to obtain the master degree of Maritime Safety and Environmental Management (MSEM) at WMU and DMU. I am profoundly grateful to all people who have supported and helped me in various ways during my studies.

First and foremost, I would like to express my deepest gratitude to Tianjin VTS, Tianjin MSA, where I have worked for almost 5 years. It is my leaders and colleagues that provide me with this precious opportunity to join the MSEM program in Dalian, and they really helped me a lot with my research paper.

I would like to thank my supervisor Professor Shi Guoyou, for his patience and encouragement and for guiding me through the process of this project. His help is indeed valuable.

I must give my heartfelt thanks to all professors attending the MSEM 2015 program. Their professional knowledge broadened my eyesight and instilled in me new ideas and methodologies, without which the study would not have been completed.

I remain very grateful to all the classmates of MSEM 2015. I thank them for their company and for sharing their views and experiences. Together we experienced a nice time in DMU.

ABSTRACT

Title of Research Paper: **Risk Assessment of Water Area Covered by Tianjin VTS**

Degree: **MSc**

Tianjin port is located in the central position of the Bohai port region of China and it is one of the most important foreign trade ports and the important node of Beijing Tianjin Hebei modernization comprehensive transportation network.

With the rapid development of maritime economy, the vessel traffic flow is increasing sharply and marine traffic situation is becoming more and more complex, which brings harmful effects and difficulty on the communication order and traffic organization. How to do with the challenges faced by VTS, how to identify the key sources of risk, and how to optimize risk management have become a series of serious problems.

This paper analyzes the characteristics of Navigation, collision avoidance and grounding avoidance in the area covered by Tianjin VTS, and identifies the distribution of ship flow in the area and the trend of water transportation accident, then concludes the preliminary risk factors in the VTS area.

The author uses the PAWSA risk analysis method, which is necessary for risk identification, analysis, summary and identify risk level of each VTS partition for Tianjin VTS.

After risk assessment, the author tries to come up with the safety recommendations and measures, hoping to do some help to set up new supervision mode of Tianjin VTS.

KEYWORDS: Risk assessment, VTS, PAWSA, Ship accident, Statistics, Zoning management, Management mode, Assessment indexes, Risk value, Mitigation measures, Supervision mode

TABLE OF CONTENTS

DECLARATION.. ii
ACKNOWLEDGEMENTS iii
ABSTRACT.. iv
TABLE OF CONTENTS... vi
LIST OF FIGURES viii
LIST OF TABLES.. ix
LIST OF ABBREVIATIONS... x
Chapter 1 Introduction.. 1
1.1 Background of Research 1
1.2 Research significance... 1
1.3 Main research method 2
1.4 Domestic and foreign research status.. 2
1.4.1 Risk assessment 2
1.4.2 VTS supervision.. 6
Chapter 2 Analysis of navigable environment in Tianjin VTS area...................... 8
2.1 Natural environment.. 8
2.1.1 Air temperature 8
2.1.2 Precipitation... 8
2.1.3 Wind... 8
2.1.4 Fog 9
2.1.5 Relative humidity... 9
2.1.6 Disastrous weather... 9
2.1.7 Tide 9
2.1.8 Wave.. 10
2.1.9 Sea ice 10
2.2 Port profile.. 10
2.2.1 Status quo of Tianjin port.. 10
2.2.2 Status quo of Tianjin VTS system and its planning 11
2.3 Traffic flow.. 17
2.3.1 Statistical analysis of vessel traffic flow.. 17
2.3.2 Ship size.. 18
2.3.3 Ship type 19

2.4 Ship accident 19
2.4.1 Ship accident types 19
2.4.2 Accident time statistics 20
2.4.3 Accident spatial distribution statistics 23

Chapter 3 Risk assessment of VTS area 27

3.1 The analysis process of PAWSA 27
3.1.1 Expert weight distribution 27
3.1.2 Risk degree of pre-assessment index 28
3.1.3 The risk degree of the whole pre-assessment index 29
3.1.4 Risk degree analysis of existing mitigation measures 29
3.1.5 Risk degree analysis of the proposed security measures 29
3.2 PAWSA for Tianjin VTS area 30
3.2.1 Dividing water areas 30
3.2.2 Pre-assessment index of navigation environment 30
3.2.3 Weight distribution of the members of the expert group 33
3.2.4 Division and confirmation of risk scale and risk value of pre-assessment index 34
3.2.5 Assessment results 37
3.2.6 Risk value of pre-assessment indexes after mitigation measures 41
3.3 Main risk analysis of VTS region in Tianjin 48
3.3.1 Main risk of Xingang water area 48
3.3.2 Main risks of Lingang water area 49
3.3.3 Main risks of Nangang water area 49
3.3.4 Main risks of Hangu water area 50
3.3.5 Main risks of waihai water area 51
3.3.6 Risk degree comparison and summary of every water area 51

Chapter 4 Safeguard measures and safety advice 52

4.1 Safety advice on establishing a new mode of VTS management 52
4.1.1 Safeguard measures and safety advice 52
4.1.2 The necessity of study on implementation in VTS division 53
4.2 Establishment of zoning management mode in Tianjin VTS coverage 54
4.2.1 The principle and method of Tianjin VTS zoning management 54
4.2.2 Measures to Tianjin VTS plan 54
4.2.3 Analysis on management mode of Tianjin VTS 55

Chapter 5 Conclusion 58

References 60

LIST OF FIGURES

Figure 1 Monitoring system in Tianjin VTS center

Figure 2 Ships' AIS tracks in Tianjin Port and its surrounding waters(April,2012)

Figure 3 Ships' AIS tracks in Tianjin Port and its offshore waters(April,2012)

Figure 4 Ship size statistics in Tianjin port monthly from 2008 to 2013

Figure 5 Ship classification statistics in Tianjin port

Figure 6 Proportion of ship accident types

Figure 7 Tianjin VTS area collision accident statistics by hour

Figure 8 Tianjin VTS area collision accident statistics by year

Figure 9 Tianjin VTS area grounding accident statistics by month

Figure 10 Collision accident spatial distribution in part 1

Figure 11 Collision accident spatial distribution in part 2

Figure 12 Grounding accident spatial distribution in part 1

Figure 13 Grounding accident spatial distribution in part 2

LIST OF TABLES

Table 1 Navigation environment assessment indexes

Table 2 Experts weight distribution

Table 3 Quantitative values of qualitative description factors

Table 4 Quantitative value interval

Table 5 Risk level of the assessment indexes-Xingang

Table 6 Risk level of the assessment indexes-Lingang

Table 7 Risk level of the assessment indexes-Nangang

Table 8 Risk level of the assessment indexes-Hangu

Table 9 Risk level of the assessment indexes-Waihai

Table 10 Risk value of assessment indexes after mitigation measures-Xingang

Table 11 Risk value of assessment indexes after mitigation measures-Lingang

Table 12 Risk value of assessment indexes after mitigation measures-Nangang

Table 13 Risk value of assessment indexes after mitigation measures-Hangu

Table 14 Risk value of assessment indexes after mitigation measures-Waihai

LIST OF ABBREVIATIONS

AIS	Automatic Identification System
CCTV	Closed Circuit Television
GT	Gross tonnage
IALA	International Association of Lighthouse Authorities
LPG	Liquefied Petroleum Gas
MSA	Maritime Safety Administration
PAWSA	Ports and Waterways Safety Assessment
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
USCG	United States Coast Guard
VHF	Very High Frequency
VTS	Vessel Traffic Service

Chapter 1 Introduction

1.1 Background of Research

With the development of Tianjin Port, more and more problems come out for Tianjin VTS, such as bad conditions of software and hardware, complex order of traffic organization and communication, shortage of incentive mechanism and disorder of responsibility distinction, which bring barriers to effective supervision and quality service.

Meanwhile, the maritime system has just experienced the restructuring and transformation, thus a long period is needed to adapt the new situation.

1.2 Research significance

Studying the risk assessment of VTS area is very important for identifying risk factor, understanding the risk level, looking for important factors for decreasing risk level, and increasing the safe level of VTS area. On the basis of risk assessment, finding the relationship between the supervision of Tianjin VTS and the safe measures to lower the risk level is really meaningful to enhance the regulatory and service effectiveness of the VTS system.

Research on the VTS zoning supervision mode is the key factor and an important safeguard measure of effectively reducing VTS region risk. It is also the most effective method to realize the coordinated management and the more effective development of the maritime system among different port areas. By researching and proposing Tianjin VTS new supervision mode as an innovation, the maritime department can get better reference to promote the healthy and harmonious development of the traffic control system more effectively (Wu, 2004).

1.3 Main research method

Based on the idea of risk assessment and risk management, firstly, this research identifies the risk factors of water area after the collection and statistical analysis of basic data; secondly, it assesses the risk level by using risk assessment; thirdly, it proposes the preliminary mitigation measures and evaluation; at last, it proposes the effective measures of new VTS zoning supervision and new mode, which can effectively reduce the navigable risk from the perspective of maritime supervision.

1.4 Domestic and foreign research status

1.4.1 Risk assessment

At present, the shipping presents a rapid, specialization and large-scale trend, but the fast and prosperous development is followed by a quantity of maritime accidents. For example, in 2010, oil spill occurred in the Gulf of Mexico on an oil drilling platform of British Petroleum Company, forming a contaminated area of 2,000 square miles and resulting in a loss of nearly $200 billion. The sinking of the Sewol of Korea in

2014 caused more than 300 casualties and the whole ship loss. Chinese Oriental Star passenger ship capsized on June 1st, 2015, causing more than 400 deaths. In order to avoid the occurrence of maritime tragedy, people should carry out the risk identification and risk management for the safety of navigation and shipping environment. After effective risk factor identification and risk management process, the risk of injury of the personnel or loss of the property can be reduced and maintained at the acceptable level. It is safe at the acceptable level or below it. Risk analysis can make people know and perceive the safe state of things in a more intuitive and understandable way (Xiao, 2006, pp38-39).

The majority of the maritime accidents occurred due to the human error of operation. Therefore, it is necessary to evaluate the safety of the job specification of existing maritime industry and develop guidelines for the assessment. At present, the popular risk analysis method has the quantitative and the analysis method based on the simulation technology and so on. For example, Det Norske Veritas made a more detailed risk analysis and assessment of seaworthiness safety of special LNG ship on the Soko island waters and lung Kwu Tan waters of Hong Kong (Det Norske Veritas, 2006). In the risk assessment of oil transportation in the Prince William Bay, the experts used some simulation models to analyze the human factors and other errors (Merrick, 2001). At the same time, some scholars make experiments to combine such types of simulation technology and quantitative risk assessment method to carry on the analysis of the corresponding shipwreck. For example, in 1995 Haya and Nakamura combined quantitative and simulation to make the collision risk analysis of the ship. Some scholars added a qualitative assessment of the relevant experts in the combination of these two methods. For example, Merrick made corresponding adaptability evaluation on the passenger ship safety navigation of Washington. Now Bayesian network theory has gradually been accepted as a new risk assessment model by some experts and scholars. They made simulation and multiple factor regression analysis by applying the underlying causing factors of the maritime accidents (Merrick, 2006, pp223-237).

Whether the risk analysis is based on the simulation or qualitative analysis, only when the source data is acquired through AIS data or accurate long-term historical official data are the results of the analysis reliable and convincing. According to the source data of a variety of kinds, the corresponding professional forecasting model is established to estimate the probability of the accident, such as Kite-Powell analyzes effectively the ship's characteristics and human error and other risk factors and makes the risk model; Maio collects the geographic conditions of the navigation area, and establishes the regression model of the waterway accident; Roeleven makes a marine accident probability forecast model with regard to the ships track and the external environment of the relevant waters as the independent variable in 1995 (Qiu, 2003).

The development of the maritime accident analysis software based on AIS statistics is changing the traditional maritime accident analysis means. Most maritime accident analysis software can carry out the quantitative and simulation analysis of the safety mode of a navigable water area at different levels. Technical University of Denmark ISESO engineering team researched and developed a grounding and collision accident analysis toolbox in 1998 to 2001. Based on AIS data, this analysis toolbox made modeling and evaluated the collision and stranding event occurrence probability, and calculated maritime accident probability occurrence. Waterway Risk Assessment Program IALA is jointly developed by Technical University of Denmark and Gatehouse. The research scope of the software is based on the GRACAT, and a number of the new types of ship hull are added. Besides, the types of collision accident and grounding accident are respectively classified. For each type of collision and grounding event, the corresponding computational simulation is established, and the results of the software are more precise and credible. Holland Maritime Research Institute spent several years researching and developing SAMSON model. It is also a software which makes dynamic risk analysis and the corresponding risk early warning based on the long-term data of the AIS ship collision accident in the Beihai area. It can analyze risk and forecast a variety of marine risks, including mainly risks between the ship, the risk of collision between the ship and mooring ship, the grounding or stranding risk as well as other ship risks and so on. In addition, MARCS, SHIPCOF and MARTRAM software all belong to the marine risk analysis and prediction software(Liu, 2014).

PAWSA is short for Ports and Waterways Safety Assessment. It is a waterway safety assessment method used by IALA, and it has been promoted by the United States Coast Guard (USCG) and obtained a satisfying application. The basic idea of PAWSA is based on the long-term statistical data of VTS and AIS. The qualitative evaluation of the experts in various fields is converted to quantitative results by particular algorithm, which is a process of Delphi method. Presently, the method has successfully made a comprehensive safety analysis of the Aleutian Islands, Los Angeles, San Francisco, Detroit, Miami, Long Island Sound and so on. People widely recognize the results and they are good guidance for the practical production (United States Coast Guard, 2005).

In China, there are also a lot of researches on similar navigable risk evaluation. For example, in the study on the safety and efficiency of navigable waters in Qingdao port, Dai Junlin used the traffic statistics, safety index evaluation and questionnaire and analyzed the ship weight by using the analytic hierarchy process. Besides, he studied the traffic safety and risk of the port water area and proposed the data to promote the development of the function of traffic management in the port water area (Dai, 2009). In Research on the navigation safety of the duplex channel in Tianjin harbor based on PAWSA, Yin Xianming made navigation safety analysis of the duplex channel in Tianjin harbor. Additionally, he identified the pre-assessment indicators of the system in the unsafe state and made quantitative description. The analysis results can partly reflect the safety state of the duplex channel (Yin, 2013, pp43-46). In Study on the Tianjin port traffic safety comprehensive evaluation index system, Zhao Lei made a comprehensive assessment of the risk by both qualitative and quantitative research according to the comprehensive analysis of Tianjin port navigation environment safety situation analysis and the various elements of the navigation environment. During the period, he used the method of marine accident statistics and system safety analysis, combining other scholars' relevant research results, statistics and analysis of the survey data, the fuzzy evaluation method and the evaluation method of the evidence theory (Zhao, 2010).

1.4.2 VTS supervision

The Dutch Rotterdam port VTS divides the Rotterdam port VTS area from the outside into a total of 12 management partitions, applying the implementation of cyclic duty and full tracking unified regulatory model. South Korea Inchon VTS divides its supervision service area into specific waters and port waters. Different regions use different regulatory channels. Hongkong VTS regulatory region is divided into three regulatory partitions, namely, Eastern and western waters and Hongkong. Different waters use different channels. Kaohsiung VTS region is divided into three zones, namely, the open sea, the first port, and the second sea port and are supervised by different channels. Guangzhou VTS is composed of two divisions within and outside the Humen Bridge, using different channels of supervision. Through the way of the division of the management, the domestic and foreign VTS effectively enhanced the effective supervision and quality service efficiency. Besides, the level of VTS center safety supervision is improved, and the safety and efficiency of the ship's traffic is ensured (Hu, 2012, pp14-22).

From the views of certain port VTS district form at home and abroad, the method of zoning supervision is an effective method to realize the reasonable and effective supervision and reduce the pressure of the diversion of traffic supervision. At present, the research on the zoning supervision of VTS focuses on the strip type ports. More of the related VTS partition studies are put into direct application while the theoretical analysis and summary of the research is less.

Chapter 2 Analysis of navigable environment in Tianjin VTS area

2.1 Natural environment

2.1.1 Air temperature

Annual average temperature 13.1℃

Average annual maximum temperature 16.4℃

Annual average minimum temperature 10.9℃

Extreme maximum temperature 40.9℃

Extreme minimum temperature -13.5℃

2.1.2 Precipitation

Annual average precipitation 363.7mm

Annual maximum precipitation 491.1mm

Annual minimum precipitation 196.6mm

The maximum precipitation of a day 157.2mm

2.1.3 Wind

Wind is an unstable factor in the meteorological elements, there are some differences between the observed statistical values in different years. According to statistics by Tianjin VTS, 12 days per year the wind is between stage 6 to stage 7 and 0.29 days when the wind is above stage 8. The most common wind direction is south, then east, and the frequency is 9.89% and 9.21% respectively.

2.1.4 Fog

Fog in Tianjin port is mainly in the autumn and winter, the fog period from October to December, which accounts for 47% of the annual fog days. The fog days in December are about 30% of the annual fog days, and the longest delay can reach 24 hours. The number of days in which visibility is less than 1000m is 16.60 every year.

2.1.5 Relative humidity

The average relative humidity is 67%.

2.1.6 Disastrous weather

Tianjin port is located in the top of Bohai Sea Bay, and the disaster occurrs during the summer typhoons period and transitional season between spring and autumn. According to statistics, the total number of 0.50m and above extratropical storm water in Tanggu meteorological station in Tianjin is 4621d, 77 days a year by average.

2.1.7 Tide

Tianjin port is not a regular semidiurnal tidal harbor, (HO1+HK)/HM2=0.53. There is a phenomenon of diurnal inequality of tides, and the low tide is significant. The direction of ebb tide in Dagukou anchorage is southeast, and the average speed is 0.67 knot. The tide speed changes sharply near the entrance of the seawall, and it could lead to the direction turning of ships, which is very dangerous.

2.1.8 Wave

Tanggu offshore station has been observed in the Gulf of Bohai in 117° 49′ E、38° 34′ N. Statistics by field data, primary waters in Tianjin VTS area small waves, big waves occur at low frequency. The directions of wave in Tianjin VTS area are mainly ENE and E, the frequencies are 9.68% and 9.53% respectively.

2.1.9 Sea ice

Varying degrees of sea ice appear in Tianjin VTS area from late December to late February. Statistics for many years show that the average sever ice age is only 10 days a year, which has little impact on port operation and ship navigation.

2.2 Port profile

2.2.1 Status quo of Tianjin port

Tianjin port is composed of center fishing port area, north port area, Dagukou port area, east port area, Haihe River port area, south port area, Gaoshanling port area and Dagang port area. The fairway is composed of main fairway, Dagusha fairway, Dagang fairway, Gaoshaling fairway and Beitang fairway and anchorage from No.1

to No. 6.

2.2.2 Status quo of Tianjin VTS system and its planning

2.2.2.1 Status quo of Tianjin VTS system

In 1995, the first-stage project of Tianjin VTS was constructed. Engineering scale was one station with one center. It mainly covered the main channel and anchorages between Dagu lighthouse and the eastern jetty. With the function waters of the Tianjin port moving out, the cargo handling capacity is increasing rapidly. Meanwhile, Tianjin VTS equipment appears aging. To improve the traffic safety in Tianjin port and its adjacent waters and improve the efficiency of the approach channel of Tianjin port, the first-stage project of Tianjin VTS was expanded in 2006. After the expansion the system scale became two stations with one center. The design mainly covered main channel, the Sluice East channel, Dagu anchorage and No.3 anchorage waters. The system has been put into operation.

The main functions of the first-stage project of Tianjin VTS are to provide information service, navigation service and transport organization service to the ship, and support joint operation service. Besides, it can provide data collection and data evaluation services to the internal. System management objects mainly include all passenger ships, oil tankers, LPG ships, bulk chemical tankers and vessels of foreign nationality and other Chinese nationality ships of 300GT above.

In addition, at the same time of the reconstruction and extension project of VTS, 5 CCTV monitoring sites are also constructed, namely, the East jetty, the Nanjiang Marine Department, Bohai Sea Petroleum building, Communication Building and

Yue Hai Park. And another CCTV monitoring center is set up at the VTS center of Tianjin MSA, realizing the three levels of monitoring network in the field monitoring point, monitoring center and main monitoring center.

VTS of Tianjin MSA currently has the East jetty radar station and the Nanjiang radar station. The main coverage of the radar is the east of the lock, and the water area west of the reporting line. The coverage of the VHF equipment includes the radar coverage and the Haihe River waters west of the lock.

The system of VTS in Xingang is VOC5060 system, provided by Norway NORCONTROL IT company. It includes radar subsystem, radar data processing equipment, multi sensor tracking equipment, traffic display and control equipment, VHF communication equipment, ship data processing equipment and record and replay equipment.

Figure 1 Monitoring system in Tianjin VTS center

Source: Photo by the author

Ships shall be executed in the waters on ‘Convention on the International Regulations for Preventing Collisions at Sea’, ‘STCW’, ‘the implementary Procedures of Safety Management of Tianjin Vessel Traffic Service’, ‘China ship reporting system’ and other stipulations on fire prevention and anti fouling.

Since Tianjin VTS officially began its external operation, the increase in the number of vessels has caused communications rush and congestion of VHF, seriously impacting communications. Even worse, it has brought many obstacles to effective supervision and first-rate service. Therefore, it needs badly to be settled. The problems of using a single channel are listed as follows.

(1)Within the VTS region, the contact between two ships, the ship and the VTS center both depend on VTS channels. Channel usage is so high that channel congestion phenomenon frequently happens. Communication efficiency is poor. In particular, it is not convenient for the VTS center to contact the ship when it provides the information service, traffic organization service and navigation service. That has a bad influence on the risk supervision and quality of service supervision of VTS center.

(2)Although the VTS center can’t effectively manage the Haihe River waters, the ships entering and leaving the Haihe River waters through the lock or the bridge need to be reported to the VTS Center. That occupies the limited communication channel resources. Currently, VHFchannel71 is used.

(3)The productive ships entering and leaving the port need to be reported to the VTS Center through VHF09. In addition, many small ships (fishing ships, constructing ships, oil supply water ships, harbor boats) often use VHF09 channels as communication links. That occupies the limited channel resources.

(4)As there is no specific VHF communications channel for maritime search and rescue on Tianjin waters, often the work channel of VTS center becomes the preferred channel. This has virtually affected the normal operation of VTS center in receiving the ship report, organizing the ship transportation and issuing a safe reminder to the ship. Even worse, it will completely disrupt the normal working order of the VTS center.

Now Tianjin port is making the trial run of researching the division frequency. For example, anchorages outside the port and the outer end of part of the main channel use VHF09. Within the harbor VHF14 is used. Haihe River waters use VHF71. The port waters using VHF09 channel. The effect of the trial run has not yet been learned. It is also necessary to improve and perfect the trial run effect in the test phase.

2.2.2.2 Status quo of system in Dagukou VTS

Dagukou VTS is the management system whose main purpose is to protect the safety of the ship navigation. It is built by the management organization in accordance with relevant regulations, through the management procedures, by using effective software and hardware facilities. It consists of three parts, namely, the management organization, equipment management and operation management. The management organization is responsible for the real-time traffic monitoring, maintenance and handling the illegal events within the water area. The equipment includes the hardware equipment and application software of the system. Operation management includes management regulations and implementation procedures. At present, the

Dagukou VTS is composed of 1 radar station, 1 VTS duty station, 1 VHF communication station, 3 CCTV stations and 3 monitoring terminals.

(1)Radar

Dagukou VTS radar station is located in the west side of a harbor basin. On the east side of the radar station is a port of a shipyard base. On the west side of the radar station, there is a chemical dock. The height of its loading and unloading facilities is not high, so it will not keep out the radar coverage. By constructing the iron tower, the radar station erects radar antenna, whose height is 47m.

(2)VHF system

VHF communication equipment is used for voice communication between VTS center and ship. Dagukou VTS sets up 1 VHF base station. VHF communication base station and radar station are constructed together. VHF antenna erection has a height of 43m. VHF can cover over 25 nautical miles. That can meet the system coverage requirements.

(3)CCTV system

Dagukou VTS sets up CCTV station in the radar station, port comprehensive office building and the most eastern end pier of the first-stage project.

(4)AIS system

In Tianjin Dagukou port and in Nanjiang port, there are many large ships and the ship AIS equipment allocation proportion is high. Accessing AIS information in Dagu VTS system can more comprehensively cover anchorage farther offshore and navigable waters. In addition, it can grasp the ship dynamic more accurately and give full play to the VTS function.

At present, the first phase of the Gulf of Bohai has been built. The AIS signal can cover the Dagukou port and the nearby waters, meeting the coverage requirements of Dagukou VTS system.

2.2.2.3 The planning of Tianjin VTS

According to the "Tianjin Port Overall Planning", during "12th Five-year Plan" the coastal zone of Tianjin will be built into a comprehensive port which has a port with eight districts and five channels. Supporting facilities are also under construction. At present, some of the port areas of the pier have been completed. The construction of the duplex channel of Tianjin port is also completed and has been put into official operation. Moreover, the Lingang VTS system has also been put into trial operation. In the future, ships and traffic forms of Tianjin harbor will become more complex. The existing traffic management cannot meet the requirements of actual monitoring and effective transportation services. To Tianjin port, it is a key issue to accelerate the research and implementation between the port VTS relationship and mode of operation and management as well as implement VTS partition management. That needs to be solved urgently.

According to the planning of Tianjin MSA, new VTS system will be set up in Xingang, Hangu, Dagang, Dagukou and out sea area respectively. In the sea, three new radar stations will be built on three platforms (CFDll-1, 34-1 and PLl93)

(Tianjin transportation and port administration, 2012).

2.3 Traffic flow

2.3.1 Statistical analysis of vessel traffic flow

According to the Tianjin MSA statistics, the total traffic flow in 2010, 2011, 2012 and 2013 was 60271, 56273, 75885 and 76131 respectively in Tianjin Xingang port. The daily traffic flow of the main channel of Tianjin port reached 200 / day. We can also learn the static and dynamic distribution of the ship in Tianjin port from the ship trajectory diagram provided by the AIS center, as shown below.

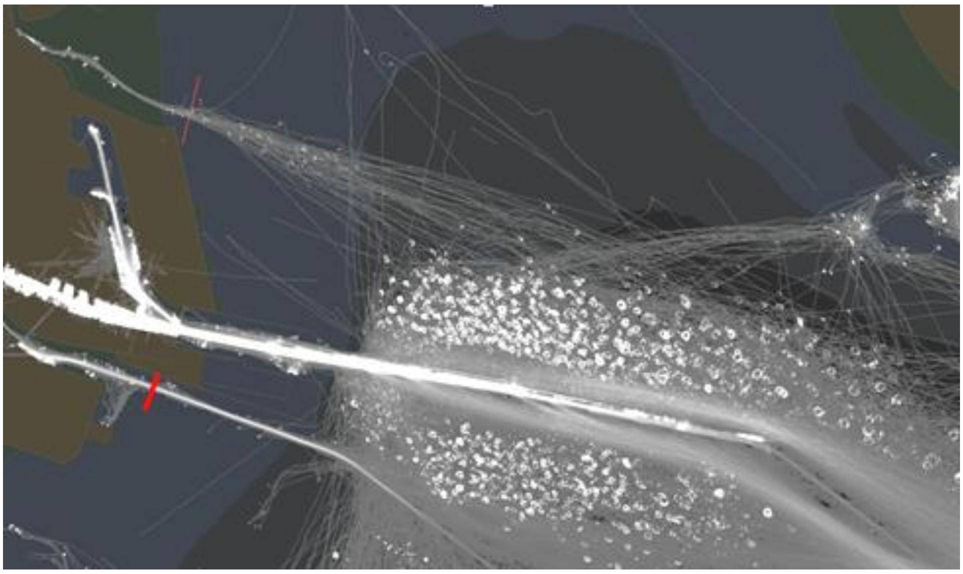

Figure 2 Ships'AIS tracks in Tianjin Port and its surrounding waters（April,2012）

Source: AIS equipment records by Tianjin AIS Center.

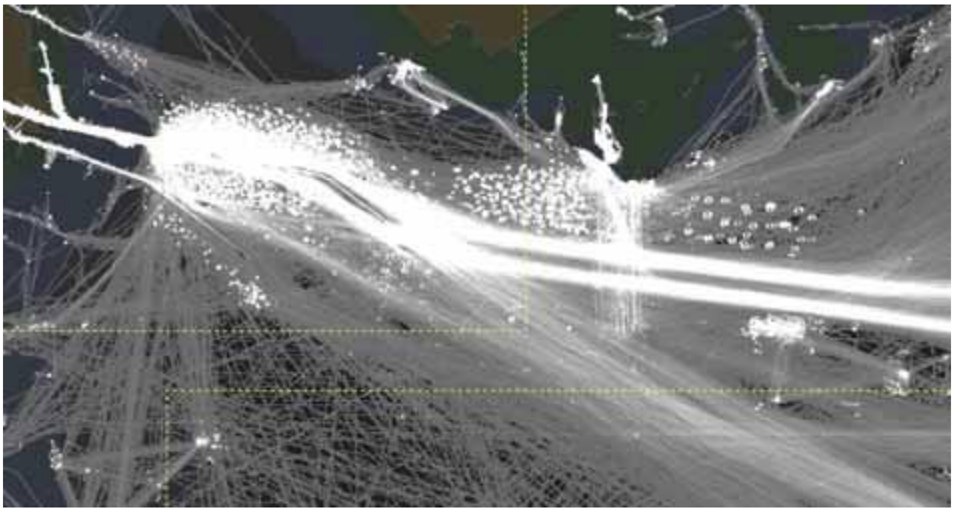

Figure 3-Ships'AIS tracks in Tianjin Port and its offshore waters（April,2012）

Source: AIS equipment records by Tianjin AIS Center.

2.3.2 Ship size

Distribution of ship size by month in Xingang Tianjin from 2008 to 2013 shows that, the length of the ship is mainly concentrated in 60-200m, as shown below.

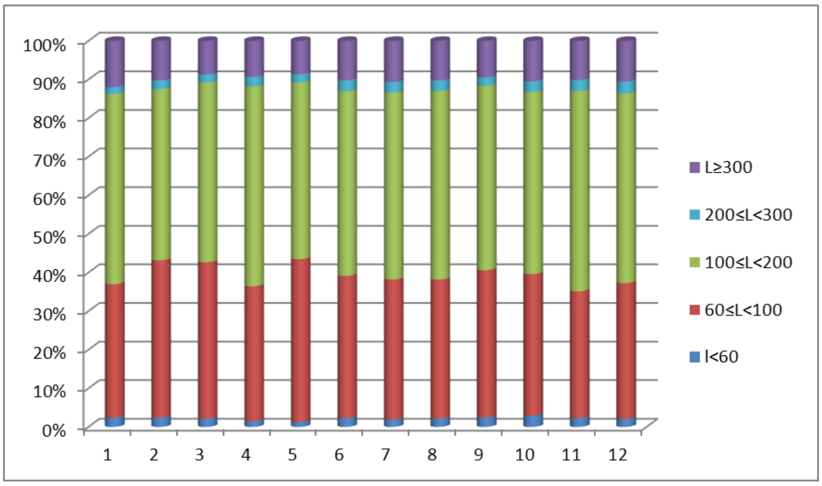

Figure 4 Ship size statistics in Tianjin port monthly from 2008 to 2013

Source: Tianjin MSA. (2015).

2.3.3 Ship type

According to the statistics of traffic flow in Tianjin port, the distribution of the ship types in Tianjin port by month is shown in Figure below.

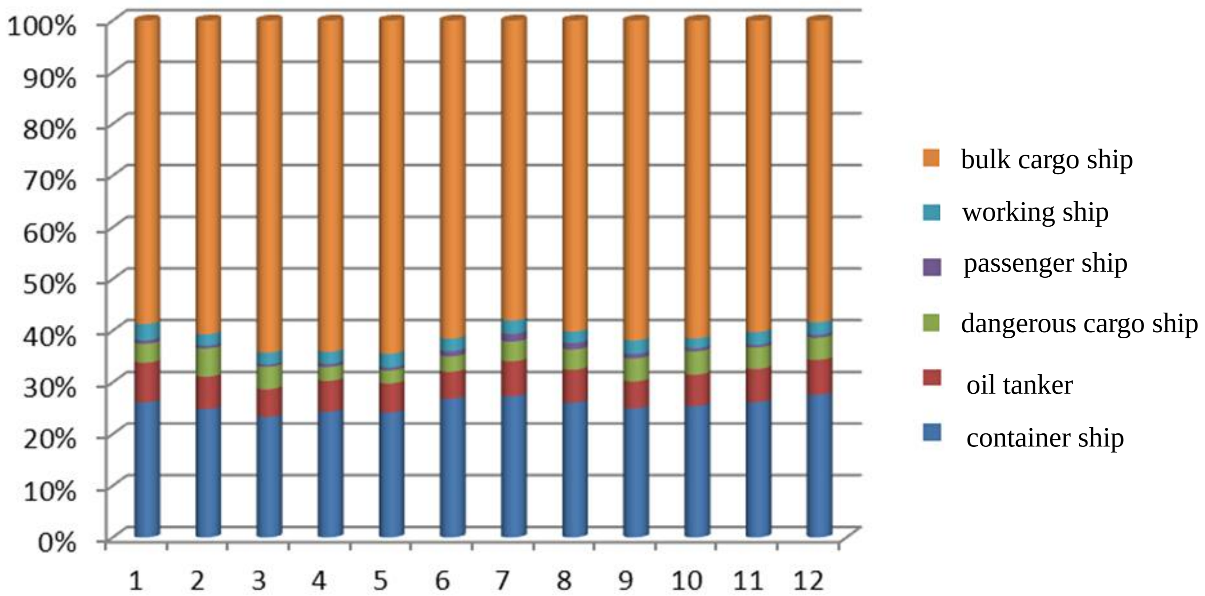

Figure 5 Ship classification statistics in Tianjin port

Source: Tianjin MSA. (2015).

2.4 Ship accident

2.4.1 Ship accident types

The traffic accident statistics from January 1, 2007 to February 26, 2014 in VTS area of Tianjin are shown in the table. It indicates that in the last 8 years, the ship accidents in this area were mostly mechanical fault(71.56%), followed by collision(14.16%), damage(6.35%) and stranding(4.99%).

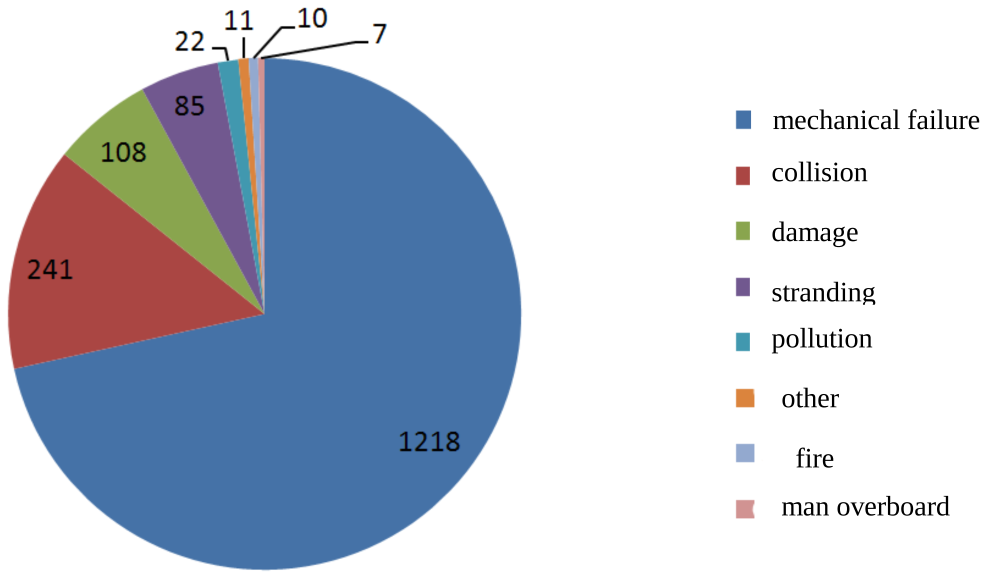

Figure 6 Proportion of ship accident types

Source: Compiled by Author. (2015).

2.4.2 Accident time statistics

2.4.2.1 Time distribution of collision accident

2.4.2.1.1 Diurnal variation distribution

The collision accident diurnal variation distribution means the distribution of the number of collision incidents occurring during the day and night in 24 hours.

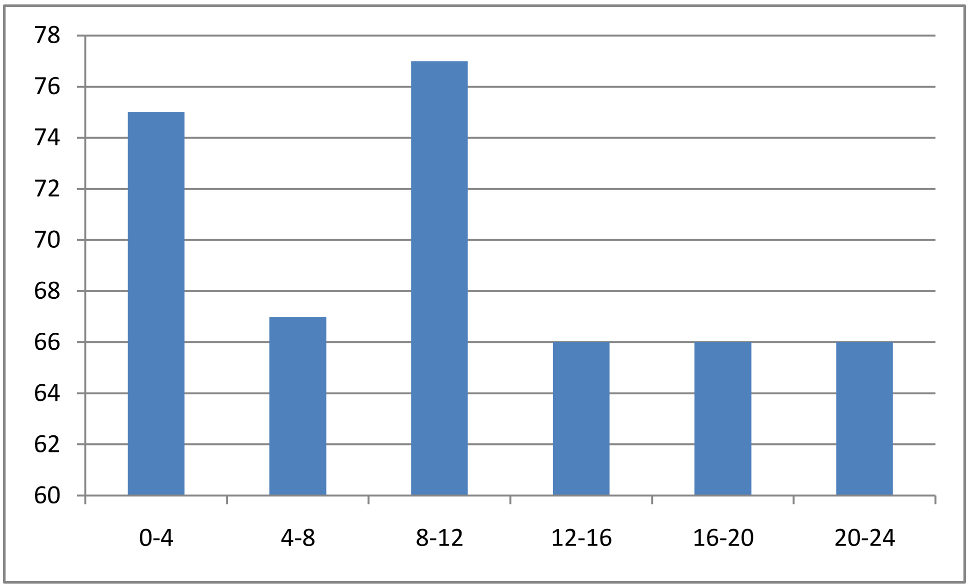

Figure 7 Tianjin VTS area collision accident statistics by hour

Source: Compiled by Author. (2015).

As can be seen from the above statistics, Tianjin Port collision accidents are prone to the period of 0000-0400 and 0800-1200, which are mainly caused by man-made factors. The ship operator's carelessness and physical fatigue are important causes leading to accident.

2.4.2.1.2 Annual change distribution

Annual change distribution reflects the characteristics of time distribution in a longer period, and can help to learn the relationship of ship accidents and ship flow, to examine the effect of the new ship traffic safety management measures, and to find the impact of new navigational aids on the safety of ship traffic.

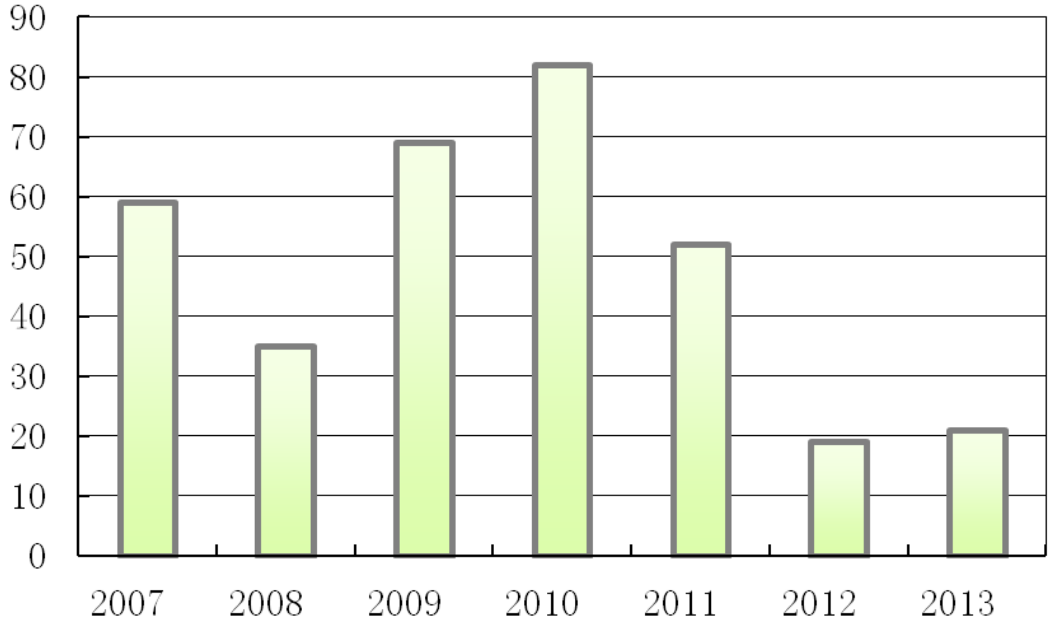

Figure 8 Tianjin VTS area collision accident statistics by year

Source: Compiled by Author. (2015).

As can be seen from the above statistics, in recent years the total number of collision accident has fluctuated to a certain extent. The shipping market downturn occurred in 2011, so fewer ships arrived or departed from Tianjin port , and accident had a downward trend, but we should pay attention to the accident changes after shipping market is booming.

2.4.2.2 Time distribution of grounding accident

The purpose of mastering the time distribution of the grounding accident is to grasp the relationship between the grounding accident and the factors such as the meteorological factor, traffic quantity and so on.

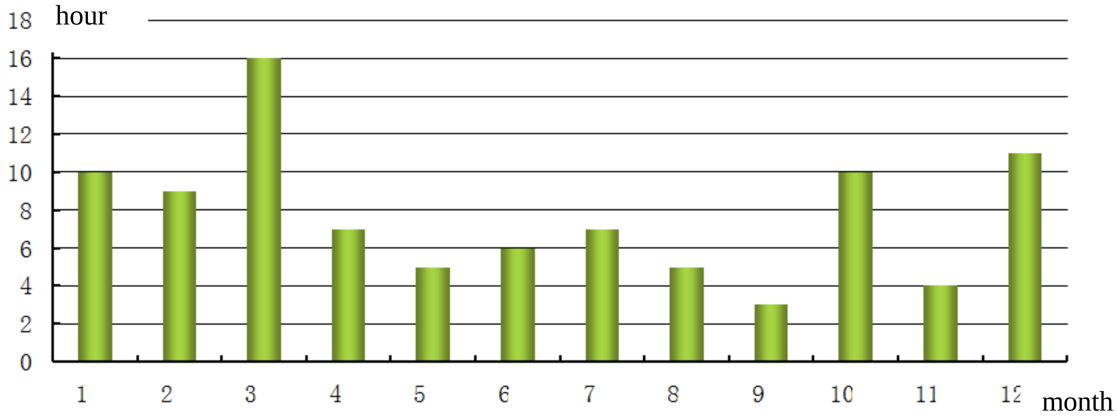

Figure 9 Tianjin VTS area grounding accident statistics by month

Source: Compiled by Author. (2015).

It can be seen that the grounding accidents occurred more often in winter than in summer, because the wind is generally relatively large in winter in the VTS area, which makes ships' control much more difficult.

2.4.3 Accident spatial distribution statistics

2.4.3.1 Spatial distribution of collision accident

According to the statistics by Tianjin VTS, the collision accidents from January 1, 2007to February 26, 2014 were analyzed, and the spatial distribution of the collision accident in this area was obtained, as shown below. Because the main channel of the Tianjin VTS area is long, the water can be divided into two parts. The first part is the channel and nearby waters from ship lock to 9+000, and the other is from 9+000 to the Dagukou anchorage.

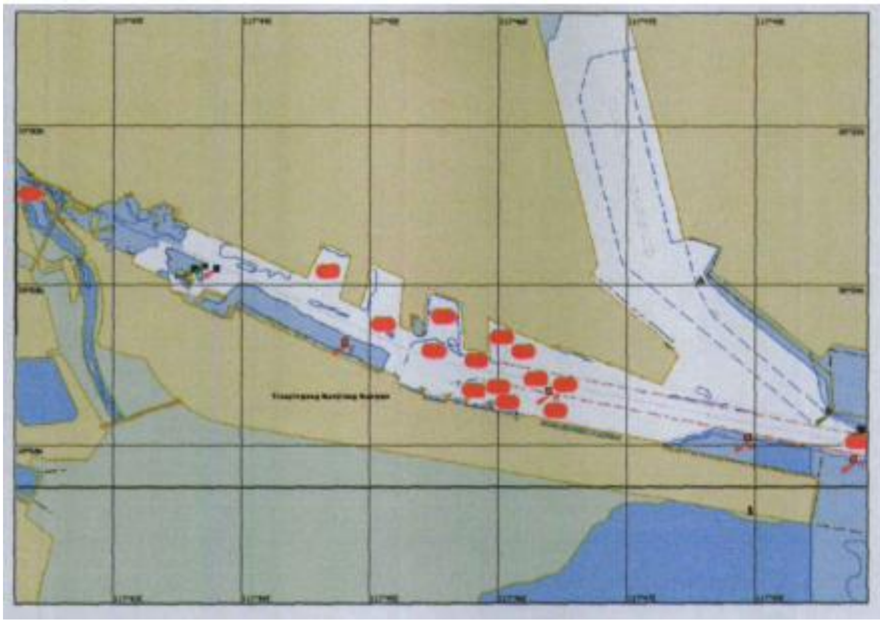

Figure 10 Collision accident spatial distribution in part 1

Source: Compiled by Author. (2015).

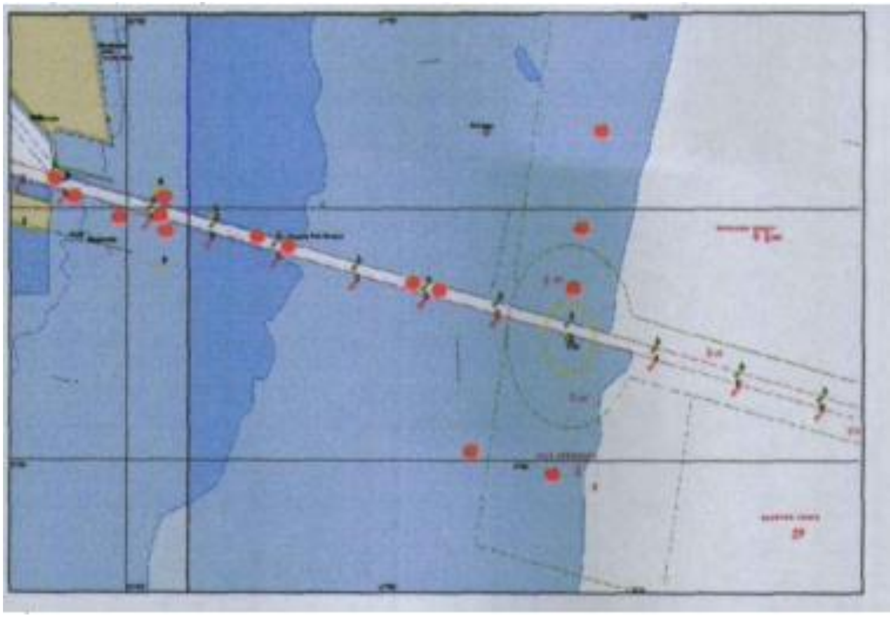

Figure 11 Collision accident spatial distribution in part 2

Source: Compiled by Author. (2015).

In the lock, because the ship need to face a lot of complex situations when passing the lock, and there are a lot of small docks nearby, ships are more likely to encounter collision accident.

Ship density is large from No.3 basin to east jetty, with many ships berthing and unberthing in this area, and the view is limited because of the tall buildings, so a few more accident occurred in this area.

In part 2, the most dangerous area is the channel nearby the Seawall, because the incoming vessels need to slow down while the outgoing vessels may accelerate and navigation environment becomes more complex, resulting in more collision accidents.

2.4.3.2 Spatial distribution of grounding accident

According to the statistics by Tianjin VTS, the grounding accidents from 2007 to 2013 are analyzed, and the spatial distribution of the grounding accident in this area was obtained, as shown below.

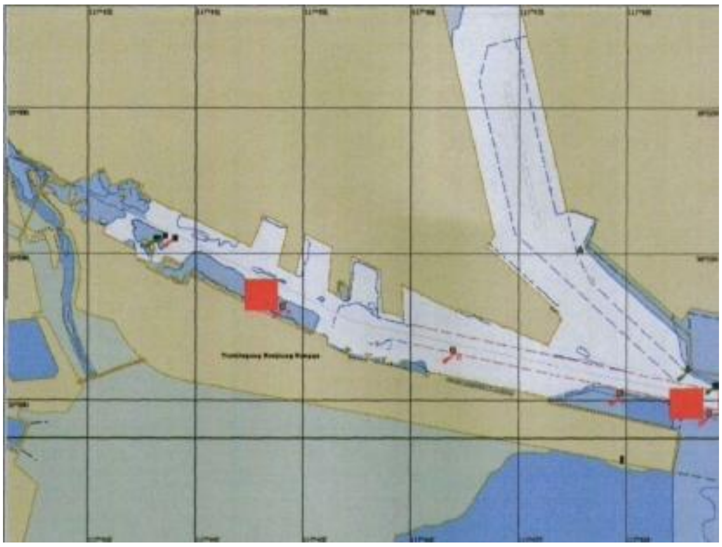

Figure 12 Grounding accident spatial distribution in part 1

Source: Compiled by Author. (2015).

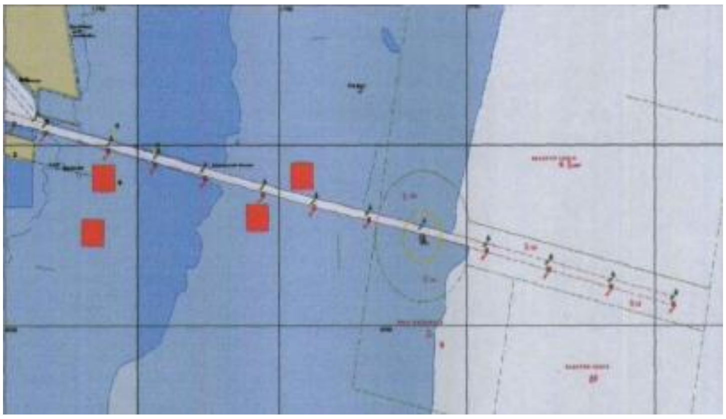

Figure 13 Grounding accident spatial distribution in part 2

Source: Compiled by Author. (2015).

In part 1, the most dangerous area is the No.1 basin nearby area and the intersection between main channel and north branch channel, because the anti-collision operation may reach the shallow water area and has a grounding accident.

Chapter 3 Risk assessment of VTS area

3.1 The analysis process of PAWSA

3.1.1 Expert weight distribution

Experts participating in security analysis may come from different areas, and have different professional background and professional knowledge. So it is necessary to arrange the weight of each expert in every pre-assessment index. Generally speaking, whether the weights of the members of the expert group are appropriate or not will directly affect the results of the final risk assessment, so it needs a cautious treatment. The basic weight distribution process is as follows:

(1) According to each expert’s professional background and pre evaluation index type, the experts are divided into groups. In the process of grouping, each expert group should take advantage of weight in at least one index type.

(2) The members of the expert group should master the basic information and safety status of the assessment object. And on that basis, every expert group should take turns to make a speech on the comprehension of the safety of the pre-assessment indicators of the assessment target. That can let each group of experts understand

each other’s familiarity.

(3) In PAWSA, the degree of familiarity of the pre-assessment indexes is divided into three levels: high, medium and low. Through mutual understanding between the expert groups, each expert group should compare its degree of familiarity of the pre-assessment indicators to other groups and analyze the result to give itself a grade (high, for example). And then through a certain algorithm, the qualitative grade assessment is changed into quantitative weight description.

(4) If there is an obvious deviation between the final assessment results and the actual situation, this shows that the experts have errors in the process of self-evaluation. At this time, the new weight distribution should be obtained by the mutual evaluation between the expert groups, and another evaluation should be carried out (Yin, 2013, pp43-46).

3.1.2 Risk degree of pre-assessment index

In the risk assessment of port channel in PAWSA, the risk degree of each pre-assessment index has qualitative description factors, namely “safe and stable”, “safe but need prevention”, “dangerous but acceptable”, “dangerous and need alert”. Then the comparison of the two adjacent qualitative descriptive factors is applied to get the quantitative values of the risk degree. To unify the assessment process, there are 9 scales between two adjacent qualitative descriptive factors, that is, the quantitative value of risk. The scale 1 value is much safer, and the scale 5 indicates two qualitative descriptive factors have the same degree of risk. Similarly, the scale 9 is much more dangerous. According to the above method, each pre-assessment index is calculated and analyzed. That can get the risk quantitative values of every pre evaluation index, and then calculate the risk degree of the whole evaluation system.

3.1.3 The risk degree of the whole pre-assessment index

On the basis of the second step, the quantitative value of the risk degree obtained by each expert member or the members of the expert group is aggregated. The quantitative interval values of different degrees of risk of the whole system are calculated. At the same time, the risk level of the pre evaluation index factors is determined.

3.1.4 Risk degree analysis of existing mitigation measures

On the basis of understanding the safety status of the current navigable environment in the pre-assessment waters, the risk degree of the relevant pre-assessment indicators for the mitigation safety measures which have been adopted is quantitatively compared and analyzed. Then new risk values are obtained. People should compare the new risk value with the risk degree before the implementation of the safety mitigation measures, and analyze the degree of its change.

3.1.5 Risk degree analysis of the proposed security measures

For the above pre-assessment indicators whose risk value is still relatively high (generally in dangerous state), people should propose security mitigation measures. At the same time, the risk degree of the index should be recalculated and the new risk value will be obtained. The new risk value must be outside the dangerous condition at least.

3.2 PAWSA for Tianjin VTS area

3.2.1 Dividing water areas

The whole water area is divided into some areas: Xingang water area, Lingang water area, Nangang water area, Hangu water area and Waihai water area. In order to reduce the risk level of the VTS region, it is necessary to analyze and assess the environment of navigable water in each area and find the risk factor, then propose effective measures,

3.2.2 Pre-assessment index of navigation environment

According to IALA risk management tool theory and the status quo of navigation environment in Tianjin port, in the assessment of each sea area, the pre evaluation index is divided into six types, including the cause of the casualties and the variable of effect of the waterway casualties. Each type of pre evaluation index also contains different types of pre-assessment factors, namely:

Traffic flow. The number of ships in the study waters and the influence between ships, the ship density and the traffic flow mode;

Ship's performance. The ships' structure, quality and crew quality, including ship performance of medium and above ships and below medium ships, sand gravel ship and all kinds of workboats;

Channel conditions. Channel physical characteristics, including assistant navigation facilities, the overall layout, dimension and quality of the channel bottom;

Natural conditions. The environmental conditions of the vessel in which the wind condition, water flow (tide, wave, etc.) and the visibility are involved in the waterway;

Short-term impact on accident. The direct impact of accidents: human injury or loss of life, overflow of harmful substances, and the need for emergency resources as well as the disruption of the maritime transport system. That includes casualties, oil leakage and chemical leakage, the block degree and so on.

Long-term impact on accident. The indirect effect of an accident can be shown in many years after the accident, such as the closure of coastal facilities, unemployment, the reduction or disappearance of species, the destruction of fishing areas, the reduction of living conditions as well as the pollution of water source (United States Coast Guard, 2005).

Table 1 Navigation environment assessment indexes

Ship' s performance	Medium and above ships	Below medium ships	Gravel boats and workboats	
Traffic flow	Density of medium and above ships	Density of below medium ships	Traffic flow mode	
Natural conditions	Wind	Visibility	Tidy	Wave
Channel conditions	Assistant navigation facilities	Channel layout	Channel dimension	Channel bottom
Short-term impact on accident	Casualties	Oil leakage	Chemical leakage	Block degree
Long-term impact on accident	Economic influence	Environmental impact	Health and safety	

Source: Compiled by Author. (2015).

There is one thing that needs to be pointed out. In Table 1, the way of the traffic flow refers to the scheduling mode of ship's entering port with high tide, entering or leaving port single or two-way. The block degree is the impact of the occurrence of maritime accidents in the waterways or ports on the use efficiency of the channel. That effect is generally short-term. The impact of health and safety generally refers to the impact of the pollution of the maritime accidents on the living and safety of the nearby residents and the aquatic organisms in the surrounding areas.

3.2.3 Weight distribution of the members of the expert group

In the course of study, according to the total number of experts, experts source units and the experts' relevant professional knowledge and the degree of familiarity with each other, experts are divided into three expert groups (The members of the expert group generally come from institutions, design and management departments and so on). Next is self assessment, namely, the self evaluation of degree of familiarity with pre-evaluation index by each expert group. The following is the mutual assessment phase. After a period of mutual understanding process, different expert groups carry out peer evaluation on each other. Finally, by quantitative analysis of the results of the self-assessment and mutual evaluation, the weight of the expert groups in each kind of pre-assessment index is obtained.

Table 2 Experts weight distribution

Risk type/Group	Group 1	Group 2	Group 3
Ship's performance	37%	25%	38%
Traffic flow	28%	43%	29%
Natural conditions	20%	31%	49%
Channel conditions	35%	26%	39%
Short-term impact on accident	41%	18%	41%
Long-term impact on accident	38%	28%	34%
Average	33.2%	28.5%	38.3%

Source: Compiled by Author. (2015).

As we can see from the table above, the average distribution value of each group experts is 33.2%, 28.5% and 38.3% respectively, close to the ideal distribution value 33%, so the mode of group weight distribution is reasonable.

3.2.4 Division and confirmation of risk scale and risk value of pre-assessment index

Through the analysis of the impact of the various pre-assessment indicators in the water environment, the expert groups can get the quantitative values of the descriptive factors of the various pre-assessment indicators. According to the quantitative value, the corresponding risk scale is obtained. The quantitative values of descriptive factors at all levels of the pre-assessment indicators are listed below.

Table 3 Quantitative values of qualitative description factors

Pre-assessment index	A	B	C	D
Medium and above ships	1.0	3.2	5.8	9.0
Below medium ships	1.0	3.1	5.7	9.0
Gravel boats and workboats	1.0	3.0	5.7	9.0
Density of medium and above ships	1.0	3.3	5.5	9.0
Density of below medium ships	1.0	3.1	5.4	9.0
Traffic flow mode	1.0	2.5	5.3	9.0
Wind	1.0	3.1	5.1	9.0
Visibility	1.0	2.4	5.5	9.0
Tide	1.0	2.7	5.6	9.0
Wave	1.0	3.3	5.6	9.0
Channel bottom	1.0	2.7	5.2	9.0
Channel dimension	1.0	2.6	5.1	9.0
Channel layout	1.0	3.0	5.8	9.0
Assistant navigation facilities	1.0	3.0	5.6	9.0
Economic influence	1.0	2.7	5.3	9.0
Environmental impact	1.0	3.0	6.1	9.0
Health and safety	1.0	3.0	5.9	9.0
Block degree	1.0	3.2	5.7	9.0
Chemical leakage	1.0	2.3	5.1	9.0
Casualties	1.0	2.6	5.2	9.0
Oil leakage	1.0	2.7	5.5	9.0
Average	1.0	2.8	5.5	9.0

Source: Compiled by Author. (2015).

Table 4 Quantitative value interval

Risk indicator	value
A（Safe and stable）	1.0
B（Safe but need prevention）	2.5 ~3.0
C（Dangerous but acceptable）	5.0 ~6.0
D（Dangerous and need alert）	9.0

Source: Compiled by Author. (2015).

The expert groups evaluate separately each port area, in which, they make analysis of the safety assessment of each pre-assessment indicator. 5 assessment index tables of risk levels of pre-assessment indicators are obtained.

3.2.5 Assessment results

Table 5 Risk level of the assessment indexes-Xingang

Ship's performance	50,000 GT and above	Below 50,000 GT	Gravel boats and workboats	
	4.3	6.7	8.6	
Traffic flow	Density of ships above 50,000 GT	Density of ships below 50,000 GT	Traffic flow mode	
	1.2	3.2	6.6	
Natural conditions	Wind	Visibility	Tide	Wave
	4.7	7.7	1.3	5.2
Channel conditions	Assistant navigation facilities	Channel layout	Channel dimension	Channel bottom
	7.1	5.9	8.1	6.6
Short-term impact on accident	Casualties	Oil leakage	Chemical leakage	Block degree
	1.0	7.8	8.5	7.4
Long-term impact on accident	Economic influence	Environmental impact	Health and safety	
	6.1	5.4	4.5	

Source: Compiled by Author. (2015).

Table 6 Risk level of the assessment indexes-Lingang

Ship's performance	50,000 GT and above	Below 50,000 GT	Gravel boats and workboats	
	4.0	6.9	8.9	
Traffic flow	Density of ships above 50,000 GT	Density of ships below 50,000 GT	Traffic flow mode	
	1.1	3.1	6.3	
Natural	Wind	Visibility	Tide	Wave
	4.7	7.8	2.0	5.3
Channel conditions	Assistant navigation facilities	Channel layout	Channel dimension	Channel bottom
	7.6	5.4	8.0	6.3
Short-term impact on accident	Casualties	Oil leakage	Chemical leakage	Block degree
	1.5	7.7	8.9	5.7
Long-term impact on accident	Economic influence	Environmental impact	Health and safety	
	6.2	5.8	5.8	

Source: Compiled by Author. (2015).

Table 7 Risk level of the assessment indexes-Nangang

Ship's performance	10,000 GT and above	Below 10,000 GT	Gravel boats and workboats	
	1.4	5.1	7.7	
Traffic flow	Density of ships above 10,000 GT	Density of ships below 10,000 GT	Traffic flow mode	
	1.3	1.9	5.6	
Natural	Wind	Visibility	Tide	Wave
	3.8	6.9	1.7	5.7
Channel conditions	Assistant navigation facilities	Channel layout	Channel dimension	Channel bottom
	7.8	5.4	8.4	6.3
Short-term impact on accident	Casualties	Oil leakage	Chemical leakage	Block degree
	1.3	7.1	5.9	5.9
Long-term impact on accident	Economic influence	Environmental impact	Health and safety	
	6.4	5.7	4.6	

Source: Compiled by Author. (2015).

Table 8 Risk level of the assessment indexes-Hangu

Ship's performance	Deep draft	Shallow draft	Gravel boats and workboats	
	2.2	6.5	7.8	
Traffic flow	Density of deep draft ships	Density of shallow draft ships	Traffic flow mode	
	1.1	4.1	7.7	
Natural	Wind	Visibility	Tide	Wave
	4.8	6.7	3.1	4.6
Channel conditions	Assistant navigation facilities	Channel layout	Channel dimension	Channel bottom
	5.7	4.9	6.7	6.1
Short-term impact on accident	Casualties	Oil leakage	Chemical leakage	Block degree
	1.5	3.2	1.9	6.4
Long-term impact on accident	Economic influence	Environmental impact	Health and safety	
	5.3	5.4	2.3	

Source: Compiled by Author. (2015).

Table 9 Risk level of the assessment indexes- Waihai

Ship's performance	50,000 GT and above	Below 50,000 GT	Gravel boats and workboats	
	5.3	7.8	7.9	
Traffic flow	Density of ships above 50,000 GT	Density of ships below 50,000 GT	Traffic flow mode	
	4.4	5.3	7.7	
Natural	Wind	Visibility	Tide	Wave
	6.8	6.7	5.1	5.7
Channel conditions	Assistant navigation facilities	Channel layout	Channel dimension	Channel bottom
	7.9	5.0	5.9	6.1
Short-term impact on accident	Casualties	Oil leakage	Chemical leakage	Block degree
	1.9	7.7	8.2	6.4
Long-term impact on accident	Economic influence	Environmental impact	Health and safety	
	6.4	7.8	6.5	

Source: Compiled by Author. (2015).

3.2.6 Risk value of pre-assessment indexes after mitigation measures

In view of all the above pre-assessment indicators, especially the indicators in the risk state, related responsibility departments and other relevant management departments will take corresponding security mitigation measures, and play a positive role in the preliminary prevention of marine accidents.

Existing risk mitigation measures are mainly divided into 9 categories, including: (1) coordination / planning, (2) the independent training, (3) conventions and procedures, (4) positive traffic organization, (5) compulsory enforcement, (6) radio communications, (7) navigation / hydrological information, (8) changing waterway conditions, (9) other strategies(Li, 2012, pp15-20).

In the following risk assessment process, the members of the expert groups will evaluate and analyze the safety mitigation measures. At the same time, the risk value of the assessment index is re-judged. The judgment is listed as follows

Table 10 Risk value of assessment indexes after mitigation measures-Xingang

Ship's performance	50,000 GT and above		Below 50,000 GT		Gravel boats and workboats			
	4.3	3.1	6.7	5.1	8.6	6.7		
	balance		probable		no			
Traffic flow	Density of ships above 50,000 GT		Density of ships below 50,000 GT		Traffic flow mode			
	1.2	1.1	3.2	2.3	6.6	5.8		
	balance		balance		probable			
Natural	Wind		Visibility		Tide		Wave	
	4.7	3.9	7.7	6.5	1.3	1.1	5.2	4.4
	probable		no		balance		balance	
Channel conditions	Assistant navigation facilities		Channel layout		Channel dimension		Channel bottom	
	7.1	5.7	5.9	4.9	8.1	5.5	6.6	4.3
	balance		probable		balance		no	
Short-term impact on accident	Casualties		Oil leakage		Chemical leakage		Block degree	
	1.0	1.0	7.8	6.8	8.5	5.4	7.4	3.9
	balance		probable		balance		balance	
Long-term impact on accident	Economic influence		Environmental impact		Health and safety			
	6.1	5.7	5.4	3.7	4.5	2.7		
	balance		probable		balance			

Source: Compiled by Author. (2015).

Table 11 Risk Value of assessment indexes after mitigation measures-Lingang

<table>
<tr><td rowspan="3">Ship's performance</td><td colspan="2">50,000 GT and above</td><td colspan="2">Below 50,000 GT</td><td colspan="2">Gravel boats and workboats</td><td colspan="2"></td></tr>
<tr><td>4.0</td><td>4.0</td><td>6.9</td><td>5.1</td><td>8.6</td><td>6.7</td><td></td><td></td></tr>
<tr><td colspan="2">probable</td><td colspan="2">probable</td><td colspan="2">no</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Traffic flow</td><td colspan="2">Density of ships above 50,000 GT</td><td colspan="2">Density of ships below 50,000 GT</td><td colspan="2">Traffic flow mode</td><td colspan="2"></td></tr>
<tr><td>1.1</td><td>1.1</td><td>3.1</td><td>2.3</td><td>6.3</td><td>3.8</td><td></td><td></td></tr>
<tr><td colspan="2">balance</td><td colspan="2">balance</td><td colspan="2">balance</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Natural</td><td colspan="2">Wind</td><td colspan="2">Visibility</td><td colspan="2">Tide</td><td colspan="2">Wave</td></tr>
<tr><td>4.7</td><td>3.9</td><td>7.8</td><td>6.5</td><td>2.0</td><td>1.1</td><td>5.3</td><td>4.4</td></tr>
<tr><td colspan="2">probable</td><td colspan="2">no</td><td colspan="2">balance</td><td colspan="2">balance</td></tr>
<tr><td rowspan="3">Channel conditions</td><td colspan="2">Assistant navigation facilities</td><td colspan="2">Channel layout</td><td colspan="2">Channel dimension</td><td colspan="2">Channel bottom</td></tr>
<tr><td>7.6</td><td>5.7</td><td>5.4</td><td>1.9</td><td>8.0</td><td>5.5</td><td>6.3</td><td>4.3</td></tr>
<tr><td colspan="2">balance</td><td colspan="2">balance</td><td colspan="2">balance</td><td colspan="2">no</td></tr>
<tr><td rowspan="3">Short-term impact on accident</td><td colspan="2">Casualties</td><td colspan="2">Oil leakage</td><td colspan="2">Chemical leakage</td><td colspan="2">Block degree</td></tr>
<tr><td>1.5</td><td>1.0</td><td>7.7</td><td>6.8</td><td>8.9</td><td>6.4</td><td>5.7</td><td>3.9</td></tr>
<tr><td colspan="2">balance</td><td colspan="2">probable</td><td colspan="2">probable</td><td colspan="2">balance</td></tr>
<tr><td rowspan="3">Long-term impact on accident</td><td colspan="2">Economic influence</td><td colspan="2">Environmental impact</td><td colspan="2">Health and safety</td><td colspan="2"></td></tr>
<tr><td>6.2</td><td>5.7</td><td>5.8</td><td>3.7</td><td>5.8</td><td>2.7</td><td></td><td></td></tr>
<tr><td colspan="2">balance</td><td colspan="2">probable</td><td colspan="2">balance</td><td colspan="2"></td></tr>
</table>

Source: Compiled by Author. (2015).

Table 12 Risk value of assessment indexes after mitigation measures-Nangang

Ship's performance	10,000 GT and above		Below 10,000 GT		Gravel boats and workboats			
	1.4	1.1	5.1	5.1	7.7	6.7		
	balance		probable		no			
Traffic flow	Density of ships above 10,000 GT		Density of ships below 10,000 GT		Traffic flow mode			
	1.3	1.1	1.9	1.7	5.6	3.4		
	balance		balance		balance			
Natural	Wind		Visibility		Tide		Wave	
	3.8	3.7	6.9	6.5	1.7	1.1	5.7	5.6
	probable		no		balance		balance	
Channel conditions	Assistant navigation facilities		Channel layout		Channel dimension		Channel bottom	
	7.8	5.8	5.4	4.4	8.4	7.6	6.3	5.9
	balance		balance		probable		no	
Short-term impact on accident	Casualties		Oil leakage		Chemical leakage		Block degree	
	1.3	1.1	7.1	6.7	5.9	5.5	5.9	3.8
	balance		probable		probable		balance	
Long-term impact on accident	Economic influence		Environmental impact		Health and safety			
	6.4	5.6	5.7	3.8	4.6	2.9		
	probable		balance		balance			

Source: Compiled by Author. (2015).

Table 13 Risk value of assessment indexes after mitigation measures-Hangu

Ship's performance	Deep draft		Shallow draft		Gravel boats and workboats			
	2.2	2.1	6.5	5.1	7.8	7.7		
	balance		probable		no			
Traffic flow	Density of deep draft ships		Density of shallow draft ships		Traffic flow mode			
	1.1	1.1	4.1	2.3	7.7	5.8		
	balance		balance		probable			
Natural	Wind		Visibility		Tide		Wave	
	4.8	3.9	6.7	6.5	3.1	2.1	6.1	4.5
	probable		no		balance		balance	
Channel conditions	Assistant navigation facilities		Channel layout		Channel dimension		Channel bottom	
	5.7	3.7	4.9	1.9	6.7	5.5	6.1	4.5
	balance		balance		balance		no	
Short-term impact on accident	Casualties		Oil leakage		Chemical leakage		Block degree	
	1.5	1.1	3.2	1.9	1.9	1.8	6.4	3.9
	balance		balance		balance		balance	
Long-term impact on accident	Economic influence		Environmental impact		Health and safety			
	5.3	5.7	5.4	4.7	2.3	2.0		
	balance		probable		balance			

Source: Compiled by Author. (2015).

Table 14 Risk value of assessment indexes after mitigation measures- Waihai

Ship's performance	50,000 GT and above		Below 50,000 GT		Gravel boats and workboats			
	5.3	4.2	7.8	7.4	7.9	6.7		
	probable		no		no			
Traffic flow	Density of ships above 50,000 GT		Density of ships below 50,000 GT		Traffic flow mode			
	4.4	4.1	5.3	4.3	7.7	6.8		
	probable		probable		probable			
Natural	Wind		Visibility		Tide		Wave	
	6.8	5.9	6.7	6.5	5.1	4.1	5.7	5.0
	no		no		balance		probable	
Channel conditions	Assistant navigation facilities		Channel layout		Channel dimension		Channel bottom	
	7.9	6.7	5.0	3.9	5.9	3.5	6.1	5.3
	probable		probable		balance		no	
Short-term impact on accident	Casualties		Oil leakage		Chemical leakage		Block degree	
	1.9	1.5	7.7	6.9	8.2	7.4	6.4	3.8
	balance		no		no		balance	
Long-term impact on accident	Economic influence		Environmental impact		Health and safety			
	6.4	5.5	7.8	5.7	6.5	3.7		
	balance		probable		balance			

Source: Compiled by Author. (2015).

3.3 Main risk analysis of VTS region in Tianjin

3.3.1 Main risk of Xingang water area

In the 21 assessment indicators of the pre-assessment of the Xingang water area, 14 pre-assessment indexes show the quantitative value of current risk is above the “dangerous but acceptable” state. There are 5 pre-assessment indexes whose risk quantitative values are at “dangerous and need alert” state.

In the risk value of each pre-assessment index after taking the existing mitigation measures, ship performance of “ships below 50,000 GT”, “win”, “channel layout”, “environmental impact”, "traffic flow mode" and “oil leakage” are in “probable” states. “Visibility”, ship performance of “gravel boats and workboats”, “channel bottom” are in the “no” state. This indicates that the existing management measures of the management department are not able to control the dangerous state of the above factors completely. Meanwhile, the existing mitigation measures have a small effect on reducing the risk of the index.

It can be obtained by the analysis that ship hull forms in Xingang water area are complex. Ships berthing and departing and the channel navigation ships influence mutually. Traffic flow is complex in inbound and export traffic. There are many sensitive waters. For example, the north branch channel and the main channel cross. There are many ships crossing the passage. Anchorage is close to main channel. Dredging and construction vessels occupy navigable waters, which makes the channel more crowded and so on.

3.3.2 Main risks of Lingang water area

Of the 21 indicators of the pre-assessment index in the Lingang waters, 3 indicators of quantitative value are at “safe but need prevention” state. 15 pre-assessment indicators of the quantitative value of current risk is at “dangerous but acceptable” state and above, among which 5 pre-assessment indicators of the quantitative value of risk is at “dangerous and need alert” state.

After taking existing mitigation measures, the related ship performance, “wind”, the “environmental impact”, “chemical leakage” and “oil leakage” are all at “probable” state. “Visibility”, “gravel boats and workboats” and “channel dimension” are in the “no” state.

The main risks of Lingang water area can be summarized as follows. Fishing boats and merchant ships are mixed in Lingang Industrial Zone. Ships frequently meet. Safety hazard is great at the intersection of the channel. And infrastructure of crossing navigable waters environment and shore based support system lag behind. VTS monitoring system in Lingang port is relatively weak, which cannot effectively carry out system management.

3.3.3 Main risks of Nangang water area

In the risk level index table of the pre-assessment of Nangang port, 14 pre-assessment indicators of quantitative value for the current risk are at “dangerous but acceptable” state and above.

In the reassessment after taking existing mitigation measures, “ships below 10,000

GT”, “wind”, “economic influence”, “chemical leakage”, “oil leakage” and “channel dimension” are all at “probable” state. “Visibility”, “gravel boats and workboats” and “channel bottom” are at the “no” state.

Ship traffic in Nangang watersarea is relatively small and there is little traffic pressure. But there may exist difficult supervision such as sand and gravel transportation ship, fishing boat and so on. And some small vessels are difficult to monitor. Free sailing is common. These all increase offshore regulatory difficulty. Marine security risks still exist.

3.3.4 Main risks of Hangu water area

In all of the pre-assessment indicators for the waters of Hangu, 11 pre-assessment indicators show the quantitative value of current risk at “dangerous but acceptable” state or above. The quantitative value of 2 pre-assessment indicators is at "dangerous and need alert" state.

In the reassessment after taking existing mitigation measures, “shallow draft ships”, “wind”, “traffic flow mode” and “environmental impact” are all at “probable” state. “Visibility”, “gravel boats and workboats” and “channel bottom” are in the “no” state.

It can be obtained by the analysis that the main problems of Hangu water area are the lack of VTS monitoring, more small ships and common random navigation of small ships.

3.3.5 Main risks of waihai water area

In the pre-assessment indicators for the offshore waters of Tianjin, 19 pre-assessment indicators of the quantitative value of the risk degree are at “dangerous but acceptable” state or above. The risk degree of 7 pre-assessment indicators is at “dangerous and need alert” state.

In the reassessment after taking existing mitigation measures, “ships above 50,000 GT”, “traffic flow mode”, “waves”, “density of all ships”, “channel layout”, “assistant navigation facilities” and “environmental impact” are all at “probable” state. “Wind”, “visibility”, “ships below 50,000 GT”, “gravel boats and workboats”, “channel bottom”, “chemicals leakage” and “oil leakage” are in a “no” state.

Obviously, the existing VTS monitoring scope of the waters off the coast of Tianjin is difficult to cover and it’s far from the port. General supervision power is difficult to implement the supervision and management normalization. And the distribution of oil wells off the coast is complex. Ship traffic is large and complicated, also, traffic state is complex. So the relevant departments should strengthen supervision of the waters off the coast and establish long-term supervision mechanism.

3.3.6 Risk degree comparison and summary of every water area

It can be drawn from the analysis of the navigable risk of the port areas that, Waihai water area has the highest risk. Xingang water area is behind it. The following are Lingang water area, Nangang water area and Hangu water area. So it is very important to establish the VTS center in various port areas and to monitor the VTS area separately.

Chapter 4 Safeguard measures and safety advice

4.1 Safety advice on establishing a new mode of VTS management

4.1.1 Safeguard measures and safety advice

Analyz the level of risk by current pre-assessment in VTS water areas according to the last chapter, the analysis should be made on the result of index to pre-assessment, which is marked by "can" and "cannot", and further safety measures and advice should be put forward accordingly. Moreover, analysis should be made on index to pre-assessment whose value of risk is excessive in implementation of some mitigation measures, and then recommendable safeguard measures should be proposed. The safeguard measures contains：

(1) Strengthening the communication with the competent authorities of the channel
(2) Improving ship-ship and ship-shore communication
(3) Conducting relevant training to mariners
(4) Developing a long-term/short-term schedule
(5) Formulating new regulations to adapt to variable risk factors
(6) Intensifying the supervision of implementation of some rules and regulations
(7) Releasing navigation information about chart, tide, weather etc. on time

(8) Broadening/deepening/straightening channel/increasing navigational equipment
(9) Establishing/improving VTS and other navigational aids

It is especially important to strengthen the study and supervision of VTS system for Tianjin port.

4.1.2 The necessity of study on implementation in VTS division

China VTS construction started late in the world. However, it developed rapidly. Nowadays the pivot ports and water areas at home have established VTS systems, which are playing important roles in improving traffic organizing efficiency at sea and port areas, maintaining a good traffic environment and protecting the life at sea, also protecting the sea environment.

The whole world running 228 VTS centers according to the 4th world VTS survey, of which 210 radars are in operation, accounting for 92.1%, and that all the main VTS systems employ radar without any exception. The management system and operational mode differs on account of deference in VTS construction, development degree and development environment, which can be divided into two types in general. The first type is “enterprise-oriented management”, in which pilot institution or port authority is in charge of VTS system, and it puts emphasis on ship pilotage, coordinating port operation and port safety, VTS system in European countries are the typical examples of this type. The other type is “government-oriented management”, mainly running in Japan and North America as coast guard, with which aims at environment protection and the safety of life at sea (Jia, 2011).

It is reasonable and effective to adopt division management and control to fulfill sound management and VTS communication diversion according to the national and international experience. Hence, systematic studying on the basic theory and principle in VTS sub-area, furthermore proposing Tianjin VTS management mode based on VTS division plan, is a supplement study on VTS division management, and also minimizes the risk of vessel traffic in Tianjin VTS coverage in an effective way.

4.2 Establishment of zoning management mode in Tianjin VTS coverage

4.2.1 The principle and method of Tianjin VTS zoning management

(1)the sub-area of VTS should be located in the scope of radar coverage.
(2)the sub-area of VTS should be located in the scope of VHF base station.
(3)The sub-area of VTS should accommodate planning and strategic development for the port areas.
(4)the sub-area of VTS in its coverage should be as few as possible.
(5)The boundaries in each VTS sub-areas should not be located in the passage meeting area, near water converging area and traffic intersection area.
(6)The boundaries should avoid water areas with frequent traffic accidents.
(7)the sub-area of VTS should facilitate coordination and management.
(8)The plan should be easy to operate and be safe(Yang, 2009, pp27-29).

4.2.2 Measures to Tianjin VTS plan

Tianjin VTS, named Xingang VTS（known as Tianjin VTS center now）, is seated at east jetty along Xingang NO.2 street. Its key responsibilities contain monitoring main channel, anchorage area and port waters in Tianjin port; Lingang VTS mainly targets at monitoring vessel traffic in Lingang waters, which is in trail-running phase.

Tianjin VTS coverage is divided into 5 sub-areas, considering its location, distribution of MSA, traffic environment in the vicinity, the coverage of monitoring devices , development plan, distribution of port waters and anchorage. The 5 subareas are Hangu VTS, Xingang VTS, Lingang VTS, Nangang VTS and open waters VTS in Tianjin port in succession from the south (Hu, 2012, pp14-22).

4.2.3 Analysis on management mode of Tianjin VTS

According to current regulations, the frequently-used management mode in and out of home VTS and systematic transfer of MSA, three plans are alternative for the management of Tianjin VTS sub-areas. By contrast, it is unified management, regionalized management and a combination of the above two (Zhang, 2011, pp47-51).

(1) Plan1: unified management

Tianjin VTS center, which is an office under Tianjin MSA, serves as a minister department together with other MSA branches. Tianjin VTS center not only ministers its own VTS operators, equipment in each VTS sub-area, resources and daily operation, but also manages personnel affair, training and other human resources. In other words, it is Tianjin VTS center that governs the devices, daily operation and related personnel. Besides, it centralizes watch-keeping but takes charge separately from the 5 VTS branches.

(2) Plan2: regionalized management

Tianjin VTS center, which is an office under Tianjin MSA, operates jointly with SAR center, thus keeps sufficient personnel to distribute the VTS resources, train VTS operators, examine the operation of equipments and guide the affairs. Each MSA branch monitors its own equipment maintenance, operational management and distribution of watch man. In addition, each of them are responsible for vessel traffic control and service in their jurisdiction, and manage the VTS operators working in them. At last, 5 individual VTS center subordinating to each MSA branch and 1 office （see as general VTS center）under Tianjin MSA responsible for professional guidance is the blueprint.

(3) Plan3: a combination of unified management and regionalized management

Tianjin VTS center is responsible for the maintenance and management of Xingang VTS and open waters VTS, and focuses on traffic flow in Xingang water area and open waters, besides ministers and keeps the staff working in this center. Lingang VTS center, Hangu VTS center and Nangang VTS center are in charge of equipments, operation, management and staffing level in their MSA branch respectively. The MSA branch ministers equipment and resources in each VTS branch, and also responsible for traffic schedule in their coverage, meanwhile in charge of staff management subordinating to them. The general VTS center takes charge of equipment distribution, Resource adjustment, personnel training, examination of operation and other professional guidance for all the branch VTS centers.

All VTS branches accept guidance from general VTS center and MSA branch. And each MSA branch is responsible for equipment performance, daily management and staffing level for VTS branch in their own. Tianjin general VTS center takes charge of resources, equip , training management and staff management in general VTS center, what’s more guides daily operation for VTS branch. Eventually, it structures 1 general VTS center and 3 individual VTS branches.

Combining of current configuration and future development of Tianjin port, and current organization and future planning of Tianjin MSA, it is recommended to adopt unified management mode for main port waters and open waters in Tianjin port, meanwhile the MSA branch ministers their own port waters. As a result, the management mode of combination of unified management and regionalized management is a recommendation. Tianjin VTS center is responsible for the operational management and traffic schedule of Xingang VTS branch and open waters VTS branch（main port waters and open waters）. Lingang VTS center, Hangu VTS center and Nangang VTS center are in charge of equipments, operation, management and staffing level in their MSA branch respectively. Each VTS branch is escrowed by Tianjin VTS center in the phase of initial construction, then shift the right of management to each MSA branch to ensure the smooth transition of VTS system.

Chapter 5 Conclusion

(1)Based on statistics and analysis of basic data, the distribution form of ship flow in Tianjin area and its operating law and water transportation accident trend are obtained. The length of the ships entering and leaving Tianjin port ranges mainly between 60 to 200m. The ships whose overall length is above 300m or less than 60m are fewer. The ship type is mainly cargo ships and container ships. In addition, oil tankers and passenger ships also occupy a certain proportion. The entire Tianjin port area has a dense ship traffic, so the shipping situation is grim. The traffic accidents are unstable. Traffic accidents mainly lie in collision, grounding and contact damage, most of which are small.

(2)Based on the risk assessment and traffic situation in Tianjin VTS region, the traffic risks in Tianjin VTS region mainly contain the following aspects.

The traffic flow is complex and there are many sensitive waters in Xingang water area. The environment infrastructure of port navigable waters and shore based support system lag in Lingang water area. Fishing vessels mix with merchant ships. VTS monitoring system is relatively weak. The ship traffic of Nangang waters and the Hangu water area is relatively small. But they lack VTS monitoring and there are many small ships. The VTS monitoring range is difficult to cover the Waihai water area. Even worse, it’s far from the port, so it is difficult to implement the normalization of supervision.

(3) Risk degree of each VTS partition is summarized through risk assessment. It can be drawn from the analysis that, Tianjin Waihai water area has the highest risk. Xingang water area is behind it. The following are Lingang water area, Nangang water area and Hangu water area.

(4) The PAWSA risk analysis method is applied to the practice of the VTS area in Tianjin. Qualitative and quantitative methods are combined to make risk identification and risk analysis of the navigable environment of the VTS area in Tianjin. The main navigable risk factors of the area are summarized, and the related mitigation measures and suggestions are put forward.

(5) Through risk assessment, the safety suggestions and safeguard measures for effectively reducing the risk of VTS region are proposed, namely, making a detailed analysis of the VTS partition management program and creating a new model of Tianjin VTS regulation.

References

Chen, W. J. (2011). Research on the evaluation model of port navigation environment safety. *Journal of Transportation Engineering*, 38(5), 57-59.

Dai, J. L. (2009). *Research on the safety and efficiency of the navigable waters of Qingdao port.* Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Det Norske Veritas, (2006). *Black point and south soko lng import marine quantitative risk assessment.* Hong Kong: Castle Peak Power Company.

Ding, C. (2007). Analysis of data exchange based on VTS and ship dynamic management. *China Waterway*, 36(32), 25-31.

Hu, W. D. (2012). VTS system frequency division and supervision mode. *China Navigation*, 35(4), 14-22.

Jia, J. R. (2011). *Research on the integrated information system of VTS ship traffic management.* Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Jun, M. (2010). Study on collision avoidance in busy waterways by using AIS data. *Ocean Engineering*, 483-490.

Li, H. (2012). Research on risk mitigation measures. *China waterway*, 36(16), 15-20

Liu, T. S. (2014). *The Research on the Risk Assessment of Tianjin VTS Areas.* Unpublished master's thesis, Dalian Maritime University, Dalian, China.

Luo, J. (2002). *Research and application of VTS post evaluation method*. Unpublished master’s thesis, Wuhan University of Technology, Wuhan, China.

Merrick, J. R. W. (2001). *Modeling risk in the dynamic environment of maritime transportation*. Proceedings of the 2001 Winter Simulation Conference, 1090-1098.

Merrick, J. R. W. (2006). Speaking the truth in maritime risk assessment. *Risk Analysis*, 12(1), 223-237.

Qiu, M. (2003). *Ship traffic engineering*. Beijing: People's Communications Press.

Tianjin transportation and port administration. (2012, February). *Overall planning of Tianjin p*ort(2011-2030). Tianjin, China.

United States Coast Guard. (2005). *Ports and Waterways Safety Assessment Workshop Guide*, Washington, DC, America.

Wu, Z. L., & Zhu, J.(2004). *Marine traffic engineering*. Dalian: Dalian Maritime University Press.

Xiao, Y. (2006). Cause and prevention of marine traffic accident. *China Waterway*, 36(9),38-39.

Yang, X. (2009). Discussion on the supervision mode of maritime cruise based on VTS. *Journal of Wuhan Institute of Shipbuilding Technology*, 12(1), 27-29.

Yin, X. M. (2013). Analysis of the navigation environment risk based on PAWSA in Tianjin harbor complex channel. *Tianjin Navigation*, 26(2), 43-46.

Zhang, S. G. (2009). Research on the application of real time publishing technology of port information. *Navigation Technology*, 12(5), 64-70.

Zhang, Y. W. (2011). Discussion on the division frequency management of VHF communication in the VTS area of Tianjin port. *Tianjin Navigation*, 26(4), 47-51.

Zhao, L. (2010). *Research of Tianjin Lingang port navigation safety comprehensive evaluation index system*. Unpublished master's thesis, Wuhan University of Technology, Wuhan, China.