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Navigation safety management on Hangzhou Bay Sea-crossing Bridge

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Navigation Safety Management on Hangzhou Bay Sea-crossing Bridge

By

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Declaration

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

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

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Acknowledgment

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Title: **Navigation Safety Management on Hangzhou Bay Sea-crossing Bridge**

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ABSTRACT

The research paper is a study of the navigation safety management of Hangzhou Bay Sea-crossing Bridge by applying the science of management. Based on the common practices and experiences on navigation safety of bridge, present problems are illustrated and some pieces of advice are rendered by the author.

First, the nature, impact and reasons for ship-bridge collision are analyzed. Then, the practices and experiences for navigation safety management of bridge are detected. It ranges from the international convention, industry standard, measures for navigation, protections for minimizing the force impact and new technology.

By applying the science of management, Jiaxing MSA's work for the bridge is comprehensively reviewed and checked. Through planning, organizing, leading and controlling process, the navigation safety of bridge is monitored and protected effectively.

The present problems restricting the navigation safety of the bridge are analyzed based on achieved researches. It contains national regulation, hardware facilities, management crew and interest for many parties. At last, some pieces of advice are rendered based on the situation and future challenges.

KEYWORDS: Navigation Safety Management, Hangzhou Bay Sea-crossing Bridge

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List of Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ABS	American Bureau of Shipping
AIS	Automatic identification system
CCTV	Closed-circuit television
China MSA	Maritime Safety Administration of the People's Republic of China
COLREG	Convention on the International Regulations for Preventing Collisions at Sea, 1972
DWT	dead weight
FEM	Finite Element Modeling
FSC	flag state control
GT	gross tonnage
IABSE	International Association for Bridge and Structural Engineering
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IMO	International Maritime Organization
MBO	Management by objectives
MSA	Maritime Safety Administration
NM	nautical mile
PRC	People's Republic of China
SAR	search and rescue
SOLAS	International Convention for the Safety of Life at Sea, 1974
STCW	International Convention on Standards of Training, Certification and Watch keeping for Seafarers, 1978
TEU	Twenty-foot Equivalent Unit
VHF	Very high frequency
VTS	Vessel traffic service

Chapter 1 Introduction

1.1 Motivation

With economic development, transportation demands are higher and higher. To avoid area restriction and minimize the distance, more bridges rise across the water. Hangzhou Bay Sea-crossing Bridge (hereafter called Hangzhou Bay Bridge for short.) was born in the prosperous Yangtze River Delta economic development zone to the time. As the recorded longest sea-crossing bridge in the world, its construction and operation has positive economic and political meanings.

Jiaxing Maritime Safety Administration (MSA) as the administration for navigation safety management, devotes much energy to the bridge safety navigation. As a member of the organization responsible for the ship-bridge collision prevention, I am very proud of having participated in lots of activities securing bridge safety and improving transport efficiency.

1.2 Aims and objectives

The aim of the research paper is to find out the present problems for the bridge on navigation safety management in order to improve the future work for better navigating and crossing the bridge. The objectives of this research paper are as follows:

- Make clear nature, impact and reasons for ship-bridge collision.
- Detect the practices and experiences for navigation safety of bridge.
- Review the environment for bridge- water area, including nature and navigation.
- Apply the science of management to the Jiaxing MSA's work for the bridge.
- Analyze present problems that restrict the navigation safety of the bridge
- Present suggestions to improve the effectiveness for the future work

1.3 Methodology

By applying the science of management, Jiaxing MSA's work for the navigation safety management of Hangzhou Bay Bridge will be comprehensively reviewed. By studying the common practices and experiences for other bridges, present problems and good suggestions can be found out and rendered easily.

Chapter 2 Literature Review

2.1 Definition of ship-bridge collision

Any structure established in navigable waters constitutes a hazard to the shipping. And it is prone to be attacked by the moving objectives in turn especially the ships. That a ship reaches bridge alignment far from the navigation span does necessarily imply that a collision will occur. This will depend on the geometry of the ship (breadth, air draft), the size and location of the piers and the vertical clearance beneath the girder (Gluver & Olsen, 1998, p. 92).

There are three patterns for ship-bridge collision. First, contact with the pier. When the officer is not familiar with the channel or the main engine breaks down, it will lead to the ship collision with pier. Second, collide with the span. It can be caused by the improper evaluation of the vertical clearance. Third, stand up to the under surface of the bridge girder. It is normally seen in the inland water, where tide rises very quickly (Zhejiang MSA, 2012, November).

2.2 Impact of the collision

When the collision occurs, certain loss will come. First, bridge is damaged. Second, persons or vehicles on the bridge are affected. Third, ships or shipping companies afford external cost, for example, ship repairing, salvage fee, cargo damage, even the claim by the bridge owner. Fourth, business breaks off. The transport on the bridge has to be stopped as the result of the collision. The channel is blocked by the collision wreck. Fifth, water is polluted. Marine pollution are always companying the accident, influencing ecology balance. Sixth, deteriorate social impact. The public are not satisfied with the government or protest when a bad accident happens, bringing terrible influence (Zhejiang MSA, 2012, November).

2.3 Reasons for ship-bridge collision

Based on the man-machine-environment system, many factors are involved in ship-bridge collision. First, the crew is not qualified or poor quality. The shipping company's ability to manage is weak. Second, the condition of ship is not so good that machine failure happens. The bulbous bows of the ships increase the impact load. Bridges are poorly sited or designed with inadequate navigation clearance (Larsen, 1993, p.2). The bridge is lack of protection system for minimizing force impact. Third, the nature environment is poor, for example, strong wind, thick fog, rush tide and wave etc.. Vessel traffic flow is too intense. Aids to navigation are not clear enough.

2.4 Common practices and experiences for bridge

Table 1- Fatalities in ship-bridge collisions (1960-2002)

Bridge	Year	Fatalities
Severn River Railway, UK	1960	5
Lake Ponchartain, USA	1964	6
Sidney Lanier, USA	1972	10
Lake Ponchartain, USA	1974	3
Tasman, Australia	1975	15
Pass Manchac, USA	1976	1
Tjorn, Sweden	1980	8
Sunshine Skyway, USA	1980	35
Lorraine Pipeline, France	1982	7
Sentosa Aerial Tramway, China	1983	7
Volga River Railroad, Russia	1983	176
Claiborn Avenue, USA	1993	1
CSX/Amtrak Railroad, USA	1993	47
Port Isabel, USA	2001	8
Webber-Falls, USA	2002	12

Source: Gucma, L. (2009, June). METHODS OF SHIP-BRIDGE COLLISION SAFETY

EVALUATION. Maritime Traffic Engineering Institute, Maritime University of Szczecin, Szczecin, Poland.

Table 1 presents most important casualties of accidents involving ships and bridges (Gucma, 2009).

2.4.1 Introduction of navigation regulation

The International Maritime Organization (IMO), as the United Nations specialized agency with responsibility for the ship safety, security and marine pollution prevention related, has always paid great attention to the improvement of navigational safety by introducing conventions, recommendations and other instruments. The most popular in the shipping industry related with navigation safety are the conventions like International Convention for the Safety of Life at Sea, 1974 (SOLAS); the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREG); and the International Convention on Standards of Training, Certification and Watch keeping for Seafarers, 1978 (STCW) (IMO, 2013a).

2.4.2 Installation of navigational aids on the bridge and in the waterway

A navigational aid (also known as aid to navigation) is any sort of marker which aids the traveler in navigation determining their position or safe course, or warning them of dangers or obstructions to navigation. Common types of such aids include lighthouses, buoys, fog signals, and day beacons (Wikipedia, 2013).

International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) as a non profit, non governmental international technical association established in 1957 has devoted to harmonize aids to navigation worldwide. More knowledge may well be obtained from the fourth edition of *IALA Aids to Navigation Guide (Navguide)* (IALA, 2013a).

Larsen (1993, pp. 85-86) described some better types of aids for installation on the

bridge structure and in the waterway near the bridge crossing. Larger buoys with strong lights and fluorescent paint and recons activated by the radar signals of passing vessels were strongly recommended. Of course, the most suitable arrangement of aids should be achieved with the help of manoeuvring simulations with pilots.

In fact, the numbers and types of navigation aids installed are normally determined by the nature environment, navigation environment and the expectancy by the administration. The most used international practice is to do a risk management for the waterway crossing. Sometimes, the empirical knowledge applies to the decision making.

2.4.3 Implementation of vessel traffic management system

The most widely used and proved effective method among vessel traffic management system is the Vessel Traffic Service (VTS) which is shore-based system ranging from the provision of simple information messages to ships, such as position of other traffic or meterological hazard warnings, to extensive management of traffic within a port or waterway (IMO, 2013b). Typical VTS systems are comprised by radar, closed-circuit television (CCTV), Very high frequency (VHF) radio telephony and automatic identification system (AIS) to keep track of vessel movements and provide navigational safety in a limited geographical area.

The purpose of vessel traffic services detected in the *Guidelines for the Vessel Traffic Services* is to improve the safety and efficiency of navigation, safety of life at sea and the protection of the marine environment by providing information and advice on other traffic and navigational hazards to the vessels participating in the system (IMO,1997).

The Vessel Traffic Service (VTS) Committee of IALA deals with all aspects of VTS, such as the training of personnel, operational procedures, equipment requirements,

the impact of AIS on VTS and the role of VTS in security and global traffic monitoring systems (IALA, 2013b). The newly revised edition of *IALA VTS Manual* is published in 2012 which is due to edited every 4 years. It aims to fully meet the needs of the profession and those responsible for managing its activities, and is considered to be a general source of reference on any related topic (IALA, 2013c).

2.4.4 Ships' routeing systems and reporting systems

Ships' routeing systems and ship reporting systems are proved to improve safety of life at sea, safety and efficiency of navigation, and increase the protection of the marine environment (IMO, 2003, January).

The ships' routeing systems are used for the convergence of navigation route, high density or area restricting the ship activities. It is mandatory or recommendatory for ships passing by. There are many elements for the ships routeing system: traffic separation scheme, traffic lane, separation zone or line, roundabout, inshore traffic zone, recommended route, deep-water route, precautionary area and area to be avoided. They can be applied independently or assembly.

Ships' reporting systems ask the ships to report basic information to the shore-based station. The station will send some service in return. It enhances the communication between the ships and the shore. Chapter V Safety of Navigation of SOLAS Convention stipulates some requirements for ships.

2.4.5 Proper vertical clearance for ship plan

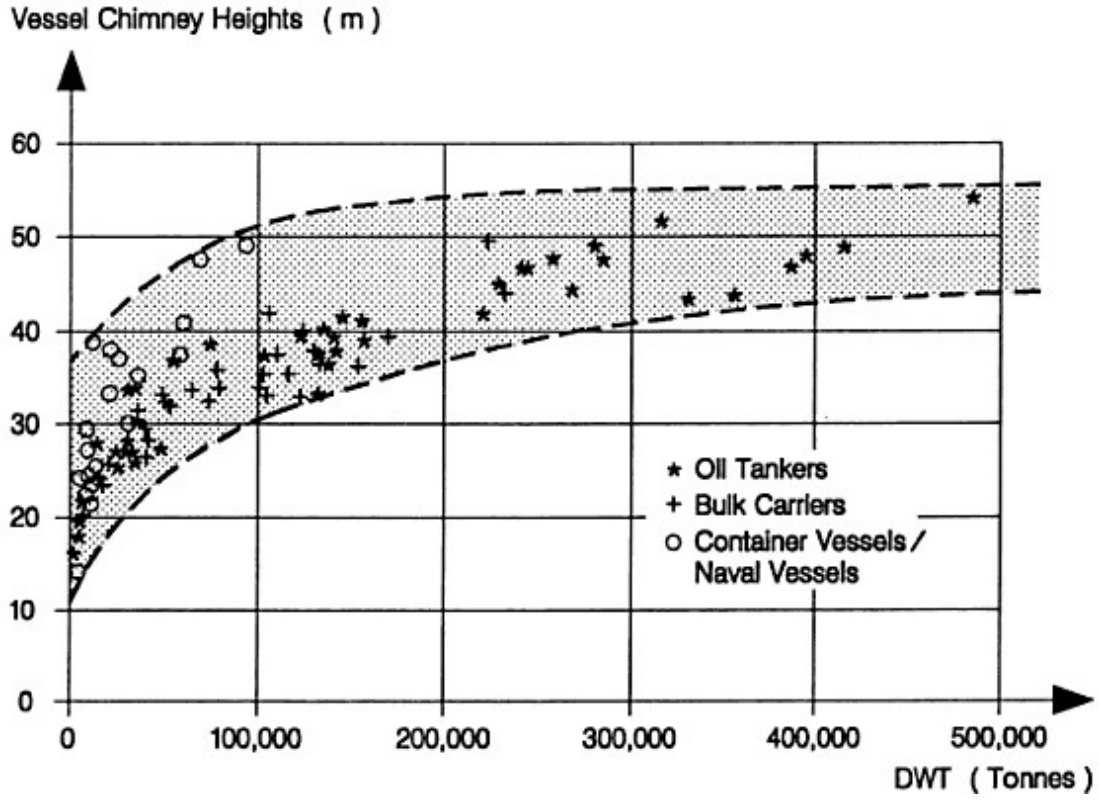

Figure 1- Typical height of chimneys above waterline of different types and sizes of vessels in ballast

Source: Larsen, D. (1993). Ship Collision with Bridges: The Interaction Between Vessel Traffic and Bridge Structures. *International Association for Bridge and Structural Engineering* (p. 9). Switzerland: Author.

According to shipping practice, the vertical clearance of a bridge for the ship crossing should be planned to allow the highest part of the ship, such as mast or antennae. It should permit the passage of the highest vessel in ballast condition at high water level with due allowance for vertical vessel movements (Larsen, 1993, p.9). However, data of vessel for the highest part is not available in public ship registers. Figure 1 shows the chimney height, which is less than the required air draft, providing some information on the height for reference. To obtain the final air draft, the height of auxiliary equipment such as mast and antennae should be added. A vertical clearance of 65m above high water level is enough for the existing merchant and naval ships some of which are listed in Table 2 for comparison,

special purpose vessels like crane vessels and offshore drilling rigs are not included.

Table 2 - Vertical clearance for some long span bridges

Bridge Name	Country	Completion Year	Navigation Span (m)	Vertical Clearance (m)
George Washington	USA, New York	1931	1067	65
West Bay	USA, California	1936	704 × 2	65
Golden Gate	USA, California	1937	1280	67
Bronx-Whitestone	USA, New York	1939	701	46
Tacoma Narrows	USA, Washington	1950	853	56
Mackinac	USA, Michigan	1957	1158	45
Forth	Great Britain, Scotland	1964	1006	52
Verrazano Narrows	USA, New York	1964	1298	69
Severn	Great Britain, England	1966	988	37
Tagus	Portugal	1966	1013	70
Angustura	Venezuela	1967	712	64
Kanmon	Japan, Honshu-Shikoku	1973	712	61
Bosphorus (1st)	Turkey	1973	1074	64
Humber	Great Britain, England	1981	1410	30
Innoshima	Japan, Honshu-Shikoku	1983	770	50
Ohnaruto	Japan, Honshu-Shikoku	1985	876	41
Minami Bisan-Seto	Japan, Honshu-Shikoku	1988	1100	65
Kita Bisan-Seto	Japan, Honshu-Shikoku	1988	990	65
Shimotsui-Seto	Japan, Honshu-Shikoku	1988	940	31
Bosphorus (2nd)	Turkey	1989	1090	64

Source: Larsen, D. (1993). Ship Collision with Bridges: The Interaction Between Vessel Traffic and Bridge Structures. *International Association for Bridge and Structural Engineering* (p. 10). Switzerland: Author.

2.4.6 Protection measures

Larsen combined several scholar's research findings and concluded that, the protection system should be designed to not only make the bridge structure out of force impact, but also to protect the vessel and environment against serious damage. If the force resistance of the protection system is higher than the vessel crushing force, the contact area of vessel will crush and the impact energy will be primarily absorbed by the vessel. Otherwise, the impact energy will be diverted to the

protection system. So, different types of protection system should be considered separately. Some are located directly on the bridge, such as a bridge pier fender. Others are independent from the bridge structure, like dolphin. Also, the commonly used protection systems for bridge are discussed further among fender system, pile supported system, dolphin protection, artificial island or reef protection and floating protection system (Larsen, 1993, pp. 91-92). They can be applied independently or together with final objective for reducing strike force from the vessel and prevent damage to the bridge.

In fact, every method for the bridge protection have been innovated and improved by engineers since it was first used. Kerry (2003) together with his team invented high energy impact absorption fender system using valvular control logic which was patented in the United States. An energy-absorbing "smart" bumper system features a variably controllable valve which is responsive to impact conditions.

Svensson (2009, pp. 21-32) summarized the development of pier protection against ship collision over the last 25 years. Comparisons of impact forces from general formulas for equivalent loads, based on collision tests, to numerical Finite Element Modeling (FEM) simulations are given. Further, examples of the structural protection of 18 bridges are described. He pointed out that, three options are available for protecting bridges against ship collision: place out of reach on shore, deflect ship by artificial islands or guide structures and make piers strong enough to withstand direct collisions. At last, he concludes the two most important considerations for protective measures are the determination of impact forces and the structural design of collision protection.

2.4.7 Risk assessment

Bridges located over the navigable waterways could be threatened by the force impact of passing ships with vertical or horizontal waterway borders. The bridge safety for navigation could be defined as its possibility to resist loads from ships

when collision occurs. Many bridges especially historical ones are not designed to fulfill this criterion mostly due to extensive growth of ships capacities and its dimensions (Proske & Curbach, 2003). To identify potential problems before the accident so that risk-handling activities may be planned and invoked as needed to mitigate adverse impacts on achieving objectives, risk management is usually applied to the bridge management. The risk could be defined as combination of probability and consequences of given kind of accident (Schroder, 2012). Figure 2 shows the process of risk assessment.

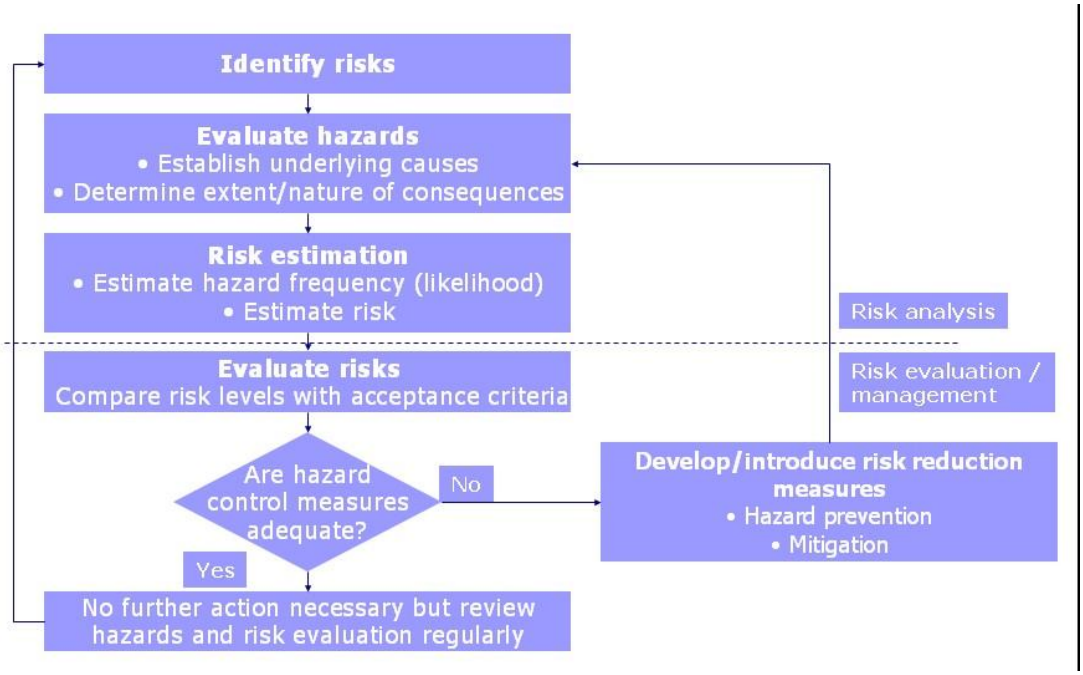

Figure 2 - Risk assessment process

Source: Schroder, J. U. (2012, November). *Risk management in maritime sector*. Unpublished lecture handout. Dalian Maritime University, Dalian, China.

Assessment of bridge risk in aspect of ship collision is very important and several national and international regulations and guidelines have been already developed. American Association of State Highway and Transportation Officials (AASHTO) first initiated the method in *Guide Specification and Commentary for Vessel*

Collision Design of Highway Bridges in 1991 following the 1980 collapse of the Sunshine Skyway Bridge crossing Tampa Bay in Florida. Duckett (2004) discussed the acceptable probability of failure for structures and to highlight a possible mismatch between the accepted risk for variable loads and accidental loads. The truth is in all cases the level of risk to human life should be acceptable considering the cost benefit analysis and consultation with the relevant authorities. Gucma (2009) described whole range of knowledge about ship-bridge collisions problems till that time, necessary for practical risk assessment and presented methods and models used for risk assessment. At last measures of bridge protection were rendered.

2.4.8 New technology

Surveillance equipment invented by Professor Ni Yiqing of Polytechnic University's Department of Civil and Environmental Engineering can actively monitor ships near a bridge and warn them of hazards to prevent vessels from colliding with the bridge. The technology incorporates an automatic identification system (AIS) measuring vessel's speed, direction and course, along with a vision-based system determining collision risk. If a ship is fitted with the AIS, warnings could be received automatically. Otherwise, the crew would be alerted by lasers and broadcast warnings. What is more, the system also measures the impact force and evaluates the damage if a collision does happen. Hit-and-run incidents can also be avoided as the system can easily identify ships. It is developed at a cost of HK$8 million with HK$5 million for installation of the system on each bridge. It is expected to apply to the Hong Kong-Zhuhai-Macau bridge, which is currently under construction and due to open in 2016 (Lee, 2013).

Chapter 3 Basic knowledge about the bridge

3.1 Introduction to the bridge

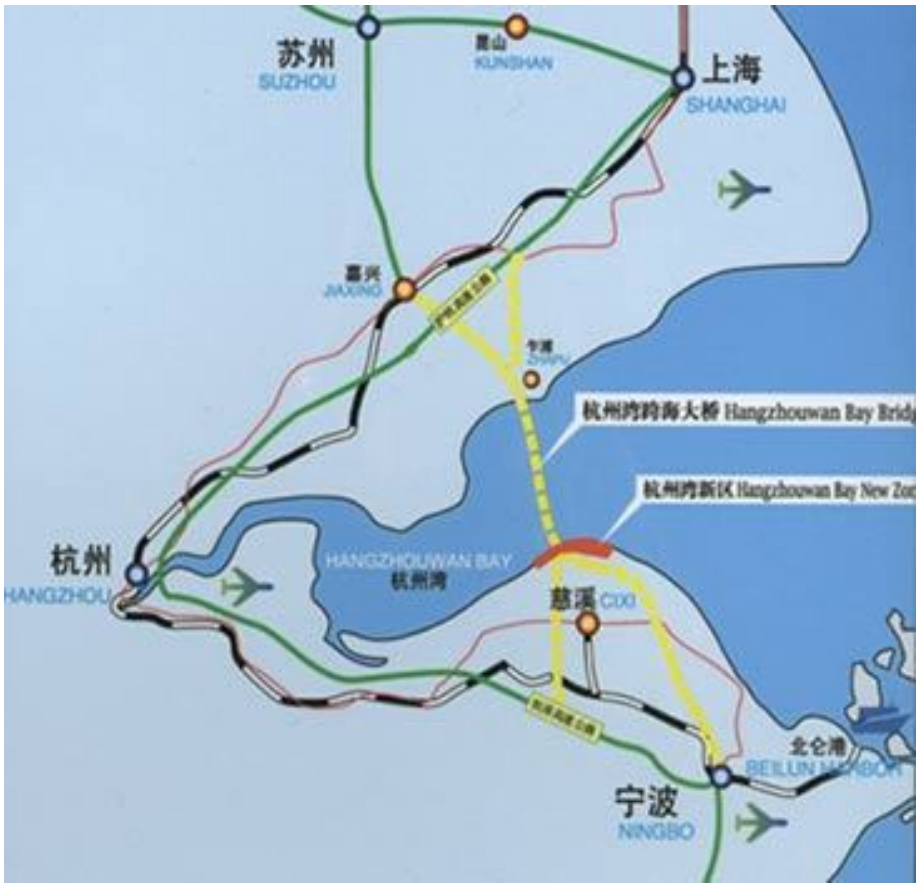

Figure 3 - Position of Hangzhou Bay Bridge

Source: Scandnet AB. (2013). Introduction to the Hangzhou Bay Bridge. Retrieved on June 5, 2013 from the World Wide Web: http://www.hangzhoubaybridge.com/bridge.asp

Hangzhou Bay Bridge which lies in the Hangzhou Bay in the East China Sea was open on May 1, 2008. The Bridge is an S-shaped stayed-cable bridge with six lanes in both directions and connects Jiaxing city in the north with Ningbo city in the south. Figure 3 shows the position of the Hangzhou Bay Bridge. It is the recorded longest sea-crossing bridge in the world with 36 kilometers long. The Hangzhou Bay

Bridge is expected to have a 100-year lifespan and cost ￥11.8 billion. The distance between Shanghai city and Ningbo city is shortened by 120 km (Scandnet AB, 2013).

3.2 Nature condition

3.2.1 Tide

Waters of Hangzhou Bay Bridge is irregular semi-diurnal tide, great tidal range and rush flow. The measured maximum flow rate reaches 516 cm/s in spring by observing stations, tide tables and other relevant information. During the spring tide, the speed of tide flow can be more than 300 cm/s for 2 hours, and lasting for 4 to 5 days, irregularly distributed. The deeper of the water, the smaller of the tide flow speed. Generally, the tide flow speed on the bottom is 1/2-1/3 that of the surface.

3.2.2 Wave

The biggest wave height is 3.5m around Hangzhou Bay Bridge, average 0.22m for a year. Wave is obvious during the rising tide and falling tide. 1m high wave can be seen at the same time.

3.2.3 Wind

3.2.3.1 Monsoon

It is normal to see wind force 7 and stronger ones around Hangzhou Bay Bridge. Winter monsoon concentrates NW direction and Spring, summer mainly blows SE, autumn with irregular rules. The monsoon in spring and summer has obvious effects within Hangzhou Bay Bridge waters.

3.2.3.2 Typhoon

The Hangzhou Bay Bridge belongs to sub-tropical maritime climate, with 2.56 typhoon per year, especially during July to October. The recorded wind speed around the bridge water was NO. 4906 in 1949, reaching 31.7 m/s.

3.2.4 Fog

Put the visibility less than 1000m as a reference, the overall fog days are 35.6, mainly during October to December. The recorded longest time is 22.9 hours.

3.3 Navigation condition

There are two fairways near Hangzhou Bay Bridge, the north fairway and the south fairway. Three navigation channels in the north and one in the south are used for crossing. Table 3 introduces the basic information of different navigation channels.

Table 3 - Basic information of different navigation channels

navigation channel	NO.1	NO. 2	NO. 3	NO. 4
width x height (m)	28x110	47x325	28x110	31x250
position	North, Auxiliary	North, Main	North, Auxiliary	South, Main
tonnage for passing (T)	<1000	<35000	<1000	<3000

Source: Compiled by the author based on Hangzhou Bay Bridge Regulation.

Ships crossing Hangzhou Bay Bridge is 16 per day on average in 2012. While up to June 18 in 2013, the number is 22 per day on average. Table 4 shows the specific data for different types of ships. Some unidentified ships with large quantities may be very small ships or fishing boats.

2 accidents of which 1 vessel sank happened during the ship construction from the year 2004 to 2008. Only 1 accident occurred since the bridge was open into service.

Table 4 - Number of ships crossing Hangzhou Bay Bridge

Time period	2012.01.01 to 2012.12.31		2013.01.01 to 2013.06.18	
Position	north	south	north	south
Ordinary cargo vessel	486	116	308	20
Tug boat	5	1	4	1
Engineering vessel	1	0	8	1
Official boat	153	20	163	62
Type not specified	103	120	145	174
Unidentified	1070	3713	547	2165
Total	1818	3970	1175	2423

Source: VTS. (2013, June). Automatic statistics of ships passing the bridge reporting line by VTS system. Compiled by the author.

Chapter 4 Navigation safety management of the bridge by Jiaxing MSA

4.1 Science of management

Organized activities and management have existed for thousands of years. The two famous projects like Egyptian pyramids and the Great Wall of China are evidence for that before modern times. Because of the tremendous scope and tens of thousands of people, plans had to be well organized and achieved by some knowledge, some kind of management. For centuries, many professors and industrial revolution contributed to the perfection of management, for example Adam Smith's division of labor, Frederick Taylor's scientific management, Fayol's principles of management and Max Weber's bureaucracy of organization and variety of management approaches (Robbins & DeCenzo, 2005, pp. 23-38).

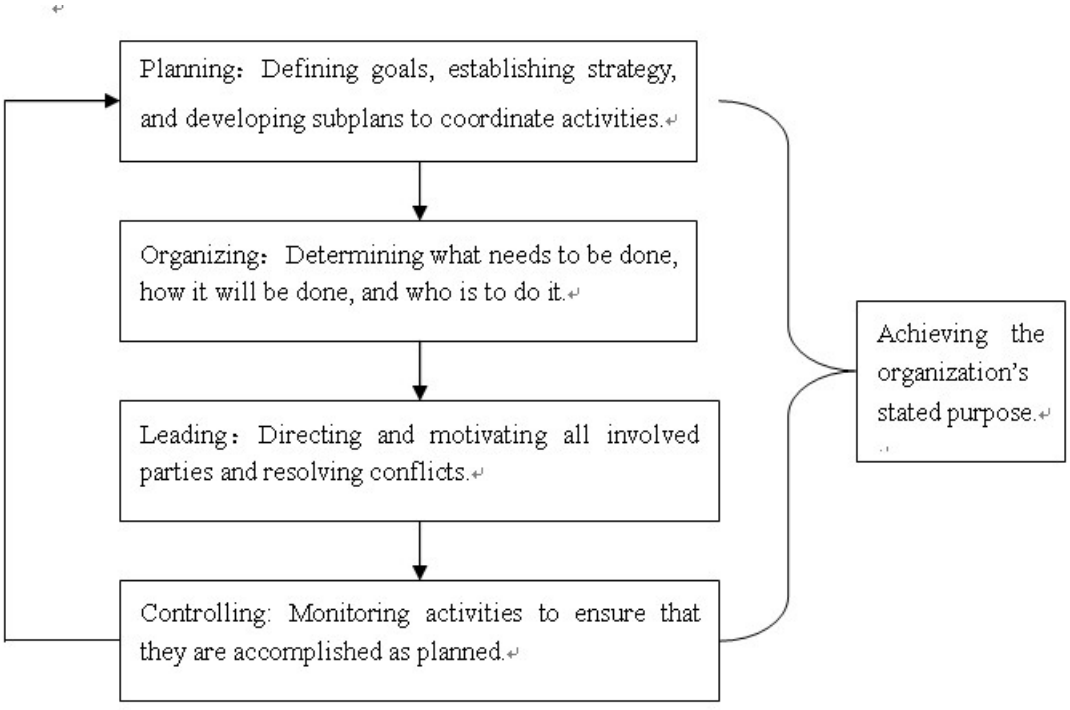

Figure 4 - Specific process of management

Source: Compiled by the author based on management theory of Robbins

Perhaps, the most widely used definition of management is the process of getting things done effectively and efficiently through and with other people. The management process is generally condensed to the basic four parts: planning, organizing, leading, and controlling (Robbins & DeCenzo, 2005, pp. 6-8). Figure 4 states the specific process of management.

4.2 Structure of the organization

4.2.1 Brief introduction

Ningbo Hangzhou Bay Bridge Development Co.,Ltd., as the owner of Hangzhou Bay Sea-crossing Bridge, was established on October 17, 2001. It is made up by Ningbo Transport Investment Holding Co.,Ltd., China Steel Corporation, Jiaxing Hangzhou Bay Bridge Investment and Development Co., Ltd., Cixi Jianqiao Investment Co., Ltd. and other 16 companies. The overall enrollment capital is 4.935 billion, with the state-owned capital 78 percent and private capital 22 percent separately, opening the period of combination of private capital and state-owned capital in the implementation of large infrastructure. The company is mainly responsible for the investment, construction, operation, maintenance and management for Hangzhou Bay Bridge and related ancillary facilities and equipments (Ningbo Hangzhou Bay Bridge Development Co.,Ltd., 2013).

Hangzhou Bay Bridge Authority performs some administrative functions under the commission of Ningbo and Jiaxing municipal government. It coordinates relevant administrative departments of Bridge for unified management to ensure safe and smooth operation. Further, operation, maintenance, safety, technology and other related work by the owner for the bridge is monitored and directed by the authority (Hangzhou Bay Bridge Authority, 2013a). For better management, Hangzhou Bay Bridge Authority set up a coordination group which combines almost all the administrative authorities responsible for activities related with the bridge such as the traffic police station, fire fighting station, road administration, troubleshooting

station and other service providers (Hangzhou Bay Bridge Authority, 2013b).

4.2.2 Organization for the navigation safety management of the bridge

In China, Maritime Safety Administration of the People's Republic of China (China MSA) under the Ministry of Transport takes the responsibilities of maritime safety, security, prevention of pollution from ships, and protection of seafarers' rights (China MSA, 2013). So, the administrative organization for the navigation safety management of the bridge is the Maritime Safety Administration.

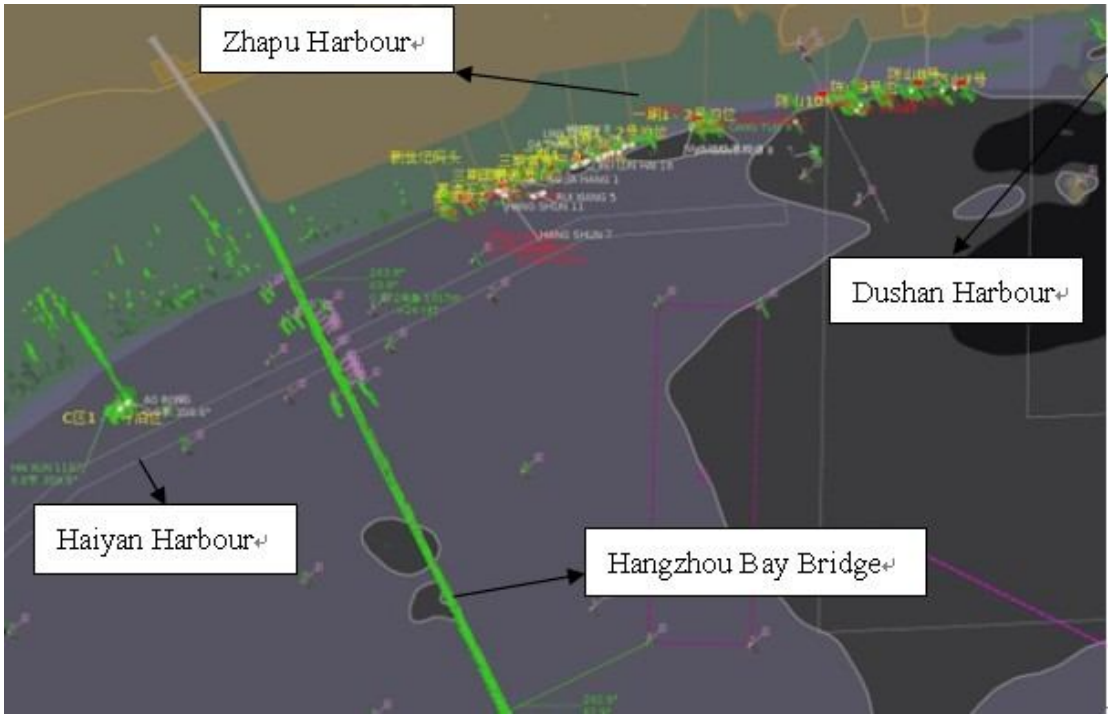

Figure 5 - Three harbours within Jiaxing MSA

Source: Compiled by the author based on VTS

In Zhejiang waters, navigation safety management is divided into three levels. They are agencies directly under China MSA, branches and dispatched divisions from the top to the bottom. Zhejiang Maritime Safety Administration of People's Republic of China (Zhejiang MSA) as an agency directly under China MSA, is

responsible for the Macro-management in the whole province. Jiaxing Maritime Safety Administration of People's Republic of China (Jiaxing MSA) as a branch of Zhejiang MSA, directly regulates the navigation safety for the convenience of regional management. The dispatched divisions of Jiaxing MSA are specifically working for the navigation safety.

As is shown in Figure 5 there are three harbours within Jiaxing MSA, named Haiyan harbour, Zhapu harbour and Dushan harbour. Haiyan harbour and Zhapu harbour are located on the upstream and downstream of the bridge separately. As to the navigation safety of bridge, Jiaxing MSA comprehensively regulates that. Three departments of Jiaxing MSA are working closely with it named Control Centre, Law Enforcement Department and Maritime Safety Department up to now. Figure 6 illstrates the relationship between different organizations in Zhejiang MSA.

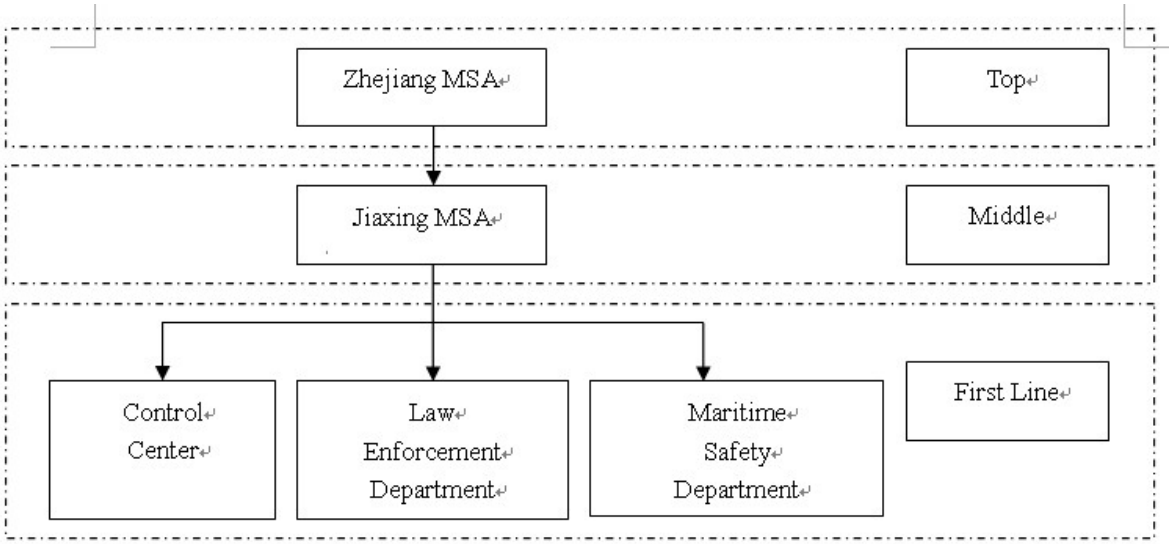

Figure 6 - Relationship between different organizations in Zhejiang MSA

Source: Compiled by the author

Control Centre is equipped with VTS system. Law Enforcement Department owns a patrolling ship with length 33.2m and power 2090 KW. Maritime Safety

Department is working in the harbor.

4.3 Planning for the administration and quality control

4.3.1 Mission, safety policy and objective

Planning is necessary in order to determine direction where an organization is going. Figure 7 tells the planning process for the organization.

Figure 7 - Planning process

Source: Fan, Z. Z. (2012, November). *Quality system and organizational management.* Unpublished lecture handout. Dalian Maritime University, Dalian, China.

The business of the navigation safety management of MSA is defined by Maritime Traffic Safety Law of the People's Republic of China and the marine environment

Protection Law of the People's Republic of China. The mission statements of China MSA is that safer shipping, cleaner ocean.

The organization should establish a safety policy which describes how to ensure safety at sea, and prevent human injury or loss of life, to define the continuous improvement to achieve objectives (ABS, 2002, p.7).

In Zhejiang Waters, navigation safety policy can be described as (Zhejiang MSA, 2013):

- Draft and implement guidance, policies, regulations, technological codes and standards in national navigation safety supervision;
- Identify the navigation risk of ships in the waters and take steps to mitigate it;
- Supervise water safety and prevent marine pollution;
- Provide marine emergency responses;
- Make traffic flow in good condition.

Jiaxing MSA as a branch of Zhejiang MSA implements the safety policy of Zhejiang MSA. As to the navigation safety management of the bridge, Jiaxing MSA has made many practices. The direct leading departments are Control Centre, Law Enforcement Department and Maritime Safety Department.

The Control Centre is the department for the traffic monitor and control. Law Enforcement Department patrol the waters and respond to the on-site contingency such as maritime search and rescue (SAR) and pollution prevention. Maritime Safety Department supervises ships which are mooring.

4.3.2 Quality control

The performance of an organization must be verified by control process. Figure 8 tells how to check whether everything occurs in conformity with the plan adopted,

the instruction issued and the principles established.

In MSA, the control method is the management by objectives (MBO). Normally, the high level administration makes up the assessment plan by MBO, then it is detailed by the lower level until it is implemented. For example, Jiaxing MSA will distribute the objectives to different departments according to the Zhejiang MSA MBO. In common practice, Zhejiang MSA will evaluate Jiaxing MSA by paper review and field investigation. Before the visit of Zhejiang MSA, the Jiaxing MSA will ask its departments to check by themselves first, then check each other. Some non-conformities and better suggestions will be rendered. Then correction will be made.

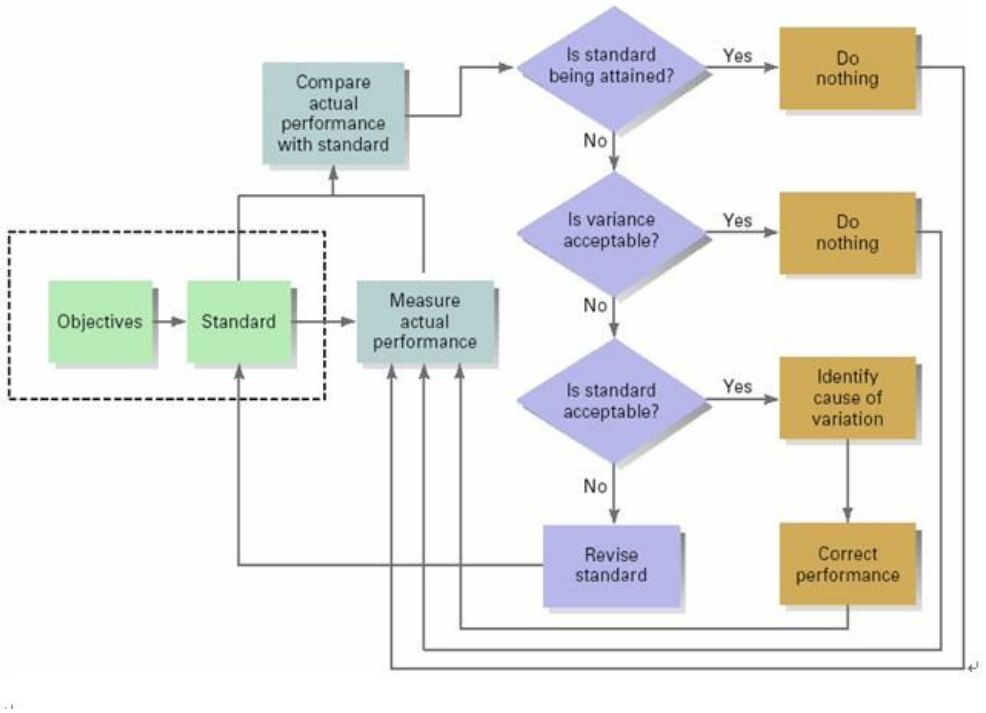

Figure 8 - Control process

Source: Fan, Z. Z. (2012, November). *Quality system and organizational management.* Unpublished lecture handout. Dalian Maritime University, Dalian, China.

4.4 Leading to the navigation safety of the bridge

4.4.1 Making instructions

The navigation safety management regulations of Hangzhou Bay Sea-Crossing Bridge (hereafter, it is called Hangzhou Bay regulation for short.) was adopted on May 1, 2008 by Zhejiang MSA. It plays an important role in unifying the activities related with navigation, operation and berthing within Hangzhou Bay Sea-Crossing Bridge waters. Also, it promotes the safety supervising and secures the safety of bridge and ships. In fact, all the activities related with the navigation safety of bridge shall comply with the regulation. Otherwise, it will be punished.

Jiaxing MSA issued Jiaxing vessel traffic management system rules for safety supervision and management on October 1, 2011. It strengthens ships' navigation safety management, secures the transport safety, protects navigation orders, improves shipping efficiency and prevents marine pollution. It instructs on reporting system, traffic organization, service providing and SAR.

4.4.2 Vessel traffic management

Control Centre manages the vessel traffic through VTS system. Many procedures have to be done complying with the bridge regulation. First, the pilots shall report to the Control Centre of the beginning time of pilotage, place, pilot's name or number and the time after finishing pilotage when they pilot the ship and facilities. Second, all the ships and facilities navigating, berthing and operating within Jiaxing VTS area shall obey the management of Control Centre. Third, Control Centre organizes the traffic based on the traffic flow and navigation environment. The navigation plans of ships can be adjusted and changed according to the actual situation of the traffic organization. 60 ships are monitored on average everyday by VTS system (Control Centre, 2013).

4.4.3 Vessel traffic services and SAR support

Control Centre usually provides services to the ships. For example, Control Centre can broadcast vessel movements, aids to navigation, hydrological and meteorological information, navigation notices (warnings), and other relevant information if necessary. Further, suggestions and warnings may be proposed by the Control Centre for the purpose of navigation safety. 26 services are provided by Control Centre(Control Centre, 2013).

4.4.4 Ship position reporting system

Reporting to the Control Centre is a proved and good method to grasp the overall information of ships within Jiaxing area. The Jiaxing vessel traffic management system rules for safety supervision and management regulates that those ships and facilities shall report to the Control Centre.

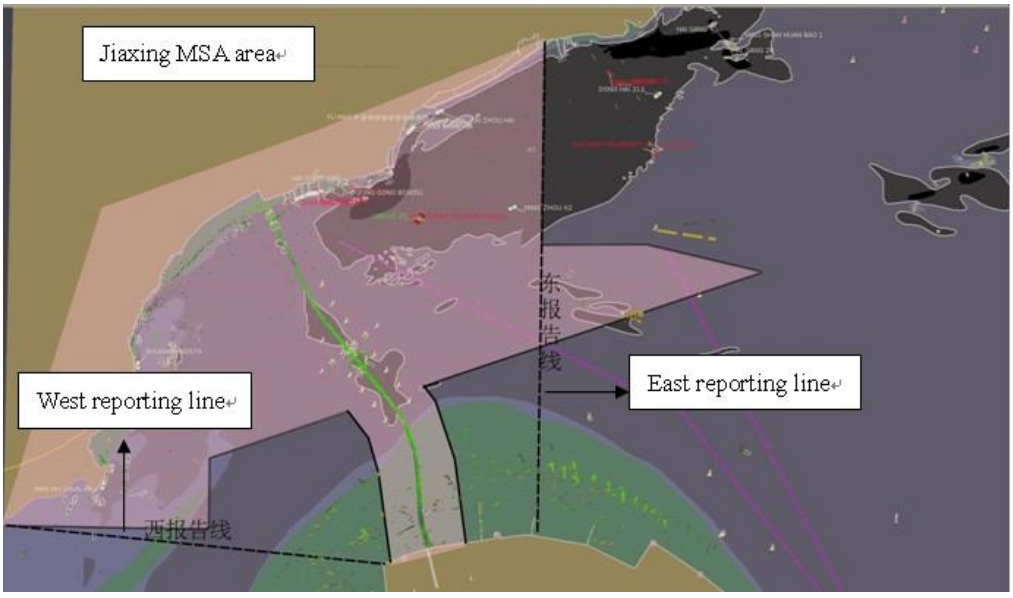

Figure 9 - Reporting lines

Source: Compiled by the author based on the VTS

- Passenger ships;

- Foreign ships and facilities;
- Ships carrying dangerous cargo;
- Towing fleet and other vessels or facilities that restricted in her ability to maneuver,
- Other ships flying China flag 300GT above.

Ships and facilities flying China flag 300GT below may participate in the reporting system voluntarily if they are equipped with VHF.

In reality, three kinds of condition shall be reported to the Control Centre. First, pass the reporting line. Ships and facilities shall report to the Control Centre about the name, nationality, position, draft, destination port and other information required via VHF if they pass the West Reporting Line and East Reporting Line. Figure 9 points out the two reporting lines. The West Reporting Line is the straight line between 30°20′48″N, 120°50′13″E and 30°19′26″N, 121°08′35″E, while the East Reporting Line is the straight line between 30°41′32″N, 121°16′00″E and 30°20′48″N, 121°16′00″E. Further, dead weight (DWT), vertical clearance and the intended navigable channel shall be added if they are passing the Hangzhou Bay Bridge. Second, routine operation of ships: Ships and facilities shall report to the Control Centre when they intend to anchor or moor 15 minutes before and obey the instructions of Control Centre. After they have dropped the anchor or finished mooring the details like position or chain scope should be reported. If they weigh anchor or leave the berth, it is also needed to be reported 15 before. Third, contingency or abnormal conditions: equipment failure which poses hazard to the navigation safety or accident, pollution and other near misses shall be reported to the Control Centre immediately.

4.4.5 Grid management

Jiaxing MSA issued to adopt grid management in the area on September 20, 2011. The goal is to further strengthen dynamic enforcement in the important area of the

waters, improve the pertinence and effectiveness for the on-site patrolling, enhance emergency response capacity to maritime accidents and near misses, promote the integration of patrolling and rescue within area and boost scientific development of maritime traffic (Jiaxing MSA, 2011, September).

Control Centre is responsible for the leading and organizing dynamic grid management, periodical evaluating the effectiveness and supervising the activities by the on-site department. Law Enforcement Department implement the patrolling within the grid. Specifically, the on-site work is done by the Law Enforcement Department with the help of patrol craft.

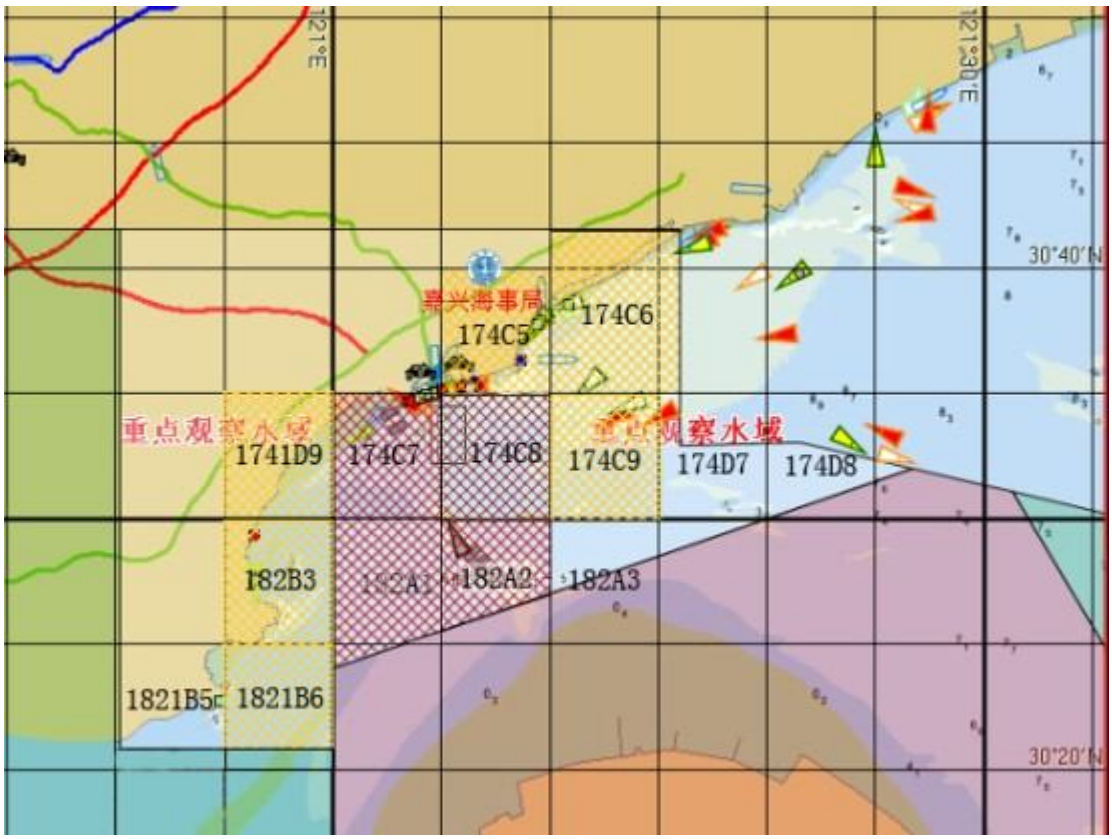

Figure 10 - Encoding of grid management

Source: Jiaxing MSA. (2011, September). Jiaxing MSA dynamic monitoring and grid management plan. Jiaxing: Author.

The boundary for grid management is the whole area of Jiaxing MSA area. The grid is plotted every 5 minutes in latitude and longitude with the round latitude and longitude as the baseline. If it is involved in shoreline or boundary area, the grid will be integrated by adjusting the adjacent grids. The method for encoding complies with the fish zone directed by the Ocean and Fishery Department. Figure 10 indicates the encoding of grid management.

The grids are divided into three classes: first class, second class and third class. Table 5 tells the details of grids. Different standards are implemented according to the different class of grid.

Table 5 - Details of grids

	Code	Category	Standard	Colour
1	174C7	first	Main channel Core harbor water Passenger line Bridge area Intensive area	red
2	174C8	first		red
3	182A1	first		red
4	182A2	first		red
5	174C5	second	Anchorage area Construction waters Pier for discharging dangerous good	yellow
6	174C6	second		yellow
7	174C9	second		yellow
8	1741D9	second		yellow
9	1821B3	second		yellow
10	1821B6	second		yellow
11	174D7	third	Other area exclude above	NIL
12	174D8	third		NIL
13	182A3	third		NIL
14	1821B5	third		NIL

Source: Jiaxing MSA. (2011, September). Jiaxing MSA dynamic monitoring and grid management plan. Jiaxing: Author.

The first class grid should be patrolled not less than 1 time every working day. 3 times should be distributed to the second class grid every week. What is more, the patrolling time for the first and second class grid should not be less than 2/3 of the total patrolling time. Further, the bridge area should be paid more attention.

In the 2012, Law Enforcement Department have patrolled 506 times, total mileage 6968 nautical miles (NMs), dispatched officers 1379 persons (Jiaxing MSA, 2013).

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4.4.6 Pilotage

To secure the safety of bridge, certain ships crossing the bridge shall be piloted for mandatory：

- Foreign ships;
- Ships restricted in her ability to maneuver;
- Ships passing through south navigation channel with DWT 2000t and above;
- Ships passing through north navigation channel with DWT 10000t and above;
- Other ships for special purpose

In the assessment report, which was carried out three years after the adoption of navigation safety management regulations of Hangzhou Bay Sea-Crossing Bridge in April 2011, it said that, the pilot station had piloted 10 times crossing the bridge for mandatory and 830 times for berthing in the vicinity of the bridge. The pilotage relieved the trouble of unfamiliarity of Jiaxing port, avoiding accidents or near miss (Jiaxing MSA, 2011, April).

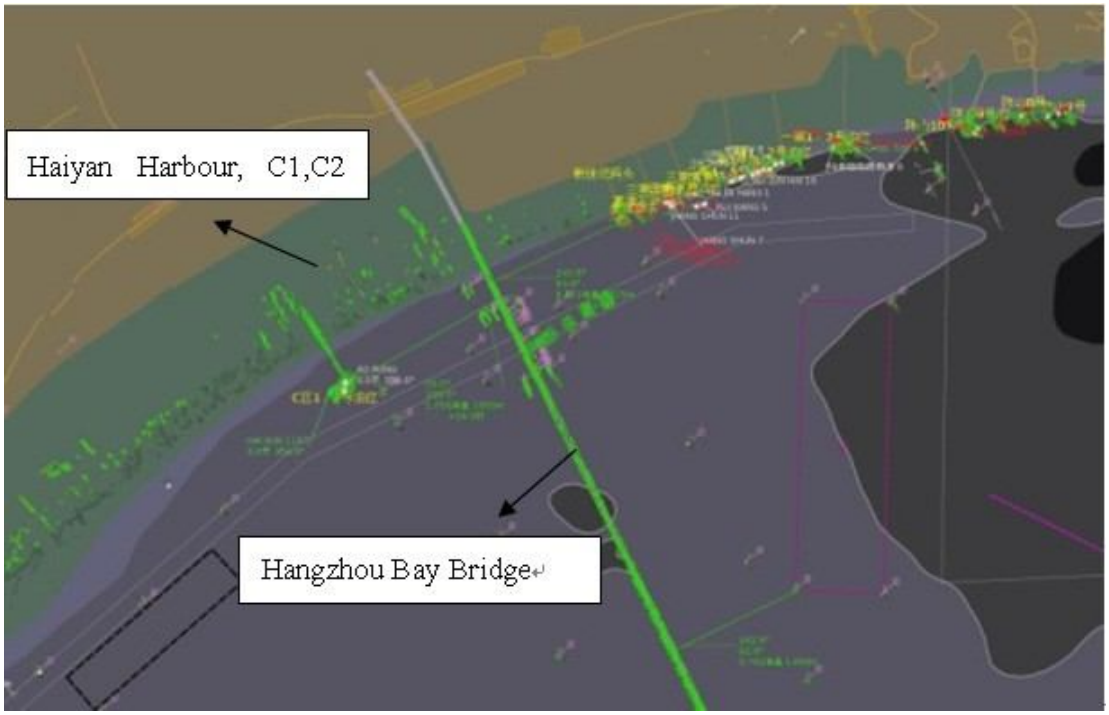

Figure 11 - C1 and C2 berth of Haiyan harbour

Source: Compiled by the author based on the VTS

What is needed to say, the C1 and C2 of Haiyan harbour berth have come into service since January, 2012 as is shown in Figure 11. The scale for ship berthing is 10000. The designed throughput capacity is 1.6 million a year. The berth is used for discharging coal, steel and other cargoes. Up to June 26, 2013, about 106 ships carrying more than 10000 t cargoes are piloted to C1 and C2 since it was put into service in February 2012.

4.4.7 Escort

In the Hangzhou Bay, (west of the Hangzhou Bay Bridge), there are several ship manufacturing companies. Once in a while, some unequipped new ships are towed outward Hangzhou Bay, needing crossing the bridge. This time, the Law Enforcement Department will convoy the ships crossing the bridge. They have tried 26 times for the escort of towing fleet until April, 2011 (Jiaxing MSA, 2011,

April).

4.4.8 Tug for berthing

As the existence of the bridge, high risk operation of ships must be guaranteed by the tugs. It is stipulated that, ships carrying 3000 tons and above dangerous goods and other goods of 10000 tons and above shall use the help of the tug for berthing in the vicinity of the bridge. After the bridge came into service, the overall tug for berthing were 2583, avoiding the near misses (Jiaxing MSA, 2011, April).

4.4.9 Keeping engine standing by

It is stipulated that anchoring ships whose distance is less than 2 NMs from the bridge shall keep engine standing by. Because the tide in Hangzhou Bay is so strong that it can reach 6 NMs sometimes. What is more, the bottom for anchorage is mud, not really good. Imagine that, a ship is dragging, 20 minutes is left for them to take action.

Law Enforcement Department and Maritime Safety Department paid more attention to the engine within 2 NMs from the bridge. Law Enforcement Department boards the ships that anchor within 2 NMs from the bridge to check the condition of the engine. Maritime Safety Department also verifies the truth by checking the log book, engine log book and clock log book. If any actions break the regulation, it will be punished. In three years after the bridge in service, the administration has punished 25 ships, fined ￥64100 and deduct marks of the crew 108 points (Jiaxing MSA, 2011, April).

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4.4.10 Safety checklist for crossing the bridge

It is advised that, ships crossing through the bridge should maintain sufficient vertical clearance. Further, the ship should select the proper navigation channel according to its own tonnage and maximum height. It is prohibited to navigate

through the bridge whose scale is not permitted by the bridge. To achieve the objective, the Maritime Safety Department drafts a safety checklist for crossing the bridge. The captain must make sure that:

- Captain and officer are familiar with the Navigation safety management regulations of Hangzhou Bay Sea-Crossing Bridge and navigation environment of Jiaxing port ;
- The ship is equipped with the Navigation safety management regulations of Hangzhou Bay Sea-Crossing Bridge and nautical charts of Jiaxing port (50112, 50103, 50108) ;
- The ship has planned the route for crossing the bridge ;
- The ship can pass through the bridge vertically.

The pier manager, cargo owner or the agency normally mail or fax the checklist to the coming ship or ship company. The captain makes everything good complying with the list. When the ship is going to pass through the bridge, the Control Centre also checks the results of checklist via VHF. When the ship finishes berthing, the officer of Maritime Safety Department will board the ship to do an inspection. It greatly improves the awareness of captain and effectiveness of the work.

4.4.11 On-site inspection

Maritime Safety Department pays more attention to the ship safety inspection and crew operation procedure. They board the ship to check if the ship is equipped with right charts, port guidance and other nautical books. Also, the navigation plan and bridge resource management will be evaluated. They verify the accuracy of information which the agency or the company delivers by communicating with the crew. What is more, they give more warning to the ship when they come to the service hall for formalities.

4.4.12 No berthing during rush tide

By researching the rule of the accidents and near misses, it is found that, they are likely to happen when the tide is rush. So, it is advised by the Jiaxing MSA, the ships may avoid berthing 1.5 to 3.5 hours after low tide. The accident rate drops dramatically, especially during the rush rising tide, declining 80 percent. It is implemented by the Control Centre via VTS.

4.4.13 Warnings and measures in advance for bad weather and sea condition

In 2011, warnings and measures in advance for bad weather and sea condition within Jiaxing MSA area was adopted. The bad weather means strong wind and poor visibility, tropical cyclone not included. In 2013, it is revised by adding the strong wave. The objective is to publish warnings on bad weather and sea condition timely and effectively, take proper measures, protect the maritime traffic, prevent maritime emergencies and reduce the loss of life and property.

The warnings are divided into two levels, yellow warning and red warning.

Yellow warning is any one of the followings:

- The wind in Hangzhou Bay water will reach 7 (gust reach 8) within 12 hours;
- The visibility is between 1500 m and 500 m;
- Strong wave within 12 hours in Hangzhou Bay water (wave height 2.5 to 4.0 m).

Red warning is any one of the followings:

- The wind in Hangzhou Bay water will reach 8 (gust reach 9) within 12 hours;
- The visibility is less than 500 m;
- Huge wave within 12 hours in Hangzhou Bay water (wave height > 4.0 m).

Control Centre is the leading department for bad weather and sea conditions. It is responsible for searching the information, evaluating and broadcasting warnings.

Also, dynamic supervising via AIS, VTS, VHF is implemented. It urges Law Enforcement Department and Maritime Safety Department to take proper and effective measures. Law Enforcement Department forces the ships to take measures by patrolling and escort. What is more, it shall help the Control Centre collect data for visibility and wind. Maritime Safety Department shall deliver the information to the relevant companies and ships within administration.

When the wind reaches yellow warning, the Control Centre shall broadcast warning per hour by automatic broadcasting. The key content is that ships are prohibited crossing No.1 and No.3 navigation channel if the wind reaches 8. If the wind is 7, the ships carrying dangerous good shall stop operating. Communicate the information with the Law Enforcement Department on the violation of crossing the bridge. Law Enforcement Department will intercept the ships. This time, Law Enforcement Department will go on patrolling on the important sea area as if it can resist the wind. Maritime Safety Department will go to the berth to check whether ships carrying dangerous goods have stopped operation.

When the wind reaches red warning, the Control Centre shall broadcast warning every half hour by automatic broadcasting. The key content is that ships are prohibited crossing the bridge if the wind reaches 9. If the wind is 8, all the ships shall stop operating.

When the visibility reaches yellow warning, the Control Centre shall broadcast warning per hour by automatic broadcasting. They will remind the ships to obey the fog navigation regulations and keep watching carefully. Further, ships whose length is over 100 meters (including towing length) and ships carrying dangerous goods are prohibited from crossing the Hangzhou Bay Bridge and navigating nearby channel.

When the visibility reaches red warning, the Control Centre shall broadcast warning

every half hour by automatic broadcasting. They will remind the ships to obey the fog navigation regulations and drop anchor nearby. The ships are prohibited to navigate, berth and operate 3000 metres within the bridge.

As to the wave warning measures, Control Centre may refer to the wind warning. The draft clearance is the key to remind.

In 2012, Jiaxing MSA has issued warnings 35, especially in spring with thick fog and winter with strong wind.

4.4.14 Plan against typhoon

To fight against typhoon, minimize the loss and protect the property and life, Jiaxing MSA set up the plan against typhoon. In the plan, the responsibility of departments against typhoon is defined and the procedure is made. The work is divided into 4 classes according to the wind power.

In 2012, Jiaxing area is attacked by "Saola" etc. 6 typhoon. Jiaxing MSA beat typhoon with the plan. 139 ships evacuated from Jiaxing area, 462 officers and 186 cars were dispatched. 1489 safety information and 16 faxes were sent to the company, agency and ships.

4.4.15 Inspection of ships for construction

With the development of the economy, many projects have taken place in water. Normally, they are not far from the bridge and constructed by the unpowered vessels. Jiaxing MSA takes many steps to secure that they are working in a safety way. The Law Enforcement Department does flag state control (FSC) to all the construction ships. Until the deficiencies are all rectified, the ships can be permitted to participating in the construction. The unpowered vessels have to be guarded by the towing ship. Also, the crew are competent and keep a good watch. The communication equipments are checked frequently. Measures for ship safety and

pollution prevention are implemented.

4.4.16 Promoting the protection of the bridge

When the bridge came into service in 2008, there is pier protection against ship collision on the north and south main navigation channel. Figure 12 shows the box structure for resisting the force impact of ships. The force resistance of the protection system for the north and south main navigation channel is 4470t, 2270t separately (Hangzhou, 2008).

Figure 12 - Box structure for resisting the force impact of ships

Source: Jiaxing MSA. (2012). Risk research on navigation safety of Hangzhou Bay Bridge. Unpublished research. Jiaxing: Author.

For the safety of the Hangzhou Bay Bridge, Jiaxing MSA make many suggestions for the protection against ship collision. After the scientific research of the institution, more and more protection measures have been taken. Up to now, not only the auxiliary navigation channels, but also some of non-navigation channels have owned the protection system. Table 6 illustrates the protection system.

Table 6 - Protection system

Position	Representative ship type
North main navigation channel	5000GT multi-purpose ship
North auxiliary navigation channel	1000 GT cargo ship
South main navigation channel	3000 GT multi-purpose ship
South auxiliary navigation channel	300 GT cargo ship
Two sides of north navigation channel	3000 GT
Two sides of south navigation channel	500 GT
Platform for sightseeing	300 GT

Source: Jiaxing MSA. (2012). Risk research on navigation safety of Hangzhou Bay Bridge. Unpublished research. Jiaxing: Author.

4.4.17 Doing ship-bridge collision prevention exercises

The Control Center periodically tests the ability of emergency response. Sometimes, they intended to make some troubles for the SAR during the exercises. The last time, Jiaxing MSA organized an emergency training on March 21, 2013. At first, they did not tell the truth to SAR team. Control Center informed the SAR team that, a ship was dragging in Lianjian anchorage and the main engine broke down. The shifting speed is 6 NMs at 1939. The SAR team managed to reach the accident spot and take actions at 2012, costing 33 minutes overall. The emergency team is exercised.

4.4.18 Removal of fishing nets

Every winter to next spring, the fishermen lay a lot of fishing nets in the area of channel, anchorage and the waters near the bridge, which poses a potential risk for ships. Especially on both sides of the navigable channel of Hangzhou Bay Bridge,

it will affect the safety of the ship crossing the bridge. In order to ensure the ship bridge area, fairway and anchorage safe and smooth, the Law Enforcement Department strengthens the activities for patrolling and finds out the location of fishing nets. Next, they will organize relevant administration to remove the fishing nets, eliminating potential hazards for navigation.

4.4.19 Monitoring the aids to navigation

The aids to navigation have been set up by the beacon station at the beginning of the operation of the bridge. The Law Enforcement Department always monitors the aids to navigation when they patrol the area. If they find out the breakdown or damaged aid, the information will be recorded. Then it will be delivered to the beacon station, the beacon station will maintain and remedy according to the actual situation. The Law Enforcement Department also invites the officer from beacon station for patrolling. These activities not only help beacon station check the effectiveness of the aids, but also promote a better navigation environment.

4.4.20 MicroBlog for Jiaxing MSA

MicroBlog is a platform based on information sharing, dissemination and acquiring. Users can set up its own community by WEB and WAP. Normally, it is within 140 words and updates instantly. The earliest and most famous MicroBlog is twitter from American (Baike, 2013a). Official MicroBlog is used for the government. 50561 Official MicroBlogs have been verified until December 10, 2011 (Baike, 2013b). As the maritime administration, Jiaxing MSA has set up its own MicroBlog on December 12, 2011, which has been verified by Sina net. It has 3023 fans and issues 274 news comprising weather broadcasting, bad weather and sea condition warning and special supervising. It delivers information to shipping company, agency and seafarer at the first time, reducing the cost, improving the efficiency and acquiring much praise (Jiaxing MSA, 2013, June).

Chapter 5 Analysis of the present problems for the bridge

5.1 Anchorage too close to the bridge

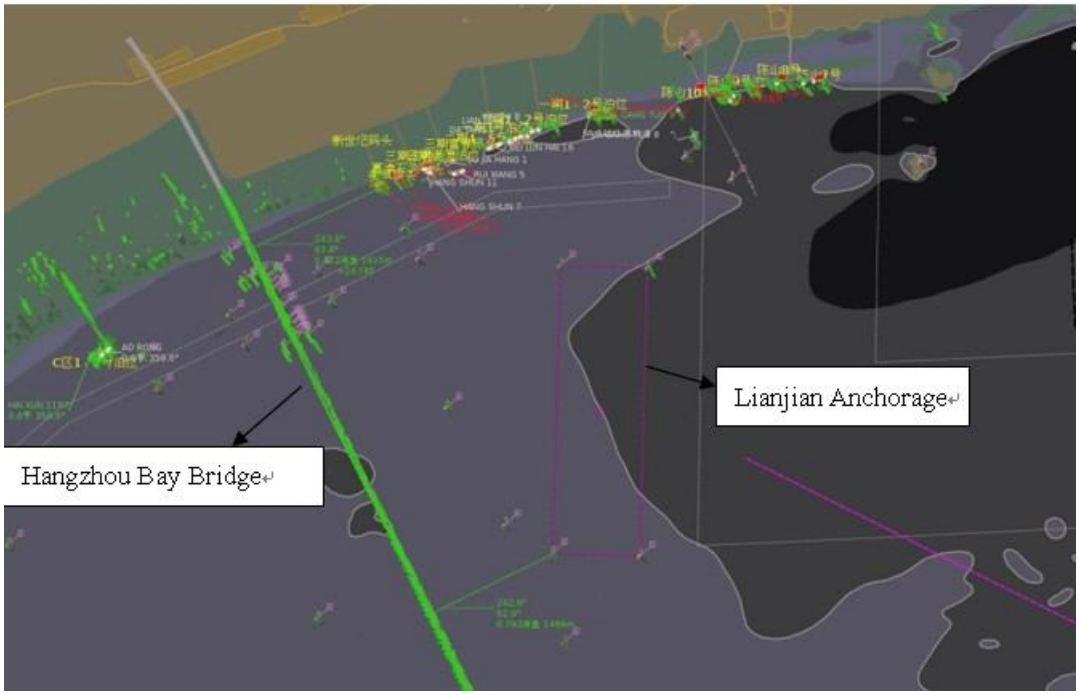

Figure 13 - Lianjian anchorage

Source: Compiled by the author based on VTS

As is shown in Figure 13, Lianjian anchorage is too close to the Hangzhou Bay Bridge, once the ship is dragging, it is likely to collide with the bridge. Because of the construction of the bridge, the anchorage is adjusted in 2006, where the nearest point is only 0.7 NM to the bridge. Imagine a ship is dragging at the speed of 3 NMs from the 1NM distance to the bridge, then it will collide with bridge in 20 minutes. Moreover, the average speed of tide is 4 NMs, reaching 6 NM sometimes. Once, the ship is dragging or the main engine loses power, tugs will be needed. However, the tugs will consume 20 minutes from standing by to reaching the place. The Singapore tanker BITUMEN EXPRESS (3300GT) was just the case on August

11, 2006. It got touch with the pier and span of the constructing bridge after dragging, bringing about ￥10 million economic loss.

5.2 Traffic flow increase

With the development of port, the quantity of ships increases continuously, enlarging the probability of ship collision with bridge. In recent years, Jiaxing port has confronted with dramatic development, with berths rapidly increasing. The throughput capacity is nearly 60 million tons, twice of 2008. Right now, there are 6 berths upstream of Hangzhou Bay Bridge in Haiyan Harbour. It is expected to establish other new 7-8 berths. So, the traffic flow passing the north navigation channel will rise, bringing more risks for the collision. It is checked on June 26, 2013 that, the number of ships for the newly built port C1 and C2 came up to 164 since it opened to the public in February 2012, among which carrying more than 10000 t cargoes sum up 106, needing mandatory pilotage. Further, the nearest distance from the bridge upstream and downstream is 1900m and 1300m separately. If the ship needs to turn around when it berths in the vicinity of the bridge, especially in time of rush tide, the ship is likely to be pressed to the bridge. The accident or near miss will happen with improper operation of the ship or main engine failure.

5.3 Capacity and quality of the anchorage

More and more ships call at Jiaxing port. There is not enough room for the ships, especially for anchorage. Figure 14 showed the crowded anchorage on March 1, 2013. The capacity of the anchorage needs to be increased. What is more, the quality of bottom for the anchorage is not good, mainly made up of mud. If the wind is strong, ships are likely to dragging. Especially when the typhoon is coming and boost to power 10 , ships have no place for anchorage and have to leave for other port.

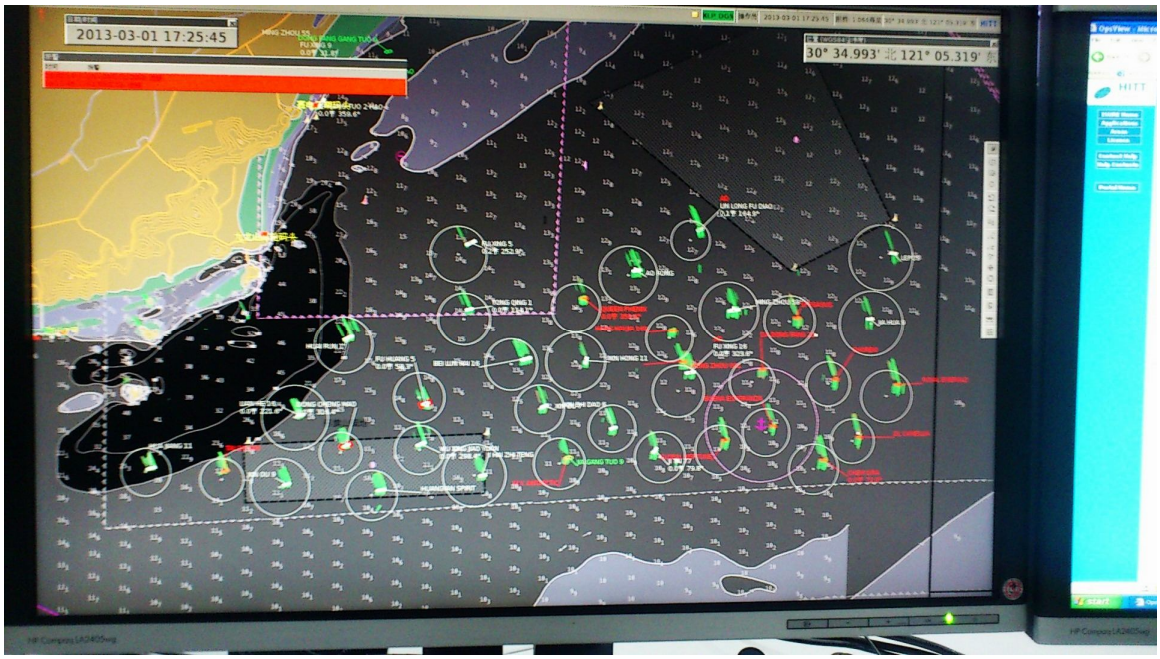

Figure 14 - Crowded anchorage

Source: Compiled by the author based on VTS.

5.4 Interest of fishermen

In the past, the shipping industry in Jiaxing area is not prosperous. The local residents live on fishing. They usually set up many fishing nets in the water near the coastline, which are berth, navigation channel, anchorage and so on. Nowadays, though it is necessary to adjust the position and capacity, difficulties are confronted by the administration. The fishermen refuse to abandon fishing and removing the nets. On the other hand, the huge compensation for the interest of fishermen can not be afforded by the government or society. When it comes to the adjustment issue of anchorage, further work can not be achieved.

5.5 Inadequate staff for work

The throughput capacity of Jiaxing port is 53.94 million, the container is 0.68 million

Twenty-foot Equivalent Unit (TEU). The number of arrival and departure report for national ships, international ships and carrying dangerous goods are 46261, 1664 and 5509. There are only 70 staff in Jiaxing MSA responsible for much work like ship register, FSC, PSC, patrolling, traffic organization and service providing, routine inspection and so on. So, in most cases, the staff of Jiaxing MSA is not busy improving the quality of management, but only achieving the work.

5.6 Responsibility of navigation safety facilities not clear

The responsibility for navigation safety of bridge among owners (construction and manage company) is not clear. The Channel Regulation of People's Republic of China (PRC) issued by Transport Ministry stipulates that construction and management company are responsible for the construction and maintenance work of navigation safety facilities. However, it applied to the inland river, not including sea-crossing bridge, because, it did not expect the appearance of sea-crossing bridge in 1991. Right now, the owner of the bridge is reluctant to afford the responsibility for maintenance and management work of navigation safety facilities.

5.7 Non-navigation channels lack of protection system

According to the regulation, it is not mandatory to set up protection system against ship collision for non-navigation channels. However, if the crew are not familiar with the channel or careless, or confronting with main engine failure or bad weather or sea condition, the probability for the crew navigating into the non-navigation channels is big. So there is risk for the collision without protection system against ship collision.

Chapter 6 Challenge and future work

6.1 Perfect the law, regulations and relevant instructions

It is advised that, the responsibility of construction, maintenance and management work of navigation safety facilities for the sea-crossing bridge should be cleared by the law. The Channel Regulation of PRC shall be revised to the new edition according to the present situation of PRC. The construction and management company shall be the right organization for the construction, maintenance and management work of navigation safety facilities for the sea-crossing bridge.

The relevant instructions on the bridge shall be periodically evaluated and revised, for example, Navigation safety management regulations of Hangzhou Bay Sea-Crossing Bridge and Jiaxing vessel traffic management system rules for safety supervision and management. By this process, the instructions will be perfect and promote better management objectives.

6.2 Coordinate interests and adjust the anchorage

Jiaxing MSA shall continue to go on proposing the government to handle the anchorage as soon as possible. Though many interests are involved in the adjustment of the anchorage, it has to be settled. Otherwise, it will affect the development of the shipping industry in Jiaxing port, which is truly to be a disaster for the local economy.

6.3 Press to settle down protection system of non-navigation channels

Based on the increasing traffic flow and the actual condition, Jiaxing MSA shall give more pressure to the owner for the protection system of non-navigation channels. The owner will be reluctant to do so, considering the cost. Jiaxing MSA may lead

to a scientific research on the necessity for the system.

6.4 Remind to apply the technology to the navigation safety

With technology advanced, more and more equipments are invented for the better monitoring of ships near the bridge. Jiaxing MSA can remind that some high technology product is suitable to the bridge at the proper time.

6.5 Risk management for the bridge

Risk management is a continuous and forward-looking process that is an important part of business and technical management processes. In modern society, many projects are managed by the risk theory. The Hangzhou Bay Bridge can apply the risk management to check what endangers the achievement of critical objectives. After the cost-benefit approach, measures will be used to mitigate the risks effectively.

6.6 Design ships' routeing systems

At present, the traffic flow passing the bridge is not crowded. It is expected to rise to the high density in the near future. If it comes true one day, the probability for ship collision with bridge is due to increase. Then it is time to consider the ships' routeing systems. In routine patrolling, the Law Enforcement Department shall find out the rules for ships crossing the bridge. It can be a good reference for the future plan.

6.7 Improve emergency response abilities

There are no limits for emergency response abilities. Jiaxing MSA shall pay more attention to improve emergency response abilities continuously. By organizing

exercises on bridge collision prevention and SAR, the procedure for cooperating and communicating should be checked and improved step by step. The team for fighting will be experienced and competent in handling the emergency. What is more, better equipments for emergency response shall be delivered to the team in near future, for example, tugs combined with fire fighting function. Also, rescue ships with strong wind resistance, fast speed, big power and good turning performance are really welcomed.

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