8-27-2017

Demand analysis of the search and rescue resources in Tianjin Haihe River Downstream

Yanfu Li

WORLD MARITIME UNIVERSITY
Dalian, China

DEMAND ANALYSIS OF THE SEARCH AND RESCUE RESOURCES IN TIANJIN HAIHE RIVER DOWNSTREAM

By

Li Yanfu
China

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

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2017

DECLARATION

I certify that all the materials in this research paper that are not my own work have 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: Li Yanfu

Date: 1st July 2017

Supervised by: Bu Renxiang
Professor
Dalian Maritime University

Assessor:

Co-assessor:

ACKNOWLEDGEMENTS

It is a great honor for me to be a student of the World Maritime University and complete a year of study on Maritime Safety and Environment Management at Dalian Maritime University. In this period, many people have supported and helped me in various ways.

Firstly, I would like to express my appreciation to all of the professors of WMU and DMU for their wonderful lessons. The same appreciation shall be given to the teachers who are in charge of organizing the courses for their hard-working.

Secondary, I want to thank my supervisor Professor Bu Renxiang for his encouragement and patient guidance during the process of writing this paper. Indeed, it is a great help for me.

Last but not least, my deepest grateful need be given to my family, my colleagues in Tianjin MSA and all of the classmates in MSEM for their support and encouragement during the whole 18 months' study.

ABSTRACT

Title: **Demand analysis of The Search and rescue resources in Tianjin Haihe River Downstream**

Degree: **MSc**

The Haihe River Downstream, as an estuary of Haihe River, is a section of river with a variety of transport functions which is locate at Binhai New Area, Tianjin, China. And it used to be the busiest water for freight transportation in Tianjin. Due to the municipal development plan of Tianjin, the function of this area will be changed to mainly for passengers traveling. But the existing search and rescue resources in this area are not suitable for the potential risks of passenger ships accidents. In this paper, the first chapter introduce the background of the search and rescue demand in this area as well as the research methodology of this paper. Chapter 2 compares the different SAR practice in different counties as a lesson for the Haihe River Downstream. Chapter 3 introduce and discuss the natural environment and navigation circumstance of Haihe River Downstream and introduce the current condition of the search and rescue resources. Chapter 4 calculate the full demand of rescue boat in case of MRO caused by passenger ships. Chapter 5 introduce the development of the SAR resources, and verify the result of the research. Finally, the chapter 6 is a short conclusion in order to summarize the entire paper.

Keywords: Demand, Search and rescue, Resources, Transportation function, Changes.

LIST OF CONTENTS

LIST OF TABLE

LIST OF FIGURE

LIST OF ABBREVIATIONS

SAR	Search And Rescue
MSAR	Maritime Search And Rescue
MRO	Mass Rescue Operation
MSA	Maritime Safety Authority
GT	Gross Tonnage
AMSA	Australia Maritime Safety Authority
IMRF	International Maritime Rescue Federation
USCG	United State Coast Guard
ADF	Australian Defense Force
IAMSAR Manual	International Aeronautical and Maritime Search and Rescue Manual

Chapter 1 Preface

1.1 The concept of maritime search and rescue

Today, the development of science and technology is rapidly over the world, and more and more of these scientific and technological achievements have been applied to the transportation system by sea. The strength of the ship’ s hull is becoming increasingly stronger. The safety devices on board have been improved day by day. The communication between ships and shore is becoming increasingly reliable. All of these improvements seemly provide the traffic on sea a strong guarantee of safe sailing environment. However, the limitations of the ship’ s own conditions are not the only factors for the safe sailing. Accidents can be caused by human failure, material failure or bad weather, and this may can lead to the damage that takes the form of the loss of the vessel, damage to the hull, personal damage, human loss and ecological damage (Cahill, 1983). Due to these factors, the various accidents and dangers are still unavoidable. An accident at sea is an event which affects the vessel as a whole, constituting a grave danger to itself, the persons on board, the cargo and/or the environment (Marriot, 1987).

Therefore, it is necessary to establish a special maritime organization to carry out the search and rescue operation and help the ships or personals who are in distress timely and effectively. It is the common aim of the International Maritime Organization (IMO) and National Maritime Safety Authorities to control the fatality and the property losses on sea at a level as low as possible. The IMO defines "search" as “an operation, normally co-ordinated by a rescue co-ordination centre or rescue sub-centre, using available personnel and facilities to locate persons in distress” and “rescue” as the “operation to retrieve persons in distress, provide for their initial medical or other needs and deliver them to a place of safety.”(IMO, 1974) From technical view of point, search and rescue (SAR) refers to the process of finding and providing assistance to those who are in danger or at risk from an external action. Any action aimed at avoiding a great ecological or economic tragedy can also be considered in the law as a rescue operation (Achutegui, 1996). According to the different terrain, the search and rescue operation can be divided into mountain search and rescue, ground search and rescue, urban search and rescue and maritime search and rescue. Maritime search and rescue means the SAR operations are carried out by the SAR forces after obtaining the distress information from the ships or personnel on board in danger. Specifically, the maritime search is sending maritime salvage personnel and facilities to search for and determine the location of the personnel and ship in distress. And the maritime rescue means using any available salvage force to rescue the personnel and ship in distress and transfer them to a safety place. In the modern time, the maritime SAR including the use of elements of aerial intervention, the increase in marine traffic and especially in leisure crafts, which led to radical changes in the field of maritime search and rescue (House, 1988).

One of the earliest search and rescue record in the world was that after the accident of the Dutch merchant ship "Vergulde Draeck" on the west coast of Australia on October 4, 1655, the survivors had sent a distress signal, and in response three independent search and rescue operations in Australia were conducted. Unfortunately, they did not succeed.(West Australia Museum, 1656)

1.2 The background in Haihe River Downstream

The Haihe River is the largest river in northern China, and its downstream near the estuary is a section of river with the function of water transportation. It is located at the Binhai New Area, Tianjin, China. According to the Urban Development Planning of Tianjin and Binhai New Area, the function of lower reaches of Haihe river will gradually transform to tourism from freight transportation, and vigorously develop the tourist boats and yachts. At present, the annual number of passengers traveling on the Haihe River is more than 5,000,000 including ferry and tourist boat. In the next few years, the passenger ships sailing on the Haihe River will gradually increase, and this will bring a substantial increase of the passengers traveling on the water. Once these passenger ships are involved accidents, a lot of people will be put into danger.

Usually, this kind of traffic accidents on water is difficult to conduct rescue but it is easy to lead to major personal death and economic losses due to it is always suddenly happening. For instance, at 21:32 of June 21, 2015, a Chinese passenger liner “Oriental Star” was sunk in the Yangtze River when sailing from Nanjing to Chongqing. There was a total of 454 passengers on board the vessel when the accident was happened but only 12 persons, including crew members, was fortunately survived. The accident has caused negative social impact and greatly stimulated people’s safety demands of traveling on water. So, strengthen the construction of search and rescue system and reduce the fatality and economic losses is one of the most important task in current China.

China joined *the 1974 International Convention for the Safety of Life at Sea (SOLAS)* in 1982, and joined *the 1979 International Maritime Search and Rescue Convention (SAR)* in 1985. It is the international obligation for the contract states to implement the convention and ensure the safety of the traffic and human in the corresponding area of responsibility. It is of great significance to enhance the ability to deal with the mass search and rescue forces on Haihe river.

1.3 Research methods and research purposes

1.3.1 Research purposes

Maritime search and rescue work is the last line of defense to protect the safety of life and property at sea, and the arrangement of the search and rescue forces is directly related to the result. And efficiency of the SAR operation. In order to minimize the number of fatalities and property damage in the lower reaches of Tianjin Haihe River, it is urgent to study the maritime search and rescue operation in Haihe River and analyze the gap between the demand and supply of search and rescue resources, so as to make the layout of the search and rescue resources more optimized. It seems as a correct way to deal with the safety problem on Haihe River. However, most of the research and decision-making relating to this problem are based on the qualitative analysis. The qualitative analysis has the advantage of fast and intuitive but there are also many shortcomings of fuzzy, resource utilization and waste. Thus this research paper is trying to conduct quantitative analysis on the demand of the search and rescue resources for the human life rescue in the Lower Reaches of Tianjin Haihe River.

1.3.2 Research methods

First is the literature research method. This method is adopted through substantial reading and studying of the relevant literature to confirm the content of the research.

Second is the comparative study method. When considering the configuration of search and rescue forces, this paper compare the situations of public services both national and international, and finds the proper SAR system to meet the characteristics of the Haihe River.

The third method is to use the GM (1,1) model to predict the future accident in Haihe River according to Gray Decision Theory.

The fourth method is the field investigation method. This method is through investigation of the navigation condition and the existing SAR system of Haihe River to study the demand of SAR resources.

1.4 Summary of this chapter

Maritime SAR operation is the last barrier to protecting the life at sea. As an important water transport channel in China, Haihe River Downstream has an urgent demand of SAR resources. And this paper will analyze the demand of SAR resources both in qualitative and in quantitative methods through field investigation, mathematical model, etc.

Chapter 2 The maritime search and rescue system in different countries

On April 27, 1979, IMO passed the "International Convention on Maritime Search and Rescue ", and it entered into force on 22 June 1985. Following the adoption of the Convention, IMO's Maritime Safety Committee divided the world's oceans into 13 search and rescue areas, where the countries concerned delineated the search and rescue areas they were responsible for.

2.1 United State

The National Search and Rescue Committee is the highest administrative agency in the United States which is responsible for search and rescue, but it does not undertake actual search and rescue affairs. It is also responsible for formulating the US national search and rescue policy and coordinating the search and rescue affairs of the federal agencies. Among them the water search and rescue is mainly conducted by the Coast Guard (USCG, 2007). The detail construction of the system is shown as the figure 2.1:

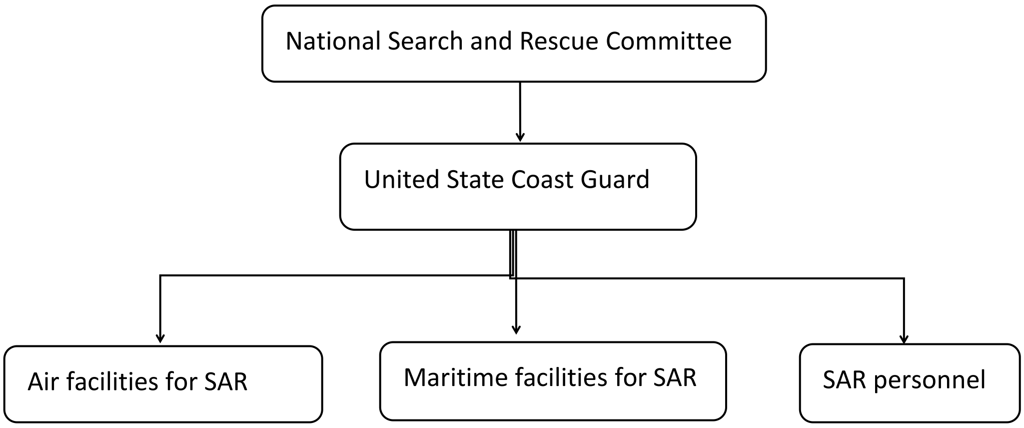

Figure 2.1 United State maritime SAR system

Source:(USCG, 2007)

The United States Coast Guard is the major force in the United States to carry out maritime search and rescue. In the respect of air search and rescue, the Coast Guard equipped with a considerable number of aircraft for maritime search and rescue, including fixed wing aircraft for long-range and medium-distance search, medium-distance rescue helicopters, short-range rescue helicopters, so as to ensure the rapid response to the distress alarm. In the respect of search and rescue operation on water, the United States Coast Guard is equipped with many types of boats. According to the length of the division, they are mainly divided into two categories: the length of 65 feet and above large ships such as icebreakers, patrol boats, navigation supplies, tugs and so on. The others are less than 65 feet in length, such as motorized lifeboats, port security vessels, navigational facilities, etc. In addition to the above search and rescue facilities, the Coast Guard is also equipped with adequate personnel who are qualified for maritime search and rescue operations.

2.2 Australia

The Australian National Search and Rescue Committee (NATSAR) was established in 1976 by the representatives of the following authorities:

Australian Maritime Safety Authority (AMSA)

Australian Defense Force (ADF)

Federal, state and district police

The National Search and Rescue Council is the highest administrative body in Australia that is responsible for the search and rescue work. The subordinate search and rescue agencies are divided into two levels: the federal government and the state / territory government. The federal-level government search and rescue organization is composed of the Australian Maritime Security Service and the Australian Defense and Military Forces and they are responsible for civil and military search and rescue work respectively. The state / territory-level government search and rescue organization is mainly served by the state / territory of the police (Marine). In addition to the official search and rescue organization, there are also some non-governmental organization to conduct by the SAR volunteers (AMSA, 2017). The detail construction of the system is shown as the figure 2.2:

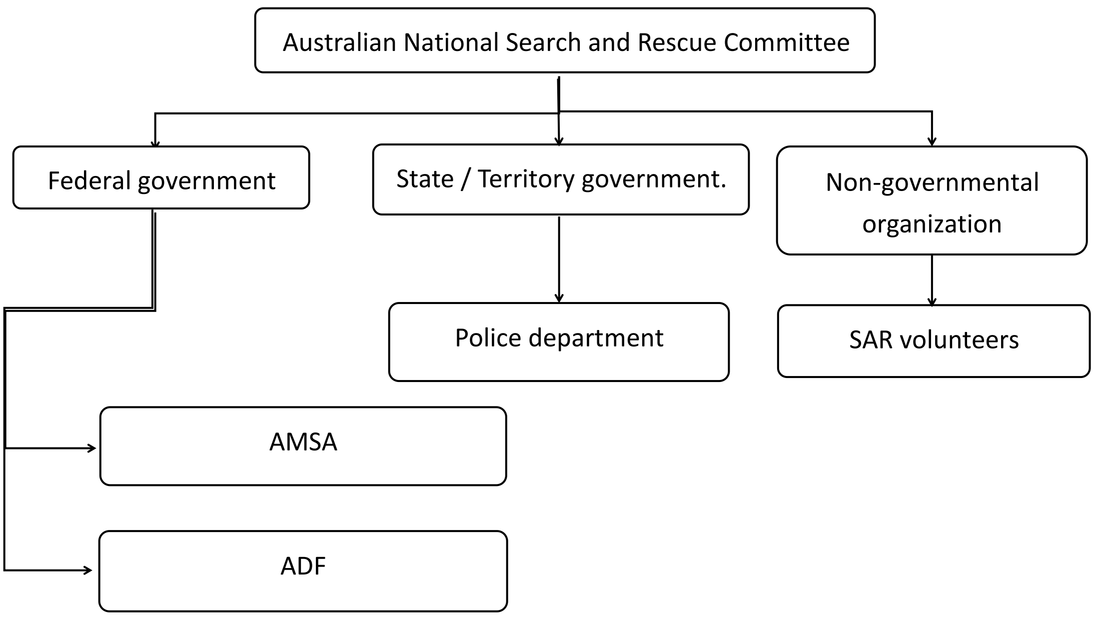

Figure 2.2 Australia maritime SAR system

Source: (AMSA, 2017)

The Australian government does not hold a professional rescue force which is with professional search and rescue ships and aircraft. However, the government maintain the search and rescue resources in form of long-term fixed contract with the commercial institutions to hire all kinds of aircraft and high-powered tugs as an alternative. Through the development of relevant standards and procedures, the Australian government ensure a variety of rescue forces timely and effectively to participate in the emergency search and rescue action.

2.3 China

2.3.1 Organization and command system

In China, the maritime search and rescue management and command system is divided into three levels. the highest organization responsible for maritime search and rescue is the National Maritime Search and Rescue Inter-ministerial Joint Meeting, the China Maritime Search and Rescue Center is in charge of manage the daily national search and rescue work, the Provincial Maritime Search and Rescue Center and Branches are the basic level and in charge of the organization of the detail SAR, such as the organization and maintenance of SAR forces and arrangement of SAR forces during the SAR operation （Ministry of Transportation,2006). The construction of the system is shown as the figure 2.3:

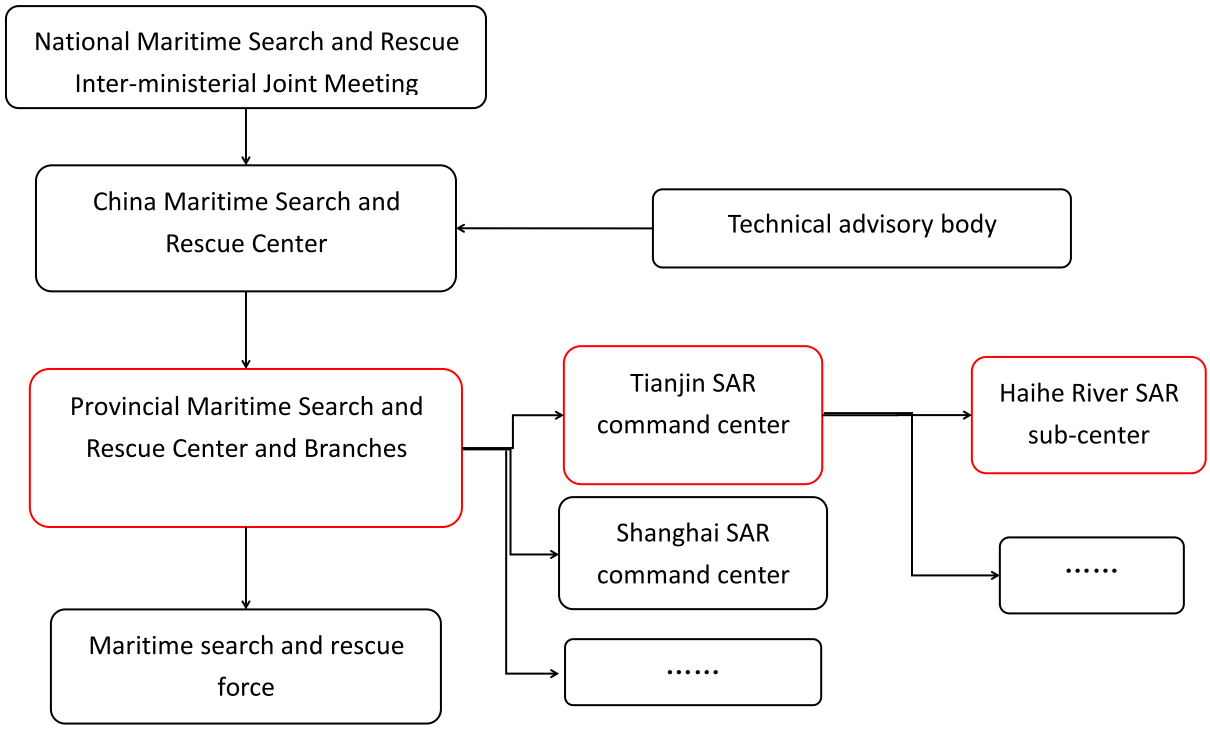

Figure 2.3 China maritime SAR system

Source: (Ministry of Transportation,2006)

The National Maritime Search and Rescue Inter-ministerial Joint Meeting was formally approved by the State Council in 2005, and it is led by the Ministry of Transport, including 16 member units and departments like the General Administration of Customs, the Ministry of Public Security, the State Oceanic Administration, the Chinese People's Liberation Army General Staff, etc. It is mainly responsible for discussing, coordinating and resolving maritime search and rescue work, organizing major maritime search and rescue operations, guiding and supervising the emergency response work of maritime search and rescue in provinces level, and determining the responsibilities of member units of the joint meeting in search and rescue activities.

China Maritime Search and Rescue Center was established in 1989 by the Ministry of Transport. It presides over the daily work of the national maritime search and rescue inter-ministerial joint meeting, and under the leadership of the Ministry of Transport. The technical advisory body is composed of the designated maritime search and rescue expert group and other related areas advisory body, responsible for maritime search and rescue operations command, maritime search and rescue forces and other important issues to provide advisory services. Provincial maritime search and rescue center and branches are subordinate agencies of China Maritime Search and Rescue Center in the provinces. At this level, they are mainly responsible for the maritime search and rescue organization and coordination of the work in their jurisdiction respectively. Haihe River SAR Sub-center, as a branch of Tianjin SAR Command Center is at this level, and is presided by Haihe Maritime Safety Administration.

2.3.2 SAR resources

In China, maritime search and rescue forces are mainly consist of ships, aircraft and personnel belong to the member units of the National Maritime Search and Rescue Inter-ministerial Joint Meeting. These search and rescue forces can be divided into two major categories: professional search and rescue forces and non-professional search and rescue forces. And in the actual search and rescue operations, the professional forces are always played as the primary roles and the non-professional forces are played as assistance.

(1) Professional SAR forces

The professional SAR forces are mainly composed of two part. One is the SAR forces of China Maritime Safety Administration, and the other is SAR forces of Salvage Bureau. China MSA is the sub-ordinate of the Ministry of Transport and the office of Maritime Search and Rescue Center is located in the China MSA. China MSA and its sub-ordinate agencies have many kinds of the petrol vessel and this is an important force in the SAR operation. These vessels contain petrol vessels of 3000GT, 1500GT and 60m, 45m, 35m and the fast speed yacht with 12m and 8m. Like the MSA, the Salvage Bureau is another sub-ordinate agency of Ministry of Transport. The Salvage Bureau have built 20rescue bases, 4 rescue flight service teams, with 75 rescue ships, 123 salvage vessels and 17 rescue aircraft. All of these professional SAR resources stand by all day long and ready to carry out maritime SAR operation in all-weather .

(2) Non-professional SAR forces

China Maritime Search and Rescue Center has established a social search and rescue force database system since 2006. The database contains the units or personnel who have the ability to conduct maritime search and rescue operation. The non-professional search and rescue forces can be divided into four categories:

Ships and aircraft of the army

The official ships and aircraft (except those belong to Ministry of Transport)

The ships and aircraft belong to the company and personnel

The merchant ships and fishing vessels sailing around the accident area

2.4 Summary of this chapter

In the respect of maritime SAR system construction, organization and command, the common practice of international is a government-led completion. However, there are some differences in the composition of search and rescue forces. In Australia, the SAR forces are mainly social forces with long-term contract to government. In the United States, search and rescue forces are mainly by the Coast Guard. In China, the major forces are composed of the official resources. Under China SAR system, the SAR forces in Haihe River Downstream should be conducted under the lead of government.

Chapter 3 Current situation of navigation and SAR system in Haihe River

The lower reaches of the Haihe River refer to a section of river between the Haihe River Erdao Gate (39 ° 01'N, 117 ° 27'E) and the Newport ship lock (38 ° 59'N, 117 ° 42'E), and its length is about 39.5 km and the width is about 200--450m (figure 3). This chapter mainly analyzes natural condition and navigation environment of the lower reaches of the Haihe River, and the current SAR situation in the river.

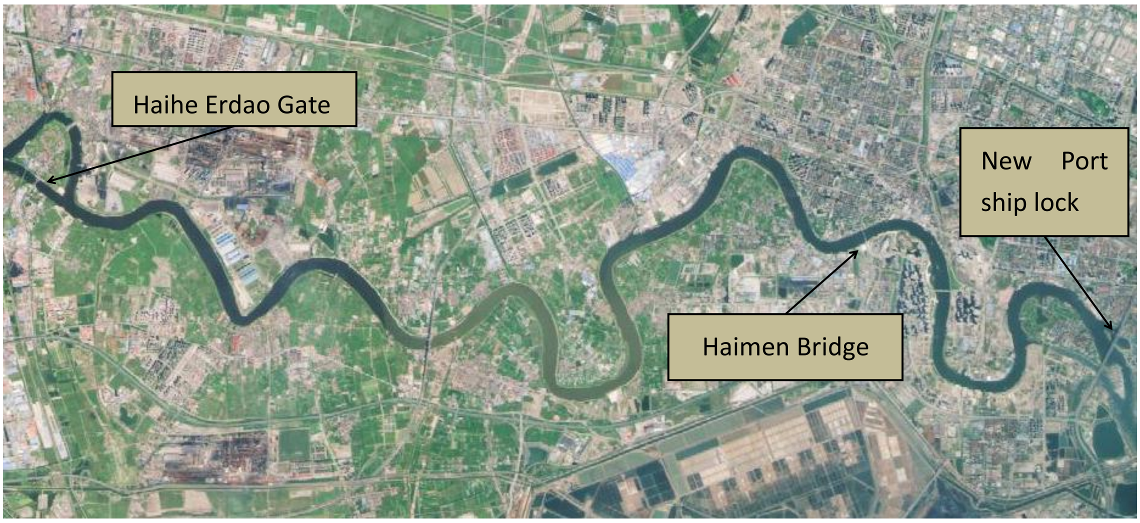

Figure 3 The range of the Haihe River Downstream

Source: http://map.baidu.com/

3.1 Natural condition

3.1.1 Meteorological

(1) Wind

The wind is an unstable factor of the meteorological elements. There are some differences from the annual observed statistics. In order to reflect the real wind conditions of Tianjin Port. We use the statistics report of the wind speed based on the observation 24 times one day for years. Table 3.1.1 is the statistics of the frequency of wind speed in different direction of Tianjin port. It shows that:

The wind direction in vicinity of Tianjin port is rather dispersed, the frequency of each occurrence is not more than 10%. In contrast, S, SW, E, NW appear more frequently, more than 8%; and SE and W to more than 7%. The average wind speed was 4.2 m / s, where E was the largest with 6.2 m / s, and ENE was 5.4 m / s. The maximum wind speed is 21.6m / s, occurs in NE direction; the second maximum wind speed is 20.3m / s, which occurs in E direction. The frequency of wind speed below 5.4m / s is the largest, reaching 75%, and the frequency of wind speed exceeding 10.8m / s is about 2%.

Table 3.1.1 Wind speed wind direction distribution table in Tianjin Port

Speed （m/s）	**N**	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**C**	**Summation**
0.0-5.4	3.67	2.18	2.86	2.52	3.79	3.38	4.61	4.05	6.15	5.65	7.65	6.33	6.80	3.70	5.69	4.96	0.73	74.73
5.5-7.9	0.59	0.34	0.73	1.01	2.12	1.37	1.91	1.60	2.05	0.76	0.65	0.46	0.35	0.18	1.55	1.28	0.00	16.94
8.0-10.7	0.18	0.15	0.31	0.63	1.49	0.58	0.60	0.34	0.29	0.07	0.04	0.03	0.02	0.03	0.73	0.54	0.00	6.03
10.8-13.8	0.05	0.05	0.08	0.24	0.70	0.12	0.06	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.20	0.11	0.00	1.65
13.9-17.1	0.00	0.01	0.01	0.05	0.15	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.28
≥17.2	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Summation	4.48	2.74	4.01	4.44	8.26	5.46	7.19	6.02	8.51	6.48	8.34	6.83	7.17	3.91	8.18	6.91	0.73	100
Average wind speed	3.6	3.7	4.2	5.4	6.2	5.0	4.8	4.5	4.4	3.7	3.3	3.1	3.0	2.6	4.4	4.4	—	—
Maximum wind speed	15.4	17.6	21.6	19.7	20.3	19.8	18.5	18.8	20.2	16.4	12.5	17.8	14.6	15.8	18.4	17.5	—	—

Source: (Haihe MSA, 2016)

(2) Temperature

For many years, the average water temperature of Haihe River temperature is at 11 ~ 15 °C. The lowest temperature is in January with 0.1 ~ 2.5 °C. The highest temperature is in July with 27~42 °C. Usually, the surface of Haihe River is frozen in winter, and it begins from approximately late November to the middle of March. The frozen days last for 50 to 80 days in average.

(3) Precipitation

Haihe River upstream is the Daqing River and Yongding River two watershed, and their location is the windward slope of Taihang Mountains and Yanshan Mountains. the Haihe River Downstream is near the Bohai Sea where is a dry and humid climate transition zone. Due to the monsoon, the precipitation is concentrated in the flood season from July to September, accounting for 75-80% of the year. The changes between different years are also great, generally the average of 400-600mm.

The average annual precipitation is 413.3mm

The maximum annual precipitation is 515.9mm

The minimum annual rainfall of 194.7mm

The maximum daily rainfall is 157.2mm

Precipitation intensity ≥ light rain, with an average annual 54.3 precipitation days per year

Precipitation intensity ≥ moderate rain, average annual 12.3 precipitation days

Precipitation intensity ≥ heavy rain, with an average annual 4.5 precipitation days per year

Precipitation intensity ≥ rainstorm, with an average of 1.0 precipitation days per year

In this area, the precipitation shows a seasonal appearance, and the rainfall is concentrated in July and August each year. The precipitation in these two months is

49.1% of the annual precipitation, and the precipitation is very low from December to the following year. The total precipitation for the four months in the winter is only about 3.4% of the annual precipitation.

(4) Fog

Annually, there is an average of 16.6 days' heavy fog with the visibility of less than 1km. The fog is always occurred in the annual autumn and winter, especially in December and January. The fog day in December and January is about 40% of the foggy day of every year. Normally, the fog can last for more than 4 hours one time and the longest fog can last up to 24 hours or more.

(5) Visibility

Except for the fog, there are some other weather closely impact the visibility in Haihe River, such as rain, haze, dust storm,etc. According to statistics, the days of visible distance less than 1000m are with an average of about 23.7 days per year in the Haihe River area.

(6) Disastrous weather

The average annual thunderstorm in Tianjin is about 28 days, with a maximum of 43 days and a minimum of 15 days. Thunderstorms and lightning mainly appear in the showers and other convective intense weather. Most of the thunderstorms are happened in summer.

Generally, typhoon occurs from July to September in Tianjin area. During the past 60 years, the typhoon appeared 76 times with an average of 1.3 times a year.

3.1.2 Hydrology

(1) Tide level

The tidal morphology coefficient of Tianjin harbor is 0.53, which belongs to the irregular half day tide. According to the statistics of the tide of the East Trough, the tidal characteristics are based on the Dagu elevation[1] (the same below) as follows:

The average high tide over the years: 2.67 m

The average low tide over the years: 0.32 m

The average tidal range over years: 1.35 m[1]

The average tide rising over the years lasted : 5h40min

The average tide falling over the years lasted: 6h53min

According to the observation data of the tide over years, the highest tide rising during the flood season is with an average of 3.88m, and the highest tide of the year is 4.91m.

(2) Tide current

From 2004 to 2007, the Tianjin Water Transport Engineering Science Institute conducted a number of multi-point hydrological observation in Tianjin Port Dagu port area. In August 2008, it was lay out eight vertical measurement trend at Haihe estuary to measure the flow rate, and the result is shown in the table 3.1.2:

Table 3.1.2 The maximum and average flow rate (m/s) of the tidal current in August 2008 of Haihe estuary

Observation station	Spring Tide				Neap Tide			
	Rising (Max.)	Rising (Avg.)	Falling (Max.)	Falling (Avg.)	Rising (Max.)	Rising (Avg.)	Falling (Max.)	Falling (Avg.)
1#	0.2	0.09	0.15	0.07	0.11	0.06	0.11	0.05
2#	0.51	0.27	0.56	0.26	0.31	0.18	0.48	0.2
3#	0.21	0.12	0.2	0.09	0.2	0.1	0.23	0.1
4#	0.72	0.3	0.42	0.23	0.35	0.18	0.35	0.17
5#	0.56	0.26	0.34	0.21	0.36	0.17	0.26	0.15
6#	0.71	0.34	0.46	0.28	0.38	0.2	0.34	0.18

[1] “Dagu elevation "is based on the zero point of the tide ruler which was set in Tanggu, Tianjin in 1902, the hight measured from this point is called Dagu elevation.

7#	0.78	0.36	0.52	0.3	0.41	0.22	0.38	0.18
8#	0.75	0.36	0.48	0.27	0.4	0.21	0.39	0.17

Source:(Haihe MSA, 2016)

According to the statistical analysis, the tidal current near the Haihe estuary has the following characteristics:

The tidal current is relatively weak. The average rate of tide rising and tide falling is less than 0.36m / s and 0.30m / s during the spring tide, and the maximum rate of tide rising and tide falling is less than 0.78m / s and 0.52m / s respectively.

3.2 Port environment

3.2.1 Port

The coastline of the Haihe River is a non-deepwater coastline with a maximum berth of 5,000 tons.There are 16 cargo terminals in the lower reaches of the Haihe River. The location is mainly concentrated in the middle and lower reaches, and only three terminals are near the Erdao Gate. The berth in Haihe River are mainly mainly engaged in loading and unloading steel, coal, sand, oil and chemical products. In addition, there are five ferries and three travel companies operating passenger business on Haihe River Downstream. Along with the development of the city and the adjustment of the economic structure, the original large-scale terminal business has gradually moved out. Since 2009, the throughput of Haihe port area and its proportion of total throughput in Tianjin port has been declining. In 2009, the throughput is 16.88 million tons. However in the past three years, the throughput is respectively 6.57 million tons in 2014, 5.46 million tons in 2015 and 4.36 million in 2016 Ton. The cargo transportation function in Haihe River is weakening.

In order to meet the needs of Tianjin and Binhai New Area's urban development and industrial layout adjustment, the “Reply of the Tianjin Municipal People's Government on the Adjustment of the Planning Function of Tianjin Port and Haihe River Port Area ” (the Ministry of Transport of the People's Republic of China [2016] 811) has agreed that the function of the Haihe River downstream transform to mainly for passengers traveling service and take into account the freight function. With the implementation of this Haihe River function adjustment plan, the construction of yacht projects begins to flourish. This plan is going to build 623 yacht berth, 4 yacht clubs, 2 cruise terminal. By then, the Haihe River on the passenger ship will be very busy.

The utilization of the Haihe River shoreline is shown as the figure 3.2.1:

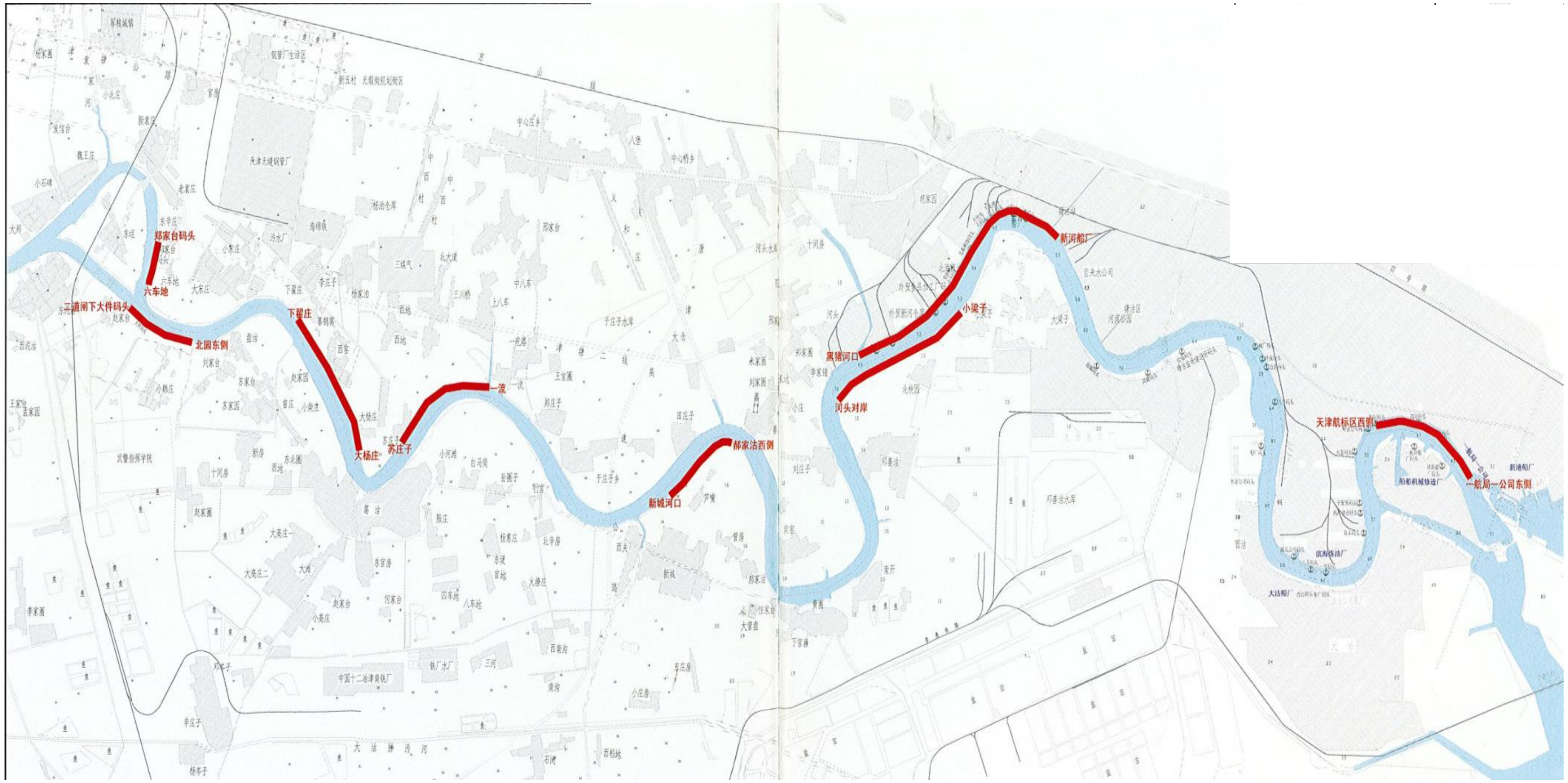

Figure 3.2.1 The utilization of the Haihe River shoreline

Source: (Bin Hai New Area, 2012)

3.2.2 Channel

Haihe River is the largest river running into the sea in northern China. Its main steam runs through Tianjin area and falling into the Bohai Sea at Binhai New area. The function of Haihe River is including drainage, shipping tourism and so on. The channel on Haihe River downstream is a section of relevant closed area. It is about 39.5km from Haihe Erdao Gate to Newport ship lock. Most of the channel is bend and there is no straight section more than 2000m. The navigable capacity can be divided into two section:

From Erdao Gate to Haimen bridge, 3,000-ton ship,

From Haimen Bridge to New Port ship lock, 5,000-ton ship

3.2.3 Anchorage

At present, there are three temporary anchorage and one temporary waiting area on the Haihe channel, and the relevant parameters are shown in table 3.2.3:

Table 3.2.3 The geographical coordinates of the anchorage

Anchorage	Geographical coordinates		
	Boundary point	N	E
NO.1	A1	39°00′03″	117°41′36″
	A2	38°59′58″	117°41′58″
	A3	38°59′50″	117°42′11″
	A4	38°59′46″	117°42′09″
	A5	38°59′54″	117°41′57″
	A6	39°00′01″	117°41′35″
NO.2	B1	38°59′51″	117°41′12″
	B2	38°59′20″	117°41′20″

	B3	38°59′18″	117°41′15″
	B4	38°59′51″	117°41′08″
NO.3	C1	39°01′03″	117°36′57″
	C2	39°00′49″	117°36′38″
	C3	39°00′52″	117°36′34″
	C4	39°01′06″	117°36′54″
temporary waiting area	D1	39°01′05″	117°27′37″
	D2	39°01′01″	117°27′42″
	D3	39°00′59″	117°27′40″
	D4	39°01′01″	117°27′35″

Source:(Haihe MSA, 2016)

The intuitional layout of the anchorage is shown by the figure 3.2.3:

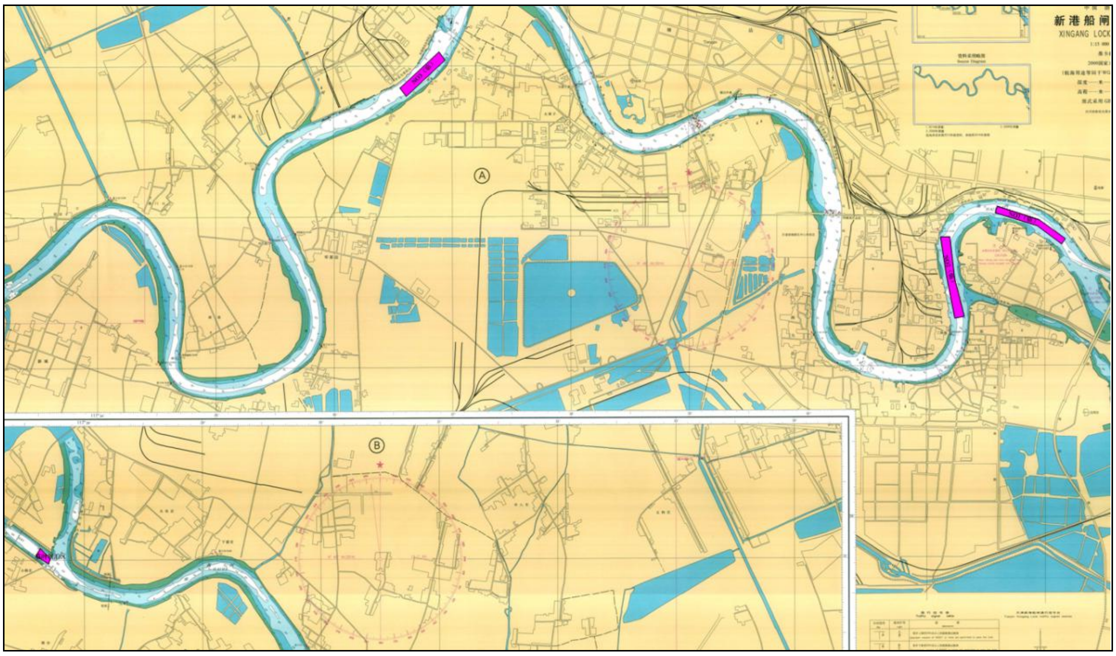

Figure 3.2.3 The anchorage layout

Source:(Haihe MSA, 2016)

3.2.4 Existed cross - river Buildings in Haihe River

(1)New Port ship lock

New Port ship lock (Figure 4.2.4(1)) is located in Haihe River estuary, and it is the only access for ships enter and departure the Haihe River. It was built from 1941 to 1945. The length of the chamber is 180 meters, the width is 22 meters, and the depth is 4.0 meters. At the beginning it is designed with a ship passing capacity of 3,000 tons , but actually the ship passing capacity is up to 10 000 tons.

Figure 3.2.4 (1) New Port ship lock

Source: http://map.baidu.com/

(2) Haimen Bridge.

Haimen Bridge（Figure 3.2.4（2））is a lift-type open bridge across the Haihe River. The total length of the bridge is 550.1m, and the width is 18m. The middle 64m of the bridge is active and the range of lift height is 24m. When the bridge is closed, the air draught is 7m while it can reach 31m after lifting. The pass-through capacity for ships is 5000 tons.

Figure 3.2.4 (2) Haimen Bridge

Source: Photos collected by the author's daily work

(3) Haihe Open Bridge

Haihe Open Bridge is located 1500m from the lower reaches of Haimen Bridge. The total length of Haihe open bridge is 868.8m, and the bridge mainly across 76m. (Figure 3.2.4(3)) The width of main navigation hole of the bridge is 68m and the air draught is 7m when the bridge is closed. While the bridge is open, the air draught is no limitation for the ships. The main bridge can be opened, and it takes 3 minutes to complete the opening and closing each time. As the wind area is very large after the bridge opened, in order to protect the structure and equipment of the bridge for opening, the bridge cannot open while the wind is greater than Beaufort Wind Scale 5.

Figure 3.2.4(3) Haihe open bridge

Figure 3.2.4(4) Binhai bridge

Source: Photos collected by the author’s daily work

（4）Binhai Bridge

The Binhai bridge is located at 10.8km downstream of the Erdao Gate. The total length of the bridge is 2800m, and the main span of the bridge is 364m. The air draught is33m. It is shown by figure 3.2.4(4).

3.2.5 The cross-river building is being built

(1) Binhai Bridge Extension

Binhai Bridge Extension stands by the Binhai Bridge, the distance between two bridge is about 33m. The main navigable hole of the Binhai bridge extension reserves 140m for the ships navigating, decreasing the original channel width. The maximum designed air draught is 14.0m. The construction site is shown as figure 3.2.5(1).

Figure3.2.5(1) Binhai Bridge Extension Figure 3.2.5(2)West Outer Ring Bridge

Source: Photos collected by the author’s daily work

(2) West Outer Ring Bridge

West Outer Ring Bridge is located 550m from the lower reaches of the Binhai Bridge. The main navigable hole of the West Outer Ring Bridge reserves 60m for the ships navigating, decreasing the original channel width. The maximum designed air draught is 12.5m. The construction site is shown as figure 3.2.5(2).

(3) Anyang Bridge

Anyang Bridge is located about 930m from the lower reaches of Haihe Open Bridge. The designed clearance width for ships navigating is 45m and the air draught is 12.5m. The construction site is shown as figure 3.2.5(3).

Figure 3.2.5(3) Anyang Bridge Figure 3.2.5(4)Yuxin Bridge

Source: Photos collected by the author’s daily work

(4) Yuxin Bridge

Yuxin Bridge is located near the estuary of the Haihe River. The designed clearance width for ships navigating is 45m and the air draught is 12.5m. The construction site is shown as figure 3.2.5(4).

3.3 Traffic condition

3.3.1 Traffic flow

(1) Traffic flow statistic

In recent years, the cargo ships sailing on Haihe River Downstream are gradually decreasing. And the table 3.3.1(1) shows the number of ships entering into Haihe River Downstream from 2010 to 2016. It can be seen that the ship flow in Haihe River is 5733, 4881, 3586, 3334, 3616, 2828, 2609.

Table 3.3.1(1) The traffic flow of Haihe River

Year	2010	2011	2012	2013	2014	2015	2016
Number of ships	5733	4881	3586	3334	3616	2828	2609

Source:(Haihe MSA, 2016)

Based on the navigable days with 330 days annually, the traffic flow is respectively 17.4, 14.7, 10.9 10.1, 10.9, 8.6 7.9 ships per day.

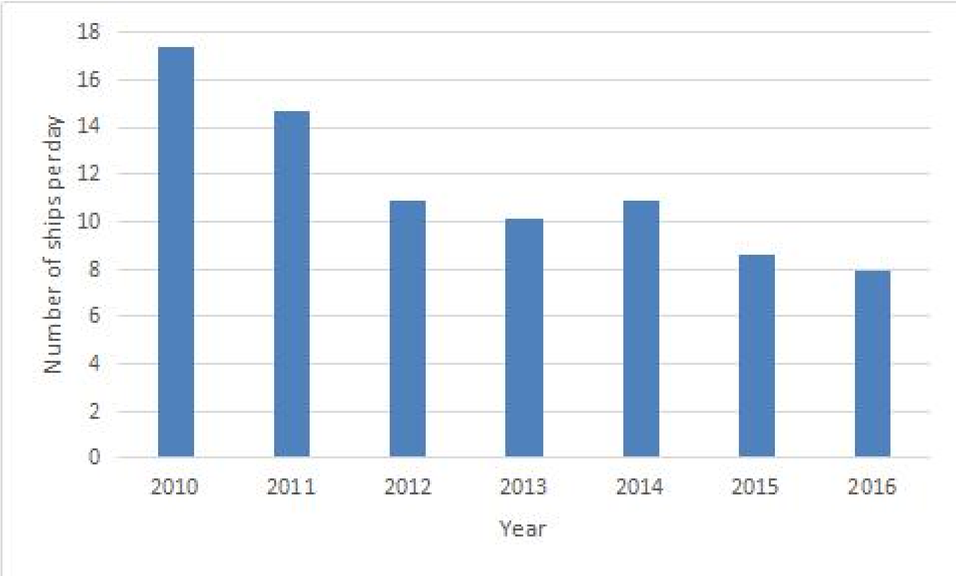

Figure 3.3.1(1)Number of ships per days in Haihe River (2010-2016)

(2) The allocation of ships

Along with the implementation of Tianjin Port planning, the freight function of Haihe area is continuously weakening. The shipping companies and terminal companies at at the upstream has gradually removed from Haihe River Port area. According to AIS data (Figure 3.3.1(2)), it is shown that the ships entering into Haihe area are mainly concentrated in the downstream wharf waters, and there are some ships in the middle reaches of the terminal waters.

Figure 3.3.1(2) The allocation of ships in Haihe area

Source: http://www.shipxy.com/

(3) Traffic characteristic

When the Haimen Bridge and Haihe Open Bridge are closed, the air draught is too small for the merchant ships to pass. So, the traveling of ships on Haihe area is concentrated at the time of the two bridges opened. According to the Haimen Bridge opening scheme, every year from April 17 to August 23 the opening time of the Haimen Bridge is at 5:15 in the morning, from August 24 each year to April 16 the following year the opening time is 13:30 in the afternoon. The opening time lasts no more than 1.5 hours one time. The Haihe Open Bridge will open synchronized with Haimen Bridge. At the closed time of the two bridge, only the small tourist ships can pass the bridge.

(4) Passenger ships in Haihe area

The passenger ships in Haihe downstream area are mainly composed of two parts: one part is the ferries used for the passengers to cross the river, the other part is the tourism ships provided for the tourists to enjoy the sight of Haihe River.

There are five ferry stations distributed in the the Haihe River Downstream. One of them is the Dagu Hua ferry station which is the biggest one. There are 3 ferry vessels served at this station, each of the ferry can carry 188 passengers and 12 vehicles. Annually, the passengers traveling by these ferries are more than 400 millions. The other four ferry stations are located in the upper reaches of the Haihe Downstream area where the economy is relatively underdeveloped. Each station has only one ferry which can carry 20 passengers.

There are 3 tourism companies engaging in the passenger traveling on Haihe River Downstream. Totally, they have 6 large luxury vessels with each capacity of 100 passengers (see table 3.3.1(4)).

Table 3.3.1(4) The tourism ships on Haihe River Downstream

Tianjin Dagu Haihe Passenger Transport Co., Ltd			Kelly Cyclot Yacht Services Ltd			Tianjin Tanggu Hai Lian Industrial Corporation		
Barge	Luxury vessel	Yacht	Barge	Luxury vessel	Yacht	Barge	Luxury vessel	Yacht
2	2	4	1	2	4	1	2	2

Source: Unpublished internal information of Haihe MSA

In recent years, the passengers traveling on the ships on Haihe River Downstream are increasing continuously. (see table 3.3.1(4))

Table 3.3.1(4) Passengers traveling on the ships on Haihe River Downstream

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015
Ferry	320	330	340	360	380	400	410	420	430
Tourism	55	80	102	120	135	155	170	195	220

Source: Unpublished internal information of Haihe MSA

Accompany by the economic development of Haihe River area, the personnel travel and transportation needs will be further increased. Especially during the tourist season, such as the May Day, National Day and other statutory holidays.

3.3.2 Traffic accident

(1) Accident category.

During the past decades, the accident happened in Haihe River Downstream area are mainly collision, ground, contact damage and some other accident. No other kinds of accident happened. The proportion is respectively 64%, 5% and 28%. The number and distribution of the traffic accidents in Haihe River Downstream in 2007-2016 is shown below as table 3.3.2(1) and figure 3.3.2(1).

Table 3.3.2 (1) The number of accident in Haihe River Downstream

Year	Collision	Ground	Contact damage	Other
2007	6	0	2	0
2008	4	0	0	1
2009	5	0	2	0
2010	6	0	2	0
2011	0	2	2	0
2012	1	0	0	0
2013	1	0	0	0
2014	0	0	2	0
2015	1	0	0	0
2016	1	0	1	0
Total	25	2	11	1

Source: Source: Unpublished internal information of Haihe MSA

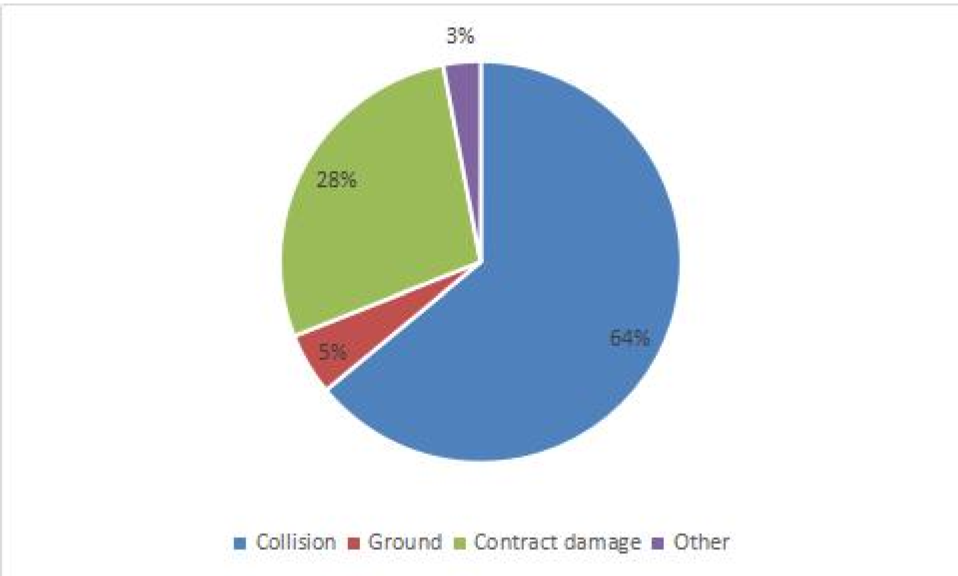

Figure 3.3.2(1) The proportion of accident category

(2) Accident level

According to the statistic of the accident happened during 2007 to 2016 in the Haihe River Downstream, 97% of the accidents are minor accidents. And there is no accident happened beyond major accident. The statistic of accident level is shown by table 3.3.2(2) and figure 3.3.2(2).

Table 3.3.2(2) The accident level in Haihe River Downstream

Year	Summation	minor	General	Major	Serious	Extra serious
2007	8	8	0	0	0	0
2008	5	5	0	0	0	0
2009	7	7	0	0	0	0
2010	8	8	0	0	0	0
2011	4	3	1	0	0	0
2012	1	1	0	0	0	0
2013	1	1	0	0	0	0
2014	2	2	0	0	0	0
2015	1	1	0	0	0	0
2016	2	2	0	0	0	0
Total	39	38	1	0	0	0

Source:Source: Unpublished internal information of Haihe MSA

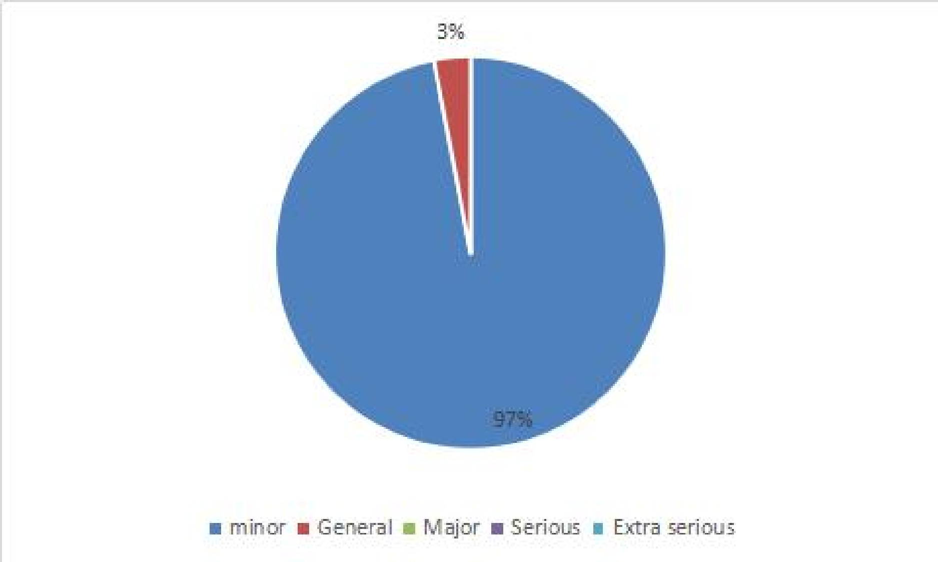

Figure 3.3.2 (2) The proportion of accident level in Haihe River Downstream

(3) Accident trend

The table 3.3.2(2) shows that in the Haihe River Downstream, there are an average of 3.9 accidents every year. And in the 2007 and 2010 the accidents occurred the most with 8 times. The main trend of the accidents is decreasing. (Figure 3.3.2(3))

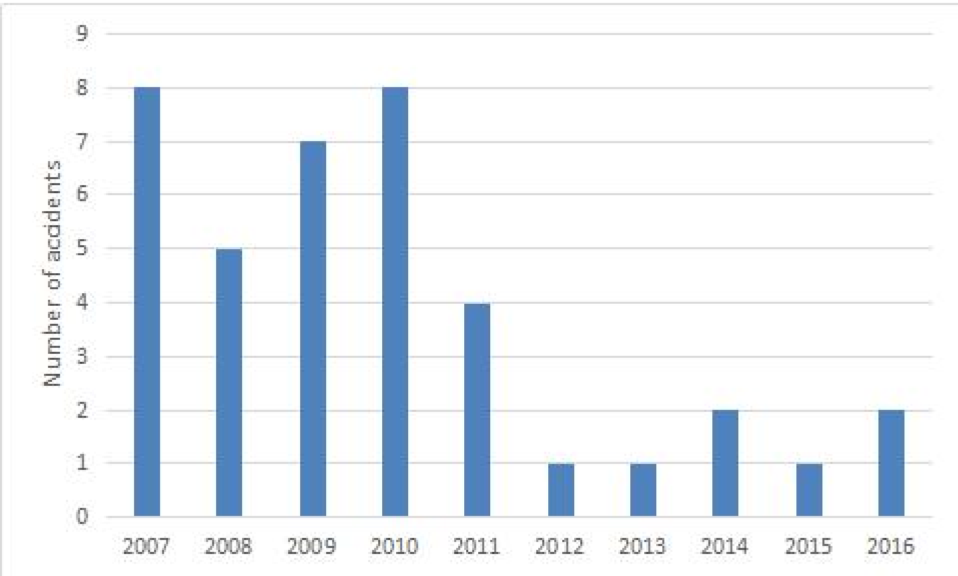

Figure 3.3.2(3) The total number of accident annually(2007-2016)

(4) Forecast of Haihe River Water Traffic Accident by GM(1.1) model

The occurrence of maritime accidents has a gray feature, so the Gray Theory can be used for accident analysis (Li, 1997). This method is accurate and easy to operate, and it is also helpful method to transform the accident analysis to the information management system. GM (1.1) model is one of the most commonly used gray prediction model. It is a model consisting of a first order differential equation containing only a single variable, and the actual predicted value is obtained after the reduction process. As there have been no casualties of the traffic accidents in the Haihe River Downstream area recent years. This paper are only use the number of accident as an indicator of the accidents.

According to the original accident data from 2007 to 2016 in Table 3.3.2(2), and this paper uses G to present the accidents number, then a gray prediction model is created. The number of accidents G prediction model is as follows:

$$F(i) = 44.6778 - 45.38\, e^{-0.2119i}$$

$$G(i) = F(i) - F(i-1)$$

After the calculation by the MATLAB (Appendix 1), the result of the prediction of the number of accident in Haihe River Downstream area is shown as figure 3.3.2 (4).

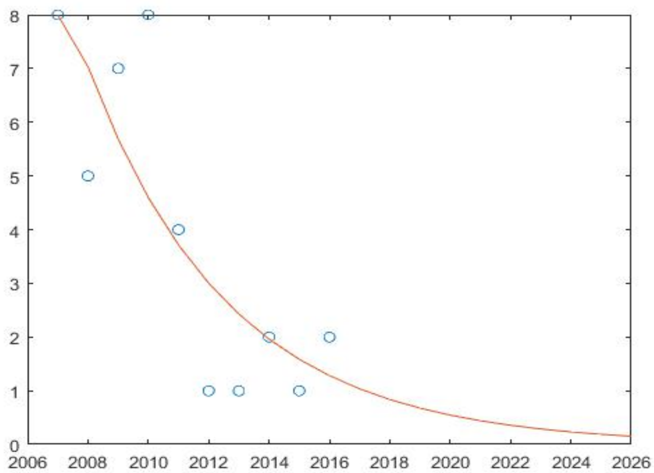

Figure 3.3.2 (4) The result of accidents prediction by GM(1.1) model

The residual error of simulation value in 2008 and 2010 is larger than the expectation. Since the value of the data specimens is small, this is still considered within acceptable limits. The result can basically present the accident trend for the Haihe River Downstream area. According to the above model, the forecast of traffic accidents in Haihe River Downstream area from 2017 to 2020 is shown as table 3.3.2 (4)

Table 3.3.2(4) Accident prediction (2017-2020)

2017	2018	2019	2020
1.0351	0.8366	0.6762	0.5465

3.4 Current SAR situation in Haihe River Downstream

3.4.1 SAR system

Haihe search and rescue system belongs to the maritime search and rescue branch level in the Chinese search and rescue system. Its higher authority is the Tianjin Maritime Search and Rescue Center. The Binhai New Area government is the primely responsible body for the SAR organization and management. And the office of the SAR center is located in the Haihe MSA, who is in charge of the routine affairs of the SAR work. When there is dangerous situation and with the request of rescue, the Haihe SAR center is in charge of the organization and command SAR operation, and the transport, medical and police department assist to carry out the rescue operation.

3.4.2 Current SAR resources

Basically, Haihe River Downstream is enclosed waters. The Erdao Gate is the up end of this river and the ships passing is not permitted. The lower end is the New Port ship lock which permits ships passing. There are no professional SAR forces in the area and the rescue boat need to pass through the New Port ship lock to enter into this area. Currently, the SAR operation relay on the social forces in the river, including:

Tianjin Port Barge Company : 2 tugs

The 3 tourism company : 6 luxury vessel and 8 yacht

The merchant ships sailing in the area

According to the municipal planning of Tianjin government, Haihe River Downstream will build a maritime SAR station equipped with certain professional search rescue boats.

3.4.3 The problem of the SAR resources

In China, almost all of the SAR operations are led by the government. But the SAR resources are nearly blank in Haihe River Downstream. There are still many problems with the task of completing the SAR operation by social forces alone.

The rescue boat is unprofessional as well as the rescue devices, this leads to the low efficiency of the operation;

The personnel that carry out the SAR operation is also unprofessional, in spite of the training by MSA annually, they are lack of SAR ability;

Under the existing system, the SAR operation for personnel is no compensation mechanism. The initiative of the company is insufficient.

The social SAR forces only stand by in the day time, and they are mainly concentrated at the lower reaches with no SAR forces in the upstream of the area.

3.4.4 SAR case

At 04:30 July 18th, 2014, a motor vessel tried to pass the Haihe Open Bridge while it was closed and caused the collision between the ship's compass deck and the bridge due to the unfamiliar with the Haihe channel. The mainmast of the ship fell down to the aft deck and the second officer who was performing a lookout mission fell overboard to avoid the mainmast. The Haihe SAR center had immediately found SAR forces to rescue the officer, but there was no answer. The tourism company were at rest at that time, and it was 2 hours later when the rescue boat reached at the man overboard. Fortunately, the second officer survived because the water temperature is high enough and the second officer found a rope connected to the bridge pier.

3.5 Summary of this chapter

Affected by the municipal development planning of Tianjin, the cargo ships sailing on Haihe River Downstream is decreasing annually, and the accident occurred is less and less. Although there is no serious accident happened during the recent years and the prediction shows the probability of traffic accident in the future is very small, the risks of traffic in this area cannot be ignored. There are many unfavorable factors existing in the area, such as the numerous bridges and bends on the river, the disastrous weather etc. The Haihe River Downstream will gradually change into passenger traveling function, and more and more passengers are involved in the safety issues of traveling on board. However, the SAR service in the area still needs to be improved for the absence of public SAR resources.

Chapter 4 The demand of search and rescue resources in Haihe River Downstream

4.1 Definition

The search and rescue resources include two aspect: the SAR organization and SAR facility. SAR organizations include all agencies that perform distress surveillance, communication, coordination and response functions. SAR facilities that include all aircraft, ships and other search and rescue facilities coordinated by the SAR coordination centers whether public or private (IAMSAR Manual: Vol ii, 1998). In this paper, it is mainly going to discuss the SAR facilities and SAR service personnel need to be equipped to rescue people in danger in Haihe River Downstream. These resources can be provided by the government public resources, usually as professional rescue resources; and they can also be provided by enterprises, groups or individuals as the social resources, which generally refers to non-professional rescue resources.

4.2 The ground for the allocation of SAR resources

4.2.1 International convention

Article VII of Chapter 5 of the SOLAS Convention provides that the contract states should bear the obligation of ensuring the arrangement of distress communication and coordination. These arrangements include the establishment, operation and maintenance of SAR facilities

Article 2.2 and 2.5 of Chapter 2 of the SAR Convention provides that the contract parties shall establish national procedure for the SAR service and to identify and designate all facilities that can be used to carrying out the SAR operation.

4.2.2 National laws and regulations

Article 38 of chapter 7 of Maritime Traffic Safety Law of the People 's Republic of China provide that the administration shall immediately organize the SAR operation after receiving the distress report. The relevant units and the ship, which are near the scene of the accident and facilities, must follow the unified command of the competent authorities.

Article 26 of chapter 2 of Emergency Response Law of the People 's Republic of China provide that the country level government or above shall integrate emergency resources to establish a comprehensive emergency rescue team. And it may set up a professional emergency rescue team according to the actual needs.

4.3 The need for SAR resources in Haihe River Downstream

4.3.1 Risk of traveling in Haihe River Downstream

Two of the most important indexes of risk are frequency and consequence. Generally, both the high frequency and serious consequence accidents can arouse the unease of the society. However, the risk can only be controlled within a acceptable range and it is always used ALARP (As Low As Reasonably Practicable) to represent in the Formal Safety Assessment, which is a method adopted by IMO for rule-making. In the FSA, the FN-diagrams can provide a good show of the relationship between the frequency and consequence of the risk (MSC, 2000). The Figure 4.3.1 shows the acceptance criterion for passenger ships shall be controlled under 0.1 fatality per ship year.

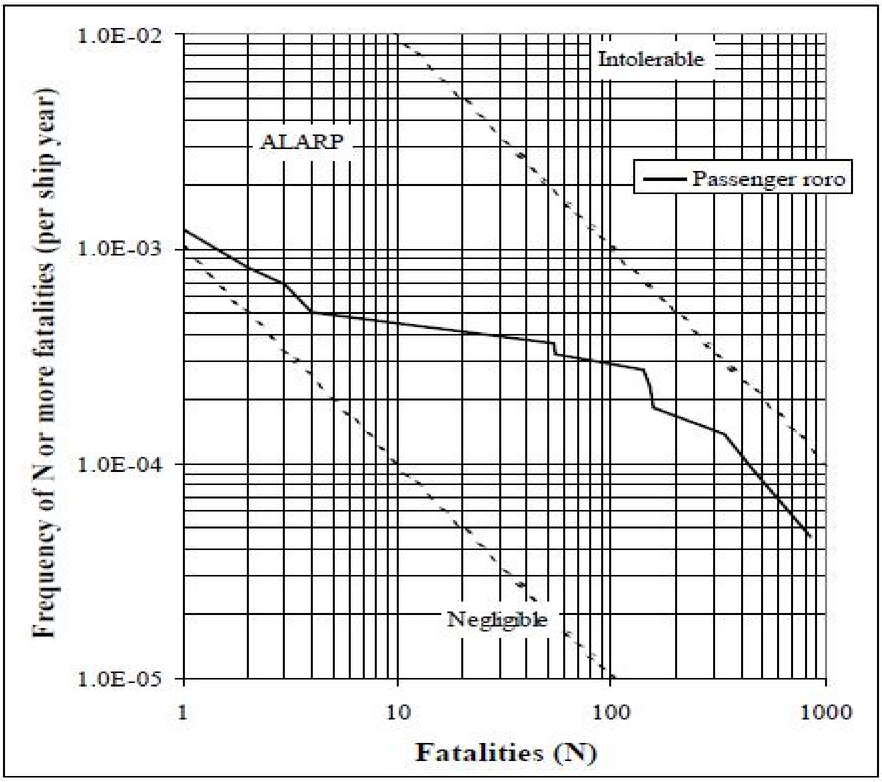

Figure 4.3.1 FN-Diagrams

Source：(MSC, 2000)

According to the history statistics, there are an average of 3.9 accidents every year during the past decade. The trend of annual accidents’ number is decreasing, but it is unrealistic to completely eliminate the risk. There will be still approximate one accident every year in the next few years predicted by the GM (1.1) model. Taking into account the transform of ship type in Haihe River Downstream, the risk involved with passengers will be more frequent. The most likely accidents occurred in Haihe River Downstream are collisions, and the consequence for a collision is always intake of water, out of control, and even worse man overboard or injured. As the last method to control the fatality on the passenger ships, the SAR resource shall be properly provided in the Haihe River Downstream.

4.3.2 Potential needs of Mass Rescue Operation

Once a collision accident is occurred the passenger ships, a great number of people will suffered from danger. Passenger ship emergency is one of the potential causes of mass rescue operation(MRO), and a large number of people will need to be rescue (IMRF, 2015). MROs are relatively low-probability high-consequence events but call for the immediate rescue of large numbers of passengers and crew in poor environmental conditions (IMO,2003). There is no doubt that it is need a mass of SAR resources to help people in emergency.

4.4 Factors that affect the success of the rescue

4.4.1 Wind and current

After the ship is out of control or the person falls into the water, they will drift under the action of wind and flow. When the search boat arrives at the reported accident location, the ship and personnel position in distress may have changed. This will increase the difficulty of SAR operation to a certain extent. Uncertainties in the prediction of weather or in the characteristic of the search object can significantly affect the results and the extension of the search area (Roberto, 2015).

4.4.2 Sweep width

Search width is an important indicator to determine the quality of the search conditions. Experience has shown that the "discovery probability curve" under harsh search conditions is usually lower than the ideal search condition (IAMSAR Manual: Vol ii, 1998). The element relating to sweep width are mainly the type of the target, visibility, the height of the searching facility. Normally the higher is the searching facility and target, the larger of the sweep width without regard to visibility. The geographic range of a target D_0 (n miles)is:

$$D_0 = D_e + D_H = 2.09\left(\sqrt{e} + \sqrt{H}\right) \quad \text{(Chen, 2007)}$$

e: search facility height(m)   H: target height(m)

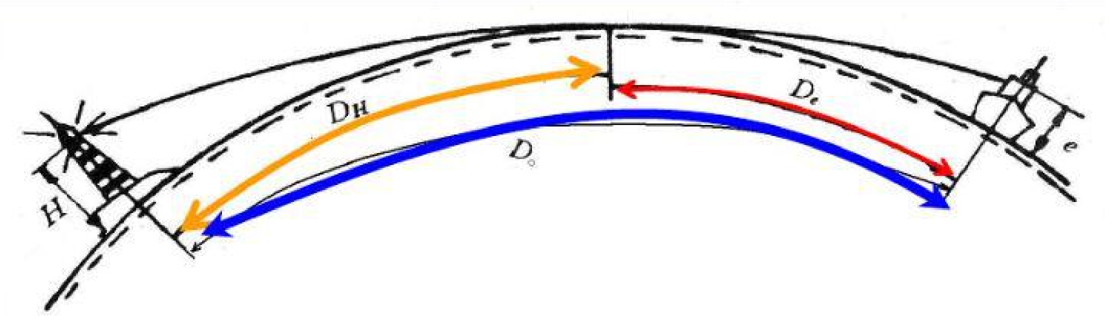

Figure 4.4.2 Geographic range

4.4.3 Temperature

While the victims immersion in the cold sea water for too long, they will experience a lot of body heat loss, resulting in decreased body temperature. Further more it will cause coma, loss of consciousness, and hardening of the blood vessels until death (IAMSAR Manual: Vol ii, 1998). The expected survival time in the cold water is shown in the table 4.4.3

Table 4.4.3 Cold water survival time

Expected Survival Time in Cold Water		
Water Temperature	Exhaustion or Unconsciousness in	Expected Survival Time
70–80° F (21–27° C)	3–12 hours	3 hours – indefinitely
60–70° F (16–21° C)	2–7 hours	2–40 hours
50–60° F (10–16° C)	1–2 hours	1–6 hours
40–50° F (4–10° C)	30–60 minutes	1–3 hours
32.5–40° F (0–4° C)	15–30 minutes	30–90 minutes
<32° F (<0° C)	Under 15 minutes	Under 15–45 minutes

Source: (United State Search and Rescue Task Force, 2017)

4.4.4 The golden time of the rescue

The ships and people in danger in the water may be spread by the wind and current over time and increase the search range. In Haihe River Downstream, the width is no more than 450m, which means that the sweep width of the searching personnel can cover all the river surface when the rescue boat sailing at the center line of the river. And the man overboard can only drift along the river. So the most important factor affect the success of SAR operation is the water temperature. It is generally believed that gold rescue time is 72 hours. If there are people fell into the water, the golden rescue time should be 12 hours in summer and 3 hours in winter. (Huang, 2014)

4.5 The choices of SAR resource

According to the MSA practical experience, the SAR operation is mainly carried out by two kinds of pattern: aircraft and rescue boat.

4.5.1 Aircraft

The aircraft used for SAR operation are mainly two kinds: the fixed wing aircraft and helicopters. The fixed wing craft are mainly used to search the people in danger and fixed their position. The helicopter can be used both search people and transfer people out of danger.

4.5.2 Rescue boat

China MSA has equipped with a variety of rescue ships from 3000GT to the rescue yacht as described in the 2.3.2 (1). These boats can be used both to search the people in danger and to transfer them to safe place.

4.5.3 Choice of Haihe River Downstream

The aircraft equipped out of the Haihe River Downstream area also can carry out the SAR operation without the limitation of the New Port ship lock and the bridge, where there is no need for the configure of aircraft. Affected by the air draught of the Haimen Bridge, the vessel's air draught equipped in the area shall be less than 7m. Among the vessel used by the MSA now, the vessel with 35m length and is smaller which is suit for the area. Considering with the factor of weather during the SAR operation, the high-speed rescue yachts can be used but may be limited in the bad weather.

4.6 Number of SAR vessels needed

According to the Tianjin SAR planing: there will be a SAR station built in Haihe River, and the station mainly cover the whole area from Erdao Gate to the New Port ship lock. In this area, the rescue boat shall reach the accident area no more than 30 minutes and the success rate for life rescue shall be more than 94%. The impact of negative factors such as wind and temperature on the success of search and rescue will be increasing over time. So, the time becomes a key point in the SAR operation. The sooner the SAR forces reach the accident area, the higher is the success rate of the SAR operation.

During the operation, the time of SAR for a rescue boat can be divided into four part. That is the preparing time T_1, the search and rescue time on site T_2 and the trip time between the accident area and the safety place T_3 and the time unloading the victims T_4.

$$T = T_1 + T_2 + T_3 + T_4$$

According to the practice of Tianjin MSA, the boat can be ready to start from the berth in 10 minutes. And the time unloading the victims is about 10 minutes. So the T_1 and T4 can be a fixed value. In 2013, there was a search and rescue drill carried out in Haihe River Downstream, the time of finding and saving a passenger in the water is approximately 30 seconds. So the total time of a SAR operation is:

$$T_{\text{total}} = T_1 + \text{n} \times C \times 0.5 + n \times \frac{2S}{V} + n \times T_4$$

n: the number of trips for rescue boat

C: the capacity of rescue boat

S: the distance between accident area and rescue station

V: the speed of the rescue boat

Assume the SAR station in Haihe River Downstream area is built at the middle point of the river, and the worst situation of 200 passengers need to be transferred, and the total time need no more than 3 hours. The SAR operation shall be finished under the following condition:

$$T_{\text{total}} \leq 180_{\text{minutes}}$$

and

$$N \times C \times \mathrm{n} \geq 200$$

Then if we use the rescue boat with the length of 35m, speed 20 Kn and capacity of 30 passengers. The number of the rescue boat N shall be more than 4. And if we use the high-speed rescue yacht with the capacity of 8 passengers and speed 30_{Kn}, the number of yachts need to be more than 9.

4.7 SAR service personnel and training

SAR service personnel means all those who provide, or may provide, a SAR service, including the SAR Co-ordinators at different levels and the crew of the SAR boat (IMO, 2006). As the SAR sub-center, there are already sufficient emergency watch keepers standing by for 24 hours a day and they are trained for SAR mission coordinators and on science coordinators in Haihe MSA. According to the current three shift mode work time of Tianjin MSA and each shift with an officer, an engineer, a sailor and an oiler, there will be a total of 12 crew members needed for the vessel with length of 35m. Each shift for the yacht is 2 personnel and the total is 6 crew for a yacht.

It is necessary to develop SAR personnel's knowledge of the special arrangements required to deal with the incident so that they will be implemented successfully.(IMO,2006) However, MRO is very unlikely to occur, so it is difficult for SAR personnel to gain experience from practice. There are a great deal of training associated with the additional challenges of major incident response needed by these SAR personnel, such as communication, dealing with injured, coordination, etc.

4.8 Recommendation for the equipping SAR resources

The best method to rescue people at sea would be fully supply the SAR resources needed. However the traffic accident have the character of uncertainty and the probability is quite low as predicted in this article 3.3.2 (4). The maintenance of a complete set of SAR resources consumes a lot of capital, and there may be no return otherwise there is serious accident happened. In the author's opinion, the Haihe SAR sub-center shall equipped with a small amount rescue boat (1 to 3 vessels) to standby for emergency and to play as on site coordinator vessel in the MRO. At the same time, the Haihe SAR sub-center shall contract with the passenger ship company for a supplement of the SAR resources.

4.9 Summary of this chapter

The risks of major accident in Haihe River Downstream are with small probability but the consequence are terrible. In order to make a quick response in the MRO, the demand of rescue boat in Haihe River Downstream is more than 4 vessels with 35m length only, or 9 high-speed rescue yachts only. The construction of these resources can be that the official resources play as leading and the social resources play as assisting. And the training program and encourage scheme shall be serious-minded.

Chapter 5 The development of SAR resources in Haihe River Downstream

As early as 2012, Tianjin MSAR center has become awareness of the lack of professional SAR resources in Haihe River Down stream, and decide to build SAR station and rescue boat in this area.

In July 2015, a proposal submitted by Haihe MSAR was adopted by the Meeting of Mayors of the Binhai New Area. It is concerned about building 3 rescue boat in Haihe River Downstream and setting up a government compensation mechanism for the social SAR entities.

In September 2016, three rescue boats for Haihe MSAR center began to be built, which are one vessel with length of 35m, speed of 20Kn , capacity of 30 passengers and two rescue yachts with speed of 30Kn, capacity of 8 passengers. All of these boats will be in operation before December 2017. They will complete work of the patrol, SAR and coordination the Haihe River Downstream, but there is still a gap between the SAR need and supply.

Haihe MSAR center will organize all the social resources with SAR capability to make up a supplement of the official resources and hold proper training and SAR drill to meet the needs of SAR in this area.

Chapter 6 Conclusion

After the transformation of the Haihe River Downstream transport function, the passengers traveling on the river are increasing annually and the protection for safety of passenger's life becomes more and more urgent.

According to the historical data, the accident in this area is declining and the prediction shows the number of accident is around 1 annually in the future 4 years.

Under the current search and rescue system in China, the SAR resources in Haihe River Downstream shall be organized and management under the leadership of the government.

The number of rescue boat needed in this area is 4 vessels with 35m length alone or 9 rescue yacht only. There are still gaps between the demand and the planning rescue resources provided by the government.

The government shall establish certain mechanism to encourage the social company with ability of SAR to provided effective SAR service, so as to eliminate the gap.

Reference

Achutegui, J. (1996). *The "Amoco Ca'diz" Stranding Could Have Been Avoided.* Wessex Institute of Technology, UK Congress: I International Conference on Environmental Problems in Coastal Regions-Coastal Environment 96, Rio de Janeiro.

Australia Maritime Safety Authority. (2017). Search and rescue arrangements in Australia. Retrieved May 24, 2017 from the World Wide Web:https://www.amsa.gov.au/search-and-rescue/australias-search-and-rescue-system/sar-arrangements-in-australia/

Cahill, R. (1983). *Collisions and their causes.* Fairplay Publications. London.

Chen Hong. (2007). *Nautical navigation.* Dalian Maritime University Press.Dalian,China.

Emergency Response Law of the People 's Republic of China, China,.(2007).

Haihe Maritme Safety Authority. (2016). *Navigation environment analysis in Haihe River Downstream 2016.* Unpublished internal report. Tianjin, China.

House, D. (1988). Marine Survival and Rescue Systems. Nautical Institute, Centreville, Maryland

Huang Mindong. (2014). Discussion on the maritime rescue time at sea. *World Shipping. Vol 23.P35, 2014.*

International Aeronautical and Maritime Search and Rescue Manual Volume ii, IMO, (1998)

International Convention for the Safety of Life at Sea 1974/1978，IMO,（1974).

International Convention On Maritime Search and Rescue, IMO, (1979).

International Maritime Organization. (2003). Guidance for mass rescue operations: COMSAR/Circ.31.

International Maritime Organization. (2006). Guidelines on the training of SAR service personnel working in major incidents:MSC.1/Circ.1186.

International Maritime Rescue Federation. (2015). MRO guidance paper: general guidance on providing support on scene. Retrieved May 24, 2017 from the World Wide Web: http://www.imrfmro.org/categoriesmro/resources/3-3-providing-support-on-scene

Li Jing, Wu Zhaolin. (1997). Gray analysis of ship traffic accident. *Journal of Dalian Maritime University, Vol 23, No.2 1997.*

Liu Sifeng. (1999). *Gray system theory and its application.* Science Press, Beijing,China.

Marriot, J. (1987). *Disaster at Sea.* Ian Allan. Surrey.

Ministry of transportation of China. (2006). *National Maritime Search and Rescue Emergency Plan.* China, (2006).Retrieved May 24, 2017 from the World Wide Web: http://www.mot.gov.cn/zhengcejiedu/tufashijianyjglgd/xiangguanzhengce/201510/t20151015_1905364.html

Maritime Safety Committee. (2000, February 1). Formal safety assessment. Decision parameters including risk acceptance criteria, MSC72/16: submit by Norway. London: Author.

Maritime Traffic Safety Law of the People 's Republic of China, China,(1984).

Roberto Vettor and C, Guedes Soares. (2015). Computational system for planning search and rescue operations at sea. *Procedia Computer Science Volume 51, 2015, Pages 2848 –2853*

Bin Hai New Area Government. (2012). *Tianjin Binhai New Area CBD yacht & tourism boat project feasibility study and general conceptual planning.* Unpublished internal report. Tianjin, China.

United State Search and Rescue Task Force. (2017). *Cold water survival.* Retrieved May 24, 2017 from the World Wide Web: http://www.ussartf.org/cold_water_survival.htm

U.S. Coast Guard. (2007). National search and rescue plan of the united state.

Retrieved May 24, 2017 from the World Wide Web: https://www.uscg.mil/hq/cg5/cg534/manuals/Natl_SAR_Plan(2007).pdf

West Australia Museum. (1656). Vergulde Draeck. Retrieved May 24, 2017 from the World Wide Web: http://www.museum.wa.gov.au/maritime-archaeology-db/roaring-40s/vergulde-draeck

Appendix A GM (1.1) model MATLAB source code

```
clear
syms a u;
c=[a u]';
A=[8 5 7 8 4 1 1 2 1 2];
Ago=cumsum(A);
n=length(A);
for i=1:(n-1)
C(i)=(Ago(i)+Ago(i+1))/2;
end
Yn=A;Yn(1)=[];
Yn=Yn';
E=[-C;ones(1,n-1)];
c=inv(E*E')*E*Yn;
c=c';
a=c(1);u=c(2);
F=[];F(1)=A(1);
for i=2:(n+10)
F(i)=(A(1)-u/a)/exp(a*(i-1))+u/a
end
G=[];G(1)=A(1);
for i=2:(n+10)
G(i)=F(i)-F(i-1);
end
t1=2007:2016;
t2=2007:2026;
G,a,u
plot(t1,A,'o',t2,G)
```