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Bridge and ship collision risk assessment and safety management countermeasures in Shanghai Port waters

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BRIDGE AND SHIP COLLISION RISK ASSESSMENT AND SAFETY MANAGEMENT COUNTERMEASURES IN SHANGHAI PORT WATERS

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THE 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.

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ABSTRACT

The ship collision is an important safety issues while building a bridge across the channel. Since 1980s, with the development of national economy, China has built and planed building a lot of bridges across the channel, and the shipping has also fast developed at the same time. The above two factors present the necessary to solve ship-bridge collision safety analysis and risk assessment. Meanwhile, Shanghai port is as an important water transportation hub, there are many bridges in jurisdiction, so researching the ship-bridge collision risk assessment is particularly prominent and important in Shanghai port water.

This paper mainly uses the method of probabilistic risk assessment for ship-bridge collision risk analysis. In fact, it is well-known that a large number of ship accidents are caused by human factors, so on the basis of the passive anti-collision facilities, the bridge safety management is more and more important. This paper gives some safety management countermeasures. Maybe it has certain reference significance for the ship anti-collision in the future.

KEYWORDS: ship-bridge collision ; bridge safety management countermeasures shanghai port water ; ship-bridge collision risk assessment passive anti-collision active anti-collision

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LIST OF ABRREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AIS	Automatic Identification System
CCTV	Closed Circuit Television
DWT	Dead Weight Tonnage
FTA	Fault tree Analysis
MSA	Maritime Safety Authority
IABSE	International Association of Bridge and Structure Engineering
NM	Nautical Mile
PIANC	Permanent International Association of Navigation Congresses
VTS	Vessel Traffic Services

CHAPTER 1 INTRODUCTION

1.1 The Background of Ship-bridge Collision Research

With the rapid development of economic construction in China, a lot of across the river and cross-sea bridges have been built up. These bridges bring the national or local economy profits, but also affect the safety of the shipping. Bridge as a cross channel structure is undoubtedly a obstacle for navigation. Meanwhile, bridge could cause the navigation environment to change, such as flow velocity, wind speed, bend, scouring and silting, tide, etc. Now as a result of the development of shipping, ships are becoming more and more large and fast, and the ship-bridge collision accidents are inevitable, It not only involves the safety of the ship navigation, but also seriously affects the safe operation of the bridge. The performances of ship-bridge collision are as follows: bridges and ships damage, people injuries and deaths, water traffic interruption, environment destruction, and social trust crisis, etc. As the situation of the bridge engineering is increasing, the navigation density is growing, and the ship-bridge collision accidents occur frequently. Based on these, making the ship-bridge collision risk assessment and researching the bridge against ship collision are very necessary, and have a great economic and social value (Geng & Wang, 2007, p.34). Shanghai Port, as an important water transportation hub, has tens of thousands ships coming in and out of the Yangtze river estuary and the Huangpu river every day. Only the Huangpu River has 7 bridges, forming a complex navigation environment. So how to take effective management measures to reduce ship-bridge collision occurrence and the loss is of great significance for Shanghai Port.

1.2 The Current Research Status of Ship-bridge Collision

The first systematical research on the problem of ship-bridge collision in the world began in 1978, when several ship crash bridge malignant accidents happened in the United States. Then, the United States government and the university of Maryland civil engineering department signed a research contract (AASHTO, 1991), to research the impact protection system of bridge and pier. In June 1983, the International Association of Bridge and Structure Engineering (IABSE) held an international academic conference in Copenhagen, Denmark, named “Ship Collision with Bridge and Offshore Structure”. It is the first seminar for this subject, a part of which is about the report of ship impact bridge and offshore construction accidents.The meeting offered a proposal to build a international database of ship bridge collision accidents. Its main content was about ship-bridge collision accidents which happened around the whole world from the 1960's. Since the 1980s, some technical consultancy companies and research institutions, including the Cape, Lush, COWI and the Logistic company, carried out individualized researches on ship-bridge collision successively around the Denmark Sea Bridge ,the Australia Tasman Bridge, the USA Sunshine Bridge, the Gibraltar Strait Bridge and Louisiana waterway piers, and obtained some important research results (Yang, 1990).

In 1980, 11 states of the United State and the USA Federal Highway Administration jointly invested and carried out a research project. The most significant achievement of this research work is the birth of the United State first guideline “Design of Highway Bridge Ship Collision” in 1991 (AASHTO. Lrfd, 1994). And it is the first relatively integrated and widely used technical document about ship-bridge collision. At present, part of the guideline has been written into some chapters of the America “Highway Bridge Design Code”, and it becomes a practical specification on bridge anti-collision design. In 1991, the IABSE accepted a article which had been written by Larson as the chief copywriter about ship bridge collision - “the Influence Between Vessel Traffic and Bridge Structure (Review and Guide)”. To conclude and summarize on the research results of ship-bridge collision. And the article as the IABSE file, was officially published in 1993. It systematically discussed the ship collision risk and anti-collision design problem during the bridge plan and design, and it further promoted the research work on the problem of ship-bridge collision. After this, some European countries also made some technical standards or specifications on this subject (Pan, 2010, p.24).

In 1995, the work-group of the Permanent International Association of Navigation Congresses (PIANC) was set up, specially researched the problems of ship-bridge collision, it includes 9 member countries: Belgium, France, Germany, Japan, Spain, Sweden, the United Kingdom, the United States and the Netherlands. The group has gone through five years of research and by the year 2000, has set up a database including 151 ship-bridge collision accidents, and analyzed the related problems.

In China, the relevant technical department and workers gradually realized the importance of research on the safety of the ship-bridge collision. Researching the ship-bridge collision was since the late 1980s, from the Huangshi Yangtze River Bridge beginning, combining the construction of large-span channel bridge project (e.g., the Sutong Bridge, Zhanjiang Bay Bridge, Shanghai Yangtze River Bridge, the Hangzhou Bay Bridge, the East China Sea Bridge, etc.), they carried out in-depth research work step by step.

1.3 The Objective in This Paper

As we know, the main reason of ship accidents are human factors and technical reasons. So is the ship-bridge collision. Taking effective measures to reduce human error and avoid steering gear failure and navigation system failure are fundamental to prevent ship-bridge collision accident. At the same time it is useful making reasonable management regulations and navigation rules in bridge zone, implementing effective monitoring and guidance to ship navigation with the help of modern information technology, also real-time informing channel, hydrology, meteorology, ship flow distribution to ship navigation. Building ship-bridge collision risk assessment system is an important way of real-time monitoring ships when crossing bridge zone, so using the ship-bridge collision risk assessment system to send danger alarms and remind ship navigation is the effective guarantee of bridge against ship.

However, the defensive measures of ship-bridge collision are mainly concentrated in the passive anti-collision of bridge, and researching the active defense measures of ship-bridge collision is still in its infancy. So the paper focuses on the active defense measures of ship-bridge collision, to achieve the following objectives:

(1) Analyze bridge zone safety involving related party interests, management responsibilities and ship-bridge collision accident responsibility investigation, etc. put related parties into bridge zone safety management, and promote the bridge zone safety management together.

(2) Establish and improve the management mechanism, elaborate safety management measures and requirements of the relevant parties, weave “safety net of bridge zone management”, and provide a solid guarantee for the bridge anti-collision management.

(3) Set up dynamic risk assessment of ship and bridge collision and early warning system, provide dynamic (real-time) risk measurement and early warning, and build the risk level assessment, which provides strong support and takes effective measures to prevent danger happening.

(4) Discuss the bridge anti-collision management countermeasures, present the concept of hierarchical management mechanism, establish bridge anti-collision security classification management system, as normal, early warning, emergency three levels and formulate corresponding management system, each unit implement management measures according to the different levels.

1.4 The Main Tasks in The Paper

The main tasks in this paper are as follows:

Firstly, this paper has an overview of the ship-bride collision research and status quo, and then presents that it is necessary and urgent to carry out the ship-bridge collision risk assessment research, expound the writing purpose and research content of this paper.

Secondly, the paper introduces bridges informations and parameters in Shanghai port, and gives some problems of bridges safety management in Shanghai Port waters.

Thirdly, this paper focuses on the ship-bridge collision risk management and risk assessment, an intact ship-bridge collision risk management process and three methods of ship-bridge collision risk assessment is introduced.

Fourthly, some bridge safety management countermeasures are given in this paper, combining with case to introduce and analyze.

At last, this paper gives conclusions and some suggestions.

CHAPTER 2 GENERAL INFORMATION OF BRIDGE AND SAFETY MANAGEMENT IN SHANGHAI PORT WATERS

2.1 General Situation to the Shanghai Port Bridge

Shanghai Port, which has an advantageous geographical position, connects with the east China sea, the Yangtze river and the Huangpu river. The water traffic is busy and considered as a gold port in China. Meanwhile, it has a developed and comprehensive transportation network in shanghai area, and the construction of bridge facilities enriches and perfects the urban comprehensive transportation network, which makes great contribution to shanghai economic and social development. At present shanghai port has a number of bridges: 1 Donghai bridge, 2 Yangtze river bridges and 7 Huangpu river bridges. The profile of bridges is as follows (Table1):

Table 1 - Donghai Bridge Navigation Technology Standards and Anti-collision Facilities

Name of navigable hole (south to north)	Free height (meter)	Navigable clear width (meter)	Navigation capacity (DWT)	Anti-collision device (Y/N)	Ship flow (ships/year)
NO.1	17.5	2×56	≤500	Y	NO.2 hole has about 149285 ships in 2011 years; NO.1, 3, 4 holes only less.
NO.2 (main hole)	40	300	≤5000	Y	
NO.3	27.5	2×100	≤1000	Y	
NO.4	17.5	2×56	≤500	Y	
Ban navigable hole	Ban navigable waters, set the "alarm 1" to "alarm 24" buoy, every buoy distance is about 1.1 NM			N	Part of small vessel, fishing boats illegally navigation

Source: Ying J.H. (2006). Research on the ship navigable capacity of donghai bridge main navigable hole. Shanghai: Author.

From Table 1, it can be seen that the navigation of ship main concentrates in the No.2 navigable hole, considering the wind and current is perennial large in the bridge water, high ship density causes the ship-bridge collision accidents easily (Ying, 2006, pp. 7-13).

Table 2 - Shanghai Yangtze River Bridge Navigation Technology Standards and Anti-collision Facilities

Name of navigable hole (south to north)	Free height (meter)	Navigable clear width (meter)	Navigation capacity (GT)	Anti-collision device (Y/N)	Ship flow (ships/year)
NO.1	36	146	5000 tonner	3000 tonner	about 50-60 thousand ships in 2009 year
NO.2	52.7	585	50 thousand tonner bulk carrier or 30 thousand tonner container ship	5000 tonner	
NO.3	36	146	5000 tonner	3000 tonner	
NO.4	25	102	3000 tonner	3000 tonner	
NO.5	25	102	3000 tonner	3000 tonner	
Ban navigable hole	Ban navigable waters, set the "alarm 1" to "alarm 9" buoy, every buoy distance is about 1.1 nm.			N	Part of small vessel, fishing boats illegally navigation

Source: Shanghai municipal engineering design & research institute. Shanghai Yangtze river bridge overall design and key technology. Retrieved June 16, 2014.

from the World Wide Web: http://www.docin.com/p-442615171.html

Table 2 shows, in Shanghai Yangtze River Bridge water, ship traffic volume is large with a number of large-size ships. With the development of the shipping, more and more large-size ships put into operation. In the current situation, the anti-collision device of Shanghai Yangtze river bridge has lagged behind.

Table 3 - Chong-Qi Changjiang Highway Bridge Navigation Technology Standards and Anti-collision Facilities

Name of navigable hole (south to north)	Free height (meter)	Navigable clear width (meter)	Navigation capacity (GT)	Anti-collision device (Y/N)	Ship flow (ships/year)
NO.1	28.5	152	3000 tonner	N	About 30,000 ships，most are small vessels and sand ships
NO.2	28.5	152	3000 tonner	N	
NO.3	28.5	152	3000 tonner	N	
NO.4	28.5	152	3000 tonner	N	
Ban navigable hole	Ban navigable waters，set the "alarm 1" to "alarm 2" buoy.			N	Some fishing boats through

Source: Dai, Jie. & Li, Zheng. The bridge project research of Chong-Qi changjiang highway bridge. Retrieved June 16, 2014. from the World Wide Web: http://www.doc88.com/p-268188543856.html

As shown in Table 3, the Chong-Qi changjiang highway bridge has few ship traffic every year relatively, but it is important to note, there is almost no anti-collision device. Once the ship-bridge collision accidents happen in this area, there are more severe consequences.

Table 4 - The Navigable Hole Design Parameters of Huangpu River Bridges

Name of bridge	Free height (meter)	Navigable clear width (meter)	Navigation capacity (GT)
Yangpu Bridge	52	423	10000
Nanpu Bridge	48	340	10000
Lupu Bridge	48	340	10000
Xupu Bridge	47	300	10000
Minpu Bridge	43	330	10000
Fengpu Bridge	29.5	315	8200
Minpu II Bridge	28	218	4500

Source: Juharin. The general survey of Shanghai Huangpu river bridges. Retrieved June 16, 2014. from the World Wide Web: http://wenku.baidu.com/view/6a4c6328e2bd960590c677a0.html

The channel of Huangpu river is narrow and there are more bends and bridges. In fact, the ship flow is also large perennial, which increases the ship-bridge collision risk. Meanwhile, the bridges only have simple anti-collision device. Obviously, it cannot meet the needs of bridge safety management (Chao, 2002, p.18).

2.2 The Problems and Difficulties of Shanghai Port Bridge Management

Shanghai port has a large number of bridge facilities, whose status and role to shanghai local economic and social development is self-evident, so the local government and relevant functional departments continue to increase investment and system construction in the bridge safety management (Sun & Feng, 2000, PP. 34-37). However, there is a long distance to get up to scientific and standardized management, mainly embodied in the following aspects:

(1) Legislation is insufficient to shanghai port bridge safety management

Shanghai government issues the regulations about bridge safety management which cannot meet the needs of water and land comprehensive management.

Firstly, there is no unified clear administrative department in charge of bridge safety management. The bridge safety management involves many departments, such as municipal engineering management department, the construction and traffic committee, road administration department, etc. but the administrative department has not been unified. This situation is very bad to bridge safety management.

Secondly, the existing relevant management regulations have fallen behind. At present, the relevant provisions of shanghai has not covered the safety management of the east China sea bridge, the Shanghai Yangtze river bridge, and the Chong-Qi changjiang highway bridge, but the water safety risk of the three bridge is very highlight, and there is lack of relevant legal support to the water safety management.

Thirdly, the management department concerning bridge safety management is difficult to meet the demand of management. Although the bridge owner unit and the operating unit are in charge of bridge water traffic safety department, the regulations do not cover them in Shanghai.

And the last, there is no special agency for the bridge safety management. The existing relevant government functional departments are related to bridge safety management, but are not specialized in bridge safety management, so there are some problems to bridge safety in professional management, and almost have no the functional departments to supervise.

(2) The bridge safety comprehensive management coordination mechanism is not yet mature

The bridge safety management involves many departments, but due to lack coordination between each other, it is prone to poor sharing information and communication in daily management, the hidden perils and emergency disposal work, and so on, which is adverse to bridge safety management.

(3) The bridge owners and operating units have “heavy bridge floor, light the water” management mode

The bridge owners and operating units are in charge of the bridge water safety and the safety situation is extremely serious, but the investment and management is very limited in water traffic safety, and it is basic in the blank stage for bridge water traffic safety monitoring and management.

(4) Shortage of bridge water supervision power and equipment

At present, the bridge water supervision and management main rely on Shanghai Maritime Safety Authority (MSA), which uses the VTS, AIS and patrol boat to supervise. In fact, the duty of MSA is water safety supervision and management and the range is the whole jurisdiction waters, although the MSA has listed the bridge waters as key monitoring object. And using the VTS, AIS to supervise part areas, the MSA is not a full-time department of bridge water safety. Further there has a problem, of the frequency of bridge waters cruise management.

(5) Lack of emergency and rescue power

Due to lack of supervision and emergency reaction base near the bridge, and no special emergency and rescue power, it cannot start emergency and rescue action immediately. For example, on July 22, 2012, “ZHE CHANG XING HUO 5280” was out of control near the Shanghai Yangtze bridge water, which could not get timely rescue. As a result, it sank near the bridge water, not only influencing ship navigation, but also increasing the potential risk of bridge.

(6) Insufficient to the bridge anti-collision

Although shanghai port set the anti-collision device over navigable hole pier of some bridges, it still cannot meet the anti-collision capability designed by the level of ship navigation. What is more, all the ban navigable hole pier of bridges in shanghai port jurisdiction did not install anti-collision device. Once the ship is out of control or strays into restricted areas, it will endanger the bridge safety directly.

(7) Lag behind to the information construction of bridge safety management

Some bridges are installed with CCTV, VTS and other monitoring equipment in shanghai port. The modern equipments provide convenience for bridge water safety management. However, quite a number of bridges have no corresponding monitoring equipments, and some bridge monitoring equipments have additional funding and maintenance (Shen, 2004, pp. 5-7).

In addition, although it is installed with CCTV, VTS, AIS, many small vessels, sandstone ships are not installed with AIS, these ships have the fact of condition poor, low personnel quality, usually navigation illegally, and the monitoring track is very difficult. General speaking, they bring danger to the bridge safety management.

(8) The ship collision risk arises due to ships not familiar with water and asymmetric information

It is more difficult to distinguish the navigable hole when the ship is not familiar with the bridge water, so they cross the bridge hole randomly, and lead to a ship-bridge collision accident eventually. Another is that after the completion of the bridge, the corresponding technical parameters of bridge are not published timely and in a wide range, such as bridge navigable level, navigable hole headroom, navigation method and so on. If the crew cannot know the essential data timely, it is easy to go a wrong navigable hole, causing ship-bridge collision accidents.

2.3 Chapter Summary

This chapter first puts forward the specific steps of ship-bridge collision risk management, and uses the flow chart of risk assessment management framework to intuitive express the whole process of ship-bridge collision risk management. The ship-bridge collision risk management is divided into three parts: the ship-bridge collision risk identification, the ship-bridge collision risk assessment and the ship-bridge collision risk countermeasures. The ship-bridge collision risk assessment mainly involves: the ship-bridge probability, the bridge vulnerability and the ship-bridge consequence assessment.

CHAPTER 3 SHIP-BRIDGE COLLISION RISK MANAGEMENT

Ship-bridge collision risk management includes the following three aspects: the ship-bridge collision risk identification, risk assessment and risk countermeasures.

3.1 Ship-bridge Collision Risk Identification

The risk identification of ship-bridge collision could be measured by the bridge suffer losses caused by ship collision:

(1) Bridge damage: repair and rebuilding costs, toll bridges loss revenue during repair or rebuild, the detection repair and replacement parts cost caused by the accident, etc.

(2) The users of bridge damage: casualties, the damage of goods and vehicles.

(3) Ship damage: casualties, ship salvage charges, ship repair fee or remake fee and beneficial damage during this period, ship goods loss, the claims of bridge users and owner, insurance fees and so on.

(4) The inconvenience to the society and business: the loss of traffic interruption and restricted passage in highway and railway, shipping disruption and business losses.

(5) Environmental damage: the goods leakage carried by the boat or vehicle cause environmental pollution, including the clean and recover cost.

(6) Social loss: the indirect social and political influence.

Bridge is a public infrastructure and the government department would be concerned with all losses, especially the casualties. A malignant ship-bridge collision accident, besides huge economic loss, might make social confusion and cause bad political influence.

3.2 Ship-bridge Collision Risk Assessment

The content of ship-bridge collision risk assessment mainly involves three aspects: the probability of ship-bridge collision, the vulnerability of bridge, and the consequence assessment of ship-bridge collision. In the field of risk analysis, the method of direct economic loss evaluation has been more mature, however, it has dissent between the casualty loss, environmental damage loss and social loss. Actually, not all the ship-bridge collision accidents include all of the above losses, so in order to facilitate risk assessment, usually the total risk, caused by the damage degree of bridge and economic, social and environmental losses, divide into 5 risk level of the ship-bridge collision:

$$D = \{d_1, d_2, d_3, d_4, d_5\} \qquad (3\text{-}1)$$

In this formula:

d_1 indicates intact, which means the affect of ship-bridge collision is less than or equal to the considered factors in the bridge design, no adverse effects to operating, and the economic loss can be ignored;

d_2 shows slight and small effect on bridge structure. Economic losses include a small amount of repair fee and the loss caused by the inadequate use of bridge and fairway;

d_3 means moderate: the bridge could continue to use after being reinforced or repaired. Economic losses include the reinforce and repair fee and the loss caused by stop operation;

d_4 shows relatively serious: the bridge structure is not collapse yet has been unable to work normally. Including the value of bridge structure and demolish rebuild cost, and the corresponding disaster losses, social and economic losses, environmental damage loss, etc.;

d_5 indicates serious: bridge has collapsed and suffered great losses. Including the bridge value, demolish rebuild cost, secondary disaster loss, casualties, social and political loss, and environmental damage loss, and so on.

The probability of ship-bridge is related to ships per year, yaw probability and geometric probability in bridge water area. In addition, it is closely related to the current, meteorological and shipping management. Whether collapsed or the degree of damage to the bridge after suffered by ship collision is related to bridge vulnerability, ship size, ship appearance, ship speed, impact angle, quantity and collision characteristic and so on(Pedersen, 2002, pp. 29-45). In fact, even if the bridge suffers the same degree of damage after ship-bridge collision, the loss of each accident is not consistent, so the risk of ship-bridge collision is actually random. The events of ship-bridge collision might happen many times during the service life of bridge. The total risk expectation can be represented as:

$$R_E = \sum_{i=1}^{n} \sum_{j=1}^{5} p_{ij} d_{ij} \qquad (3\text{-}2)$$

In this formula:

n means the bridge life (year)

d_{ij} shows the expected present value of the j level loss in the i year;

p_{ij} indicates the probability of j level loss occur in the i year, p_{ij} change along with the probability of ship-bridge collision, the vulnerability of bridge structure, the reliability of bridge anti-collision measures and the state of fairway management, it is also time-varying functions. p_{i5} is the probability of bridge collapsed. From the statistics, we can see that the less ship-bridge collision accidents cause bridge collapsed. However, the slight ship-bridge collision accidents often happen, in generally, it is characterized by $p_{i1} > p_{i2} > p_{i3} > p_{i4} > p_{i5}$. Although the low level ship-bridge collision accidents cause the loss small because of the high probability, the total loss is considerable. For serious ship-bridge collision accidents, the indirect economic loss, casualties, social and political loss, and environmental damage can far exceed the value of bridge itself.

3.3 Ship-bridge Collision Risk Countermeasures

Like the earthquake and hurricane harmful to bridges, the events of ship-bridge collision is also a small probability events. However, the main reasons for ship-bridge collision are human error, indicating the risk of ship-bridge collision can be controlled in a great extent. Studies show that in the reasons causing ship-bridge collision, the human error, mechanical failure and poor natural environment are 70%, 20% and 10% respectively. To reduce the risk of ship-bridge collision should take systematic methods, it can reduce the risk for planning to build a bridge mainly from the design aspects, such as the bridge location, shipping command, waterway planning and bridge span. These are also the main way to solve the problem of ship-bridge collision(Xiang, Fan, & Wang, 2002, pp.386-392). The ship-bridge collision risk should be considered in the above methods.

From the formula (3-2), the best way to decrease the total risk expectation R_E of ship-bridge collision is to reduce p_{ij}. It can be achieved through the following measures: reduce the vulnerability of bridges, reduce the strength of ship-bridge collision, and reduce the probability of ship-bridge collision. The first two measures can be achieved by the “passive anti-collision”, and the last measure belongs to “active anti-collision”. In other words, the “passive anti-collision” and “active anti-collision” measures are two basic measures to reduce the risk of ship-bridge collision.

Passive anti-collision shows the ability of bridge to resist ship collision in the design of bridge structure, or taking anti-collision measures to reduce the direct effect of ship collision to the bridge structure. If the overall bridge has enough ability of resisting ship collision, then the anti-collision equipment is partial to prevent local damage of bridge; otherwise, it must adopt the bridge piers and the overall anti-collision measures. The main roles of bridge anti-collision equipments are to protect the bridge pier. Its working principle is to change the force direction of ship collision or absorb the impact, like cushion to achieve the purpose of protecting bridge piers.

Active anti-collision is to take comprehensive measures (for example early warning, navigation and traffic control) to reduce the probability of ship-bridge collision. The main effective measure is the MSA with the aid of buoy, radar and GPS etc. to master ship movement surrounding the bridge, to command ship safe navigation. Considering the main accidents caused by human factors, the reasonable command and management are the most basic guarantee to reduce the risk of ship-bridge collision.

3.4 Ship-bridge Collision Risk Management Framework

The aims of ship-bridge collision risk management are to identify the suffer possibility of bridge by ship collision and the consequences. It can provide the reference for the scheme design of bridge anti-collision. The administrative department, starting from the concept and technology of project risk management, established the risk management model of ship-bridge collision, with the aid of the data and conclusions of risk assessment, considering the factors of economy, politics, and environment to establish appropriate measures which reduce the ship-bridge collision.

An intact ship-bridge collision risk management system should include: ship-bridge collision safety assessment database, ship-bridge collision safety assessment module, risk acceptance criteria, active anti-collision scheme design and passive anti-collision scheme design (Geng, & Wang, 2007, pp. 34-40). So a preliminary framework is be put forward to the ship-bridge collision safety assessment (Figure.1).

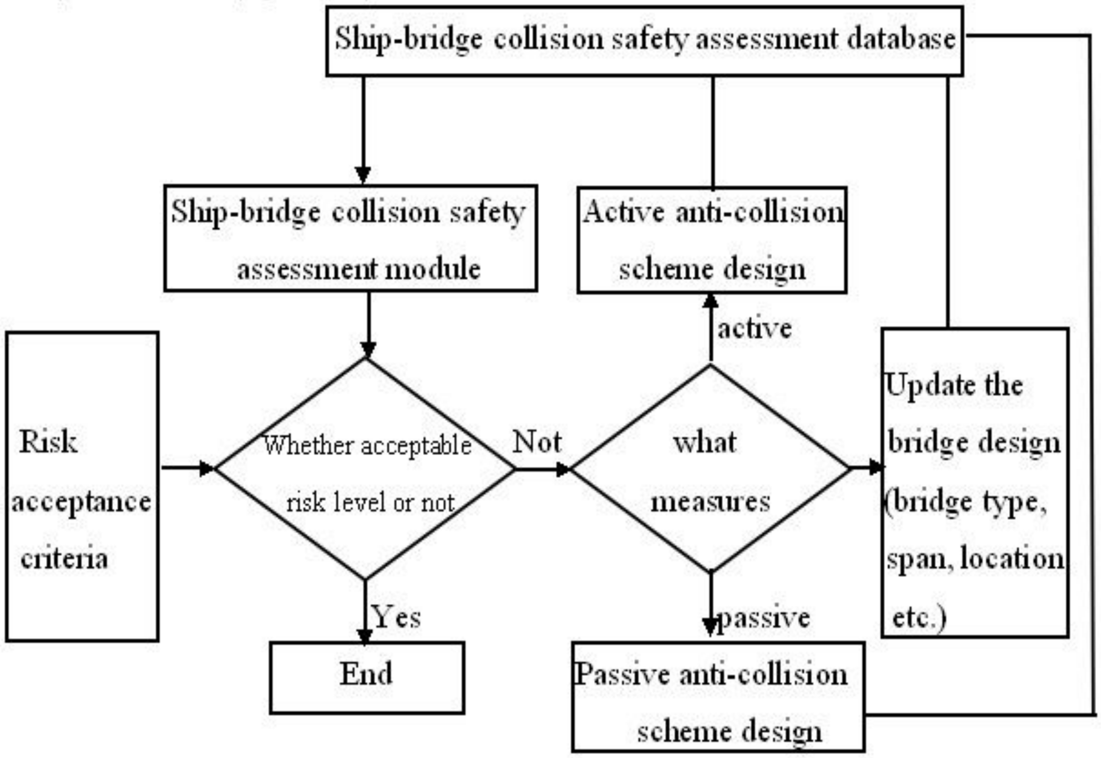

Figure.1 - the Ship-bridge Collision Risk Management System Flow Chart

Source: Jin Y.J. (2011). Research on bridge ship collision risk assessment and bridge protection facilities. Wuhan: Author.

As shown in Figure 1, ship-bridge collision risk management is a dynamic process: first risk identification by the historical materials and related data of the ship-bridge collision safety assessment database, and then risk estimates by the ship-bridge collision safety assessment module and risk acceptance criteria, according to whether meet the acceptable risk level, to decide whether to take risk countermeasures, if it does not meet the acceptable risk level. Risk countermeasures is followed by risk analysis and risk estimation, so repeat until meet the acceptable risk level.

3.5 Chapter Summary

This chapter puts forward some specific steps to the ship-bridge collision risk management, and the ship-bridge collision risk management is divided into three parts: ship-bridge collision risk identification, ship-bridge collision risk assessment and ship-bridge collision risk countermeasures. Among the ship-bridge collision risk assessment main involves three aspects: ship-bridge collision probability, bridge vulnerability and the consequences assessment of ship-bridge collision. The ship-bridge collision risk countermeasures include passive anti-collision and active anti-collision. At last, referring to previous research results, the whole process of ship-bridge collision risk management is presented visually by the ship-bridge collision risk management system flow chart.

CHAPTER 4 SHIP-BRIDGE COLLISION RISK ASSESSMENT METHODS

4.1 Risk Assessment Common Methods

The risk assessment is to measure and evaluate the risk occurrence likelihood and consequence by using risk occurrence probability on the basis of risk identification. That is to say the reasonable risk assessment generally adopts the combination of qualitative and quantitative, first qualitative and then quantitative, and it generally uses a single method or several methods to analyze. In the actual engineering projects, the common methods for assessment project risk mainly include Brainstorming Method, Event Tree Analysis (ETA), Fault Tree Analysis (FTA), Failure Mode and Effects

Analysis (FMEA), Hazard and Operability Analysis (HAZOP), Delphi Method, Probabilistic Risk Assessment Method, Fuzzy Comprehensive Evaluation Method, etc. (Jin, 2011, p.26).

4.2 Common Methods of the Ship-bridge Collision Risk Assessment

In the study of ship-bridge collision risk assessment, scholars adopted corresponding research methods to carry out ship-bridge collision risk assessment research according to their views and experience. At present, the more mature methods mainly include the Fault Tree Method, Fuzzy Comprehensive Evaluation Method and the Probabilistic Risk Assessment Method. This section introduces the application of the three methods in ship-bridge collision risk assessment research, and analyzes the merits and demerits of the three methods.

4.2.1 The Fault Tree Method to Ship-bridge Collision Risk Assessment

Fault tree analysis is a graphics deductive method, which is a kind of top to down, and from the top to the basic events, which can make qualitative or quantitative analysis for the events such as ship-bridge collision probability. Comprehensive analyzing the factors of ship-bridge collision, it can adopt the fault tree method to the ship-bridge collision risk assessment of general channel or wide waters. General speaking, the river or canal waterway is narrow and bend and the river regime and hydrological changes frequently, in addition, there are a variety of other factors to make the problem of ships collision complex; In contrast, the bay bridge water is open and navigation condition is good, so the ship collision accident is mainly caused by human error, and the safety assessment is simple with the general channel. For complex problems, the structure of fault tree is relatively complex. Under normal condition, ships impact bridge piers due to the ship's yaw, here the structure of fault tree for ship's yaw is, (Figure.2).

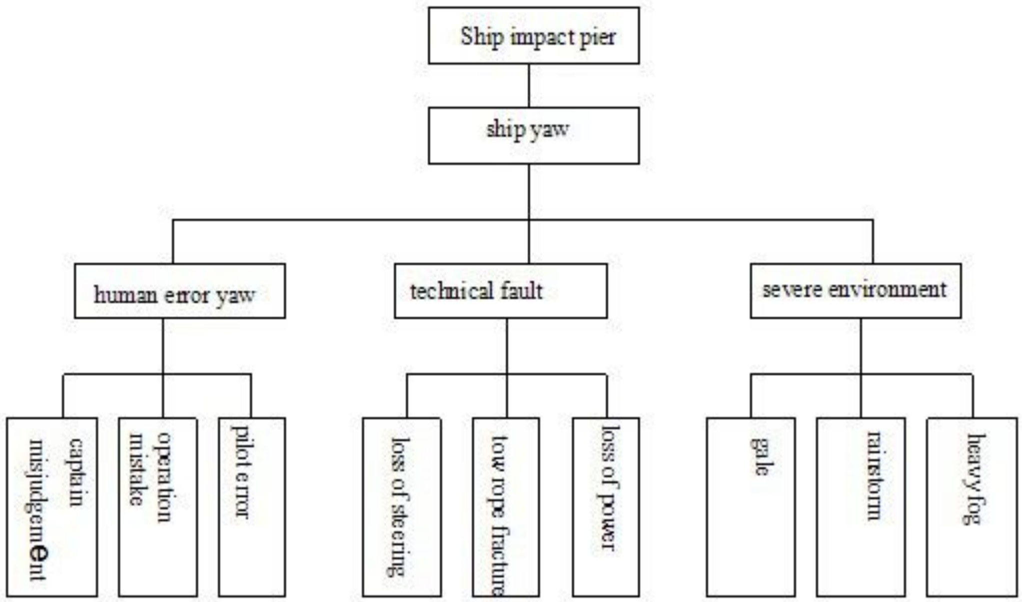

Figure.2 - the Fault Tree Structure of Ship Yaw

Source: Jin Y.J. (2011). Research on bridge ship collision risk assessment and bridge protection facilities. Wuhan: Author.

As shown in Figure 2, the method of FTA can analyze all of the fault reasons. However, it is easy to cause omission or error when using large system. In general, using the analysis method step by step like FTA, it needs the ship-bridge collision accident database as the foundation, this process need to accumulate and develop constantly. In the current engineering practice, there is a big difficulty to get such comprehensive historical data.

4.2.2 Fuzzy Comprehensive Evaluation Method

The fuzzy comprehensive evaluation method put the qualitative evaluation into the quantitative evaluation, which use fuzzy mathematics to make overall evaluation for the restricted things. It has the characteristic of clear results and strong systematicness and it can solve the problem well which is hard to quantify. The process of fuzzy comprehensive evaluation is as follows(Chen, & Ou, 2009, pp. 50-51):

(1) Establish factors sets: $X = \{X_1, \ X_2, \ \ldots, \ X_n\}$

(2) Establish judge sets: $Y = \{Y_1, \ Y_2, \ \ldots, \ Y_n\}$

(3) Establish weight sets: $A = \{A_1, \ A_2, \ \ldots, \ A_n\}$

(4) Establish evaluation matrix R. (the line i reflect the membership degree which the i factor to the each element of the evaluation sets, the j column reflect the membership degree which all factors to the j element)

(5) Establish fuzzy evaluation matrix: $B = A \times R = \left[b_1, \ b_2, \ \ldots, \ b_p\right]$

(6) According to the judgment matrix B, to find the maximum membership degree b_i , and then find the corresponding evaluation index Y_i in judge sets, that is the evaluation results (Chen, & Ou, 2009, pp. 50-51).

Ship-bridge collision risk assessment can be divided into two directions: the evaluation of collision probability and the severity of consequences. Next taking the severity of consequences for example to specific introduce the fuzzy evaluation method. The steps are as follows:

(1) Establish the evaluation factors sets

According to the possible consequences of ship-bridge collision, take the factors set: $X = \{X_1, \ X_2, \ X_3, \ X_4, \ X_5\}$, the $X_i (i = 1, 2, \ldots, 5)$ stand for casualties, economic loss of maintenance, traffic loss, environmental pollution loss and negative social influence loss in turn.

(2) Establish the consequences evaluation set

Because the consequences of ship-bridge collision accident are fuzzy, the consequences evaluation set can be divided into five levels, whose corresponding evaluation sets are:

$Y=\{Y_1,\ Y_2,\ Y_3,\ Y_4,\ Y_5\}$, the $Y_i(i=1,2,\ldots,5)$ stand for very mild, slight, moderate, more serious and most serious respectively.

(3) Establish weight set

According to specific situation of the project, through the focused select assessment factors, determine the function relation scientifically between the evaluation value and the evaluation factor value, and determine the weight of the evaluation factors reasonably. With basis of the reference and experts consulting, and combining the evaluation factors to structure the following judgment matrix:

$$P=\begin{bmatrix} 1 & 4 & 4 & 3 & 5 \\ 1/4 & 1 & 1 & 1/2 & 2 \\ 1/4 & 1 & 1 & 1/2 & 2 \\ 1/3 & 2 & 2 & 1 & 4 \\ 1/5 & 1/2 & 1/2 & 1/4 & 1 \end{bmatrix}$$

(4) Establish evaluation matrix

According to the relevant provisions of our country, the casualties and direct economic losses as the standard of accident grade, at the same time considering the characteristics of transportation industry, formulate the corresponding evaluation criteria.

According to the data characteristics of each evaluation factor, it can be divided into the quantitative factors and qualitative factors. To the quantitative factor, adopt the ridge type membership function which is commonly used in the engineering; to the qualitative factor, on the basis of the fuzzy membership function to determine the membership degree.

(5) Fuzzy comprehensive evaluation

First through matrix operations to get fuzzy evaluation matrix, and then according to the principle of maximum membership degree to get the consequences severity degree grade of the ship-bridge collision accident (Chen, & Ou, 2009, pp. 50-51).

The fuzzy comprehensive evaluation method is based on the fuzzy set and it is a comprehensive evaluation to the membership level status of the evaluate things from a number of indicators. On the one hand, considering the hierarchy of objects, to make evaluation standard and fuzziness of effect factors to reflect; on the other hand, it needs to give full play to human' experience according to the characteristics of each evaluation factor in the evaluation, and to determine the function relation between the evaluation value and the evaluation factors value (which means membership degree function). So, on the basis of combining qualitative and quantitative factors and expanding the amount of information, the fuzzy comprehensive evaluation method is very dependent on the expert's experience, and it has a certain historical and subjectivity (Jin, 2011, p. 30).

4.2.3 Probabilistic Risk Assessment Method

Probabilistic risk assessment method is the common research and application method of evaluating ship-bridge collision risk, it mainly covers three aspects: the collision probability, the collision consequences and risk criteria. According to the definition, the Probabilistic Risk Assessment needs to solve the following two questions: the probability of an accident and the consequences of an accident.

To measure risk from the angle of mathematics, on the basis of the different definitions of risk it can be summarized as the following categories: $R = f(p, c, q, b)$.

In the formula: p means the probability of risk events;

c means the loss caused by the risk events;

q means the realization probability of the target yield;

b means the action of target yield.

The risk of ship-bridge collision (R) should remove the target yield, and just consider the probability of ship-bridge collision (P) and the possible consequences of ship-bridge collision accident (C), using mathematical expression it can be expressed as:

$$R = f(p, c)$$

R is some function form of p and c. The $R = P \times C$ grading method is a combination of quantitative and qualitative method, and it is also a more popular of the risk assessment methods over the world at present. So this paper suggests to use the $R = P \times C$ grading method, using the product of accident probability and the corresponding damage probability to stand for the ship-bridge collision risk.

4.2.4 Classical Probability Calculation Model

The probability calculation of ship-bridge collision is one of the core content of ship-bridge collision risk assessment. In the theory, it can first find out the potential risk factors of ship-bridge collision, and then calculate and determine the collision probability caused by each risk factor, and finally calculate the total collision probability (Lin, 2007, pp. 181-186). However, there are a lot of influence factors to the ship-bridge collision accident and short of statistics, so this method still has certain difficulty in practice. Therefore, it can use experience comprehensive probability method at the same time, according to some theoretical research results and statistical analysis of existing accident data, to establish a global analysis method of collision probability. In practice, usually the experience comprehensive probability method is given priority, combined with component analysis to determine the ship-bridge collision probability. The observation statistics method and experience mathematical model method are the two basic methods of the experience comprehensive probability method, next to expounding the characteristics of experience comprehensive probability method from the two aspects.

The observation statistics method calculates the probability of ship-bridge collision accident according to the statistics and analysis of ship-bridge collision accident. Such as the Danish great Belt bridge, the COWI company estimated the probability of ship sailing on the expected impact bridge track, and they thought the collision probability of 40,000 DWT ship is 1.1×10^{-4}, and less than the 40,000 DWT is 3.2×10^{-4}. The advantage of this observation statistics method is easy to understand and apply. The disadvantage is that it needs a lot of statistical data, the authenticity, continuity and adaptability of data cannot effectively reflect, so that it makes the statistical work quite difficult. So it is difficult to use the single method to estimate the ship-bridge collision probability, and the result is not reliable.

The experience mathematical model, based on the ship-bridge collision accident statistics and the knowledge of channel and navigation management, is a mathematical model of ship-bridge collision. The advantage of this method is simple and practical, and it can adjust according to the different navigation environment. The point is to reasonably determine the parameters of model according to specific circumstance. This method is widely used in ship-bridge collision design. After many years research, the international scholars have presented some more mature experience mathematical model to calculate ship-bridge collision probability. For example, the AASHTO LRFD model, KUNZ model and O.D. Larsen model. Besides these, the scholars also set up their own model during the research process, such as Huang P.M. Direct Path model, Dai T.Y. Ship-bridge Collision Probability Calculation model (Jin, 2011, p.31). Along with the accumulation of observational data, the simple and practical experience mathematical model has become the main approach to the research of the ship-bridge collision probability. This paper takes the KUNZ model briefly introduce the calculation method of ship-bridge collision probability (Figure.3):

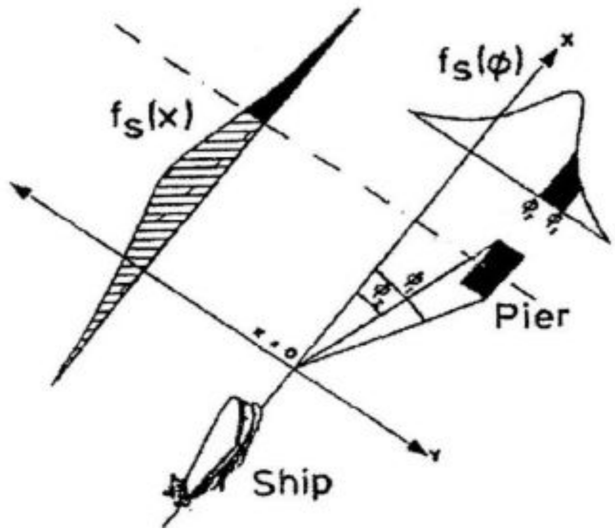

Figure.3 - KUNZ Probability Calculation Model

Source: Geng Bo (2008). Research on calculation model for probability of bridge crashed by vessels in Three Gorges area. Shandong: Author. Retrieved 10 June 2016 from the World Wide Web: http://www.docin.com/p-379352248.html

As shown in Figure 3, C.N. KUNZ (Germany) considered each position of ship and piers before collision, and presented a ship-bridge collision probability calculation model with two random parameters. One of the variables is the ship's yaw angle ф, which means the angle of navigation direction with a predetermined course, the other variable is the parameter S of stopping distance, to a specific bridge and certain ship type, based on integrating various influence factors like the ship machinery performance, tonnage, average speed, boundary dimension, the officers average quality, water features in bridge site, bridge dimensions and so on. Here the minimum free distance S which can avoid the bridge obstacle component is a normal random variable. Φ and S are influenced by many independent factors, assuming the random variables of normal distribution expressed as:

$$F_\phi(\phi) = \frac{1}{\sqrt{2\pi\sigma_\phi}} \int_{-\infty}^{\phi} \exp\left\{\frac{(\phi-\mu_\phi)}{2\sigma_\phi^2}\right\}^2 d\phi$$

$$F_s(s) = \frac{1}{\sqrt{2\pi\sigma_s}} \int_{-\infty}^{s} \exp\left\{\frac{(\phi-\mu_s)}{2\sigma_s^2}\right\}^2 ds$$

So the mathematical expression of probability model is: $P_c(T) = nT\int \lambda(s)W_1(s)W_2(s)ds$

In this formula: $P_c(T)$ means the collision probability within a specified time T;

n means the number of navigable ships in T;

$\lambda(s)$ means the probability of failure for ship sailing per unit distance;

$W_1(s)$—$W_1(s) = F_\phi(\phi_1) - F_\phi(\phi_2)$, the probability of collision track;

$W_2(s)$—$W_2(s) = 1 - F_s(s)$, the probability of the uncontrolled accident before collision.

It is worth mentioning that the KUNZ model considers the influence of human factors during the ship-bridge collision, and it really reflects the process and mechanism of accidents in a certain extent.(Wang, 2008, p. 49)

4.2.5 Ship-bridge Collision Risk Acceptance Criteria

Risk acceptance criteria means the acceptable risk level in the stipulated time or within a certain behavior stage, which reflects the society, the public or personal to acceptance level. Risk acceptance criteria can directly provide the reference basis for risk level assessment, risk response and decision. If the same calculation results according different risk acceptance criteria to make decision, then the processing way also has difference (Yang, 2012, p. 130). So, making a reasonable risk acceptance criteria is particularly important.

If making the ship-bridge collision event as risk events, it must be a wide acceptable risk level, which is considered as the design basis of ship-bridge collision. At present, the more perfect risk acceptance criteria are the AASHTO ship-bridge collision design guidelines. And the European specification also gives the corresponding reference value, but no specific provision. The brief introduction to the risk acceptance criteria of ship-bridge collision are as follows:

(1) The ship-bridge collision risk acceptance criteria of AASHTO LRFD

In the aspect of ship-bridge collision risk criteria, at present the relatively perfect is the AASHTO ship-bridge collision design guidelines. Its risk acceptance criteria adopt the designated target fall frequency method, for the target fall frequency of general bridge is 10^{-3} , for the important bridge is 10^{-4} . So it makes the engineer more intuitive and quantitative understandings.

(2) The ship-bridge collision risk acceptance criteria of EUROCODE

The EUROCODE adopts the designated target reliability method. The EUROCODE divides the security level of structure into three classes, the target fall frequency of a typical bridge is most likely 10^{-6}. To the risk acceptance criteria, the EUROCODE has no specific explain.

(3) Other ship-bridge collision risk acceptance criteria

Some specific bridges have special ship-bridge collision criteria, (Table 5).

Table 5 - the Risk Acceptance Criteria of Some Specific Bridges

The project name	Risk acceptance criteria
Louisiana bridge	Bridge destroy:100 years 0.01
The ISO 1987 standard "the unexpected risks caused by the human activities"	For too much the impact energy: 100 years 0.02
Beside ship collision, include fire, explosion, ice ram, train accident	Railway and highway connection line destroy: 100 years 0.02 Highway connection line destroy: 100 years 0.10 Railway connection line destroy: 100 years 0.10

Source: Dai T.Y. (2002). Ship impact against bridge and its risk assessment. Harbin: Author.

As shown in Table 5, the target fall frequency of the Louisiana bridge is 10^{-4}, the same to the AASHTO LRFD; meanwhile, the acceptable frequency of "unexpected risks caused by the human activities" is also in the range of AASHTO LRFD. Summarizing the above analysis, the ship-bridge collision risk acceptance criteria are all in the recommended range of ASSHTO LRFD. On the other hand, the target fall frequency, which is the ship-bridge collision risk analysis to several bridges in china (such as Sutong bridge, Donghai bridge, Jintang bridge, etc.), is reference to the AASHTO LRFD to select. So this paper would adopt the bridge target fall frequency of the AASHTO LRFD to the ship-bridge risk assessment (Dai, 2002, pp. 19-20).

4.3 Measures to Reduce the Ship-bridge Collision Risk

Generally speaking, the measures to reduce the ship-bridge collision risk are divided into two directions: one is to reduce the probability of ship-bridge collision, and the other is to reduce the consequence severity of the ship-bridge collision, usually called the active anti-collision and passive anti-collision.

4.3.1 Active Anti-collision Measures

Active anti-collision, as the name implies, is to take the methods of active avoidance collision or reduce the collision probability to reduce the ship-bridge collision risk.

(1) Set the navigation mark. The navigation mark is used for ship positioning, navigation or for other special purposes. The navigation mark makes a sound or visual signal to arouse the attention of crew, to help the ship navigation safety and to ensure the safety of water traffic.

(2) Ship navigation routing scheme. Considering the water traffic is busy, the governments sets up ships navigation routing scheme in the important water areas, such as the traffic separation schemes, one-way navigation, etc.

(3) Set up the ship sailing warning zone. In order to avoid the ship collision, and regulate the behavior of ship sailing, it is necessary to set up warning zone in the complicated sailing water areas. Warning zone reminds special vigilant navigation when ships pass.

(4) Ship pilot. In certain waters, in order to reduce ship collision accidents, pilots board the ship and pilot the ship to sail into or out of the port safely.

(5) Install ship AIS system, set the vessel traffic service system. AIS is mainly used for collision avoidance between ships, but combining with the vessel traffic service system (VTS), it can reduce the ship-bridge collision accidents.

(6) Personnel safety training. According to the statistics, 80% of the marine accidents is caused by human factor. So, to strengthen the crew safety awareness training could also reduce the probability of the ship-bridge collision in a certain extent.

(7) Improve the bridge environment. The probability of bridge ship collision events is also related with the bridge itself, such as bridge location, bridge span arrangement, bridge construction and bridge navigable free height and so on. Bridge location should be in the traffic channel linear area. And the bridge axis should be orthogonal with the mainstream of water flow and ship design route as far as possible, the normal Angle of the mainstream of water flow and the bridge axis should be no more than 5 degree. Meanwhile, the bridge pier should be set in water as less as possible, and in order to avoid large-size ship collision, the bridge pier should be built in shoal waters (Li, 2011).

4.3.2 Passive Anti-collision Measures

Passive anti-collision sets anti-collision devices around the piers to reduce the impact of ship to the bridge pier, by reducing the bridge collapse rate or damage degree to reduce the ship-bridge collision. The purpose of bridge anti-collision device is to prevent ship collision over the withstanding capability of the bridge piers from damage and to protect the safety of bridge structure. By using different forms of anti-collision facilities can stop the ship collision force from reaching the pier, or through a buffer efficiency anti-collision facilities to extend the time of ship collision, so reducing the ship collision force, and achieving the purpose of protecting the bridge finally.

The bridge can have effective discount to ship collision force if it adopts passive anti-collision system, as follows:

$$P_P = \alpha_P \cdot P$$

In this formula: P_P means ship collision force on the bridge with anti-collision facilities;

α_P means ship collision force correction factor with anti-collision facilities;

P means ship collision force on the bridge without anti-collision facilities.

The discount effect of the different anti-collision system is different to ship collision force, For example, the independent anti-collision pier can stop the ship impacting bridges, or it has been depleted of energy when ship reached the pier, the ship collision force is too small to damage the bridge pier. In this case, the ship collision force correction factor α_P can get smaller. If using the attached type system, such as anti-collision box, the ship collision is larger than the independent anti-collision, and the correction factor α_P is also larger. Through comparing the ship collision force on some domestic cross-sea and across-river bridges with and without anti-collision box, it concludes that: with anti-collision pier, ship collision force tends to have a certain reduction, the discount rate range is from 5% to 69%, usually floating between 8% and

30%, and the average is 25%. However, due to lack of research data, the ship collision correction factor of other types anti-collision devices still needs further research.

4.4 Chapter Summary

This chapter first introduces the common methods of risk assessment, and then introduces the common methods of ship-bridge collision risk assessment: Fault Tree Analysis method, Fuzzy Comprehensive Evaluation method and Probabilistic Risk Assessment method. The Probabilistic Risk Assessment method is widely used for quantitative calculation at present, so the method is reviewed in detail: through the collision probability, the ship collision force, risk assessment and risk measures four aspects. This chapter also puts forward the personal opinion on the basis of comparative analysis of classical bridge ship collision probability calculation model. Finally, the chapter gives a brief introduction to the current authoritative risk assessment criteria. And considering the risk assessment criteria of the AASHTO specification as the calculation basis of this chapter. In the aspects of response to the ship collision risk measures, the chapter gives a brief introduction from two aspects: active anti-collision and passive anti-collision. And the active anti-collision measures will be focused on the back of this paper. Now, an intact ship-bridge collision risk assessment framework and method have been formed.

CHAPTER 5 BRIDGE SAFETY MANAGEMENT COUNTERMEASURES

This chapter, mainly from the perspective of management, and combining with the active anti-collision measures, presents some bridge safety management countermeasures in Shanghai port. Safety cannot leave human intervention to the "man, machine and environment" system, which means, the generalized control is the "management", so the "management" should be the accident control system and safety management system, and is one of the basic elements of safety science. The human intervention of ship-bridge collision risk is the main method to reduce risk by the management methods. And the management countermeasures include planning, organizing, coordinating, forecast, prediction, supervision, education, publicity and other aspects.

(1) The local government

The government is responsible of safety management, and also the coordinator of comprehensive treatment, is on the leading position of "responsibility chain". The management methods of the local government in the ship-bridge collision risk include: by setting the corresponding local laws and regulations, realize the risk control; Supervise the situation of ship-bridge collision risk; Coordinate the relevant departments to establish the safety management measures of ship-bridge collision risk (Lei, 2006, p.56).

(2) Bridge owners and operating management units

Bridge owners and operating management units are in charge of bridge safety production. Its main safety management methods include: to carry out the bridge safety management measures including install bridge anti-collision devices, and set the navigation warning facilities and so on. Do the bridge maintenance, such as the maintenance of bridge itself and its ancillary facilities, as well ensure the bridge safety technical condition.

(3). The traffic management department and highway management department

The traffic management department and the highway management department are the supervision and management department of bridge within the domain. And it includes the supervision and management of bridge floor and piers. Its main safety management methods include: to supervise and inspect the executive condition of concerning highways laws and regulations; to maintain the highway according to the specified technical specifications and operation procedures.

(4) The maritime administrative department

The maritime administrative department is the competent authority for national water safety supervision, in accordance with the legal authority to carry out safety supervision and navigation management to ship, the crew, the ship company and the relevant waters. Its main safety management methods include: in regulatory, to supervise and manage the ship seaworthiness, the crew competency and bridge zone navigation order; the emergency rescue and accident treatment of the ship-bridge collision accidents. The specific measures of the bridge zone navigation order supervision and management include the site traffic management, VTS command, bad weather to close navigation in bridge waters, anchored ship leave the bridge in the bad weather, make navigation speed limit in bridge waters, regular broadcast navigation information in bridge waters, set electronic screen to remind (Chen, 2010, p.29).

(5) Beacon management and channel mapping departments

Beacon management department is the supervision and administration department of beacon industry, strengthening the beacon monitoring, repairing in time if it is abnormal, and ensuring the normal working state of beacon. The channel mapping departments are the competent department to provide hydrographic data, such as the channel depth changes in bridge water, then the channel mapping departments shall provide the related information and data in time.

(6) Channel management department

Channel management department is the maintenance department of fairway, Its main safety management methods include: to enhance the channel and channel facilities construction, management and maintenance, to ensure the channel facilities in good technical status, to guarantee the bridge channel to satisfy the navigation condition.

(7) Water affairs and ocean, meteorological departments

Water affairs and ocean departments are the management department of water resources monitoring and the Yangtze river channel sand mining; the meteorological department is a technology department of issuing weather forecast and sea condition. The main safety management methods include: supervise and manage sand mining and waste dumping in bridge zone and the surrounding waters; issue the accurate meteorological and sea condition information timely, and provide meteorological services for bridge zone safe navigation.

(8) Fishery department

Fishery department is the fishery industry management department, whose main intervention methods include: supervise and manage the fishing work in bridge navigable waters, delimit fishing work zones, avoid fishing work impeding the bridge zone navigable waters sailing safety.

(9) Ship inspection department

Ship inspection department is the ship legal checking agency, whose main intervention method is in control of ships, which means through the implement legal inspection, to ensure that the ship conforms to the standard of international conventions and domestic laws and regulations, as well as the ship and the equipments keep good technical status.

(10) Ship company (owners, operators, managers)

Ship company is the main body of the ship safety operation, whose main safety management methods include: to ensure the crew competency, to equip the ship with enough competency crew, and carry out the crew training, etc.; to ensure the ship seaworthy, ship maintenance, keep good technical condition, etc.; to strengthen the ship company personnel quality training, and do a good job of management according to the requirements of safety management system.

(11) Crew training institutions

Crew training institutions are the education institutions responsible for the crew knowledge, safety consciousness, skill improvement, whose main safety management methods include: crew training and knowledge update, improve the safety knowledge, safety skills and safety consciousness.

(12) Pilot institution

Pilot institution is the legal person to provide professional pilotage service, whose main safety management methods include: through training to improve pilot safety knowledge, safety skills and safety awareness; ensure the pilot abide by inland relevant laws and regulations, and lead ship into and out of the port safely.

(13) Water aid agency

Water aid agency is the rescue department for water people lives and property, such as Shanghai Salvage Bureau, whose main safety management methods are for disaster response in time, rescue, salvage shipwrecks, remove oil spill, restore navigation quickly and so on.

(14) Financial insurance institutions

Financial institutions provide financing services for shipping units and shipowners, and provide insurance for the ship, the crew and bridge, in a certain extent to impact the safety management of the shipping company and bridge owner, such as strictly control the insurance assessment audit process.

(15) The news media and the masses

The news media and the masses are the propaganda and supervision department, whose main safety management methods include: widely publicize the ship-bridge collision risk, reports the ship-bridge collision accident and danger to raise the safety consciousness and quality of the general public; the news media and masses through inform the water illegal behavior to supervise related units or individuals in the ship-bridge collision risk.

CHAPTER 6 SHIP-BRIDGE COLLISION CASE ANALYSIS

6.1 Brief Introduction to the Accident

In March 27, 2008, the ship "Qinfeng128", belonging to Taizhou luqiao Qinfeng shipping limited company (gross tonnage 7122; net tonnage 3988; dead weight tonnage 10452; the ship length 134 meters; breadth 19 meters; depth 9.2 meters; the host power 2500 kw), was left Zhenhai for Tianjin, when the ship sailed to the Huibieyang waters (30 ° 03 '. 5 N, 121 ° 47 '. 2 E), about 0015, ship fore mast and bridge impacted the box girder of Jintang bridge E19 and E20 pile. It caused about 60 meters 3000 tons reinforced concrete box girder fell off and pressed the "Qinfeng128" deck and bridge parts, the bridge pier damaged, and the ship fore mast collapsed fracture, bridge severe deformation and radar mast collapsed. A total of 20 crew members was on the ship and 16 people was rescued, 4 people died (the captain, chief officer, second officer, and a sailor on duty).

6.2 Accident Reason Analysis

6.2.1 Designed Wrong Plan Route

The ship “Qinfeng128” used the unmodified nautical chart, which is the important reason causing the wrong plan routes design. According to the survey, the bridge main navigable hole and related navigation mark was put into formal use in February 1, 2007, but the ship used the 2005 version navigational charts and did not make corresponding revision. The ship’s planning route deviated the main navigation hole nearly a mile. “Qinfeng128” ship fore mast height 24.4 meters, minus the forward draft 2.4 meters. In fact the fore mast about 22 meters above the water, and the bridge compass deck height 21.8 meters, minus aft draft 5.2 meters, about 16.6 m above the water. Meanwhile, the height of bridge box girder minus the tide height 2.92 meters, the actual height less than 15.1 meters only, so the ship was apparently unable to properly through. (See the Figure.4 and Figure.5).

Figure.4 - “Qinfeng 128” Impacted the Jintang Bridge

Source: Retrieved 10 June 2016 from the World Wide Web:

http://news.sina.com.cn/c/2008-03-28/012715240206.shtml

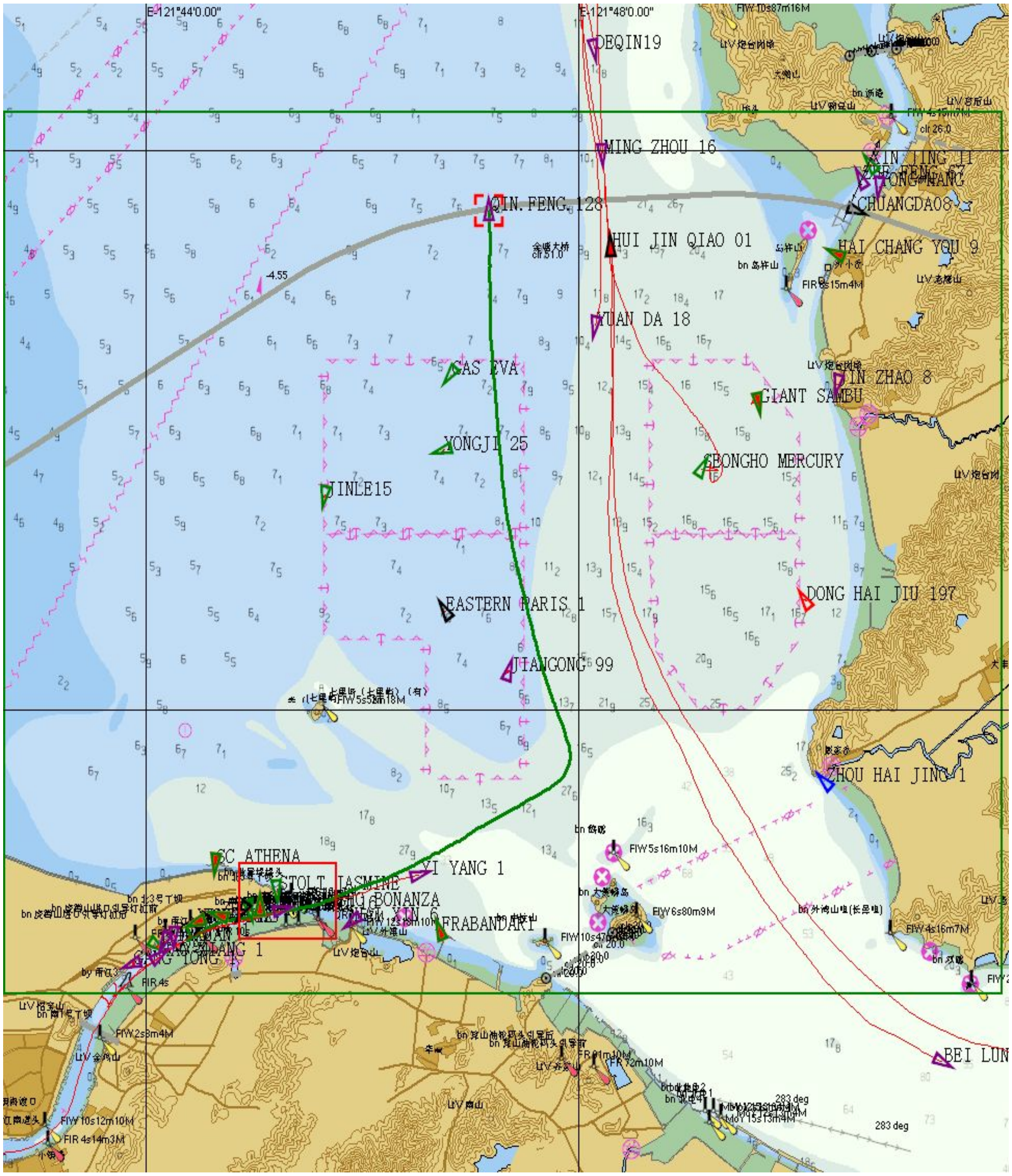

Figure.5 - The Impact Schematic of "QinFeng" Ship

Source: Retrieved 10 June 2016 from the World Wide Web:

http://wenku.baidu.com/view/416c40f37c1cfad6195fa78f.html

6.2.2 Lack Of Safety Awareness and Poor Sailing Quality

Before accident, the duty officer thought the ship could safely pass the bridge, so did not take any action to avoid collision, and had serious lookout negligence. There was not strong winds and heavy fog when the accident happened, the visibility was good and did not affect identifying the beacon light. If the officer of "Qinfeng128" strengthened bridge lookout, observed the radar echo and the navigation mark and identified the target property in time, and controlled sailing speed early, the accident could be avoided (Wang, 2009, pp.76-77).

6.2.3 Anti-collision Management Fall Behind

Although the main navigable hole of Zhoushan Jintang bridge opened in February 1, 2007, the phenomenon that ships wandered across the ban navigable holes still existed. It also suggest that the ship navigation warning system of bridge water and the avoidance collision measures of ban navigation hole were not enough in place. If it informed the "Qinfeng128" early while it had diverged from the main channel, or if set anti-collision devices nearby the ban navigation hole, maybe the accident could be avoided, or the loss reduced.

CHAPTER 7 CONCLUSION

The ship impact on the bridge often causes disastrous consequences: casualties, property loss, environment damage and so on. To eliminate and reduce the accident is the goal and wish of all countries. The study of ship-bridge collision problems will spread to multiple disciplines. The researchers have done a lot of related work all over the world. This paper combines the scholar's research and the actual situation of Shanghai port waters, discusses the ship-bridge collision risk assessment and the calculation of ship-bridge collision probability formula, and later puts forward some bridge safety management countermeasures in Shanghai port waters in my personal views. And through the case analysis to clarify the necessity of bridge safety management. This paper involves the main works as follows:

(1) Briefly introducing the background of ship-bridge collision research, presenting the accidents mainly caused by human error, summarizing the research history and current situation to the ship-bridge collision.

(2) Focused on the general information of Shanghai port bridges, and presenting some problems and difficulties of bridge safety management in Shanghai port waters.

(3) Presenting the content and process of the ship-bridge collision risk management.

(4) Risk assessment is the key step of risk management. Through reading a lot of literatures, summing up three research methods which are widely used in the ship-bridge collision risk management: the Fault Tree Analysis method, the Fuzzy Comprehensive Evaluation method and the Probabilistic Risk Assessment method. Through analyzing and comparing the three kinds of ship-bridge risk assessment methods, and proposing that considered the probability risk assessment method as the main research method of the ship-bridge collision risk assessment.

(5) In view of the bridge safety management problems and difficulties in Shanghai port, from the perspective of human factors (that is management), put forward some bridges safety management countermeasures.

(6) Throughout the full paper, the main solved problem is the risk assessment methods of ship-bridge collision and bridge safety management countermeasures, and combined with the relevant case to deepen understanding.

Due to my shallow knowledge and the limited task time, the work of this paper is hard to avoid being superficial. There are many works for further study, such as constantly enriching the information database of our country ships and shipping; further developing and researching more effective and economic bridge anti-collision facilities; considering the bridge anti-collision as the part of bridge design, and establishing the corresponding design specification in China, promoting the development of our transportation.

REDFERENCE:

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