

World Maritime University

# The Maritime Commons: Digital Repository of the World Maritime University

---

Maritime Safety & Environment Management  
Dissertations (Dalian)

Maritime Safety & Environment Management  
(Dalian)

---

8-27-2017

## Research on optimal allocation of oil spill contingency resources base on oil spill risk assessment in Taizhou port

Liangyu Wang

Follow this and additional works at: [https://commons.wmu.se/msem\\_dissertations](https://commons.wmu.se/msem_dissertations)



Part of the [Oil, Gas, and Energy Commons](#), and the [Risk Analysis Commons](#)

---

This Dissertation is brought to you courtesy of Maritime Commons. Open Access items may be downloaded for non-commercial, fair use academic purposes. No items may be hosted on another server or web site without express written permission from the World Maritime University. For more information, please contact [library@wmu.se](mailto:library@wmu.se).

**WORLD MARITIM UNIVERSITY**

Dalian, China

**REARCH ON OPTIMAL ALLOCATION OF OIL  
SPILL CONTINGENCY RESOURCES BASED  
ON OIL SPILL RISK ASSESSMENT IN  
TAIZHOU PORT**

**By**

**Wang Liangyu  
The People's Republic of China**

A dissertation 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)**

**2017**

© Copyright Wang Liangyu, 2017

## 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.

(Signature): Wang Liangyu

(Date): 20 June, 2017

Supervised by: Jiang Xin

Professor

Dalian Maritime University

Assessor: \_\_\_\_\_

Co-assessor: \_\_\_\_\_

## ACKNOWLEDGEMENTS

I feel grateful to World Maritime University for offering me this precious opportunity to study and improve myself. I also have deep gratitude for Prof. Shuo Ma, Vice President of WMU, for guidance to my whole studies and especially for provide chance to to study in Malmo, Sweden. This unforgettable experiences bring me a deep inspiration. I also deeply appreciated Dalian Maritime University for let me return campus. All the facilities are adequate and give convenience to my study and life.

I am sincerely gratitude to my superiors in Taizhou MSA for give the opportunity to study as a postgraduate students, the knowledge and the way of research will broaden my horizon and benefit for my further career. I also feel indebted to my college in Taizhou MSA for sharing my working responsibilities for such a long period and always enthusiastic to give me favor.

I also deeply thankful to my my supervisor Prof. Jiang Xin, for his careful instruction and assistance in my research. From the topic of the thesis to the choice of content, Prof. Jiang Xin has given patient guidance and strict review. His research and work attitude will guide me in my whole life.

I am grateful and beloved to my parents and parents-in-law for giving me full support to clear disturb to me, and my dear wife Xu Qiong for taking my duty to take good care of whole family especially my little son and sharing touch moment of grown of my son. I also appreciate my classmates for the friendship they giving me, they will be my close friends in my whole life.

## ABSTRACT

Title of Dissertation: **Research on optimal allocation of oil spill contingency resources base on oil spill risk assessment in Taizhou port**

Degree: **MSc**

With the continuous increase in maritime oil transportation and rapid development of construction for bunker terminal, the risks of oil spill caused by ships is increasing which threaten the marine environment severely. prevention of oil pollution from ships has attracted attention of the shipping industry. Currently, the prevail countermeasures is development of contingency response capacity after assessment of oil spill risk.

However, the establishment of oil contingency response capability for each individual terminals will cause waste of resources and could not effectively address the oil spill risk. It is necessary to introduce shared area to develop joint oil spill response capability and undertake proper allocation of oil spill contingency resources.

In this dissertation , after reviewing the countermeasures to oil spill such as risk assessment, the method of probability direct calculation is applied to study the risk of oil spill in Taizhou port based on adequate statistical data. Then, the divided sharing area has been presented through the method of Fuzzy clustering.

According to the calculated risk of oil spill in the sharing area, the joint contingency capability shall be established. And the solution of optimal allocation of oil spill contingency resources has addressed based on calculation of sharing proportion of each terminals.

**KEY WORDS:** oil spill, risk analysis, oil contingency response, Taizhou port, sharing area, optimal allocation

## TABLE OF CONTENTS

|  |             |
|--|-------------|
| <b>DECLARATION.....</b>  | <b>II</b>   |
| <b>ACKNOWLEDGEMENTS.....</b>   | <b>III</b>  |
| <b>ABSTRACT.....</b>   | <b>IV</b>   |
| <b>TABLE OF CONTENTS.....</b>  | <b>V</b>    |
| <b>LIST OF TABLES.....</b>   | <b>VII</b>  |
| <b>LIST OF FIGURES.....</b>  | <b>VIII</b> |
| <b>LIST OF ABBREVIATIONS.....</b>  | <b>X</b>    |
| <b>CHAPTER 1.....</b>  | <b>1</b>    |
| <b>INTRODUCTION.....</b>   | <b>1</b>    |
| 1.1 Background of research.....  | 1           |
| 1.2 Objectives of research.....  | 3           |
| 1.3 Methodology.....   | 3           |
| <b>CHAPTER 2.....</b>  | <b>4</b>    |
| <b>HAZARDS OF MARITIME OIL SPILL AND COUNTERMEASURES.....</b>  | <b>4</b>    |
| 2.1 The harm of oil spill to marine industry.....  | 4           |
| 2.1.1.Damages caused by oil spilling to the marine fishery.....  | 4           |
| 2.1.2.Damages caused by the oil spill to the terminals and industries.....                             | 5           |
| 2.1.3.Damages caused by spilled oil to the marine transportation.....                                  | 5           |
| 2.1.4 The influence caused by the oil spilling to the shallow water area and shoreline.....            | 5           |
| 2.2 Analysis of marine oil spill accidents.....  | 6           |
| 2.3 Analysis on the risk factors of oil spill from ships.....  | 6           |
| 2.3.1 Natural environmental factors.....   | 7           |
| 2.3.2 Navigation factors.....  | 8           |
| 2.3.3 Ship factors.....  | 8           |
| 2.3.4 Human factors.....   | 8           |
| 2.3.5 Sensitive Environmental Factors.....   | 9           |
| 2.4 Common approach to response to risk of oil spills.....   | 9           |
| 2.4.1 Oil Spill Risk Assessment.....   | 10          |
| 2.4.2 Development of oil spill contingency plan.....   | 11          |
| <b>CHAPTER 3.....</b>  | <b>13</b>   |
| <b>OVERVIEW OF TAIZHOU PORT AND ANALYSIS OF ALLOCATION OF OIL SPILL<br/>CONTINGENCY RESOURCES.....</b> | <b>13</b>   |
| 3.1 General natural situation of Taizhou port.....   | 13          |
| 3.1.1meteorologic condition.....   | 14          |
| 3.1.2Hydrological conditions.....  | 15          |

|  |           |
|--|-----------|
| 3.1.3 Distribution of Sensitive Environmental Resource.....                                | 17        |
| 3.2 Navigation Situation of Taizhou Port.....  | 18        |
| 3.2.1 Ships entering and departing Taizhou port.....                                       | 20        |
| 3.2.2 Statistics of oil spill accidents in Taizhou port.....                               | 22        |
| 3.3 Analysis on Allocation of Oil Spill Contingency Resource in Taizhou Port.....          | 23        |
| 3.3.1 General requirements in Taizhou Port.....  | 23        |
| 3.3.2 Analysis on Oil Spill Contingency Resource in Taizhou Port.....                      | 24        |
| <b>CHAPTER 4.....</b>  | <b>27</b> |
| <b>RISK ANALYSIS OF SHIP OIL SPILL IN TAIZHOU PORT.....</b>                                | <b>27</b> |
| 4.1 Probability estimation of oil spill from ships.....                                    | 27        |
| 4.1.1 Mathematical Model of Probability Prediction of Ship Oil Spill Accident.....         | 27        |
| 4.1.2 Probability Prediction of Ship Oil Spill Accidents in Taizhou Port.....              | 31        |
| 4.2 Estimation of volume of oil spillage in Taizhou port.....                              | 32        |
| 4.2.1 Probability Distribution of Volume of oil spillage.....                              | 32        |
| 4.2.2 Probability Distribution of Volume of oil spillage in Divided Area.....              | 34        |
| <b>CHAPTER 5.....</b>  | <b>38</b> |
| <b>OPTIMAL ALLOCATION OF OIL SPILL CONTINGENCY RESOURCES IN TAIZHOU PORT.....</b>          | <b>38</b> |
| 5.1 method of optimal allocation.....  | 38        |
| 5.2 The division of sharing area.....  | 39        |
| 5.3 Calculation of oil spill risk from ships in shared area.....                           | 42        |
| 5.4 Model of oil spill contingency resources allocation and management in Taizhou port.... | 49        |
| 5.4.1 The Provision and Management Mode of Oil Spill Contingency Resources.....            | 49        |
| 5.4.2 Establishment and management mode of oil spill contingency response team.....        | 51        |
| 5.4.3 Development of oil spill contingency plan.....                                       | 52        |
| <b>CHAPTER 6.....</b>  | <b>54</b> |
| <b>CONCLUSIONS AND PROPOSALS.....</b>  | <b>54</b> |
| <b>REFERENCE.....</b>  | <b>56</b> |
| <b>APPENDIX :.....</b>   | <b>60</b> |

## LIST OF TABLES

|           |  |    |
|-----------|--|----|
| Table 3.1 | Temperature statistics in Taizhou area   | 14 |
| Table 3.2 | Characteristic value of sea level of Taizhou port  | 16 |
| Table3.3  | Ships of entering and departing Taizhou port with<br>classified by type of ship from 2006 to 2014          | 20 |
| Table3.4  | Ships of entering and departing Taizhou port with<br>classified by gross tonnage of ship from 2006 to 2014 | 21 |
| Table 3.5 | Statistics of oil spill accidents in Taizhou port<br>from 2006 to 2014                                     | 22 |
| Table 5.1 | The most likely volume of spilled oil in whole area of<br>5 areas in Taizhou port                          | 46 |
| Table 5.2 | The most probable volume of oil spillage of each terminals<br>In Sanmen area                               | 47 |



## LIST OF FIGURES

|            |   |    |
|------------|---|----|
| Figure 3.1 | Water map of Taizhou administrative area  | 13 |
| Figure 4.1 | Relationship between the number of annual ship oil spill accidents and its probability in Taizhou Port.             | 32 |
| Figure 4.2 | The function distribution of oil spill volume and its occurrence probability  | 33 |
| Figure 4.3 | Interval for amount of spilled oil from ship and its oil spill probability distribution                             | 34 |
| Figure 4.4 | The relationship figure between the number of ships' annual oil spill accidents and probability within divided area | 36 |
| Figure 4.5 | The probability distribution figure of oil spilling volume within divided area                                      | 36 |
| Figure 4.6 | The probability distribution figure of oil spilling volume within divided area                                      | 37 |
| Figure 5.1 | Cluster analysis of terminals in Taizhou port   | 40 |
| Figure 5.2 | Distribution map of terminals in Taizhou area   | 41 |
| Figure 5.3 | The most likely volume of spilled oil in whole area and at terminal in Sanmen area                                  | 43 |
| Figure 5.4 | The most likely volume of spilled oil in whole area and at terminal in Linhai area                                  | 44 |
| Figure 5.5 | The most likely volume of spilled oil in whole area and at terminal in Jiaojiang area                               | 44 |
| Figure 5.6 | The most likely volume of spilled oil in whole area and at terminal in Wenling area                                 | 45 |

Figure 5.7      The most likely volume of spilled oil in whole area and at      46  
terminal in Yuhuan area

## **LIST OF ABBREVIATIONS**

|        |   |
|--------|---|
| IMO    | International Maritime Organization   |
| SEPA   | State Environmental Protection Administration of China  |
| ITOPF  | The International Tanker Owners Pollution Federation Limited  |
| US     | United States of America  |
| UK     | United Kingdom of Great Britain and Northern Ireland  |
| MARPOL | International Convention for the Prevention of Pollution From.<br>Ships, 1973 as modified by the Protocol of 1978 |
| OPRC   | International Convention on Oil Pollution Preparedness<br>Response and Co-operation 1990                          |
| OSRA   | Oil Spill Risk Assessments  |
| OSCAR  | Oil Spill Contingency And Response  |
| SCNPC  | Standing Committee of the National People's Congress  |
| S      | South   |
| N      | North   |
| E      | East  |
| SSW    | South-South-West  |
| NE     | North-East  |
| GC     | Gross Tonnage   |
| DWT    | Deadweight Tonnage  |
| MATLAB | MATrix LABoratory   |
| FCM    | Fuzzy C-means   |

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background of research**

With the sustained and rapid development of international economy, import and export trade and energy demand continues to increase, which promotes the continuous increase in maritime oil transportation and rapid development of construction for bunker terminal. In addition, the risks of pollution to the marine environment especially the risk of oil spill caused by ships is increasing due to the recent trends of bigger ship size of bunkers( Neves , et al. (2015).

In recent years, several severe oil spill accidents have occurred , such as oil pollution of Gulf of Mexico (AH.Walker, R.Pavia ,2015), collision of vessel of "Hebei spirit" (UH Yim, M Kim, SY Ha , S Kim 2012), and the major oil spill accident in Dalian on 16 ,July ,2010. The risk of marine pollution caused by oil spill shall not be ignored. Normally, the severe oil spill accidents occur in the area of busy coastal waters for oil extraction and transportation, as well as the areas with relatively fast development of economic and intensive large chemical industry, which leads to more demand of energy and dense transport ships (Stewart, T. R., & Leschine, T. M. ,2010).

Taizhou City is located in the central coastal areas of Zhejiang Province of China with close distance to Shanghai port and Ningbo port , and borders East China Sea and have the sea area of 6910 square kilometers (China SEPA,2007). Taizhou Port is an important port in coastal areas of Zhejiang Province , its geographical advantages are obvious, and the natural conditions of it are favorable. Due to the rapid

development of economy, the Taizhou port is booming and its port throughput grow rapidly. However, With the rapid development economy of Taizhou and the continuous growth of energy demand, cargo transportation of sea goods, especially oil and bulk chemicals increases sharply, and shipbuilding industry also sees a rapid development. Because of the frequent entry and depart of Taizhou waters area of large scale ships, the ship traffic is surging in this area, and the relevant operational activities leads to increasing risk of pollution to marine environment especially in the circumstance of complex navigation conditions in Taizhou area.

In response to the oil spill, IMO and China's domestic legislature have adopted large number of corresponding laws, regulations and technical guidelines about oil spill environmental risk assessment and equipment of oil spill contingency resource(IMO ,1990). In accordance with them, the port and terminals are required to to carry out ship pollution risk identification and assessment , and develop ship pollution accident contingency response capacity according to the pollution risk. (Ding Wangping,2013) However, in Taizhou area, as the requirements of the technical specifications, each terminals shall to establish oil contingency response capability independently and respectively. Which will leads to equipment of huge amount of oil spill contingency resource and facilities such as oil absorption felt, oil dispersant, etc. In the event of oil spill accidents, Only the effective use of large scale of oil spill contingency equipment, response personnel, and oil spill contingency materials can actually form the oil spill contingency force( Łukasz Jankowski, et al,2011). Otherwise, on one hand, the equipment of large number of consumptive oil spill contingency facilities in area will results in a waste of resources , on the other hand, which does not form an effective oil spill contingency capability.

A reasonable approach is to develop shared area, after ship pollution risk assessment for the shared area, it is recommended to unite the terminals and relevant companies within the shared area to establish oil spill contingency response capacity and share the cost of management. Through the implementation of the establishment of

response capability in shared area , it is possible to avoid the repeated configuration of equipment and other supplies such as asphalt felt, and reduce the burden on terminals. Meanwhile, a more effective contingency response capability can be achieved.

## **1.2 Objectives of research**

This dissertation is aim to enhance the capability of oil spill contingency response in shared area and conduct research on optimal allocation of oil spill contingency resources in Taizhou area after investigation of terminals and calculation of probability of oil spill risk in Taizhou port. Which will strengthen the establishment of ability of oil spill contingency response , improve the use efficiency of equipment and facilities, and prevent and control the bad impact of oil spill from ships on the marine environment

## **1.3 Methodology**

In this dissertation, large number of relevant literature and research reports have been reviewed to understand the current condition of tanker transport and the latest research and achievements in the field of contingency response for oil spill pollution, including the appropriate IMO documents, International Conventions, and Chinese national legal requirements. Furthermore, investigation to water environment and tanker terminals of Taizhou port, relevant shipping companies, and contingency response units have been conducted as well as collection of secondary resources and necessary statistical data to conduct adequate research. In order to solve the main points of this dissertation, two aspects of researches have been carried out including risk of ship oil spill accident and optimal allocation of oil spill contingency resources. Through estimating the risk of oil spill and analyzing the existing problems in the allocation of oil spill contingency resources in Taizhou port, optimal allocation of oil spill contingency resources have been presented to enhance the oil spill contingency response capability of Taizhou port.

## **CHAPTER 2**

### **HAZARDS OF MARITIME OIL SPILL AND COUNTERMEASURES**

With the increase of oil transportation by sea, the number of world tanker fleets entering and departing ports raise steady yearly, especially in China's port, which results in oil spill accidents occurring frequently. China is a major oil importer with transport Petroleum volume just lower than that of US and Japan, and its port oil throughput is growing at an annual rate of about 10 million Tons(Song Y X, 2015). It makes the marine environment face a great risk of oil spill because of high-density tanker terminals, oil pipelines, and transport vessels(Michel, J.et al,2013). Moreover, operation of loading and unloading on tanker terminals and storage of oil in coastal tank area may also produce oil spills. As the oil is toxic and the density is less than seawater, the spill of oil into sea will seriously contaminate marine environment and shoreline ,which cause huge losses to the marine ecological resources. In addition, marine industries such as fisheries, aquaculture, tourism will be seriously affected by oil spills (Henkel, et al. 2012).

#### **2.1 The harm of oil spill to marine industry**

##### **2.1.1.Damages caused by oil spilling to the marine fishery**

The fishes in the net cages of the fish farm cannot escape, and can become inedible after being polluted by the oil spilling( Lawrence, A., Hemingway, K. L 2003). The scallops and seaweeds will also meet the same fate. Moreover, the net cage for the culture can hardly be cleaned after being polluted, only by replacement can the problem be completely corrected, however the expenses are extremely high.

### **2.1.2.Damages caused by the oil spill to the terminals and industries**

The terminals and the yacht harboring area are also quite sensitive to the oil spill and normally the water in the port areas must be thoroughly cleaned(Yu.Q.B,2011). Thus this definitely affects entering and departing of ship. The cleaning measures should be taken for the polluted terminals and the yacht harboring areas and those measures will cost much. If the shoreline is provided with the water intake for a factory, the spilled oil will enter into the factory equipment and system, and then it may damage the equipment and even cause a factory to disable. Both salt industry and sea water desalination industry will be directly harmed by the spilled oil pollution, and lead to catastrophic economic losses (Ketkar, K. W. 1995).

### **2.1.3.Damages caused by spilled oil to the marine transportation**

If the oil spill accident occurs in a sea route or an anchorage space, it is necessary to clean the fouling timely; the use of large quantity of oil fences and other fouling cleaning devices on the high sea will occupy the original sea route or the area of the anchorage space and the vessels can only stay or make a detour at that time. Consequently, it will bring a certain level of influence to the marine transportation (Goerlandt, F., Montewka, J. 2015).

### **2.1.4 The influence caused by the oil spilling to the shallow water area and shoreline**

The shallow water area is the area with the most concentrated habitats of sea creatures such as shells, fry, coral and the like which are active in this area. This area is also the place where the seaweed resides, the sea creatures are highly sensitive to the oil spilling in this water area (Lawrence, et al 2003). If the spilled oil dispersant is used in this area, more damages are inevitable. Besides, the oil spill pollution to the shoreline will directly affect the tourism industry(ITOPF,2010).



## **2.2 Analysis of marine oil spill accidents**

The ship oil spill accident means that the ships or the operations related therewith encounter oil leakage or oily mixture leakage causing marine environmental pollution, which can be mainly categorized into the shipwreck oil spilling accidents and the operation oil spilling accidents(Jiao,J.C. 2011). There are many factors which can lead to the marine ship oil spilling accidents. Besides the oil spilling accidents caused by the operation mistakes made during the on-ship loading and unloading operation, illegal discharge of the water of the cabin bottom and the oil refueling, the factors such as ship collision, stranding, striking a reef and maritime climate change can all cause the accidents to happen (Li, X. F., Yang, Y. G. 2013).

Among them, the ship accidents, terminal oil tank area explosion and the fire hazards and explosions in the offshore drilling platform and submerged pipeline are the main accident categories which induce the major accidents. In general, the ship accident is highly likely to cause the occurrence of marine oil leakage, but as the ship building technology in recent years is improving all the time, and the techniques of the ship crew also enhance year after year (Goodman, R. 1994); the incidence of the ship accidents is decreasing year by year, and the incidence of the oil spilling accidents caused by ship accidents is also decreasing year by year.

## **2.3 Analysis on the risk factors of oil spill from ships**

The factors contributing to the ship oil spilling risk mainly include the factors which might lead to the occurrence of shipwreck accidents, the sensitive level of the water area environmental resources and the contingency disposal capability. Wherein, the shipwreck accident factors comprise mainly: Natural environment, navigation environment, management environment and human factors, and the like (DS Etkin.2000).

### **2.3.1 Natural environmental factors**

Weather and sea conditions are closely related to the ship's oil spill accident. On one hand, the heavy wind and waves will affect the safety of the ship's navigation and easily cause accident or sink; on the other hand, it will have great impact on removal and recovery of oil when the ship's oil spill occurred, in the harsh conditions, those operations even may even not be able to be carried out.

#### **Meteorology**

The wind has an obvious effect to the ships and it causes the ship to stall or accelerate, thus making the ship tilted, drift to deflect from the original route. Although there is no direct relationship between the wind and the ship oil spilling accidents, the wind can lead to the occurrence of the ship oil spilling accidents or worsen the damage consequences (Badri, M. A., Azimian, A. R. 2010).

The fog is the utmost factor which affects the visibility on the sea, and will have a direct important influence to the ship navigation, and there might be dangerous situations such as leeway, stranding, striking reef or colliding. In case of poor visibility, the ship is highly likely to collide.

#### **Hydrology**

The ship is influenced by the waves, ocean current and tide current on the sea. The higher the wave is, the ship navigation safety gets influenced to heavier extent (Boufadel, et al, 2009). As the upgrade of the shipbuilding technology, the wind and wave resistance of the ships increases. However, the influence brought by the heavy wind and waves to the ships cannot be underrated. Same as the heavy wind, high wave will also influence the cleaning and recovery of the filthy oil. If the applicable wave height range of the oil fence and oil skimmer and the like is surpassed, the fouling cleaning and controlling capabilities will be substantially undermined. In the extremely bad conditions, these facilities can be even unusable. If the sea wave is higher than 1m, most oil fences cannot effectively prevent the filthy oil from drifting.

### **2.3.2 Navigation factors**

The occurrence of the ship oil spilling accidents and the sea route conditions, and navigation and navigation assistant equipment and the like all have certain relationships(Zhu.S.L,2011). Surely, the excellent sea route condition, consummate navigation and assistive equipment and devices can reduce the incidence rate of the ship collision, and stranding and other accidents, therefore, can reduce the incidence of the ship oil spilling accidents. However, because the water area mentioned in this article is the littoral area, the oil spilling caused by the ship collision and stranding caused by navigation factors will not be considered as the major factors.

### **2.3.3 Ship factors**

The ship factors including mainly the ship types, ship tonnage, ship equipment technological conditions and ship age all have influences to some extent to the ship navigation. As to the ship type, the influence of the oil spilling accidents occurring on the oil tanker or other ships, and the consequences triggered therefrom are quite different(Song X H,2009).

The ship equipment technological condition reflects the navigability, automatic level and the operational performance and the like of the ship in a comprehensive manner. The operational performance of the ship refers to whether the ship has good course stability, tracing ability, turning ability and the ship parking performance, and whether it is possible to conduct the satisfactory control.

### **2.3.4 Human factors**

The statistics of ship accidents in shipping industry show that human factors are the main reasons for the occurrence of the ship pollution accidents. The human factors are a complex concept which encompasses a plurality of domains and influences the marine safety, security and protection and environmental protection (Raphael Baumler.2017). It includes the crew health condition, crew training

comprehensiveness, crew skills and experiences, crew occupational responsibility, crew overall level, operation procedure standard level, high level crew supervision level, and the familiarity level of the crew to the ship and the sea area, and the like(Zhang .Q,(2014). All the factors above might increase the possibility of the occurrence of the ship oil spilling accidents.

### **2.3.5 Sensitive Environmental Factors**

In an ecological environment, the resources which are highly sensitive to the environmental changes, and are prone to be affected by the ship oil spilling and oil spilling contingency reaction due to its own fragility of anti-damage capability which causes the damages, are called the environment sensitive resources(Gao.L.Y,2015) (Ulusçu.et al,2009). The marine oil spilling sensitive resources are the seashore, creatures and resources used by mankind, which might be affected by the marine oil spilling, including the recreational areas; animal nature protection zone, marine cultivating area, resource development area, cultural heritage relics, military zones and the like.

### **2.4 Common approach to response to risk of oil spills**

Because of long-term and tremendous destruction caused by oil spill pollution, prevention of oil pollution from ships has attracted more and more attention in the shipping industry. the US has held the biennial international oil spill conference since 1969 and research the the development and application of technology in the prevention of oil pollution(Chen.X,Geng H,2011). IMO has adopted a series of regulations such as MARPOL Convention and the OPRC Convention to develop a series of preparedness and response measures based on potential oil spill risks, As long as severe oil spill accidents have occurred, regional and international cooperation shall be carried out to reduce the damage caused by oil pollution through rapid and effective action. Hence, analyzing the potential oil spill impacts and taking quick response are the key activities to response the oil spill risk(Ventikos, N. P., Sotiropoulos, F. S. 2014). For the shipping industry, oil spill risk assessment and

development of oil spill contingency plan are the common measures to address oil spill risk.

#### **2.4.1 Oil Spill Risk Assessment**

The contingency response action against oil spill plays a key role in reducing and eliminating oil pollution, it is essential to carry out oil spill prediction firstly. Because the oil spill is affected by complex factors, it is random and uncertain(Qiu.P.B,2011). Risk assessment of oil spill is a necessary means to prevent accidents, and which can figure out the maximum possibility of oil spill in the sea area (Price, J. M., et al. 2003). Before the pollution accident, the risk management and countermeasures could be taken in advance according to the evaluation results .which will play a major role in preventing or reducing the occurrence of oil spill accidents. Similarly, after the oil spill occurs, the high-risk area can be determined for the first time, and contingency measures should be taken to reduce pollution damage.

Since 1960s, researchers have engaged in a lot of research on oil spill accidents, many scholars have conducted simulate and forecast for the probability of oil spill from ships through the application of stochastic theory, fuzzy mathematics, and matter element analysis method (Li, G. W. S., et al,1987) (Psarros, G., et al ,2011). Many oil spill assessment models have been developed, and numerical models for predicting and predicting oil spill and volume of oil spillage have been established. Among them, OSRA, OSCAR, and other numerical models are more advanced. The OSRA system can be used not only as simulation of oil spill but also can predict the most probable area for oil spill. It is a effective tool for the assessment of oil spill risk, after updated several times, it has been widely used in practice. (Smith,1982) (Price, J. M., et al,2004) (Johnson, 2007).In addition, The OSCAR system can provide the distribution of contingency resources and lay out simple contingency strategies, (Reed, et al,1995).In 2010, New Zealand has adopt MOSRA10 project to carry out oil spill risk assessments (Bermingham, et al,2011).

#### **2.4.2 Development of oil spill contingency plan**

In order to prevent the oil spill, chemical leakage and fire accidents caused by the operations of ships, terminal and liquid chemical operation, it is necessary to provide corresponding contingency plans to protect the terminal and marine environment resources, safeguard the safety of mankind and the sound social system (Santoli, et al,2011). Once the oil spilling, chemical leakage or fire accidents occur in terminal, the factors such as geographical environment of the terminal and the loading and unloading equipment shall be fully considered, and the contingency equipment, apparatuses and contingency personnel shall be scientifically and reasonably allocated in order to implement the fastest, most effective disposal to the oil spill and chemical leakage, thus reducing the extent of the damages caused by the accidents. And activities for oil spill shall be guided by the oil spill contingency plan including equipment of oil spill contingency resources, establishment of response team.

The ship oil spilling risk management in the US is realized through the establishment of the US ship pollution contingency system ( Konkel, R. S. 1987). The US not only enacts relatively complete laws and regulations and establishes a national anti-pollution response system, but also establishes a scientific and reasonable oil spilling prevention, control and contingency strategy system, information database system, oil spilling pollution differentiation system and oil spilling pollution damage compensation system command center, and the triple levels of oil spilling contingency response system built up by the state governments. Once there is any marine oil spilling accident, the national contingency response system and related functional departments can immediately take actions according to the oil spill contingency plan in time, and strive to control the oil pollution in the shortest time.

The ship oil spilling risk management in the UK is undertaken by the Marine Pollution Management Committee, which belongs to the Ministry of Transport of British Government, whose main responsibility is the disposal of marine pollution accidents and the beach cleaning work which is coordinated with the littoral regional

governmental departments; the local government is responsible for the cleaning of local beaches at the cost of the regional governments(Bai,J.Y,2010). For the sake of carrying out the cleaning in an even better fashion, the regional government shall dispatch specialized professional cleaning teams, and conduct training regularly.

The ship oil spilling risk management in China is mainly undertaken by MSA, as well as the littoral provincial and municipal governments for concrete measures(Zhao.G.H,2010). Base on the related requirements in the OPRC Convention and domestic marine environment protection law, all the marine boards and all levels of local people's governments enact the ship oil spill contingency reaction plan of the jurisdiction area, based on the frame of five levels of contingency system comprising the state level, sea area level, provincial level, municipal and regional level and port and terminal level, the identification and assessment of the risks that the ship pollutes the sea, and build the ship pollution accident contingency disposal capability matching with the risks.

## CHAPTER 3

### OVERVIEW OF TAIZHOU PORT AND ANALYSIS OF ALLOCATION OF OIL SPILL CONTINGENCY RESOURCES

#### 3.1 General natural situation of Taizhou port

Taizhou port locates in Southeast of China and involving with international trade, and has a coastline of 745 kilometers. Its distance to Shanghai port is 160 nautical mile and the geographical coordinates is  $121^{\circ} 27'E$ ,  $28^{\circ} 41'N$ ((China SEPA,2007)). Taizhou port is made up of six ports, which are Da Maiyu port, Linhai port, Haimen port, Huangyan port, Wenling port and Jiantiao port. According to the statistics of Taizhou maritime Safety Administration, there are 234 productive berths in Taizhou port by September 2015(Taizhou MSA,2016) .

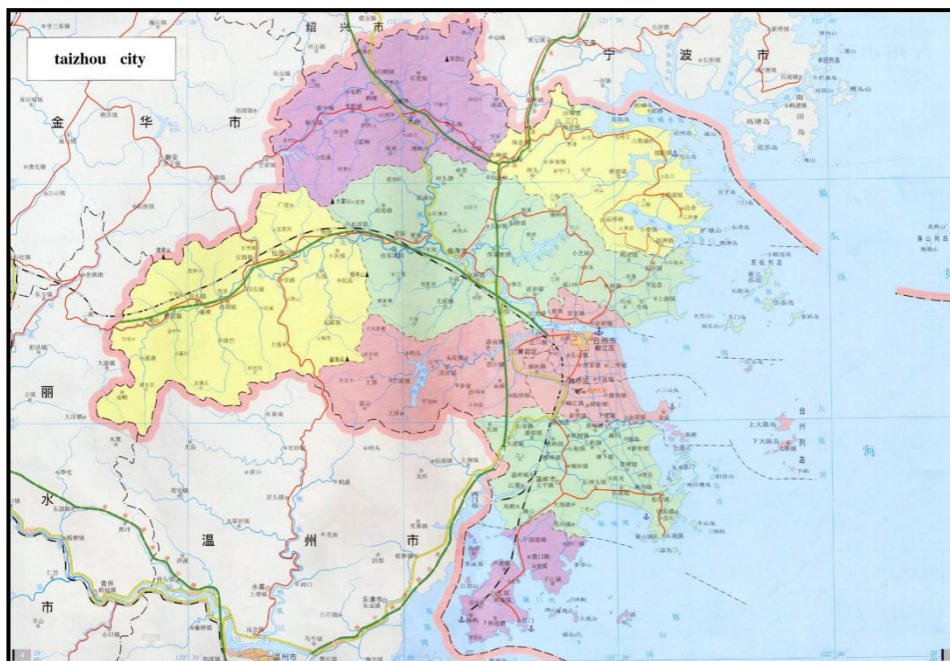


Figure 3.1 Water map of Taizhou administrative area



Source: <http://image.baidu.com/search/detail?ct=503316480&z=0&ipn=d&word>

### 3.1.1 meteorologic condition

Taizhou area is located in subtropical monsoon climate zone, affected by marine climate with comfortable meteorologic condition including distinct seasons, warm climate and humid air. In addition, there are also Adequate light and long frost free period in this area.

#### Temperature condition

Table 3.1 Temperature statistics in Taizhou area

| Statistical projects over the years                    | Temperature |
|--|-------------|
| Annual mean temperature                                | 17.0℃       |
| Extreme high temperature over the years                | 38.1℃       |
| Extreme low temperature over the years                 | -6.8℃       |
| The average temperature in the hottest month (August)  | 27.7℃       |
| The average temperature in the coldest month (January) | 6.6℃        |

Source: Taizhou MSA, 2016

#### Precipitation condition

The precipitation in this area is mainly concentrated from March to September, accounting for about 75% of the whole year. In May, June and September, it was mainly controlled by the southeast air current and the influence of plum rains and typhoons, which resulted in the majority of rainfall. From October to January, the

amount of precipitation was less, which accounted for only 20% of the total annual output. The annual average relative humidity was 73% to 82%, and the maximum relative humidity appeared during June.

#### Wind condition

This area is in a typical monsoon zone, and the change of wind direction is obvious, the northerly wind prevails in winter, whereas SSW wind is common in summer. In addition, NW wind is dominant in inland area while NNE wind is popular in islands area.

#### Typhoon (tropical cyclone)

Normally, in this area, the average duration of tropical cyclones and typhoons is around 1 ~ 3 days, even only a few hours in some circumstance. The rain usually lasts for a long time about 3 days, however it may continue 5 days when the typhoon directly land nearby.

#### Fog condition

Taizhou water area locates in brumous sea area in the East China Sea, within which the advection fog is prevalent, which usually occurs in the morning and lasts for a short time. Average foggy days over years (visibility is less than 1km) is approx 50 days. Fog mostly occurs in winter and spring, and foggy day mainly concentrates in March to June, accounting for 72% of total foggy days over the year.

### **3.1.2 Hydrological conditions**

#### Tide conditions

Tide type: a typical informal semi-diurnal tides prevails in most of the sea area. Datum of tidal level: According to the Jiaojiang river figure published by the Chinese Navy, Characteristic value of sea level: According to the master plan of Taizhou port, Characteristic value of sea level are shown in table 3.2 below

Table 3.2 :Characteristic value of sea level of Taizhou port

| Measuring station<br>Item     | Dachen | Haimen | Jiantiao | Kanmen   | Hengmen |
|-------------------------------|--------|--------|----------|----------|---------|
| Highest tide level over years | 5.03M  | 7.50M  | 7.45M    | 7.08M    | 6.38M   |
| Lowest tide level over years  | -1.17M | -0.72M | -1.77M   | -1.78M   | -1.40M  |
| Annual mean high tide         | 3.76M  | 4.30M  | 4.31M    | 4.07M    | 3.91M   |
| Annual mean low tide          | 0.30M  | 0.28M  | 0.16M    | 0.12M    | 0.23M   |
| Mean tide level               | 2.02M  | 2.20M  | 2.19M    | 2.90M    | 2.14M   |
| Maximum tide level            | 5.85M  | 6.87M  | 7.23M    | 6.85M    | 6.83M   |
| Mean range of tide            | 3.39M  | 4.02M  | 4.15M    | 3.96M    | 3.56M   |
| Mean duration of rise         | 6: 17H | 5:14H  | 6:17H    | 6:19H    | 6:13H   |
| Mean duration of fall         | 6: 07H | 7:21H  | 6:08H    | 6:06H    | 6:13H   |
| Representative port area      | Linhai | Haimen | Jiantiao | Da Maiyu | Wenling |

Soure: :Compiled by author to interpret statistics of Taizhou MSA

#### Tidal current conditions

Taizhou water area is located in a tidal bay, in which the tidal current is full of power with large tidal range and rapid velocity. The flood tide is greater than the ebb tide, while ebb flow lasts longer than the duration of flood current. In general, the flow rate is 2 to 3.5 knots and the maximum flow rate can reach more than 5 knots in the flood season or if affected by typhoon storm tide.

## Wave conditions

Taizhou Bay sea area is an open bay, and mixed waves prevail in this area, of which mainly is the surge . The most common wave direction is from N to NE with the frequency of occurrence is 53.7% while that from S to SSW is less usual with frequency is 14.6%. The direction of wave varies with the seasons, the direction of S ~ SSW is dominant in Summer while that of N ~ NE is common in other seasons. In addition , the frequency of occurrence of surge-less id 21.7% .

The average annual height of wave is 1.2m, the maximum height is 14.4m and the direction of wave is east.The height of wave is relatively high from July to November with average volume 1.3m to 1.4m and with summit of 6m to 14.4m. The average period of wave is 5.6 seconds,and the maximum period is 18.1S, from July to October, the period is relatively long with monthly average period of 5.8 ~ 6.1s.

### **3.1.3 Distribution of Sensitive Environmental Resource**

There are many important sensitive environmental resources in Taizhou port. Once a ship pollution accident occurs, it will cause immeasurable and irreversible damage to these sensitive resources

#### Tourist area

There are 6 main scenic tourist areas in near Taizhou port, including Sanmen Bay scenic area, Taozhu scenic area, Dachen Island Scenic Area, Wenling southeast coastal scenic area, Dalu Scenic Area and the Yueqing Bay Scenic Area. There are also 5 leisure tourist areas which are respectively Longwan leisure tourist area, Dongji Islands leisure tourist area, Huanglang leisure tourist area, Dacheng leisure tourist area and Kanmen leisure tourist area.

#### Aquaculture Areas

Taizhou area are rich in aquatic resources, which has several important aquaculture areas including prawn artificial rearing area, Dachen area as national fishing port and oysters artificial rearing area in Yueqing Bay.

#### Power plant

There are many power plants located in Taizhou Port, including nuclear power plants in Sanmen Bay; Taizhou power plant in Taizhou Bay; Yuhuan Huaneng power plant, Yueqing power plant Yueqing Bay area.

### **3.2 Navigation Situation of Taizhou Port**

The main inbound navigation route of the coastal area in Taizhou port are mainly comprise the entrance route of Da Maiyu port, Wenling port, Haimen and Huangyan port, Linhai port and Jiantiao port.

#### Da Maiyu port

Currently, the inbound navigation route of Da Maiyu port is composed of two routes located on East and West. The east one starts from the west route of the Southeast side of the Luxi Island and extends North through the water area between Luxi Island and Nanpan Island, then goes into Yueqing Bay through the water area between Yuhuan Island and Heng Cishan Island. The length of the route is about 31.5km, of which the minimum depth is 10.8m with length around 4.6km. The east route is in good navigation condition which can ensure ships of 30,000 GC access to the port all-weather while ships of 50,000 GC to 70000 GC access to the port with taking tide. The west route starts from Hutou Island and crosses the Huangda strait of the west side of Luxi Island, then goes into Yueqing Bay through the water area of Hengzi mountain. The natural water depth of the route can basically meet the requirements of access to port by ships of 10,000 GC through taking tide.

#### Wenling port

The inbound navigation route of Wenling port Yong'an operating area connects the high sea with the Jinqing lock, and the water depth of it can meet the needs of access port of ship with 500 GC; Shitang, Longmen operating area directly connects with the high sea, and its natural water depth can meet the needs of access port of ship with 2000 GC with taking tide; The inbound navigation route of Shanshan operating area directly connects Yueqing Bay through the water area between Shashan and Hengzi Island.

#### Haimen, Huangyan port

The inbound navigation route of Haimen, Huangyan port is the outbound route of Jiaojiang River, which extends from Taizhou first pilot anchorage to the Niutou rock with a total length of about 30km. Among which, there is a shallow route about 18KM from Laoshu mountain to Baisha with water depth only about 2m (theoretical basis, the same below). Within the port, ships with 3,000 gross tons can navigate with taking the tide, while ships with 5,000 gross tons and shallow draft ships have limited chance to access to port subject to the tide.

#### Linhai port

Linhai port consists of Lingjiang River operating area and Toumen operating area, in which Toumen operating area operating area is composed of two routes located on North and South. The north one starts from west route near the You Caihua Island and extends to the southwest, then goes into the Toumen operating area through the water area between the Tianao Island and Dongji Island. The south one starts from the East rout of east side of Da Huacha Island and extents to the south side of Liangmao Island, then head Northwest to Toumen operating area. At present, the natural water depth of the both 2 routes can meet the requirements of access to port by ships of 10,000 GC through taking tide. As for the Lingjiang River operating areas, Its inbound navigation route mainly divides by Hongguang terminal, its downstream section meets the requirements of access to port by ships of 3,000 GC

through taking tide while the upstream section allow the access to port by ships of 1,000 GC by tide.

### Jiantiao port

The inbound navigation route of Jiantiao port is composed of two routes located on North and South. The south one starts from the east route of the east side of the Dongji Island and extends Northwest to the Southeast side of the Cao Xiepo island then heads to Northwest to Goutou gate passing south water area of Da Jiashan anchorage. The north one starts from the west route of the You Caihua Island and extends Southwest to the Southeast side of the Cao Xiepo Island then connects the south route. At present, the water depth of the south line and the northern line is basically between 8 and 10 m, which can meet the needs of access of ship with 10000 GC.

### 3.2.1 Ships entering and departing Taizhou port

According to the statistical data of Taizhou MSA, ships entering and departing Taizhou port classified by ship type from 2006 to 2014 is listed by table 3.3.

Table 3.3: ships of entering and departing Taizhou port with classified by type of ship from 2006 to 2014

| Year | Cargo ship |                                     |              |                 |               |       |       | Tug  | Barge | Non-transp<br>ort<br>Ship | Summar<br>y |
|------|------------|-------------------------------------|--------------|-----------------|---------------|-------|-------|------|-------|---------------------------|-------------|
|      | Bunk<br>er | Lique<br>fied<br>gas<br>carrie<br>r | Chem<br>ical | Bulk<br>Carrier | Conta<br>iner | RO-RO | Other |      |       |                           |             |
| 2006 | 2649       | 97                                  | 861          | 2084            | 562           | 4468  | 37823 | 93   | 43    | 86                        | 48766       |
| 2007 | 3064       | 82                                  | 818          | 3400            | 273           | 2124  | 35393 | 1301 | 149   | 148                       | 46752       |

|      |       |     |      |       |      |       |        |      |     |      |        |
|------|-------|-----|------|-------|------|-------|--------|------|-----|------|--------|
| 2008 | 2769  | 53  | 769  | 3962  | 488  | 1937  | 31422  | 1049 | 86  | 119  | 42654  |
| 2009 | 3034  | 53  | 782  | 4562  | 479  | 6007  | 25930  | 880  | 74  | 163  | 41964  |
| 2010 | 3557  | 29  | 715  | 5099  | 765  | 6794  | 21836  | 1013 | 169 | 642  | 40619  |
| 2011 | 3475  | 35  | 537  | 5486  | 702  | 6008  | 20919  | 1020 | 57  | 284  | 38523  |
| 2012 | 1535  | 40  | 547  | 5530  | 588  | 5496  | 19403  | 341  | 47  | 1168 | 34695  |
| 2013 | 3013  | 32  | 545  | 5686  | 829  | 3320  | 19106  | 1089 | 75  | 574  | 34269  |
| 2014 | 3249  | 2   | 644  | 6032  | 508  | 4400  | 19900  | 782  | 30  | 644  | 36191  |
| Sum  | 26345 | 423 | 6218 | 41841 | 5194 | 40554 | 231732 | 7568 | 730 | 3828 | 364433 |

Source: Compiled by author to interpret statistics of Taizhou MSA

Statistical data for ships entering and departing Taizhou port classified by ship tonnage from 2006 to 2014 is listed by table 3.4. It can be seen that ships with gross tonnage less than 500 are dominant out of all ships entering and departing Taizhou port, of which 100 to 499 gross tonnage ships account for 55%. Hence, small and medium-sized ships are primary ships that enter and depart Taizhou port.

Table 3.4: ships of entering and departing Taizhou port with classified by gross tonnage of ship from 2006 to 2014

|      | 99 GT<br>and<br>below | 100 ~<br>499 | 500 ~<br>999 | 1,000 ~<br>2,999 | 3,000 ~<br>9,999 | 10,000 ~<br>49,999 | 50,000 and<br>above |
|------|-----------------------|--------------|--------------|------------------|------------------|--------------------|---------------------|
| 2006 | 12368                 | 25010        | 1468         | 7900             | 1993             | 27                 | 0                   |
| 2007 | 8243                  | 27192        | 849          | 8142             | 2177             | 146                | 4                   |
| 2008 | 6448                  | 25795        | 506          | 7195             | 2427             | 257                | 26                  |
| 2009 | 8227                  | 22756        | 486          | 7755             | 2395             | 296                | 49                  |



|         |       |        |      |       |       |      |     |
|---------|-------|--------|------|-------|-------|------|-----|
| 2010    | 7474  | 21550  | 437  | 8426  | 2318  | 372  | 42  |
| 2011    | 6492  | 20399  | 358  | 8621  | 2252  | 275  | 126 |
| 2012    | 6492  | 18304  | 172  | 9351  | 2015  | 206  | 150 |
| 2013    | 3629  | 19449  | 220  | 8805  | 1824  | 238  | 104 |
| 2014    | 4660  | 20410  | 114  | 8749  | 1813  | 354  | 91  |
| Summary | 64033 | 200865 | 4610 | 74944 | 19214 | 2171 | 592 |

Source: Compiled by author to interpret statistics of Taizhou MSA

### 3.2.2 Statistics of oil spill accidents in Taizhou port

From 2006 to 2014, there were 5 oil spill accidents that happened in the Taizhou port, including 4 shipwrecked accidents and 1 operational accidents. Among them, the "Hua Chen 27" collision occurred in 2006 which led to 187 tons of oil spilled into the sea, and there have been 2 accidents causing spilled oil more than 50 tons. It can be seen that with the trend of large-scale ships in Taizhou port, the risk of major oil spill accidents is increasing in this area, and the statistics of oil spill accidents in Taizhou port is shown in table 3.5.

Table 3.5: Statistics of oil spill accidents in Taizhou port from 2006 to 2014

|   | Date      | Location   | Attribution | Type of accident | Amount of spilled oil                |
|---|-----------|--|-------------|------------------|--------------------------------------|
| 1 | 21/3/2006 | Diaobing of Taizhou port                                 | Collision   | shipwrecked      | 187 tons                             |
| 2 | 8/4/2007  | About 7 nautical miles southeast of the Taizhou Islands  | Collision   | shipwrecked      | 50 tons-100 tons                     |
| 3 | 28/2/2008 | About 45 nautical miles southeast of the Taizhou Islands | Collision   | shipwrecked      | 10 tons                              |
| 4 | 13/3/2008 | About 15 nautical miles southeast of the Taizhou         | Sink        | shipwrecked      | 10 tons diesel<br>50 tons heavy fuel |

|   |          |  |                 |             |            |
|---|----------|--|-----------------|-------------|------------|
|   |          | Islands  |                 |             | oil        |
| 5 | 4/8/2008 | About 24 nautical miles<br>northeast of the Taizhou<br>Islands | Human<br>factor | operational | Few amount |

Source: :Compiled by author to interpret statistics of Taizhou MSA

### 3.3 Analysis on Allocation of Oil Spill Contingency Resource in Taizhou Port

#### 3.3.1 General requirements in Taizhou Port

At present, the oil spill contingency response force in the Taizhou port can effectively cope with the pollution incidents of ships within the coastal port area of Taizhou and offshore waters (12 nautical miles offshore). Oil spill contingency response force is distributed as follow: the capacity of oil spill comprehensive remove and control in one time shall reach 500 tons for the water area outside the port; the capacity of oil spill comprehensive remove and control shall reach 1500 tons for whole port area, in which, the capacity of Haimen port and Huangyan port shall reach 400 tons, and that of Linhai port, Wenling port, Da Maiyu port and Jiantiao port shall reach 300 tons , 300 tons, 300 tons, and 200 tons respectively. Under the circumstance of good sea or weather condition, the emergency response forces shall arrive at the pollution position in port area in 2-4 hours while they shall arrive at the pollution position outside port water area within 6 hours.

By 2020, an all-round coverage and rapid response marine environment contingency response system will be built, and the contingency response forces will cover all waters area in Taizhou port, Oil spill contingency response force is distributed as follow: the capacity of oil spill comprehensive remove and control in one time shall reach 1000 tons for the water area outside the port (Taizhou Municipal People's Government, 2014); the capacity of oil spill comprehensive remove and control shall reach 2000 tons for whole port area, in which, the capacity of Haimen port and Huangyan port shall reach 400 tons, and that of Linhai port, Wenling port, Da Maiyu port and Jiantiao port shall reach 500 tons , 400 tons, 400 tons, and 300 tons

respectively. Certain contingency response capacity for slow chemical leakage accidents shall be established. Under the circumstance of good sea or weather condition, the contingency response forces shall arrive the position in 2-4 hours no matter where the location of pollution.

### **3.3.2 Analysis on Oil Spill Contingency Resource in Taizhou Port**

In order to cope with the ship oil spilling risks in a terminal, the terminal organization shall prepare certain oil spilling contingency facilities and equipment. Based on the requirements listed in the Ship Pollution of the Marine Environment Risk Assessment Technical Specification (trial) (also known as Specification below), the port and terminal shall be equipped with the oil fences, spilled oil dispersant and adsorption materials and other related contingency materials which matches with the risk level. The oil spilling contingency materials supplied are to timely and effectively remove the spilled oil during the occurrence of the oil spilling accidents, reducing the economic losses and environmental pollution brought by the oil spilling to the sea. However, based on the actual situations in Taizhou area, the oil product terminal and the bulk cargo terminal are small in tonnage. Although each terminal is equipped with corresponding oil spilling contingency materials to guarantee that the whole jurisdiction area possesses a certain number of oil spilling contingency materials, corresponding large oil spilling contingency equipment are lacked to utilize these materials, and the shipyards in the jurisdiction area is also unable to have these materials independently; hence, if a large oil spilling contingency accident happens here, it is not possible to apply the terminal oil spilling contingency resources in a highly effective manner due to lack of large ship oil spilling contingency equipment, and therefore the oil spilling contingency capability is not built up. Therefore, except for ship oil spilling contingency materials supplied, large ship oil spilling contingency equipment and facilities are also required in Taizhou to improve the contingency capability of oil spilling.

In accordance with requirements of oil contingency plan, the Taizhou should be equipped with one oil product terminal for the professional floating oil recovery ship (the professional oil terminal in Liushuikeng, Shitang, Wenling is 5,000 DWT and 8,000 DWT); there are 66 terminals for shipyards, which are distributed in Jiaojiang River, Sanmen, Lingjiang, Wenling, Yuhuan, etc. Through analysis, large oil spilling contingency equipment should be provided in Taizhou; it can be derived that:

Several terminals in Sanmen, Jiaojiang River, Linhai and Wenling should be equipped with professional floating oil recovery ship. If each terminal is equipped with the ship independently, on one hand, it is unfulfillable due to the unbearable financial burden on the enterprise; on the other hand, the incidence rate of the ship oil spilling accidents is quite low, thus the resources will be wasted. If the professional floating oil recovery ship equipped by certain enterprise is used, and agreements are signed with other terminals, there are no extremely competitive large enterprises in Taizhou, so the ultimate outcome will still be the question "who will pay the equipment?" So, one leading force is needed to guide the terminals in the jurisdictional area to equip the large oil spilling equipment and facilities in a sharing style, and the corresponding oil spilling contingency material.

The deployment of the professional floating oil recovery ship is based on the seriousness of the risks of ship oil spilling, and the ship oil spilling risk of one region is different from the ship oil spilling risk of a single terminal, the former is higher than the latter, but the former is not the simple combination of the all the ship oil spilling risk factors of all the terminals. By merely depending on the oil spilling contingency resources equipped in the area, it is very difficult to realize the targeted capability to clean the spilled oil in comprehensive mode and one-time fashion, it is necessary to calculate the ship oil spilling risks of the area, and combined with the requirement of the one-time oil spilling comprehensive cleaning the corresponding large oil spilling contingency facilities and equipment and oil spilling contingency material are equipped to attain the effect that the region and even the whole

jurisdiction area can witness the buildup and improvement of oil spilling contingency disposal capability.

Therefore, several equipment sites for oil spill contingency, respectively invested by the government and the enterprises, could be set up in Taizhou port. The local government guides the establishment of the equipment sites, on the one hand, the government could make the contingency supplies for regional oil spilling be utilized reasonably through relying on and integrating enterprises' oil spilling contingency supplies, forming oil spilling contingency force to tackle the risk of ships' oil spilling in the whole area; on the other hand, enterprises can also tackle the risk of their own ships' oil spilling in the terminals through partially sharing the resources, thus alleviating enterprises' burden.

There are certain requirements for the construction of equipment sites for oil spilling contingency, and the details are as follows: 1. The capability of constructed equipment sites for oil spilling should cope with the risk of oil spilling for each and every terminals ship that shares such resource in the periphery of the equipment sites; 2. The capability of constructed equipment sites for oil spilling contingency should cope with the risk of ships' oil spilling in the whole shared area; 3. The capability of constructed equipment sites for oil spilling contingency shall meet the requirements over such area for reaching one-time cleaning capacity toward spilled oil.

## **CHAPTER 4**

### **RISK ANALYSIS OF SHIP OIL SPILL IN TAIZHOU PORT**

The establishment of certain quantity of preserve position for oil spill emergency equipment is not only to address the risk of oil spill from ships near the oil terminal, but also to deal with that in any region. Therefore, it is necessary to calculate and analyze the risk of oil spill from ships.

#### **4.1 Probability estimation of oil spill from ships**

The probability of oil spill accident in an area means Possibility of the possibility of oil spill accident in the region. The probability of oil spill accidents in different types of ships is various, similarly, every operation will cause different probability of oil spill accidents. Hence, it is necessary to research the probability of oil spill accident in an area to develop well-directed capability of oil spill contingency response and protect the area with high probability of oil spill.

##### **4.1.1 Mathematical Model of Probability Prediction of Ship Oil Spill Accident**

The probability of occurrence of oil spills in an area is very small, and the occurrence of oil spill between each vessel is an independent event. There are only two cases for each individual ship in the case of oil spill accident name occurrence and nonoccurrence, the occurrence of oil spill accident from any individual ship in a area means the occurrence of oil spill accident in the whole place. In mathematics, dispersed binomial distribution is introduced to calculate the number of occurrences of an event in several independent trials, hence, in this dissertation, the dispersed

binomial distribution is used to calculate the probability of occurrence of oil spills in an area.

Assuming that  $k$  times accidents occurred in the ships entering and departing the area, the probability of occurrence of the  $k$  times accidents is as follow:

$$P(x = k) = C_n^k p^k q^{n-k} \quad (4.1)$$

Where:  $P$  is the probability base value for each ship's oil spill accident (assuming that the calculated value of the ship's oil spill probability is consistent);

$q = 1 - p$  indicates the probability of nonoccurrence of oil spill from every ships

$C_n^k$  is the combined formula.

According to formula 4.1, the following two conclusions can be obtained:

$K = 0$  indicates that 0 ship out of  $n$  ships entering and departing the area were involved in an oil spill, which means there is no oil spill that occurred in the area.

$K \neq 0$  indicates that 1 or more ships out of  $n$  ships entering and departing the area were involved in an oil spill, which means there is oil spill that occurred in the area.

The process of calculating the probability of occurrence of oil spills in an area is how to calculate the probability if  $K \neq 0$  in the second conclusions based on formula 4.1. In this formula, the basic value  $p$  of the probability of oil spill accident in each ship is fundamental conditions, however, the calculation of  $P$  value is complicated, Poisson distribution will be introduced. In mathematics, Poisson distribution is suitable for describing the number of random events occurring per unit time. There is only one parameter  $\lambda$ , which is the mean of the Poisson distribution and the variance of the Poisson distribution.

The probability function of Poisson distribution is

$$P(X = k) = \frac{e^{-\lambda} \lambda^k}{k!} \quad (k = 0, 1, 2, \dots) \quad (4.2)$$

Where:  $\lambda$  is the average incidence of random events per unit time or unit area.

The relationship between the Poisson distribution and the binomial distribution is that when  $n$  is large and  $p$  is very small (usually when  $n \geq 10$ ,  $p \leq 0.1$ ), the binomial distribution can be approximated by the Poisson distribution and their relationship can be described as .

$$\lambda = np \quad (4.3)$$

Where:  $\lambda$  is the average incidence of random events per unit time or unit area,  $n$  is the ships entering and departing the area in binomial distribution and  $P$  is the probability base value for each ship's oil spill accident in binomial distribution.

For the calculation of the probability of oil spill accident in area, the ship oil spill accident is usually a small probability event due to the large number of ships entering and departing the area. Therefore, the Poisson distribution can be used to approximate the value of the oil spill probability. The probability of ship oil spill accident is calculated when  $k$  is 0, 1, ...,  $n$ , that is, the probability of occurrence of ship oil spill accident in the area from 0, 1 ...,  $n$ .

Furthermore, this method of the calculation is flexible, besides of probability of oil spill accident in area, many kinds of probability of oil spill can be calculated such as probability of oil spill occurred in a certain type of ship and the probability of a certain kind of oil spill accident as long as calculation of number for relevant ships with the unit time (normally one year). For instance, according to the cause of the accidents, the ship oil spill accidents are divided into two categories: operational oil spill accident and shipwrecked oil spill accident. The probability of oil spill for each kind of accidents can be calculated separately by this method.



The average incidence of random events per unit time or unit area( $\lambda$ ) is a vital data required for the calculation. However, if there is no ship oil spill in the area to be calculated, the calculation can not be carried out directly, but an expand for certain range of area is necessary (Assuming that the basic value of probability for oil spill in the area is the same), until there is oil spill accident data in the expansion area and then the indirect estimate can be conducted.

The calculation process of oil spill accident probability through the method of regional expansion is as follows: Assuming ships entering and departing of study area is  $n_1$  while the ships in expanded area is  $n_2$ , and the probability of oil spill from ships within 1 year is  $\lambda_2$ , then the probability of oil accident value in expanded area  $p_2$  shall be calculate firstly.

$$p_2 = \frac{\lambda_2}{n_2}$$

(4.4)

The  $P_2$  is used as the basic value of the ship's oil spill probability in the study area

$$p_1 = p_2 = \frac{\lambda_2}{n_2}$$

(4.5)

According to formula 4.3, the frequency of ship's oil spill occurring in a year in the study area is calculated as  $\lambda_1$ .

$$\lambda_1 = n_1 p_1$$

(4.6)

Then, the probability of oil spill from ships in the area can be calculate as

$$P(X = k) = \frac{e^{-\lambda_1} \lambda_1^k}{k!} \quad (k = 0, 1, 2, \dots)$$

(4.7)

#### 4.1.2 Probability Prediction of Ship Oil Spill Accidents in Taizhou Port

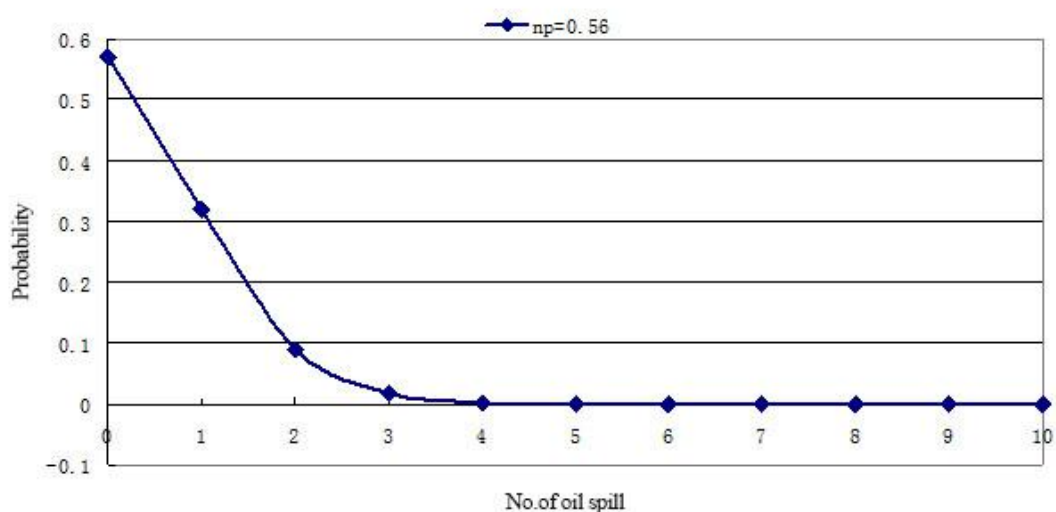
According to the above-mentioned mathematical model of regional ship oil spill accident probability, through investigating the relevant oil spill accidents data of the area, the probability of oil spill from ship in area can be calculated as well as the probability classified by the type of accident and the type of ship. The probability of ship oil spill accident could be calculated as follows:

According to statistics of Taizhou MSA, from 2006 to 2014 there are 5 oil spill accidents occurred Taizhou water area (Taizhou MSA, 2016), the number of ship spill incidents in each year could be calculated :

$$\lambda = \frac{5}{9} = 0.56$$

When  $\lambda$  is 0.56, according to the Poisson distribution map, the relationship between the number of annual ship oil spill accidents and its probability could be calculated and shown in in Figure 4.1

Figure4-1 relationship between the number of annual ship oil spill accidents and its probability in Taizhou Port.



Source: Compiled by author

According to Figure 4-1, the probability of oil spill in Taizhou area is about 0.57 per year, and the probability of 1 oil spill accidents is 0.32, and the probability of 2 oil spill accidents is 0.09. The most likely oil spill accident occurred every year is 1, and the most probable ship oil spill probability is 3 year.

## 4.2 Estimation of volume of oil spillage in Taizhou port

### 4.2.1 Probability Distribution of Volume of oil spillage

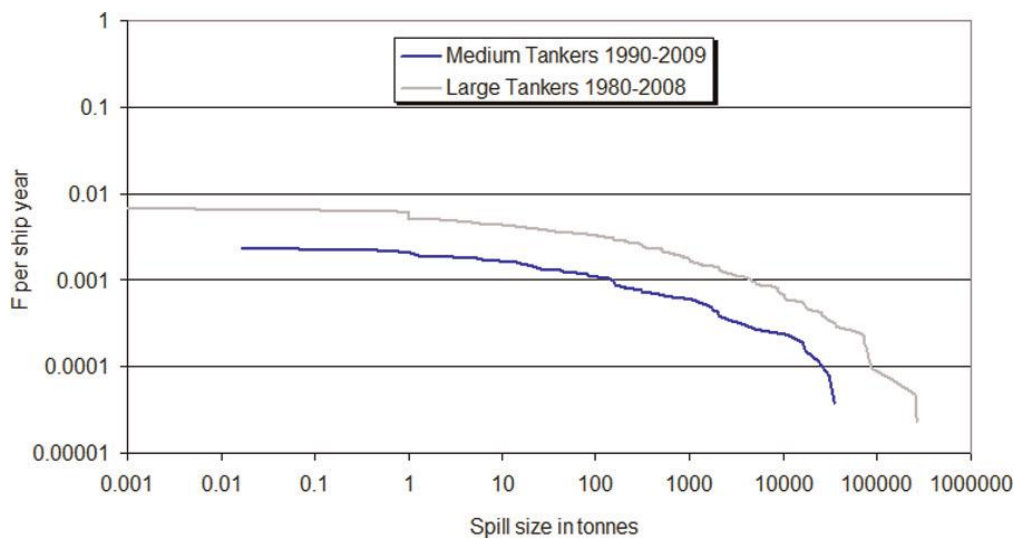
When the oil spill occurs, the volume of oil spilled is related to the type of ship and the tonnage of a ship. For a certain ship, the amount of oil spilled is uncertain and random. However, as shown by historical data of ship oil spill, it is generally that the proportion of accidents with small amount of oil spills is big while that with large amount of oil spill is small.

Generally speaking, when large bulk carrier or tanker hold cargo leaks, the amount of oil spilled are large while that is small in the event of operating oil spill accidents and some shipwrecked accidents. However, with the development of double hull bunker,

the probability of oil spills in large tankers and the amount of oil spills in the event of accidents are greatly reduced.

Some statistical analysis by experts have been carried out ,they are about oil spill accident of medium tankers from 1990 to 2009 and large tankers from 1980 to 2008(ITOPF,2009). Function distribution law about amount of spilled oil and the probability of occurrence of oil spill with that volume was introduced.

Figure4.2 The function distribution of oil spill volume and its occurrence probability



Source: compiled by author

It can be seen from Figure 4.2 that the probability of small oil is larger when the oil spill is oil spill, and the probability of occurrence of large oil spill is small, and the distribution of exponential distribution is the whole. Therefore, the method of exponential distribution was introduced to research the probability distribution of amount of spilled oil in an area when an oil spill occurs .

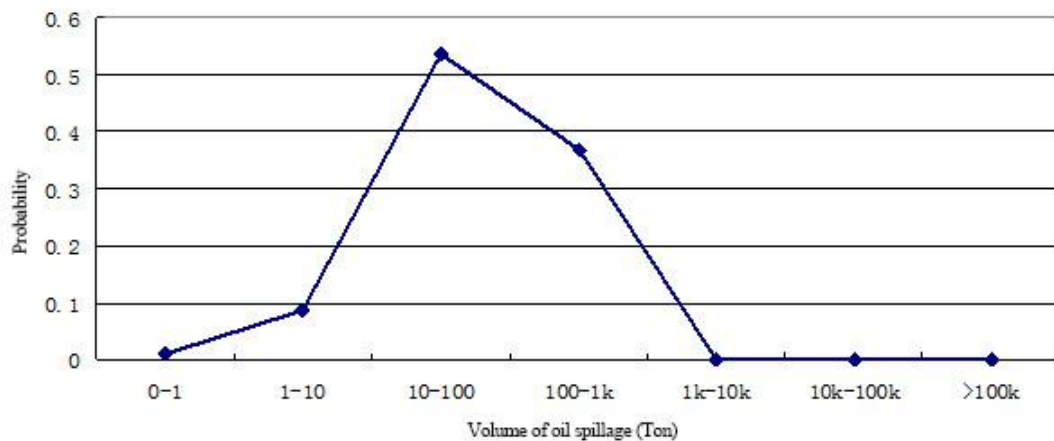
Assuming that the most likely amount of spilled oil from oil spill accident is  $\lambda$ , which means the expected value of the spilled oil amount is  $\lambda$ , in addition , the amount of spilled oil and the probability distribution of occurrence of oil spill

meet the exponential function distribution. Therefore, the probability of occurrence of oil spill with spilled oil amount  $x$  is described as:

$$p = 1 - e^{-\frac{1}{\lambda}x} \quad (3.8)$$

Specifically, it is assumed that the expected value of amount of oil spilled by one certain ship in a year is 100, which means  $\lambda$  is 100. The probability distribution of the oil spill accident with  $x$  amount of spilled oil is shown in figure 4.3. As the amount of spilled oil is continuous and is a random number between 0 and the maximum when oil spill accident occurs, the probability distribution of amount of spilled oil in a area can be calculated.

Figure 4.3: Interval for amount of spilled oil from ship and its oil spill probability distribution



Source: complied by author

#### 4.2.2 Probability Distribution of Volume of oil spillage in Divided Area

Oil spilling volume of the ships within such area mainly refers to the oil spilling volume occurs with a maximum probability within this area, identifying the

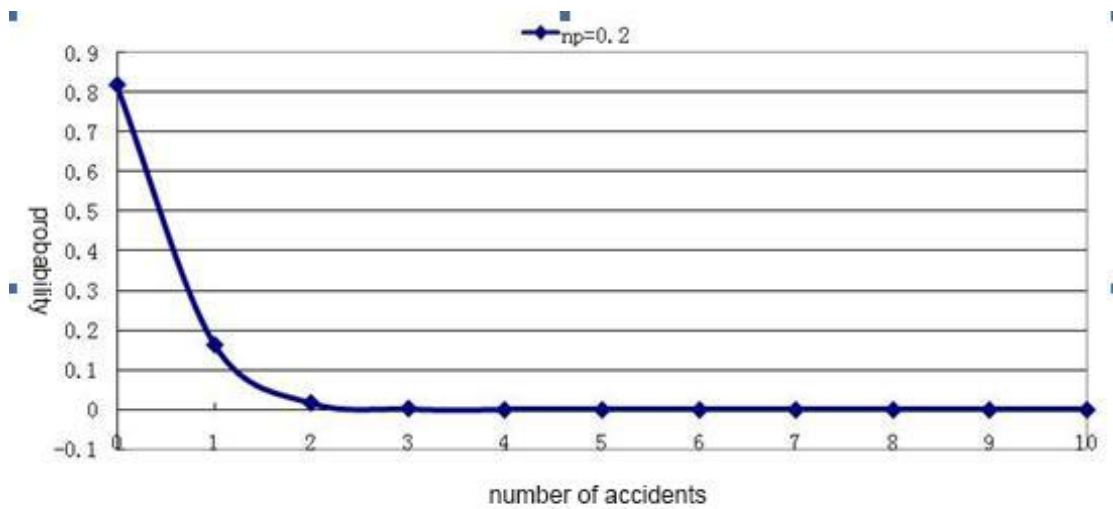
relationship between oil spilling volume and its probability of occurring oil spilling accident within the area through calculating the probability distribution of the ships' oil spilling volume within the area, which can provide scientific reference for ships' oil spilling within the area in terms of the development of contingency capacity, the supply of facility and equipment for oil spilling accidents.

There is a certain probability distribution of oil spilling volume when oil spilling occurs to ships within such area, utilizing the probability distribution function when the accident of oil spilling is happened to ships within such area, then the probability distribution of oil spilling volume within such area can be finalized. Suppose that an accident of ship's oil spilling is happened in some area in every 5 years, namely,  $\lambda$  is 0.2. Therefore, it is concluded that:

$$np=\lambda=0.2 \quad (4.9)$$

The distribution function between the No. of accident of ships' oil spilling occurred annually within such area can be drawn out according to the calculation of chapter 4, the details are shown in figure 4.4.

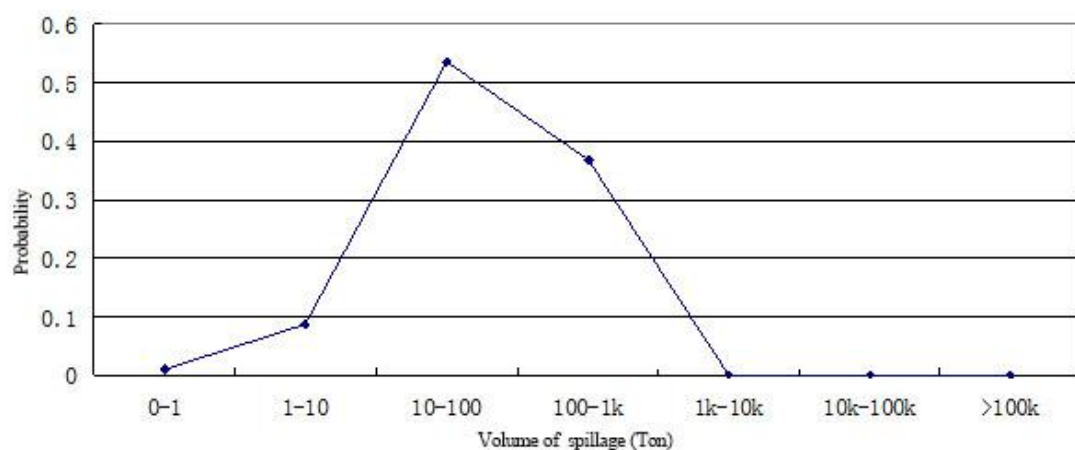
Figure4.4: The relationship figure between the number of ships' annual oil spilling accidents and probability within divided area



Source: complied by author

It is concluded from figure 4.4 that, when the No. of accident is 0, then the probability is 0.82, namely, the probability of not occurring the accident of ships' oil spilling is 0.82. Suppose that the expectation value of oil spilling volume for occurring ships' oil spilling within such area is 100, then the function relationship of probability distribution of oil spilling volume in oil spilling accident occurrence within such area is shown in figure 4. 5

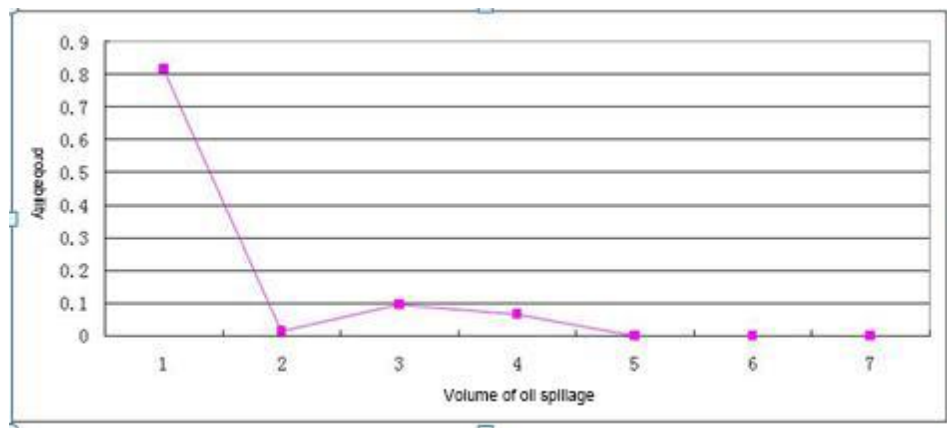
Figure 4.5 The probability distribution figure of oil spilling volume within divided area



Source: complied by author

The conclusion could be drawn by combining figure 4.4 and 4.5 that the probability distribution figure of regional oil spilling volume is shown in figure4.6.

Figure 4.6: The probability distribution figure of oil spilling volume within divided area



Source: complied by author

According to figure 4.6, the probability of oil spilling volume ranging between 0 and 1 ton is 0.82 within this area, yet the probability of oil spilling volume in other areas is very small. Therefore, spills oil occurring in such area is mainly with small volume. It can be taken as a preventive aim for oil spilling contingency within such area, so that corresponding contingency resources for oil spilling should be supplied.

Such calculation method is quite flexible, which can not only calculate the ships' oil spilling volume within some area and its corresponding probability distribution, but also purposely selects target ships, such as calculating respectively the probability distribution of oil spilling volume of oil ships, bulk carriers and general cargo ships within such area, and the probability distribution for oil spilling volume in accidents that occurred due to operational and shipwrecked reasons, etc. Providing proposals to administrations in charge and terminals for carrying out the establishment of contingency capacity to oil spill is based on demand to calculate its probability distribution of oil spilling volume.



## **CHAPTER 5**

### **OPTIMAL ALLOCATION OF OIL SPILL CONTINGENCY RESOURCES IN TAIZHOU PORT**

In order to develop effective capacity for divided regional oil spill contingency response, and reduce the pressure that local government and enterprises faced, certain quantity of preserve position for oil spill contingency equipment should be established in Taizhou Port, then, the terminals nearby should share the resources to achieve optimal allocation of oil spill contingency resources. The whole optimal process should comprise selecting location of preserve position for oil spill contingency equipment, the determination of the shared terminals and the calculation of the risk of oil spill in the shared area.

#### **5.1method of optimal allocation**

The reasonable area division of all oil spill contingency equipment supply points within Taizhou port shall be conducted in order to select the suitable location of the site and finalize its neighboring shared terminals. There are many methods of division, However, a relatively mature method of vague clustering have been introduced given that current data of Taizhou port at hand is relatively complete.

Clustering analysis is a kind of multiple analysis method in mathematical statistics, which quantitatively finalizes the sample's relationship of closeness or alienation with mathematical method, therefore objectively divides their types. Some of the boundaries among objects are definite, yet some are vague. When the clustering involves the vague boundary among objects, then the analytic method of vague clustering shall be applied.

FCM algorithm is one of the widest applied methods in vague clustering, which is based on the method of Ruspini's vague c-partition, whose idea is to make the maximum similarity of the targets divided into the same cluster, and minimum similarity of the targets in different cluster. The algorithm of vague average value C is an improvement to the algorithm of ordinary average value C, and the algorithm of ordinary average value C is rigid in terms of data partition, while FCM is a kind of flexible vague partition. The category of clustering in FCM can be set in advance, and it can also be automatically clustered according to the characteristics of the data. And the value function of FCM (or target function) is as followed:

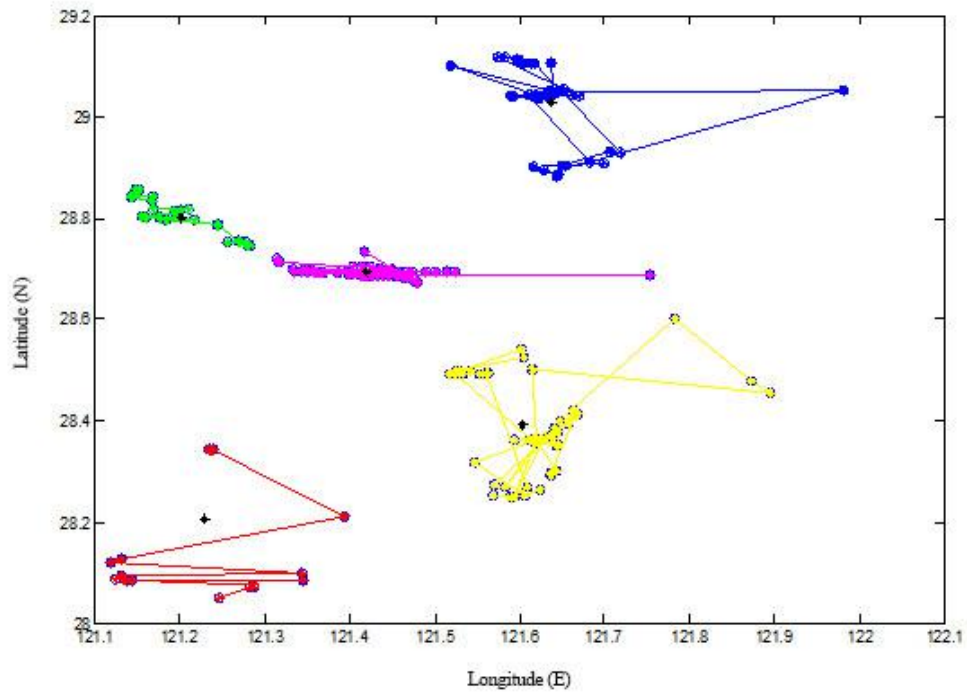
$$J(U, c_1, \dots, c_c) = \sum_{i=1}^c J_i = \sum_{i=1}^c \sum_j^n u_{ij}^m d_{ij}^2 \quad (5.2)$$

In this dissertation, the author adopts the method of dividing data into categories toward vague average value C, combining the information of terminals geographic location within Taizhou port to carry out the division over similar areas, finalizing the shared area's scope of oil spilling contingency resources .

## 5.2 The division of sharing area

According to the distribution of terminals in Taizhou area and the the development plan for Taizhou Port, the Taizhou port will be divided into 5 areas through fuzzy clustering method and the implementation of MATLAB software, and the result is shown in Figure 5.1.

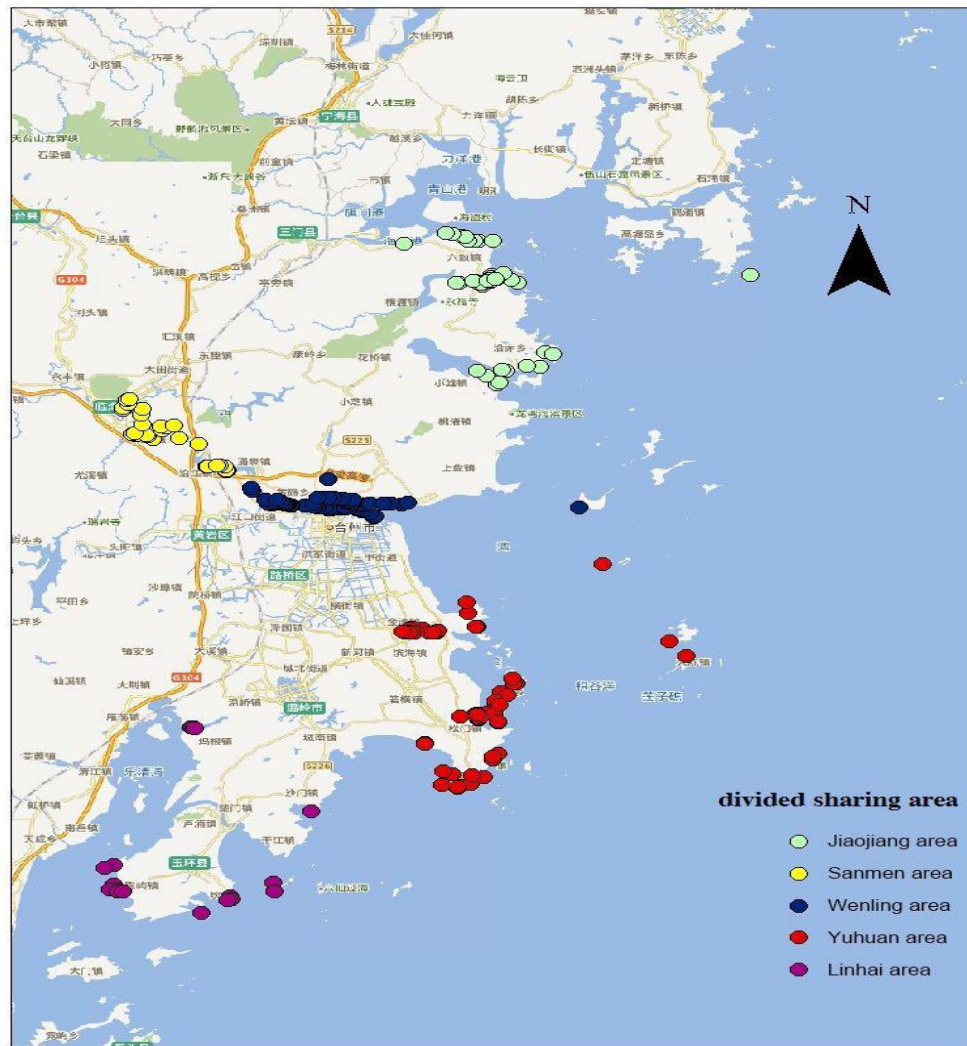
Figure5.1:Cluster analysis of terminals in Taizhou port



Source: complied by author

It can be seen from the above results, fuzzy clustering method can be used to find the optimal zoning based on the geographical characteristics of the terminal. The regional division is reasonable, in general, the terminals with close geographical location are classified in one area, otherwise, they are in different areas. Then, The MATLAB results map should be combined with actual map, the result will show in Figure 5.2.

Figure 5.2: Distribution map of terminals in Taizhou area



Source: complied by author

It can be seen from the chart that the five area of Taizhou port is divided according to the terminal location and the center point position. Obviously, there are certain differences with the administrative division, although the terminals belonging to the same administrative district are divided in the same area. As the center point is taken into consideration, the terminals in different administrative region may also be included with one shared area .

### 5.3 Calculation of oil spill risk from ships in shared area

The establishment of regional oil contingency response site is aiming to address the risk of oil spill in shared area. Therefore , it is necessary to calculate risk of oil spill in shared area and equip corresponding oil spill emergency facilities to form the emergency force in the shared area. However, there is a large number of terminals located in the shared area and each of them face the risk of oil spill. The risk of oil spill in shared area is not the summary of risk of every terminals, and the convolution calculation method is introduced to calculate it by taking the risk of oil spill of every terminals. Because there are more regional terminal and each terminal has a ship oil spill risk, regional oil spill risk is not the sum of every terminal ship oil spill risk, but the ship oil spill area risk is calculated according to each pier oil spill risk by means of convolution.

The process of convolution calculation is assuming that  $X$  ( $x=0,1,2,\dots$ ) represents the volume of oil spillage of terminal No. 1,  $Y$  ( $y=0,1,2,\dots$ ) indicates the volume of oil spillage of terminal No.2, and  $X$  and  $Y$  are discrete random variables, and they are independent of each other.  $Z=X+Y$  indicates the sum of the two terminals. Then the distribution function of  $Z$  is as:

$$P(Z = n) = \sum_{k=0}^n P(X = k)P(Y = n - k) \quad (n = 0,1,2,\dots; k = 0,1,2,\dots,n) \quad (5.3)$$

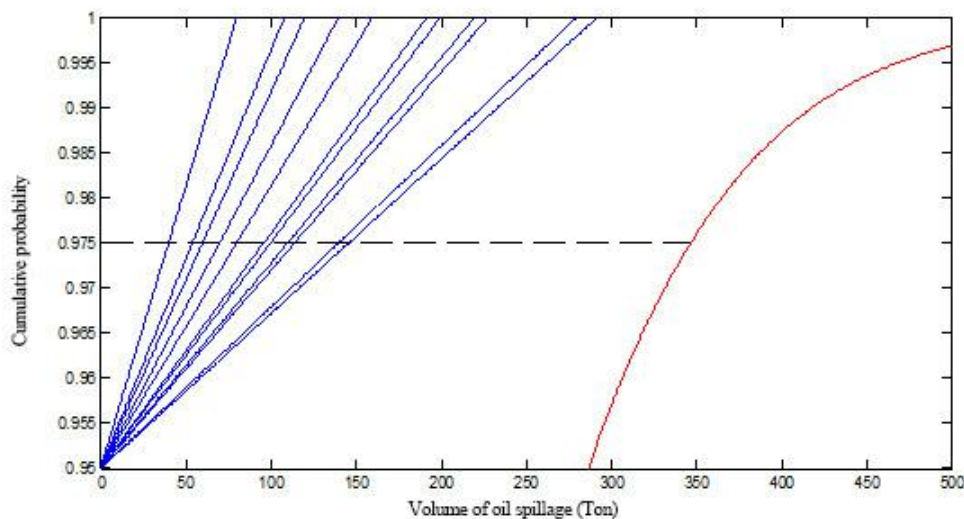
According to the above calculation methods, it can separately calculate the oil spill risk of Sanmen area, Linhai area, Jiaojiang area, Wenling area and Yuhuan area in Taizhou port.

The process of calculation method is as followed. Firstly, the most likely volume of spilled oil of the terminal shall be calculated according to its type and tonnage. Secondly, the probability of oil spill of each terminal need to be calculated. ( Because the regional division and port area division are different, the statistics of the ships entering and departing port is hard to conduct. In addition, since the probability of the ship oil spill accident is small , the probability of oil spill is 0.05 in

this dissertation). Finally, the risk of oil spill from ships in sharing area shall be calculated by the method of convolution calculation in accordance with probability of oil spill and most likely volume of spilled oil of each terminals.

According to statistics, there are 46 terminals in Sanmen area, and the most likely volume of spilled oil in area is 347 tons while the most likely volume of spilled oil of each terminal is shown in appendix(take the probability as 0.975).The results is shown in figure 5.3.

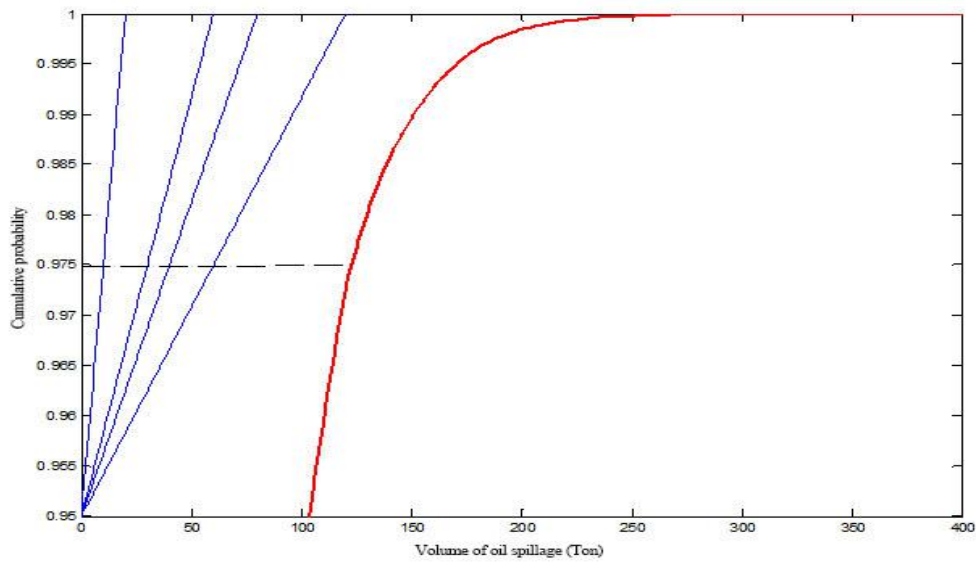
Figure 5-3:The most likely volume of spilled oil in whole area and at terminal in Sanmen area



Source: complied by author

There are 33 terminals in Linhai area, and the most likely volume of spilled oil in area is 129 tons while the most likely volume of spilled oil of each terminal is shown in appendix(take the probability as 0.975).The results is shown in figure5.4

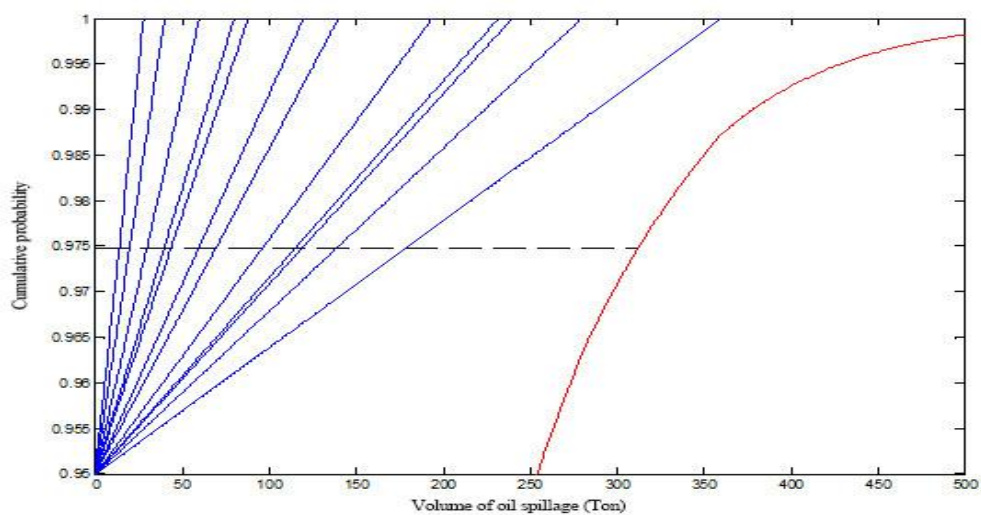
Figure 5.4: The most likely volume of spilled oil in whole area and at terminal in Linhai area



Source: complied by author

There are 84 terminals in Jiaojiang area, and the most likely volume of spilled oil in area is 129 tons while the most likely volume of spilled oil of each terminal is shown in appendix(take the probability as 0.975).The results is shown in figure 5.5.

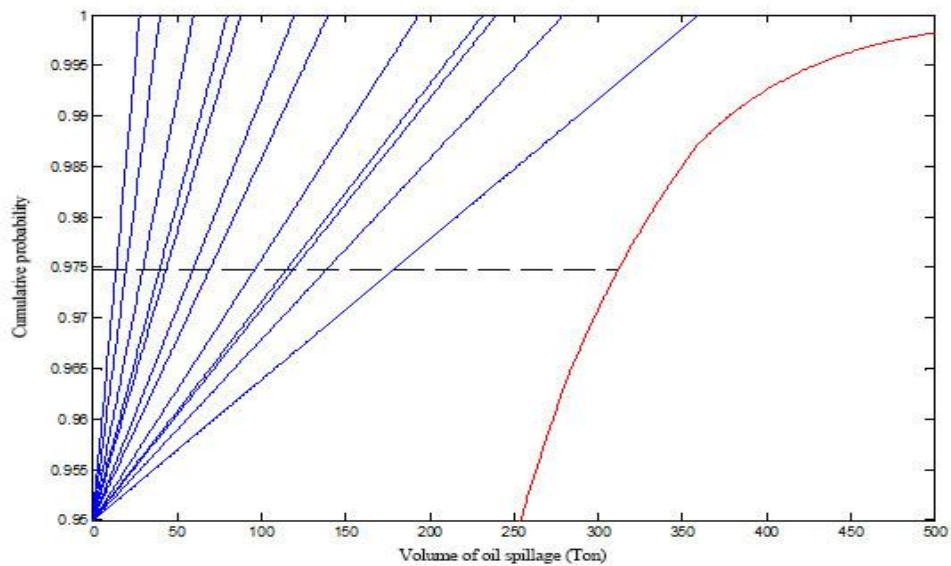
Figure 5.5: the most likely volume of spilled oil in whole area and at terminal in Jiaojiang area



Source: complied by author

There are 69 terminals in Wenling area, and the most likely volume of spilled oil in area is 313 tons while the most likely volume of spilled oil of each terminal is shown in appendix(take the probability as 0.975).The results is shown in figure 5.6.

Figure 5.6: the most likely volume of spilled oil in whole area and at terminal in Wenling area

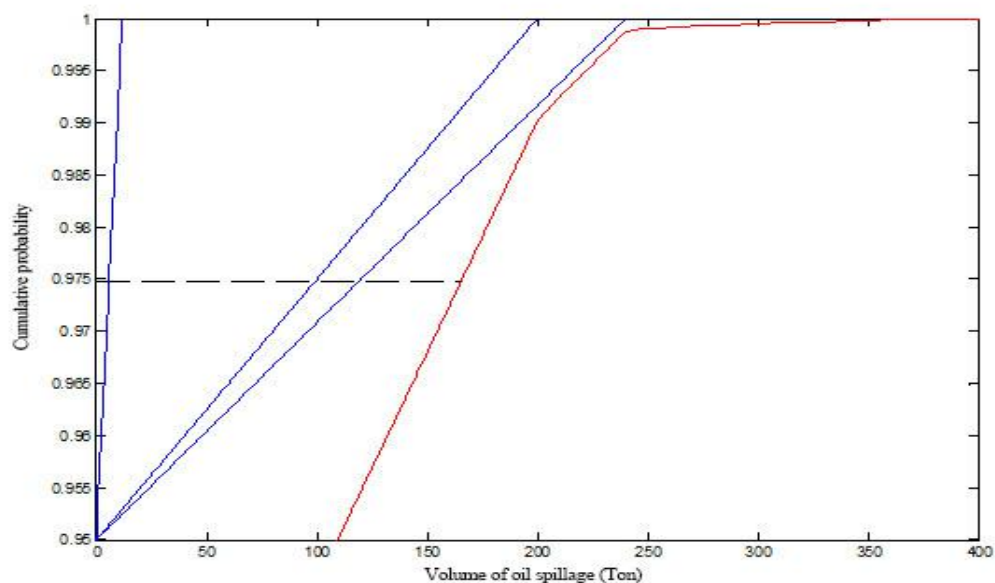


Source: complied by author

There are 25 terminals in Yuhuan area, and the most likely volume of spilled oil in area is 129 tons while the most likely volume of spilled oil of each terminal is shown in appendix(take the probability as 0.975).The results is shown in figure 5.7.

Figure 5.7:the most likely volume of spilled oil in whole area and at terminal in Yuhuan area





Source: complied by author

Table5.1: the most likely volume of spilled oil in whole area of 5 areas in Taizhou port

| area               | The summary of most likely volume of spilled oil at terminals(tons) | the most likely volume of spilled oil in whole area(tons) |
|--------------------|---|---|
| Sanmen area        | 3460  | 347   |
| Linhai area        | 1040  | 129   |
| Jiaojiang Area     | 4119  | 400   |
| Wenling Area       | 3960  | 313   |
| Yuhuan Area        | 2017  | 166   |
| Whole Taizhou area | 14596   | 709   |

Source: complied by author

According to the the most likely volume of spilled oil in whole area, the the resources for oil spill contingency response shall be equipped.The cost of purchase and management those equipment shall be paid by terminals in area in accordance

with the proportion of the risk of terminal of that in whole area. Taking Sanmen area as example, the most probable volume of oil spillage of each terminals and their sharing cost is shown in table 5.2

Table 5.2: the most probable volume of oil spillage of each terminals and their sharing cost in Sanmen area

| <b>Terminals</b>                   | <b>Location</b> | <b>Tonnage</b> | <b>Most probable oil spillage(ton)</b> | <b>Cost sharing</b> |
|------------------------------------|-----------------|----------------|--|---------------------|
| Sanmen Qianghui Shipping Co.       | Sanmen area     | 40000          | 160                                    | 4.62%               |
| Taixin shipping Co.                | Sanmen area     | 35000          | 140                                    | 4.05%               |
| Zhejiang Qinfeng Shipping Co.      | Sanmen area     | 50000          | 200                                    | 5.78%               |
| Zhejiang Chaoyu shipbuilding Co.   | Sanmen area     | 40000          | 160                                    | 4.62%               |
| Taizhou Zhongzhou shipbuilding Co. | Sanmen area     | 30000          | 120                                    | 3.47%               |
| Zhejiang Kaihang shipping Co.      | Sanmen area     | 73000          | 292                                    | 8.44%               |
| Zhejiang Zhongbo shipping Co.      | Sanmen area     | 100000         | 200                                    | 5.78%               |
| Zhejiang Fengyuan shipping Co.     | Sanmen area     | 48000          | 192                                    | 5.55%               |
| Zhejiang Jiuzhou shipping Co.      | Sanmen area     | 50000          | 200                                    | 5.78%               |

|                                    |             |       |     |       |
|------------------------------------|-------------|-------|-----|-------|
| Zhejiang Chengzhou shipping Co.    | Sanmen area | 57000 | 228 | 6.59% |
| Taizhou Jinmao shipbuilding Co.    | Sanmen area | 70000 | 280 | 8.09% |
| Binhai shipbuilding Co.            | Sanmen area | 20000 | 80  | 2.31% |
| Zhejiang Taida shipbuilding Co.    | Sanmen area | 30000 | 120 | 3.47% |
| Zhejiang Haihang shipbuilding Co.  | Sanmen area | 30000 | 120 | 3.47% |
| Zhejiang Youhao shipbuilding Co.   | Sanmen area | 70000 | 280 | 8.09% |
| Zhejiang Taihang shipbuilding Co.  | Sanmen area | 40000 | 160 | 4.62% |
| Zhejiang Jiantiao shipbuilding Co. | Sanmen area | 55000 | 220 | 6.36% |
| Sanmen Jiantiao shipyard Co.       | Sanmen area | 27000 | 108 | 3.12% |
| Sanmen multipurpose terminal       | Sanmen area | 5000  | 50  | 1.45% |
| Jinmao shipyard No.1 terminal      | Sanmen area | 10000 | 40  | 1.16% |
| Jinmao shipyard No.2 terminal      | Sanmen area | 5000  | 20  | 0.58% |
| Jiaotiao shipyard No.1 terminal    | Sanmen area | 10000 | 40  | 1.16% |
| Nuclear power plant                | Sanmen area | 5000  | 50  | 1.45% |

Source: complied by author

It can be seen that the sum of the most probable volume of spilled oil of all the terminals in the Sanmen area and the most likely volume of spilled oil in whole area is 347 tons. The cost of establishment of oil spill contingency site can be calculated by the following formula:

$$x = \frac{q_T}{Q_{\text{sum}}}$$

Where: X takes the proportion of the investment management cost of the regional oil spill contingency supply site for a single terminal, the qt is the most likely volume of spilled oil of the terminal; Qsum is the sum of the most probable volume of spilled oil of all the terminals in the area.

In this way, it can calculate the proportion of the investment management cost of other terminals and finally calculate the proportion of the cost of each terminals in the whole area . (see Appendix).

## **5.4 Model of oil spill contingency resources allocation and management in Taizhou port**

### **5.4.1The Provision and Management Mode of Oil Spill Contingency Resources**

The allocation methods of oil spill contingency resources in Taizhou port may be adopted as centralized equipment by some resources and distributed equipment by others. The centralized oil spill contingency resources should include contingency unloading equipment, oil fence laying boats, contingency oil fence, professional oil recovery ship, oil recovery machine, part of oil spill dispersant and adsorption material (taking into account the terminal unit shall be equipped with a certain oil spill dispersant and adsorption material to deal with accident with small amount of oil spillage , 1/3 dispersant and adsorption materials of all shall be distributed to each terminal while the other 2/3 dispersion method and adsorption are centralized), and large oil spill dispersant spraying device.

The distributed oil spill contingency resources should include the permanent type of oil fence (for oil terminal), part of oil spill dispersant and adsorption material ( 1/3 dispersant and adsorption materials of all to deal with accident with small amount of oil spillage) ,and proper oil spill dispersant spraying device. The centralized oil spill contingency resources shall be available on oil spill position in 2 to 4 hours due to the limit time for response of oil spill accident.

The frequency of use of oil spill contingency resource is generally low due to them only used in the event of oil pollution accident. Hence, better management and maintenance of the resources is an important part to ensure the capability of oil spill contingency response in good condition. The oil spill contingency resources are distributed to deal with the possible risk of oil spill in the daily production of the terminal. Therefore, each terminal should be equipped independently and maintain the allocated oil spill contingency resources to ensure the oil spill contingency supplies valid and the oil spill contingency facilities are available at any time. However, the centralized oil spill contingency resources is in high quantity and is shared by all the terminals in the region, they shall be maintained and managed professionally.

Therefore, the dissertation mainly focuses on the allocation, maintenance and management of centralized oil spill contingency resources. The manager of the resource shall be selected in accordance with the following standard:

All the terminals in divided area are in small scale and there is no unit that can undertake the allocation, management and maintenance of the centralized oil spill contingency resources. In this case, it is suggested that qualified oil pollution cleaning company perform the duty of allocation, management and maintenance, and they charges a certain amount of management fee to the terminals in the region every year.

There is large scale terminal in divided area which has purchased some large oil spill contingency facilities and equipment (such as spilled oil cleaning boat etc.), and have

the capable ability to allocate, manage and maintain the centralized oil spill contingency resources. Then it should be considered as shared supply point and manager.

#### **5.4.2 Establishment and management mode of oil spill contingency response team**

The equipment of oil spill contingency facilities and equipment is aiming to solve oil spill risk from ships in shared area, and only the reasonable and efficient use of oil spill contingency facilities and equipment is the formation of ability of oil spill contingency response in area. The oil spill contingency response team will quickly and orderly use oil spill contingency facilities and take active and effective measures to deal with the oil spill pollution through professional training. Hence, it is necessary to establish a regional oil spill contingency response team, and its ability is highly related to the regional oil spill response efficiency. In Taizhou port, beside the equipment of related oil spill facilities which match the risk of oil spill, capable oil spill contingency response team shall be established.

The establishment of a professional and capable oil spill response team will require substantial manpower, material resources and financial resource, including recruitment of quality of personnel with the basic skills for oil spills, professional oil spill contingency training, and constant oil spill contingency drills. However, the frequency of oil spill accidents is not high, and it is a waste to establish professional oil spill response team in each divided area. Actually the oil spill response team can arrive at the oil spill site by any means of transportation. Therefore, in the Taizhou port, as long as the oil spill contingency equipment is adequate in pollution area, the response team can quickly reach the scene of oil spill to participate in contingency activities in any area.

Oil spill response team need oil spill contingency resource and facilities to carry out daily training. But the terminals in Taizhou port are in different circumstances, and any qualified oil pollution cleaning company or certain terminal could be considered

as manager of the contingency resource. In theory, the establishment of a professional team in Taizhou port can meet the requirements of contingency response, However, for the sake of convenient operation, it is recommended that the oil spill contingency team should be established in the manner of centralized oil spill contingency resources.

The management contingency team should also be carried out by the manager of centralized oil spill contingency resources which should develop a corresponding oil spill contingency plan to and participate in spill training courses in the maritime administration or other specialized companies. Similar with the distribution of costs of oil spill contingency resource, the cost of establishment and management of the oil spill contingent team can be calculated by the manager, and it should be paid by terminals in the area according to their respective ship oil spill risk. As for the contingency personnel scattered in the various terminals, they should be recruited and managed according to oil spill contingency plans of every terminals.

#### **5.4.3 Development of oil spill contingency plan**

In the event of an oil spill accident, the reasonable contingency plan for oil spills can effectively guide oil spill contingency activities carried out properly, including how to report to the relevant departments quickly after receiving the accident report and how to adopt a positive and effective response procedure (Jaime Lima ,Flávio Diniz 2015). Therefore, all divided region should lay out detailed contingency plan for oil spills and report to the local maritime authorities. A reasonable contingency plan shall be clearly defined as follows:

Clearly division of organization and related responsibilities, Clarify clear leadership at contingency , command agencies, composition of the staff and the division of responsibilities of personnel in the organization of daily management , and the lists of the contact details of internal contingency personnel .

Internal and external reporting procedure. The plan shall stipulate procedures and contents of the internal reporting process, specify the requirements and procedures of the external reports, and list the contact ways of the external reporting units such as maritime administration.

Contingency response procedures. The plan shall define the contingency response actions of each contingency department in different levels of oil spill accidents.

List of the existing oil spill contingency equipment and attach the location map of contingency storage room at terminal.

List the detailed contact ways of the other contingency departments so as to timely call the external contingency resources for assistance and mitigate the consequences after the accident

List the detailed contact ways of the sensitive resource managers nearby, and build effective and daily contact mechanism, so as to notify the affected sensitive resource manager to take effective countermeasures in time in the event of oil spill pollution accident .

The purpose of Optimal allocation of oil spill contingency resources in Taizhou port is to effectively use the regional oil spill contingency resources to improve oil spill contingency response force to deal with the possible risk of oil spills in the area. There are numerous terminals in Taizhou port but with small size overall. Equipment of oil spill contingency resources for every individual terminal will cause waste of resources ,for instance, some vulnerable contingency resource as spilled oil dispersant will be equipped repetitively. Furthermore, due to large oil spill contingency equipment is insufficient, it is difficult to use them effectively and rapidly in the event of oil spills to built high-performance contingency forces.



## **CHAPTER 6**

### **CONCLUSIONS AND PROPOSALS**

In this dissertation, actual situation of terminals in Taizhou Port and the risk of ship oil spill in area have been analyzed, and environmental condition of Taizhou area of the terminal characteristics are fully considered. Reasonable divided area have been presented based on the the principle of efficient use of resources and the funds saving. Taizhou port will be divide into 5 areas, and Oil spill contingency equipment supply point will be established in each areas, then the oil spill contingency resources will be shared by terminals in the divided area. On one hand, The relevant companies can save allocation cost by sharing the oil spill contingency resources. On the other hand, The local government can deliver joint invest with relevant companies to built oil spill contingency equipment supply points to make reasonable use of the oil spill contingency resources. In this way, the oil spill response resources in a whole area will be used to address the probable risk of oil spill by ships in area and improve contingency response capability of oil spilling by ships.

proposals:

According to the regional oil spill risk, the local government should guide relevant enterprises to supply regional oil spill contingency equipment, provide corresponding oil spill contingency facilities and establish contingency response teams, and adopt oil spill contingency plan. The regional oil spill contingency equipment supply point can not only cope with the risk of oil spill at terminals, but also deal with the risk of oil spill from ships in whole area.

The costs of establishment and management of regional oil spill contingency equipment supply point should be shared. Part of it should be allowance by local government and the rest should be provided by relevant companies in accordance with the percentage of their own risk of oil spill from ships accounted for the sum of risk of oil spill from ships of all terminals in whole area. Correspondingly, The income arising from participation of supply points in oil spill contingency response activities shall be allocated according to the distribution proportion.

## Reference

- Badri, M. A., & Azimian, A. R. (2010). Oil spill model based on the kelvin wave theory and artificial wind field for the persian gulf. *Indian Journal of Geo-Marine Sciences*, 39(2), 165-181.
- Bai Jiayu. (2010). Discussion on emergency response mechanism of oil spill in Britain. *Ocean Development and Management*, 27(10), 62-65.
- Bermingham, G., Oldham, K., & Quinn, N. (2011). National marine oil spill risk assessment - use of interactive tools to move beyond classical risk assessment. , 2011(1), abs412.
- Boufadel, M., Li, H., & Sharifi, Y. (2009). The Role of Hydrology in the Persistence of the Exxon Valdez Oil Spill. *AGU Fall Meeting*. AGU Fall Meeting Abstracts.
- Chen Xuan, Geng Hong. (2011). Brief introduction and Inspiration of international oil spill Conference (IOSC) in 2011. *Annual Science Conference on pollution prevention of ships*
- Ding, W. P., Xu, J., & Zheng, P. J. (2014). Optimal allocation of professional oil recovery ships in port areas. *Advanced Materials Research*, 869-870, 338-342.
- DS Etkin.(2000).Worldwide analysis of marine oil spill cleanup cost factors. In: Proceedings of the 23rd Arctic and Marine Oilspill Program Technical Seminar, June 14-16, Vancouver, British Columbia
- Eide, M. S., Endresen, O., Breivik, O., Brude, O. W., Ellingsen, I. H., & Røang, K., et al. (2007). Prevention of oil spill from shipping by modelling of dynamic risk. *Marine Pollution Bulletin*, 54(10), 1619-33.
- Gao Yali. (2015). *Study on method and application of risk classification and zoning for marine oil spill pollution*. Dalian Maritime University. Dalian. China
- Goerlandt, F., & Montewka, J. (2015). A framework for risk analysis of maritime transportation systems: a case study for oil spill from tankers in a ship-ship collision. *Safety Science*, 76, 42-66.
- Goodman, R. (1994). Overview and future trends in oil spill remote sensing. *Spill Science & Technology Bulletin*, 1(1), 11-21.
- Henkel, J. R., Sigel, B. J., & Taylor, C. M. (2012). Large-scale impacts of the deepwater horizon oil spill: can local disturbance affect distant ecosystems through migratory shorebirds?. *Bioscience*, 62(7), 676-685.
- Huang Yixin. (2015). Discussion on ship oil pollution and its compensation. *Pearl River Water Transport* (12), 82-83.

- IMO.(1990) International Convention on Oil Pollution Preparedness, Response and Co-operation 1990. IMO, 1990
- ITOPF. (2009):*OIL TANKER SPILL STATISTICS: 2009*. The International Tanker Owners Pollution Federation Limited,London:author
- ITOPF. (2010). *Effects of Oil Pollution on Fisheries and Mariculture*. The International Tanker Owners Pollution Federation Limited,London:author
- Jaime Lima,Flávio Diniz( 2015) Environmental risk assessment results for oil spill preparedness IEPICCA: Parts I and II. Results from risk assessment to oil spill response planning
- Jiao Junchao. (2011). *Research on oil spill prediction system of Bohai Bay based on GIS* . Ocean University of China.Qingdao.China
- Johnson, W. R., Ji, Z. G., & Lear, E. M. (2007). Oil-spill risk analysis: contingency planning statistics for gulf of mexico ocs activities in the walker ridge planning area.
- Ketkar, K. W. (1995). Protection of marine resources: the us oil pollution act of 1990 and the future of the maritime industry ☆. *Marine Policy*,19(5), 391-400.
- Konkel, R. S. (1987). Risk management in the united states: three case studies : liquified natural gas: spectre of a marine spill in boston harbor.*Environmental Impact Assessment Review*, 7(1), 57-65.
- Lawrence, A., Hemingway, K. L (2003). *Effects of Pollution on Fish: Molecular Effects and Population Responses*. Oxford: Wiley-Blackwell.
- Li, G. W. S., Barnthouse, L. W., & O'Neill, R. V. (1987). Treatment of risk in environmental impact assessment. *Environmental Management*, 11(3), 295-303.
- Li, X. F., & Yang, Y. G. (2013). Discussion of the key factors in oil spill risk prevention in offshore oilfield development. *Advanced Materials Research*, 655-657(655-657), 2216-2219.
- Łukasz Jankowski, Koźlak, J., & Żabińska, M. (2011). Oil spill response information system and contingency planning for guinean waters.*Procedia Environmental Sciences*, 11(Part B), 693-700.
- Michel, J., Owens, E. H., Zengel, S., Graham, A., Nixon, Z., & Allard, T., et al. (2013). Extent and degree of shoreline oiling: deepwater horizon oil spill, gulf of mexico, usa. *Plos One*, 8(6), e65087.
- Neves, A. A. S., Pinardi, N., Martins, F., Janeiro, J., Samaras, A., & Zodiatis, G., et al. (2015). Towards a common oil spill risk assessment framework – adapting

- iso 31000 and addressing uncertainties. *Journal of Environmental Management*, 159, 158.
- Oil-Spill Risk Analysis: Gulf of Mexico Outer Continental Shelf (OCS) Lease Sales, Central Planning Area and Western Planning Area, 2007-2012, and Gulfwide OCS Program, 2007-2046[R], 2007
- Psarros, G., Skjong, R., & Vanem, E. (2011). Risk acceptance criterion for tanker oil spill risk reduction measures. *Marine Pollution Bulletin*, 62(1), 116.
- Price, J. M., Johnson, W. R., Marshall, C. F., Ji, Z. G., & Rainey, G. B. (2003). Overview of the oil spill risk analysis (osra) model for environmental impact assessment. *Spill Science & Technology Bulletin*, 8(5-6), 529-533.
- Price, J. M., Johnson, W. R., Ji, Z. G., Marshall, C. F., & Rainey, G. B. (2004). Sensitivity testing for improved efficiency of a statistical oil-spill risk analysis model. *Environmental Modelling & Software*, 19(7), 671-679.
- Qiu Pinbin. (2011). *Risk assessment of ship oil spill pollution accident in Xiamen Bay*. Dalian Maritime University. Dalian. China
- Raphael Baumler. (2017). *Human Factors in Maritime Safety*. Unpublished lecture handout, World Maritime University, Malmö, Sweden.
- Reed, M., Aamo, O. M., & Daling, P. S. (1995). Quantitative analysis of alternate oil spill response strategies using oscar. *Spill Science & Technology Bulletin*, 2(1), 67-74.
- Santoli, L. D., Cumo, F., Garcia, D. A., & Bruschi, D. (2011). Coastal and marine impact assesment for the development of an oil spill contingency plan: the case study of the east coast of sicily. *Wit Transactions on Ecology & the Environment*, 3(1), 42-50.
- Smith, R. A., Slack, J. R., Wyant, T., & Lanfear, K. J. (1982). Oilspill risk analysis model of the us geological survey. *Annals of the New York Academy of Sciences*, 502(5), 205-215.
- State Environmental Protection Administration of China(2007), *Technical Evaluation Report on Environmental Impact Assessment of Port Construction Project*, State Environmental Protection Administration of China, 2007, Beijing: Author
- Stewart, T. R., & Leschine, T. M. (2010). Judgment and analysis in oil spill risk assessment. *Risk Analysis*, 6(3), 305-315.
- Taizhou MSA. (2016). *Analysis of Taizhou port of 2015*. Unpublished report,

Taizhou Maritime Administration, Taizhou, China.

Taizhou Municipal People's Government(2014), *Plan for the construction of contingency capacity for marine pollution prevention of ships and their related operations in Taizhou City (2014-2020)*, Taizhou Municipal People's Government,Taizhou:Author

Ulusçu, O. S., Ozbaş, B., Altıok, T., & Or, I. (2009). Risk analysis of the vessel traffic in the strait of istanbul. *Risk Analysis*, 29(10), 1454.

Ventikos, N. P., & Sotiropoulos, F. S. (2014). Disutility analysis of oil spills: graphs and trends. *Marine Pollution Bulletin*, 81(1), 116-23.

Walker, A. H., Pavia, R., Bostrom, A., Leschine, T. M., & Starbird, K. (2015). Communication practices for oil spills: stakeholder engagement during preparedness and response. *Human & Ecological Risk Assessment An International Journal*, 21(3), 667-690.

Xi Fenghua. (2009). *Oil Spill Risk Evaluation of Tankers*. Wuhan University of Technology .Wuhan.China.

Yim, U. H., Kim, M., Ha, S. Y., Kim, S., & Shim, W. J. (2012). Oil spill environmental forensics: the hebei spirit oil spill case. *Environmental Science & Technology*, 46(12), 6431.

Yu Quanbo. (2011). Risk analysis and Management Countermeasures of oil spill in port water areas. *China water transport monthly journal*,11(2), 19-20.

Zhao Guanghui. (2010). Analysis and Countermeasures of pollution prevention by oil pollution from ships in China. *China water transport monthly*,10(3), 22-24.

Zhang Quan. (2014). Analysis of human factors in oil spill. *Water Transport Management*, 36(12), 23-26.

Zhu Shulin. (2011). Influence and treatment analysis of oil spill at sea. *Navigation*(4), 54-56.

## Appendix :

### the risk of oil spill of each terminals and their sharing cost in Taizhou area

### The risk of oil spill of each terminals and their sharing cost in Sanmen area

| Terminal                           | Port belonging | Tonnage | Most probable oil spillage(ton) | Probability of oil spill | area        | Proportion of sharing cost |
|------------------------------------|----------------|---------|---------------------------------|--------------------------|-------------|----------------------------|
| Sanmen Qianghui Shipping Co.       | Sanmen area    | 40000   | 160                             | 0.05                     | Sanmen area | 4.62%                      |
| Taixin shipping Co.                | Sanmen area    | 35000   | 140                             | 0.05                     | Sanmen area | 4.05%                      |
| Zhejiang Qinfeng Shipping Co.      | Sanmen area    | 50000   | 200                             | 0.05                     | Sanmen area | 5.78%                      |
| Zhejiang Chaoyu shipbuilding Co.   | Sanmen area    | 40000   | 160                             | 0.05                     | Sanmen area | 4.62%                      |
| Taizhou Zhongzhou shipbuilding Co. | Sanmen area    | 30000   | 120                             | 0.05                     | Sanmen area | 3.47%                      |
| Zhejiang Kaihang shipping Co.      | Sanmen area    | 73000   | 292                             | 0.05                     | Sanmen area | 8.44%                      |
| Zhejiang Zhongbo shipping Co.      | Sanmen area    | 100000  | 200                             | 0.05                     | Sanmen area | 5.78%                      |
| Zhejiang Fengyuan shipping Co.     | Sanmen area    | 48000   | 192                             | 0.05                     | Sanmen area | 5.55%                      |
| Zhejiang Jiuzhou shipping Co.      | Sanmen area    | 50000   | 200                             | 0.05                     | Sanmen area | 5.78%                      |

|                                    |             |       |     |      |             |       |
|------------------------------------|-------------|-------|-----|------|-------------|-------|
| Zhejiang Chengzhou shipping Co.    | Sanmen area | 57000 | 228 | 0.05 | Sanmen area | 6.59% |
| Taizhou Jinmao shipbuilding Co.    | Sanmen area | 70000 | 280 | 0.05 | Sanmen area | 8.09% |
| Binhai shipbuilding Co.            | Sanmen area | 20000 | 80  | 0.05 | Sanmen area | 2.31% |
| Zhejiang Taida shipbuilding Co.    | Sanmen area | 30000 | 120 | 0.05 | Sanmen area | 3.47% |
| Zhejiang Haihang shipbuilding Co.  | Sanmen area | 30000 | 120 | 0.05 | Sanmen area | 3.47% |
| Zhejiang Youhao shipbuilding Co.   | Sanmen area | 70000 | 280 | 0.05 | Sanmen area | 8.09% |
| Zhejiang Taihang shipbuilding Co.  | Sanmen area | 40000 | 160 | 0.05 | Sanmen area | 4.62% |
| Zhejiang Jiantiao shipbuilding Co. | Sanmen area | 55000 | 220 | 0.05 | Sanmen area | 6.36% |
| Sanmen Jiantiao shipyard Co.       | Sanmen area | 27000 | 108 | 0.05 | Sanmen area | 3.12% |
| Sanmen multipurpose terminal       | Sanmen area | 5000  | 50  | 0.05 | Sanmen area | 1.45% |
| Jinmao shipyard No.1 terminal      | Sanmen area | 10000 | 40  | 0.05 | Sanmen area | 1.16% |
| Jinmao shipyard No.2 terminal      | Sanmen area | 5000  | 20  | 0.05 | Sanmen area | 0.58% |
| Jiaotiao shipyard No.1 terminal    | Sanmen area | 10000 | 40  | 0.05 | Sanmen area | 1.16% |
| Nuclear power plant                | Sanmen area | 5000  | 50  | 0.05 | Sanmen area | 1.45% |



**The risk of oil spill of each terminals and their sharing cost in Jiaojiang area**

| <b>Terminal</b>                  | <b>Port belonging</b> | <b>Tonnage</b> | <b>Most probable oil spillage(ton)</b> | <b>Probability of oil spill</b> | <b>area</b>    | <b>Proportion of sharing cost</b> |
|----------------------------------|-----------------------|----------------|--|---------------------------------|----------------|-----------------------------------|
| Haidong Shipyard                 | Jiaojiang port        | 5000           | 2500                                   | 0.05                            | Jiaojiang area | 0.49%                             |
| Yuanshan Shipyard                | Jiaojiang port        | 10000          | 5000                                   | 0.05                            | Jiaojiang area | 0.97%                             |
| No.1 terminal of Haimen port     | Jiaojiang port        | 5000           | 2500                                   | 0.05                            | Jiaojiang area | 1.21%                             |
| Waisha Container terminal        | Jiaojiang port        | 5000           | 2500                                   | 0.05                            | Jiaojiang area | 1.21%                             |
| Conch Cement terminal            | Jiaojiang port        | 3000-5000      | 2500                                   | 0.05                            | Jiaojiang area | 1.21%                             |
| Forth terminal of Taizhou Plant  | Jiaojiang port        | 5000           | 2500                                   | 0.05                            | Jiaojiang area | 1.21%                             |
| Linhai Falong Shipyard           | Linhai port           | above15000     | 7250                                   | 0.05                            | Jiaojiang area | 1.41%                             |
| Taizhou Ocean Shipyard           | Jiaojiang port        | 15000          | 7500                                   | 0.05                            | Jiaojiang area | 1.46%                             |
| Qiansuo Oil terminal             | Jiaojiang port        | 1000           | 500                                    | 0.05                            | Jiaojiang area | 1.82%                             |
| Qiansuo Wuzhou Shipyard          | Jiaojiang port        | 20000          | 10000                                  | 0.05                            | Jiaojiang area | 1.94%                             |
| terminal of Taizhou Plant(10000) | Jiaojiang port        | 10000          | 5000                                   | 0.05                            | Jiaojiang area | 2.43%                             |
| Taizhou Wuzhou Shipping Co.      | Jiaojiang port        | 27000          | 13500                                  | 0.05                            | Jiaojiang area | 2.62%                             |

|                               |                |           |        |      |                |        |
|-------------------------------|----------------|-----------|--------|------|----------------|--------|
| Wenling Shenghai Shipyard     | Wenling port   | 27000     | 13500  | 0.05 | Jiaojiang area | 2.62%  |
| Jiaojiang refrigeratory       | Jiaojiang port | 1000-2000 | 1000   | 0.05 | Jiaojiang area | 2.73%  |
| Taizhou Yichang Shipping Co.  | Jiaojiang port | 30000     | 15000  | 0.05 | Jiaojiang area | 2.91%  |
| Taizhou Oil Company           | Jiaojiang port | 3000      | 1500   | 0.05 | Jiaojiang area | 4.10%  |
| Hongguang Chemical terminal   | Linhai port    | 3000      | 1500   | 0.05 | Jiaojiang area | 4.10%  |
| Haidong Shipyard              | Jiaojiang port | 50000     | 25000  | 0.05 | Jiaojiang area | 4.86%  |
| Taizhou Qiansuo Shipyard      | Jiaojiang port | 50000     | 25000  | 0.05 | Jiaojiang area | 4.86%  |
| 7816 Factory                  | Jiaojiang port | 50000     | 25000  | 0.05 | Jiaojiang area | 4.86%  |
| Zhejiang Mingfa Shipyard      | Jiaojiang port | 50000     | 25000  | 0.05 | Jiaojiang area | 4.86%  |
| Taizhou Wanchang Shipyard     | Jiaojiang port | 100000    | 50000  | 0.05 | Jiaojiang area | 4.86%  |
| Zhejiang Hongxin Shipping Co. | Jiaojiang port | 120000    | 60000  | 0.05 | Jiaojiang area | 5.83%  |
| Wanlong Shipping Co.          | Jiaojiang port | 150000    | 75000  | 0.05 | Jiaojiang area | 7.28%  |
| Huaji Shipping Co.            | Jiaojiang port | 80000     | 40000  | 0.05 | Jiaojiang area | 7.77%  |
| Taizhou Yanhai Shipyard       | Jiaojiang port | 310000    | 155000 | 0.05 | Jiaojiang area | 10.03% |
| Hongchang Shipyard            | Jiaojiang port | 320000    | 160000 | 0.05 | Jiaojiang area | 10.36% |

**The risk of oil spill of each terminals and their sharing cost in Linhai area**

| <b>Terminal</b>             | <b>Port belonging</b> | <b>Tonnage</b> | <b>Most probable oil spillage(ton)</b> | <b>Probability of oil spill</b> | <b>area</b> | <b>Proportion of sharing cost</b> |
|-----------------------------|-----------------------|----------------|--|---------------------------------|-------------|-----------------------------------|
| Zhejiang Fangyuan Shipyard  | Linhai port           | 5000           | 20                                     | 0.05                            | Linhai area | 1.92%                             |
| Linhai Huajie Shipping Co.  | Linhai port           | Below 5000     | 20                                     | 0.05                            | Linhai area | 1.92%                             |
| Taizhou Maple Shipping Co.  | Linhai port           | 20000          | 80                                     | 0.05                            | Linhai area | 7.69%                             |
| Linhai Huipu Shipyard       | Linhai port           | 20000          | 80                                     | 0.05                            | Linhai area | 7.69%                             |
| Taizhou Shipping Shipyard   | Linhai port           | 20000          | 80                                     | 0.05                            | Linhai area | 7.69%                             |
| Linhai Changshun Shipyard   | Linhai port           | 20000          | 80                                     | 0.05                            | Linhai area | 7.69%                             |
| Taizhou Hongda Shipping Co. | Linhai port           | Below 20000    | 80                                     | 0.05                            | Linhai area | 7.69%                             |
| Zhejiang Hongguan Shipyard  | Linhai port           | 15000          | 60                                     | 0.05                            | Linhai area | 5.77%                             |
| Linhai Hongzhou Shipyard    | Linhai port           | 15000          | 60                                     | 0.05                            | Linhai area | 5.77%                             |
| Linhai Haifeng Shipyard     | Linhai port           | 15000          | 60                                     | 0.05                            | Linhai area | 5.77%                             |
| Linhai Jianghai Shipyard    | Linhai port           | 15000          | 60                                     | 0.05                            | Linhai area | 5.77%                             |

|                              |             |             |     |      |             |        |
|------------------------------|-------------|-------------|-----|------|-------------|--------|
| Linhai Hangchang Shipyard    | Linhai port | 15000       | 60  | 0.05 | Linhai area | 5.77%  |
| Linhai Hongsheng Shipyard    | Linhai port | 15000       | 60  | 0.05 | Linhai area | 5.77%  |
| Taizhou Yuehang Shipping Co. | Linhai port | Above 30000 | 120 | 0.05 | Linhai area | 11.54% |
| Linhai Xundong Shipping Co.  | Linhai port | Above 30000 | 120 | 0.05 | Linhai area | 11.54% |

**The risk of oil spill of each terminals and their sharing cost in Wenling area**

| <b>Terminal</b>              | <b>Port belonging</b> | <b>Tonnage</b> | <b>Most probable oil spillage(ton)</b> | <b>Probability of oil spill</b> | <b>area</b>  | <b>Proportion of sharing cost</b> |
|------------------------------|-----------------------|----------------|--|---------------------------------|--------------|-----------------------------------|
| Wenling Xianghui shipyard    | Wenling port          | 5000           | 20                                     | 0.05                            | Wenling Area | 0.51%                             |
| Wenling Longmen shipping Co. | Wenling port          | 7000           | 28                                     | 0.05                            | Wenling Area | 0.71%                             |
| Wenling Kaili shipyard       | Wenling port          | 10000          | 40                                     | 0.05                            | Wenling Area | 1.01%                             |
| Wenling Yongli shipyard      | Wenling port          | 10000          | 40                                     | 0.05                            | Wenling Area | 1.01%                             |
| Wenling Xianfeng shipyard    | Wenling port          | 15000          | 60                                     | 0.05                            | Wenling Area | 1.52%                             |
| Jinqing Huaxuan terminal     | jiaojiang port        | 1000           | 75                                     | 0.05                            | Wenling Area | 1.89%                             |
| Yangfu Bay terminal          | Wenling port          | 1000           | 75                                     | 0.05                            | Wenling Area | 1.89%                             |
| Nangang terminal             | Wenling port          | 1000           | 75                                     | 0.05                            | Wenling Area | 1.89%                             |
| Wenling Century Shipyard     | Wenling port          | 20000          | 80                                     | 0.05                            | Wenling Area | 2.02%                             |
| Wenling Niluo Shipping Co.   | Wenling port          | 22000          | 88                                     | 0.05                            | Wenling Area | 2.22%                             |
| Wenling Ruoli Shipyard       | Wenling port          | 22000          | 88                                     | 0.05                            | Wenling Area | 2.22%                             |

|                             |                |       |         |      |              |       |
|-----------------------------|----------------|-------|---------|------|--------------|-------|
| Taizhou Yuansheng Shipyard  | Jiaojiang port | 30000 | 120     | 0.05 | Wenling Area | 3.03% |
| Taizhou Golden Bay Shipyard | Jiaojiang port | 30000 | 120     | 0.05 | Wenling Area | 3.03% |
| Zhejiang Jiaoshan Shipyard  | Wenling port   | 30000 | 120     | 0.05 | Wenling Area | 3.03% |
| Wenling Xingyuan Shipyard   | Wenling port   | 30000 | 120     | 0.05 | Wenling Area | 3.03% |
| Wenling Shipping Shipyard   | Wenling port   | 30000 | 120     | 0.05 | Wenling Area | 3.03% |
| Wenling Changhong Shipyard  | Wenling port   | 30000 | 120     | 0.05 | Wenling Area | 3.03% |
| Zhejiang Tenglong Shipyard  | Wenling port   | 35000 | 140     | 0.05 | Wenling Area | 3.54% |
| Jinqing Huayuan terminal    | Jiaojiang port | 3000  | 168.75  | 0.05 | Wenling Area | 4.26% |
| Luoxing Island terminal     | Wenling port   | 3000  | 168.75  | 0.05 | Wenling Area | 4.26% |
| Zhejiang Zhenxing Shipyard  | Wenling port   | 48500 | 194     | 0.05 | Wenling Area | 4.90% |
| Hualuo Island terminal      | Wenling port   | 3500  | 196.875 | 0.05 | Wenling Area | 4.97% |
| Shatou Oil terminal         | Wenling port   | 3500  | 196.875 | 0.05 | Wenling Area | 4.97% |
| Hongyan Oil terminal        | Wenling port   | 3500  | 196.875 | 0.05 | Wenling Area | 4.97% |

|                               |              |       |         |      |              |       |
|-------------------------------|--------------|-------|---------|------|--------------|-------|
| Gangzhou Oil terminal         | Wenling port | 3500  | 196.875 | 0.05 | Wenling Area | 4.97% |
| Zhejiang Hexing Shipyard      | Wenling port | 58000 | 232     | 0.05 | Wenling Area | 5.86% |
| Zhejiang Jingang Shipping Co. | Wenling port | 60000 | 240     | 0.05 | Wenling Area | 6.06% |
| Zhejiang Tianshi Shipyard     | Wenling port | 70000 | 280     | 0.05 | Wenling Area | 7.07% |
| Shitang Oil terminal          | Wenling port | 5000  | 360     | 0.05 | Wenling Area | 9.09% |

### The risk of oil spill of each terminals and their sharing cost in Yuhuan area

| Terminal                                    | Port belonging | Tonnage     | Most probable oil spillage(ton) | Probability of oil spill | area        | Proportion of sharing cost |
|---|----------------|-------------|---------------------------------|--------------------------|-------------|----------------------------|
| Yingdong bunker                             | Yuhuan port    | 1000        | 75                              | 0.05                     | Yuhuan area | 3.72%                      |
| Shengli chemical                            | Yuhuan port    | 1000        | 75                              | 0.05                     | Yuhuan area | 3.72%                      |
| Zhejiang Haicheng shipbuilding Co.          | Yuhuan port    | 50000       | 200                             | 0.05                     | Yuhuan area | 9.92%                      |
| Yuhuan Haihang shipbuilding Co.             | Yuhuan port    | 60000       | 240                             | 0.05                     | Yuhuan area | 11.90%                     |
| Da Maiyu multipurpose terminal(20000-30000) | Yuhuan port    | 20000-30000 | 300                             | 0.05                     | Yuhuan area | 14.88%                     |
| Da Maiyu multipurpose terminal(30000)       | Yuhuan port    | 30000       | 300                             | 0.05                     | Yuhuan area | 14.88%                     |
| Da Maiyu multipurpose terminal(50000)       | Yuhuan port    | 50000       | 333.33                          | 0.05                     | Yuhuan area | 16.53%                     |
| Huaneng Yuhuan power plant coal terminal    | Yuhuan port    | 50000/74000 | 493.33                          | 0.05                     | Yuhuan area | 24.46%                     |