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Risk assessment of water area in the Shanghai Port

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RISK ASSESSMENT OF WATER AREA IN THE SHANGHAI PORT

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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ABSTRACT

The Shanghai Port remains the champion of port container throughput in the world for 5 years. In the development of the Shanghai port and shipping industry, Shanghai has become a world-class shipping port from a small fishing village. Due to its special geographical location, a large number of goods have been transported to the other countries and inland provinces and cities along the Yangtze River. While economy and trade are increasing every day, the safety of the Shanghai Port have attracts attention and becomes the major problem. The development of shipping industry is protected by IMO that pays attention to the lives and properties and prevention of environmental pollution

According to the statistics, the safety of water area in the Shanghai Port gets the high attention from Shanghai MSA. However the number of traffic accidents does not decrease though law enforcement force has increased by Shanghai MSA. Various factors will affect the safety of water area in Shanghai Port, including human factors, vessel factors, environment factors, management factors and so on. Crew members may be nervous when they face to urgent or dangerous situation due to the lack of experience and the problem of vessel which will lead to out of control, grounding and collision accidents. Meanwhile, typhoon and visibility will influence the safety of water area in the Shanghai Port. The delay of plan, lack of technology of pilotage and interference of engineering vessels and fishing vessels are all the risky factors to the water area in Shanghai. Therefore, due to these various factors, the comprehensive evaluation mode should be used in estimating the safety of water area in the Shanghai Port.

Fuzzy mathematics has affected many fields since its emergence and development. Meanwhile these fields have developed so well due to the role of fuzzy mathematics which aims at the study of inaccurate things. The position of water area has not changed, but the different vessels which are piloted by different crews or pilots and different environment will produce different effects. In this study, a new risk evaluation of different water area in the Shanghai Port has been done according to the actual situation of Shanghai Port.

Because the mode of fuzzy mathematics is a kind of dynamic model on the risk assessment of water area in the Shanghai Port according to the analysis of five types of factors, it is important to clear all the factors and make sure the degree of importance of each factor. And then establishing the subset by these factors and considering the degree of each factor. Due to the fuzzy factors influence and different fuzzy degree of factors of water area in Shanghai Port, fuzzy mathematics theory has been used to describe and analyze. In the result, a comprehensive evaluation mode on the risk assessment of water area in the Shanghai Port has been established. The fuzzy evaluation method has been used in the evaluation system by consideration of various factors. In order to check the feasibility and reliability of mode, the actual example will be used for verification.

KEYWORDS: Shanghai Port, risk assessment, Degree of Membership，

comprehensive evaluation model

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LIST OF ABBREVIATIONS

Shanghai MSA	Shanghai Maritime Safety Administration
IMO	International Maritime Administration
FSEM	Fuzzy Synthetic Evaluation Model
AHP	Analytic Hierarchy Process
FSA	Formal Safety Assessment
FCEM	Fuzzy Comprehensive Evaluation Method
IMDG Code	International Maritime Dangerous Goods Code

CHAPTER 1

INTRODUCTION

1.1 Background

The Shanghai Port is located in the middle of coastline with a total length of 18,000 kilometers. And it is located in the delta of the corner and Huangpu River which is like the crawl track of snake crossing the entire hinterland which separates Shanghai into two blocks, Pudong and Puxi. After the reform and opening policy in 1990, a large number of funds have been invested in economic development and construction of the Shanghai Port. In 2010, Shanghai Port overtook the Singapore Port to become the world's busiest container port and its container throughput is up to the 3500~3530(10 thousand TEU) million in 2014 and the rate of growth is 4.3~5.2which keeps the champion for four years since 2010 in the world(Center for Forecasting Science [CEFS], Chinese Academy of Sciences, 2014).Today there is still about 90 per cent of the global trade transported by vessels and just as what the introduction of International Maritime Organization has noted, "shipping is the most efficient and cost-effective method of international transportation for most goods(International Maritime Organization[IMO],2015)". Due to the geographical advantage, large numbers of cargos in the Shanghai Port have been transported to the inland waters and other nations every day.

Meanwhile, the Shanghai Municipal Government does not only pay attention to the economic development but also focuses on the cultural construction. The Shanghai Port does not only provide service for the cargo ships, it still provides service for the tourism. Two major cruise terminals, Shanghai International Cruise Terminal and

Wusongkou Cruise International Terminal, serve for the international and national cruises every week. Besides due to the extremly high density of traffic flow of the Shanghai Port, it is an accident-prone area, particularly in the bad weather. In order to increase the navigational safety and protect the environment, Shanghai Maritime Safety Administration (Shanghai MSA) legislates "Yangtze River Estuary (12.5meters) Deepwater Channel Navigation Safety Management Measure (In Temporary)" which has been adopted in 2010. However, as we all know, any conventions cannot prevent all accidents and a number of accidents still have occurred each year. The most famous accident in the history was Titanic disaster which caused a large number of casualties and injuries. Due to this unparallel maritime disaster, in 1914, the first International Convention for the Safety of Life at Sea was adopted by International Maritime Organization (IMO) who is to create a regulatory framework for a special industry. In order to get the risk assessment of water area in the Shanghai Port, in this study, the Fuzzy Synthetic Evaluation Model (FSEM) and Analytic Hierarchy Process (AHP) have been used. In addition, various reasons which have impacted the safety of the Shanghai Port have been considered and used as an assessment factor.

1.2 The Purpose and Scope of the Study

The rapid development of the global economy does not depend on living without shipping trade. The covered water areas of the Shanghai Port are so large and the situation of water fairway or channel are so complex that it is difficult to define whether it is safe or not. In order to estimate and analyze the situation of water area in the Shanghai Port, it is necessary and required to divide the water areas into several blocks, namely North Passage, South Passage, Waigaoqiao Channel, Baoshan Channel, Baoshan South Channel and Baoshan North Channel and several Precautionary Areas. It is easily understood in terms of the dangerous situation of water areas by risk assessment.

However there are so many factors, vessel factors, human factors, environment factors, management factors and other relevant factors which will affect the safety of water area in the Shanghai Port. Any factor, even a slight one, just like the Butterfly Effect, may lead to a huge impact on the safety of water area. In fact, these different factors are interrelated and mutually restrictive. Vessel factors, such as ship stability, deviation angle combined with the ship heading and channel course, ship speed and the type of the cargo will affect the safety of vessel. But vessel which is just a means of vehicles are operated by crew and it reaches the destination successfully in the operation of the crew who have enough knowledge and working experience, good mentality and a clear judgment.

However, they are not isolated from the channel during the operation and they are always affected by external factors. Crew should make a reasonable judgment when they meet risk situations. It includes two aspects of external factors, water area environment and hydrometeorological environment. Vessel Traffic flow, engineering vessels, fishing boats will affect the safety of channel in the Shanghai Port. Meanwhile, tide, wind and visibility which is defined as hydrological and meteorological conditions that will have a huge impact on the safety of channel.

The last part is management factors which includes Shanghai Wusong VTS service, escorting service from patrol boats of Shanghai MSA. Obviously, the technology of Shanghai Pilot should be considered when we estimate the safety of channel.

In order to avoid randomness, it is necessary to do a comprehensive examination and risk assessment of the entire water area in the Shanghai Port in terms of a combination of qualitative and quantitative method on vessel factors, human factors, environment factors and management factors. An evaluation system should be established by considering various factors with fuzzy comprehensive evaluation of mathematical methods. Different evaluations indexes of degree of membership are calculated by establishment of fuzzy subset table of degree of membership. Each index of the importance on safety of water area is received by expert questionnaires with AHP method. The ultimate goal is to establish a Fuzzy Evaluation Model on risk assessment of water area in Shanghai Port

This model has a certain practicality and operability and it provides a comprehensive evaluation method for Shanghai Wusong VTS on channel safety in monitoring area. This study is also verified by the actual situation in Shanghai Port and some conclusion are drawn which is both valuable and of practical significance. Meanwhile, this research can obtain a positive role in the prevention of maritime accidents and can be used for Shanghai MSA in administration on safety of channel.

1.3 The Methodology of the Study

Formal Safety Assessment (FSA) is a rational and systematic process for assessing the risks related to maritime safety and protection of the marine environment, life, health and property by using risk assessment and analysis. According to the steps of FSA:

1 identification of hazards;

2 risk analysis;

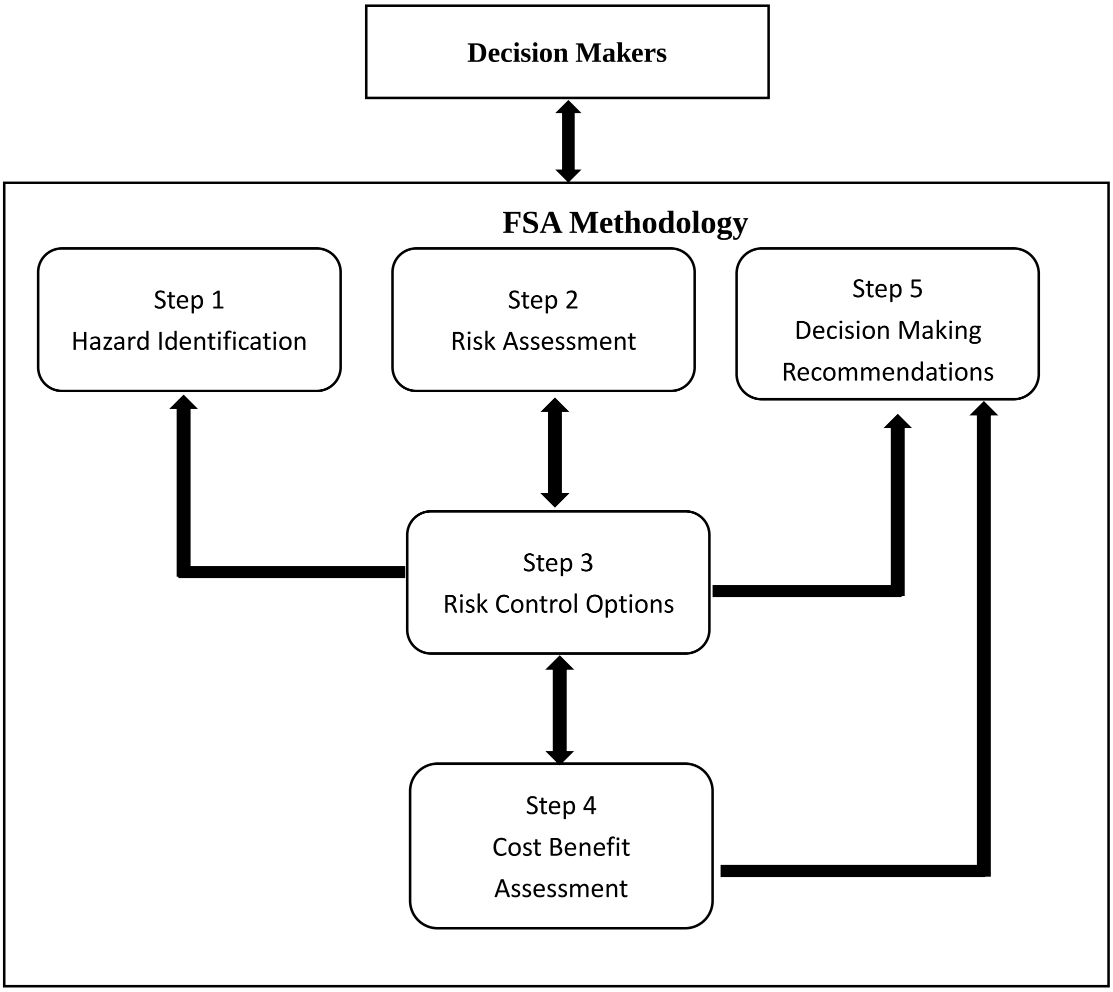
3 risk control options;

4 cost benefit assessment; and

5 recommendations for decision-making (IMO, 2002a).

According to Figure 1, finding out all the potential or feasible hazards which will affect the safety of subject and then assess all the risks which have been found in the first step and consider the probability and frequency of them. Meanwhile, the high risk area should be found when we assume the scope and extent of the risk. In step 3, suggestion and measures should be proposed. Assessment of cost has been cost in step 3 and the benefits will be decreased of the risk. Finally, a scheme of risk control should be proposed. However, this method cannot reflect to the actual status accurately and it has more limitations. It ignores many fuzzy factors which cannot be described with accurate mathematics. And it is difficult to estimate the result accurately when various factors are combined with each other.

Figure 1-Flow chart of the FSA Methodology



(Source: IMO, 2002b)

In order to attempt to solve complex problems of decision making problems where the problem of ambiguity and lack of information are combined, AHP method including presentation of scaling method for priorities (Saaty, 1977, pp.234-281) is formulated by Saaty(Sipahi &Timor, 2010, pp. 775-808). Although in the article written by Daniel

Podgórski, he reviews that the AHP method is one of the most popular and most widely used in practice(Podgorski,2015,pp.146-166), however, sometimes it is better to accept the combined way to study and then find out the measure to solve the problem. The Shanghai Port is combined with a lot of uncertain factors which will affect the safety of water area. In order to do the assessment of this water area, potential or feasible hazardous factors should be identified and analysis should be made. Sometimes these hazardous factors can easily be found. However its degree is difficult to define. The reason is that until now there was no specific standard to measure. But in this study, in order to solve this problem, fuzzy theory has been used. In 1965, Fuzzy sets were introduced by Lotfi A. Zadehand and Dieter Klaua which can be used the information is incomplete or imprecise ("Fuzzy Set", 2015). In the recent years, fuzzy comprehensive evaluation method can avoid the result of the qualitative analysis or quantitative analysis solely.

In order to assess the risk of water area in Shanghai Port in this study, APH method of it questionnaire is used to define the weight of main factors. The total number of questionnaires(Appendix: Questionnaire) is 300 and a total of 264 questionnaires were received, 68 from VTS officers, 73 from Shanghai pilots, 40 from shipping company officers and 83 from crews voyaging in Shanghai Port. From the questionnaire, according to Figure 2, it shows the human factor is the most important factor among these four factors, namely human factor, vessel factor, environment factor, management factor and other factors. However, it is difficult to define the degree of sub-factor. So that it is necessary to use fuzzy theory to define the degree of membership on 23 sub-factors. And water area will be divided into several blocks according to the channel. All the main factors and sub-factors will evaluate all blocks and HTA-ES500ECDIS which is researched by DMU is used in this paper.

1.4 Current Study of Shanghai Port

Although many studies have been done on Shanghai Port in the risk assessment of North Passage and River Bed in the Yangtze Estuary. And many pieces of advice have been proposed in the past few decades, yet few studies are particularly to estimate the water area in the Shanghai port, because the channel and involved factors are so complex, and some factors are likely to be neglected. In order to improve the safety of water area in Shanghai Port, it is necessary to do the risk assessment of water area in Shanghai Port according to the real situation.

CHAPTER 2

BLOCK DIVISION OF SAHNGHAI PORT

2.1 The Reason for Block Division

Due to the geography of Shanghai Port, it is an interaction area of two rivers, the Yangtze River and the Huangpu River. From the ECDIS, it is obvious that the North Passage and the South Passage interact with each other in the Yuanyuansha Precautionary Area and they are mixed with the Huangpu River in the Wusong Precautionary Area (Navigation Environment in the Shanghai Port, n .d.). According to the precautionary area, the main channel of Shanghai Section of the Yangtze River is divided into six parts. Meanwhile, auxiliary channel of Shanghai Section of the Yangtze River is divided into three parts.

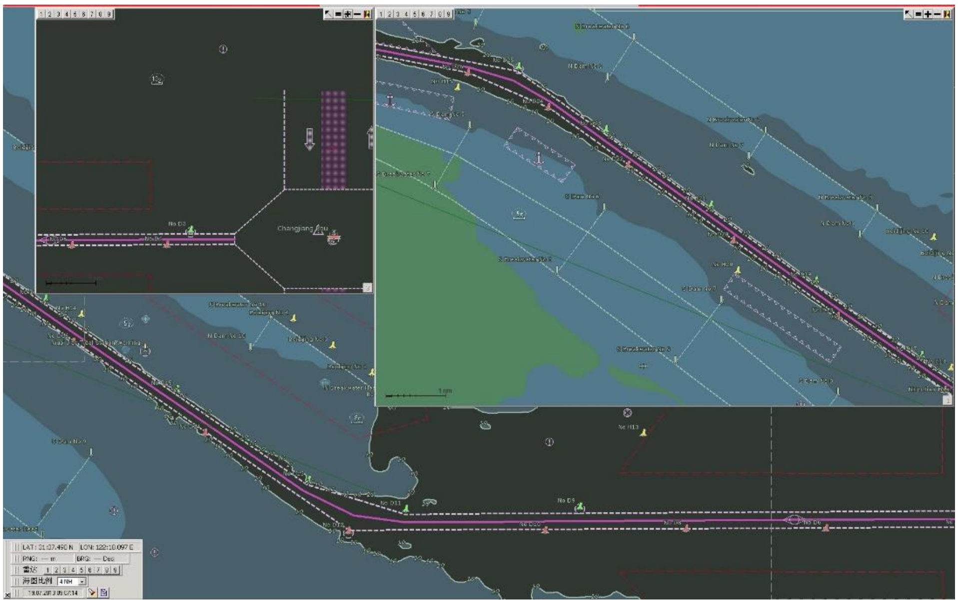
2.2 Main Channel of Shanghai Section of the Yangtze River

2.2.1 The Deep Water Channel of 12.5m in North Passage

According to Figure 2 and Figure 3, the total length of the Yangtze Estuary Deepwater Channel which is from Yangtze Estuary light vessel to Yuanyuansha light vessel is about 43n miles. This channel connects each dock along deep water channel and it connects the intersection of the Huangpu River as well. The width of channel bottom is 350 meters and the width of channel surface is 500 meters from light buoy No.D12 to No.D47 whose total length is 39.66n miles. Meanwhile, from light buoy No.D6 to No.D12, the width of channel bottom is 400 meters and set standard is 550 meters (Yangtze River Estuary (12.5meters) Deepwater Channel Navigation Safety

Management Measure (In Temporary), 2010). At present, the water depth of the North Passage is 12.5 meters. Thought sometimes it will be seriously affected by sediment and tide.

Figure 2-VTS Record of the North Passage of buoy light of D3 to D26

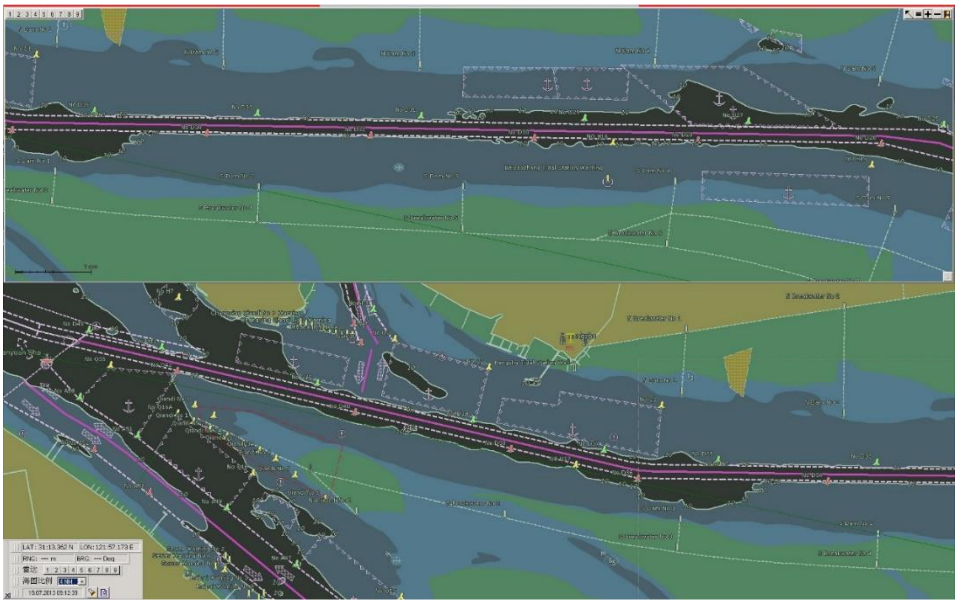


(Source: Shanghai MSA, July 2013a)

2.2.2 The Waigaoqiao Channel

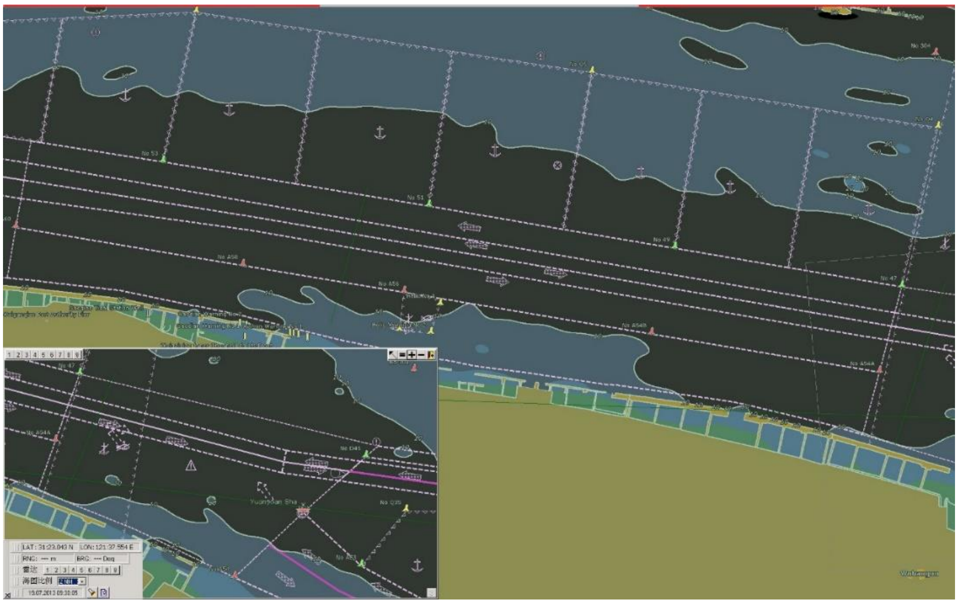
According to Figure 4, this channel whose total length is 10.4n miles is from Yuanyuansha light vessel to Wusong light vessel. The width of this channel available to the big size ship is 0.5n miles and the water depth is 12.5 meters. And in the north of the Waigaoqiao Channel, there are about eleven anchorage areas, namely No.1 Anchorage to No.11 Anchorage. Due to the water depth, the No.11 Anchorage is invalid. These ten anchorage areas are provided for the vessel which berth at Shanghai Port firstly and provided to all the vessels in emergency or in disastrous weather condition.

Figure 3-VTS Record of the North Passage of buoy light of D26 to D45



(Source: Shanghai MSA, July 2013b)

Figure4-VTS Record of the Waigaoqiao Channel



(Source: Shanghai MSA, July 2013c)

2.2.3 The Baoshan Channel

According to Figure 5, the total length of the Baoshan Channel is about 6.7n.miles which is from light buoy No.66 to light buoy No.74. The width of channel is around 0.5n.miles and the depth of water is 12.5 meter.

Figure 5-VTS Record of the Baoshan Channel

(Source: Shanghai MSA, July 2013d)

2.2.4 The Baoshan North Channel

According to the upper part of Figure 5, the Baoshan North Channel whose total length is 5.5 n miles, width is from 0.27to 0.5n.miles and depth is from 13 to 22 meters is from buoy light No.74 to the Baoshan buoy light. And there are four safe water signals, and the boat draft over 8 meters should be allowed to pass in the Baoshan North Channel.

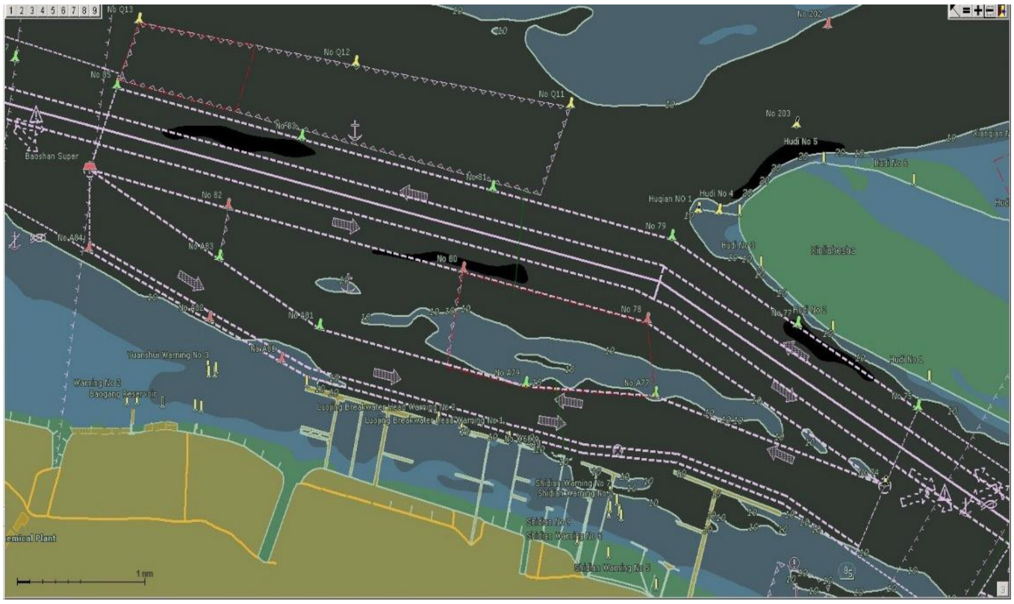
2.2.5 The Baoshan South Channel

According to the lower part of Figure 5, the total length and width of the Baoshan South Channel is about 6n.miles and around from 0.24 to 0.5n miles. The depth is over 10 meters except the area from buoy light A83 to A87 where depth is about 8 meters to 10 meters. This channel is used for the vessels which berth in the Luojing wharf, the Shanghai Baosteel wharf and the other coastal wharves

2.2.6 The Precautionary Area

There are four precautionary areas in Shanghai Section of the Yangtze River, namely the Yuanyuansha Precautionary Area, the Wusong Precautionary Area (Figure 6), the Baoshan Precautionary Area and the Liuhekou Precautionary Area respectively. These four precautionary areas are high-risk area due to the intersection of the several channels.

Figure 6-VTS Record of the Baoshan North Channel and the Baoshan South Channel



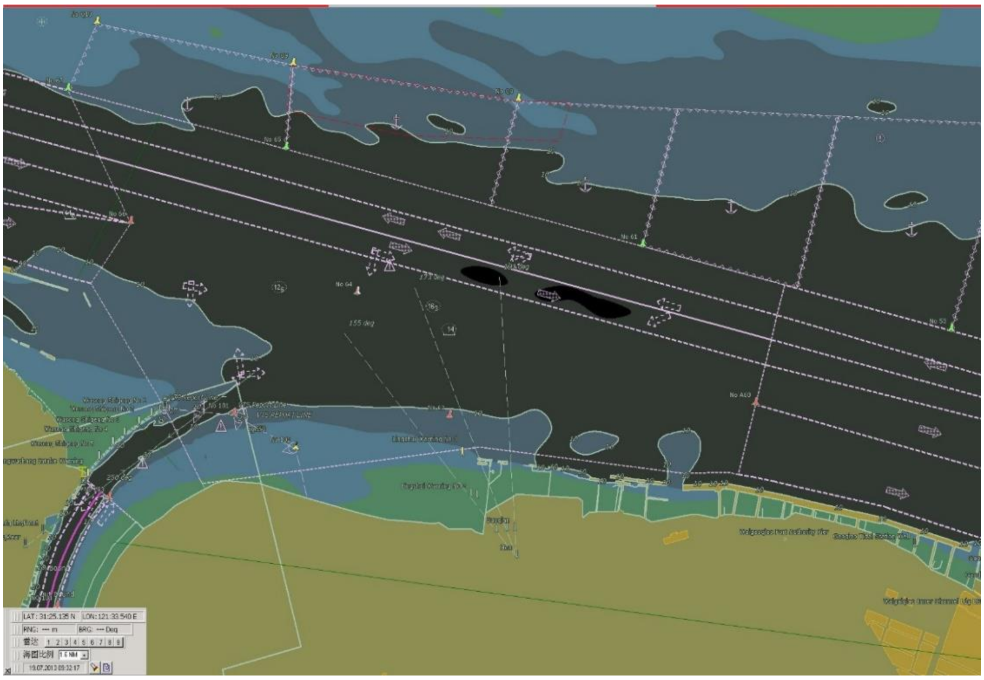
(Source: Shanghai MSA, July 2013e)

2.3 Auxiliary Channel of Shanghai Section of Yangtze River

2.3.1 Downstream Section of South Passage

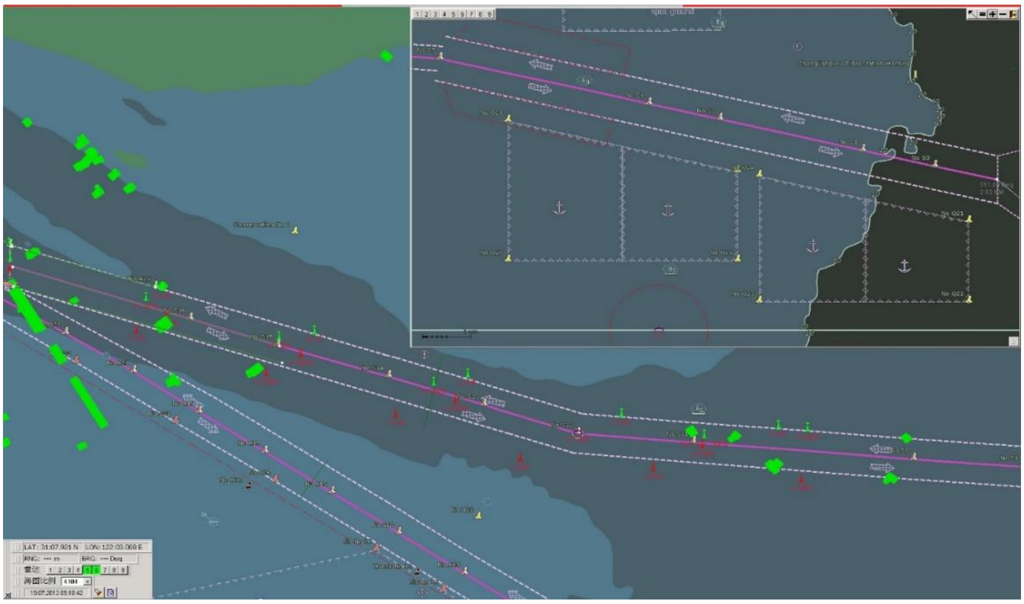
According to Figure 7, total length of downstream section of South Passage from South Passage light vessel to Jiuduansha light vessel is about 29.7n miles.

Figure 7-VTS Record of the Wusongkou Precautionary Area



(Source: Shanghai MSA, July 2013f)

Figure 8-VTS Record of Partial of the South Passage from Buoy Light S0 to Jiuduansha Vessel Light



(Source: Shanghai MSA, July 2013g)

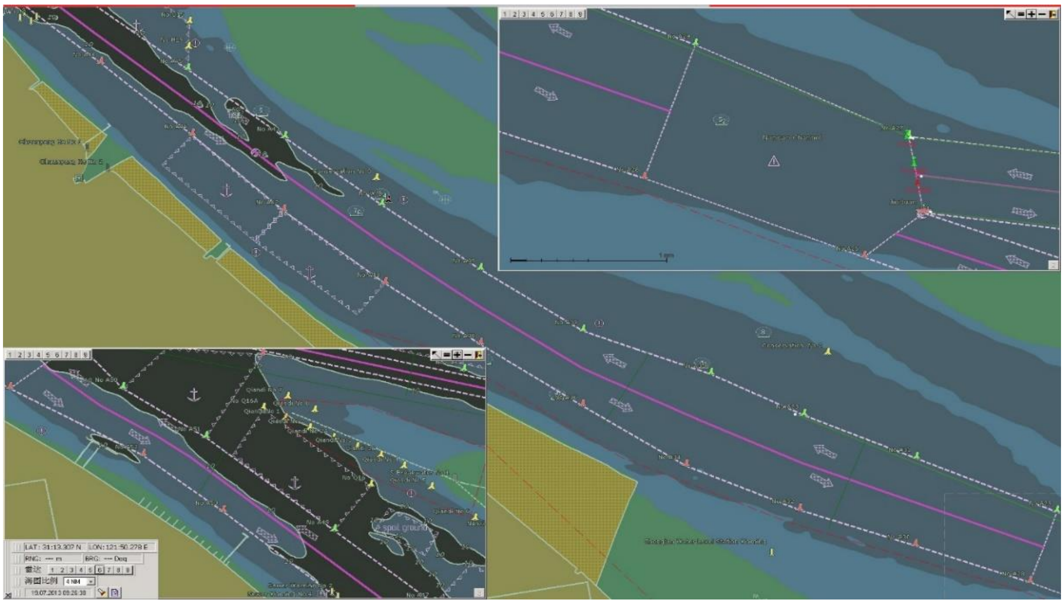
2.3.2 Upstream Section of the South Passage

According to Figure 8, the total length and width of upstream section of South Passage from Jiuduan light vessel to Yuanyuansha light vessel is around 17n miles and from 0.5 to 1.25n miles.

2.3.3 The Jiuduansha Precautionary Area

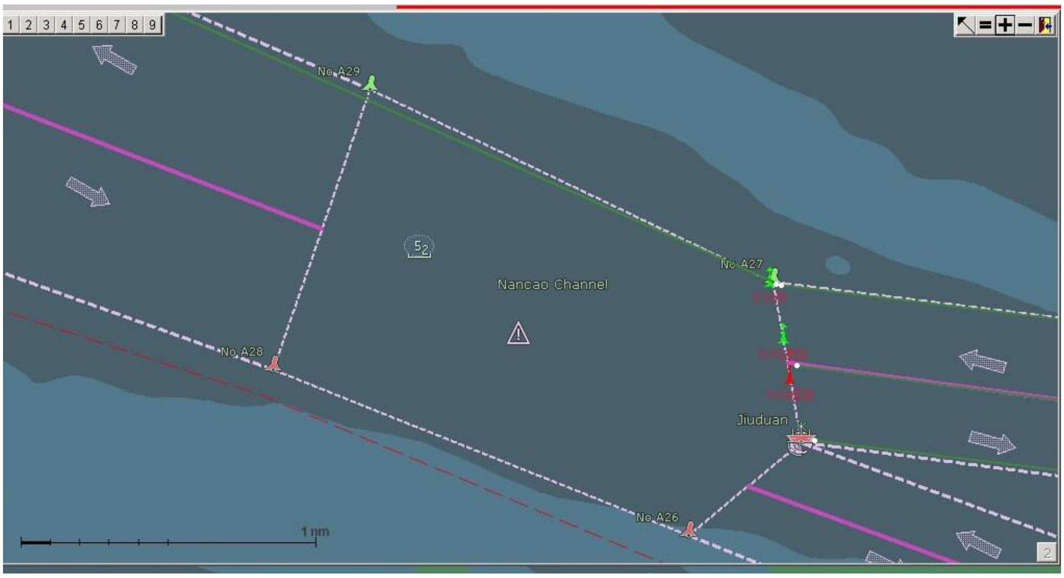
According to Figure 9, the Jiuduansha Precautionary Area is the intersection area of Downstream Section of South Passage, Upstream Section of South Passage and Branch of South Passage.

Figure 9-VTS Record of Upstream Section of South Passage



(Source: Shanghai MSA, July 2013h)

Figure 10-VTS Record of the Jiuduansha Precautionary Area

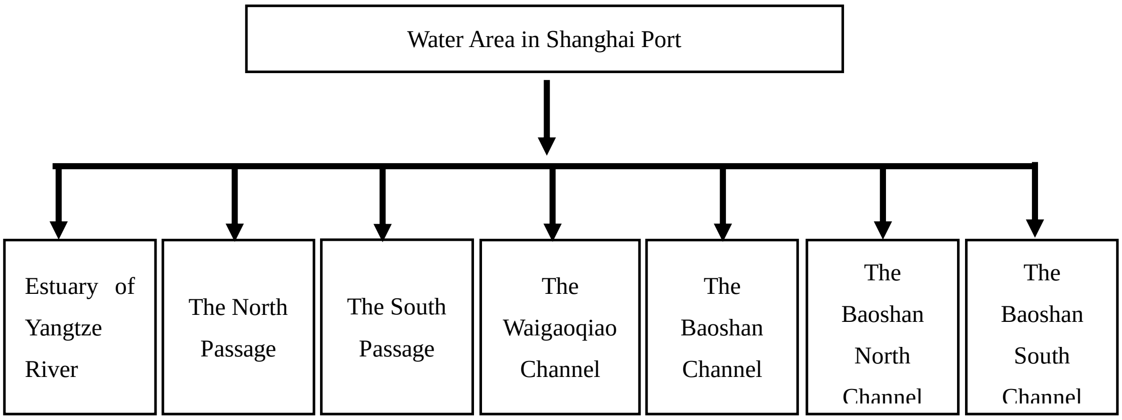


(Source: Shanghai MSA, July 2013i)

2.3.4 Analysis of Channel in the Shanghai Port

In order to do the risk assessment of the Shanghai Port, according to Figure 10, Water area of the Shanghai Port should be divided into several parts due to the length of channel and their different characteristic.

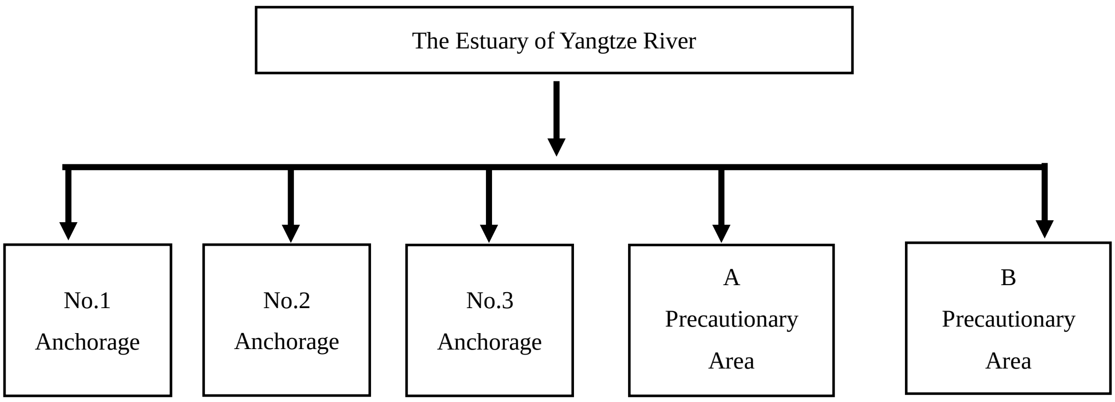
Figure 11-Water Area in Shanghai Port



(Source: Completed by the author)

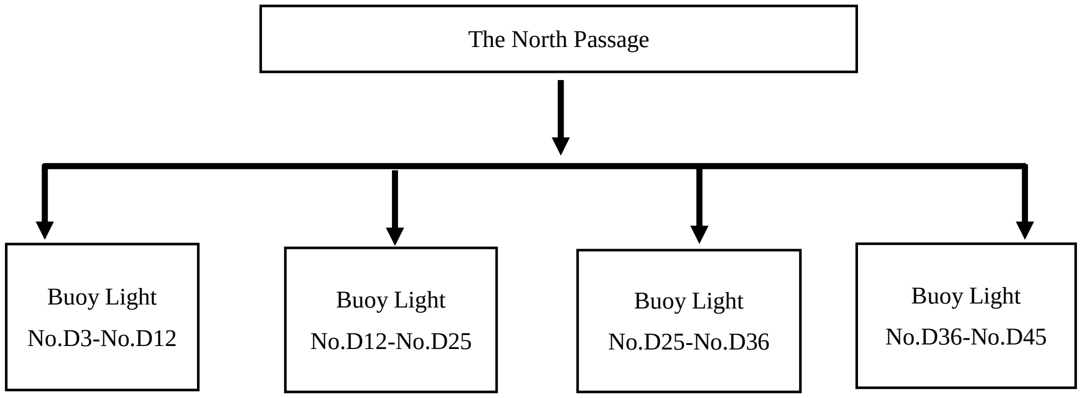
In order to reflect water safety of the Shanghai Port, the Precautionary Area will be assigned into different channel according to their position. In this study, it will be represent by Figure 11, Figure12, Figure 13, Figure 14, Figure 15 and Figure 16.

Figure 12-The Estuary of Yangtze River



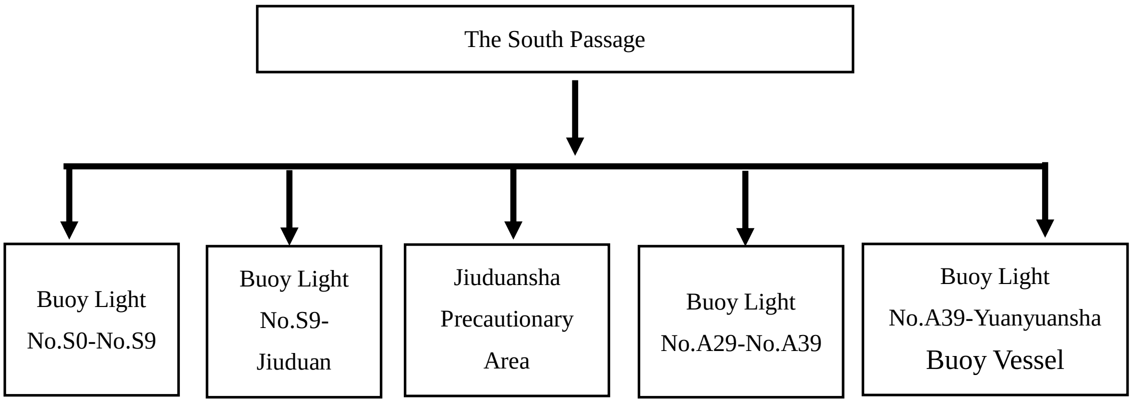
(Source: Completed by the author)

Figure 13- The North Passage



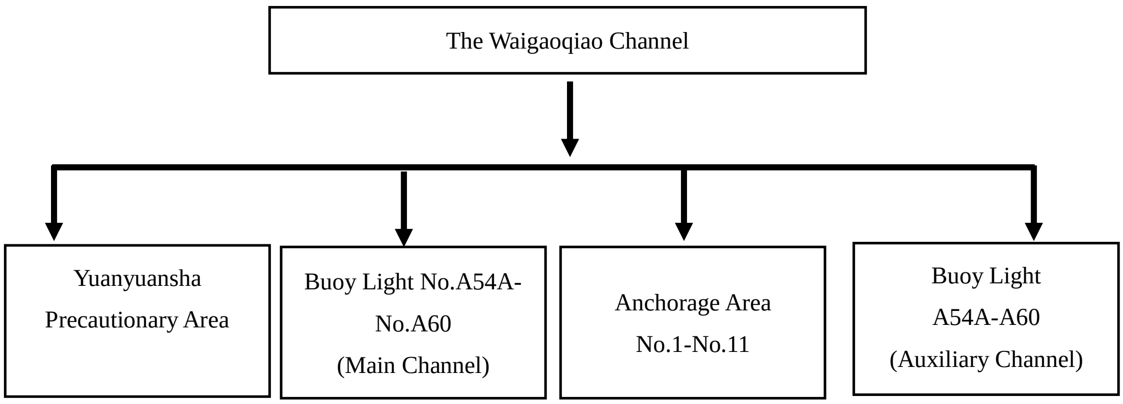
(Source: Completed by the author)

Figure 14-The South Passage



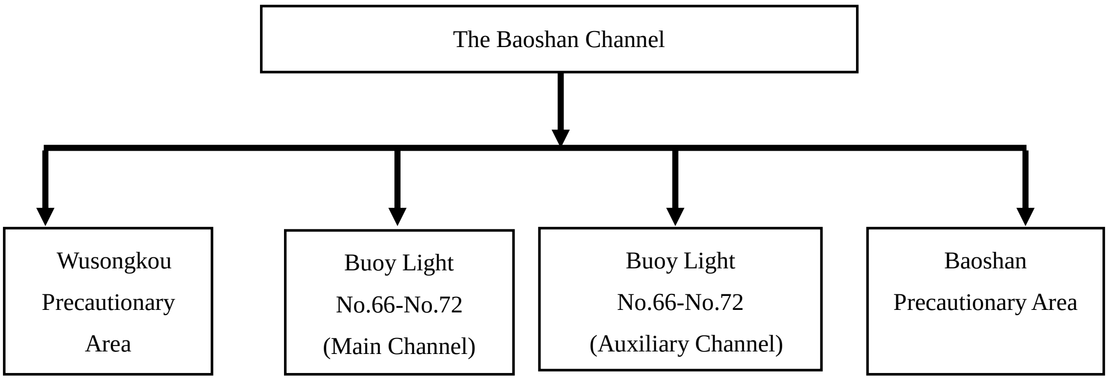
(Source: Completed by the author)

Figure 15-The Waigaoqiao Channel



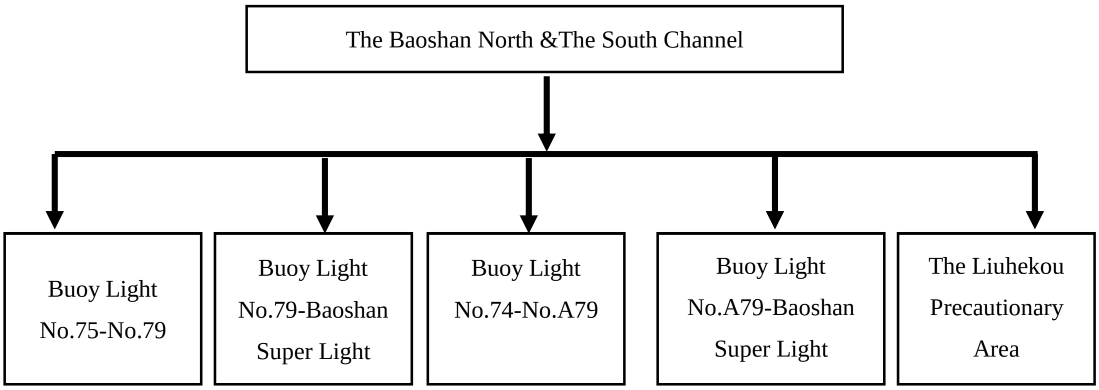
(Source: Completed by the author)

Figure 16-The Baoshan Channel



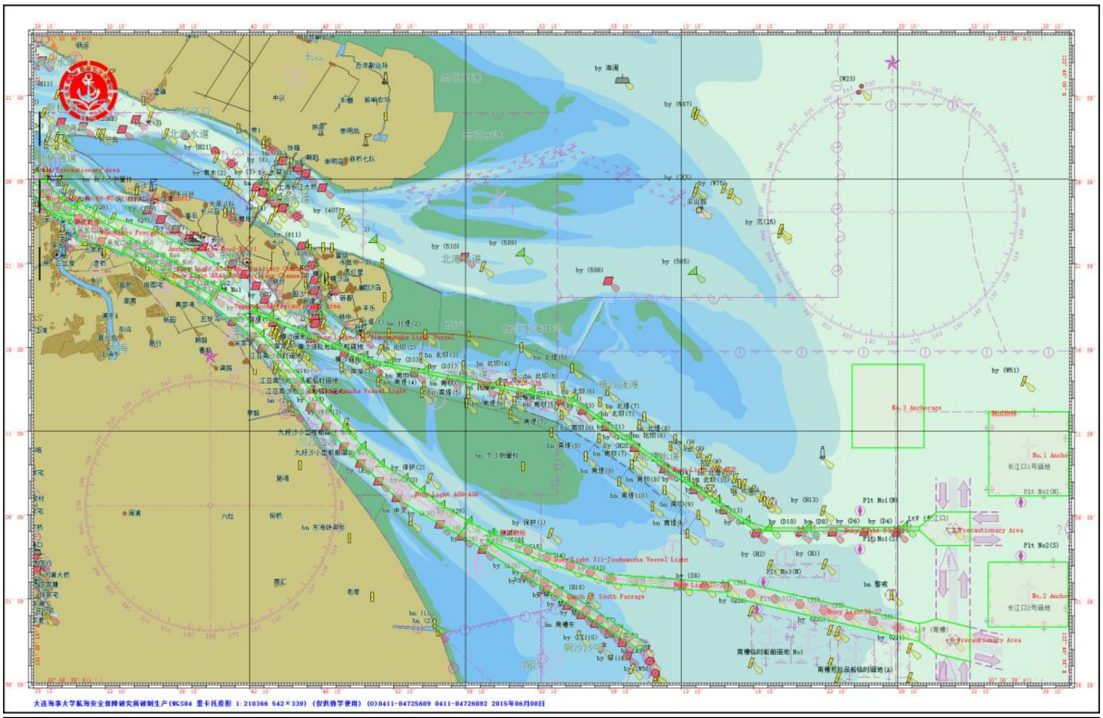
(Source: Completed by the author)

Figure 17-The Baoshan North Channel and the Baoshan South Channel



(Source: Completed by the author)

Figure 18-Water Area of Shanghai Port



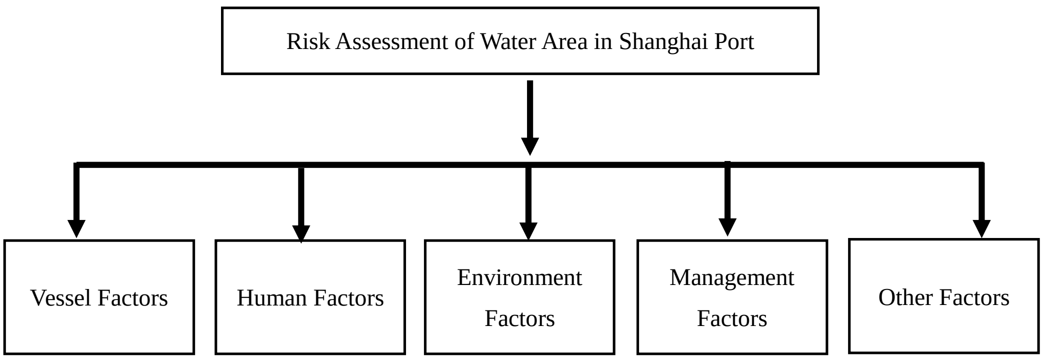
(Source: MSA China and Modified by author, 2015a)

CHAPTER 3

ANALLYSIS OF RISK FACTORS INFLUENCING SAFETY OF SHANGHAI PORT

Due to the geographical position of the Shanghai Port, many different factors which will affect the safety of water area must be considered. According to Figure 17， in order to evaluate the safety of the Shanghai Port, environment factors, vessel factors, human factors, management factors and other factors should be considered. During the assessment, many factors should be considered and it is necessary to classify different factors into different types and similar factors are collected into the same type and each evaluation is done in the same type. From the five factors, every factor is combined with four sub-factors and finally these 23 factors, according to Figure 18, should be used to estimate the risk of water area in the Shanghai Port.

Figure 19-Factors of Risk Assessment of Water Area in Shanghai Port



(Source: Completed by the author)

3.1 Analysis of Vessel Factors

In the vessel sub-factors, namely ship age, ship position, ship speed, ship type, ship stability and deviation angle of ship heading and ship course, type of vessel and type of cargo respectively, should be considered in the risk assessment of water area in the Shanghai Port.

3.1.1 Analysis of Ship Age

Ship age is an important factor which will affect the safety of vessels. Generally, the number of accidents increases with the increasing ship age, particular in the elder age. According to the criterion for ship age in Old Transport Ship Management Rules, It is well known that every ships has their own using age and these must be a mandatory retirement over her maximum service lives. Under general circumstances, older ship always needs more money on its maintenance. According to the incomplete statistics, the older ships are more prone to have accidents compared to the ship of young age.

Suppose ship age= A, according to the actual situation of Shanghai Port,

The bad ship age is $0 \le A < 5$ years or $15 \le A < 20$years

The good ship age is $5 \le A < 10$years

The normal ship age is $10 \le A < 15$years

The worst ship age is $A \ge 20$

3.1.2 Analysis of Ship Position

Due to the geography of the Shanghai Port and the characteristics of different channels, all the channels in Shanghai Port have been divided into two parts, inbound channel and outbound channel. From experience of the senior pilots who work for the pilotage over 20 years from Shanghai Pilot Station, they conclude that the best ship position is on the second part from middle if the same course channel is divided into three parts, because the depth is good for pilot and there is enough place for emergency in the both sides. The normal position is in the first part from the middle line of channel due to the good depth. The bad position is in the part of boundary side, because the depth is a serious problem and there is no enough place for emergence.

Suppose B=position of ship, the wide of channel is D, the width of inbound or outbound channel is D/2.

From the view of left boundary of channel, the inbound vessel

The normal position of ship in the channel is B=1/2D~2/3D

The best position of ship in the channel is B=2/3D~5/6D

The bad position of ship in the channel is B=2/3D~D.

From the view of left boundary of channel, the outbound vessel

The normal position of ship in the channel is B=1/3D~1/2D

The best position of ship in the channel is B=1/6D~1/3D

The bad position of ship in the channel is B=0~1/6D.

For example, the narrow width of the inbound vessel in the North Passage is 500 meters

The normal position is B=from 250 to 333 meters

The best position is B=from 333 to 416 meters

The bad position is B=from 416 meters to 500 meters.

For example, , the narrow width of the outbound vessel in the North Passage is 500 meters

The normal position is B=from 167 to 250 meters

The best position is B=from 83 to 167 meters

The bad position is B=from 0 to 83 meters.

3.1.3 Analysis of Ship Speed

Usually, there are several kinds of speed, maximum speed, minimum speed, economical speed and full speed. And now super container vessel speed is 25~32 knots and bulk freighter speed is about 12~17 knots and the speed of cargo ship is about 15~17 knots. Usually, vessel prefer using the economical speed due to the lower power consumption and cost of fuel. Vessels can voyage with the maximum speed due to the enough water depth, no shelters and low shipping density. However, when they voyage in the water area of the Shanghai Port, they must comply with the provisions. Besides according to the Convention on the International Regulation for Preventing Collisions at Sea, Rule 6, Safe speed, *Every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions* (Convention on the International Regulation for Preventing Collisions at Sea, 1972). In the North and South Passage, the maximum speed is no more than 15 knots and the minimum speed during the traffic control time is over 10 knots. Generally, the vessels in good condition always keep the speed of over 12 knots in North Passage. According to the Yangtze River Estuary (12.5meters) Deepwater Channel Navigation Safety Management Measure (In Temporary), Article 9, Paragraph 2, VTS offices advices the crew to check the main engine and do the test of steering gear, emergency generators, communication equipment in twelve hours before they voyage in North Passage (Yangtze River Estuary (12.5meters) Deepwater Channel Navigation Safety Management Measure(In Temporary),2010).

Meanwhile, voyaging in the Shanghai Section of Yangtze River including Waigaoqiao channel, Baoshan Channel, Baoshan North Channel, the maximum speed is 12 knots and if the vessel voyage in the good condition, the minimum speed is over 10 knots. If the vessel speed is just half of the specified speed, there may be some problem of the vessels. Suppose S= ship speed / specified speed according to the actual situation of Shanghai Port.

In the North Passage, the maximum speed is 15knots, the minimum speed is 10 knots.

The best speed ratio in Shanghai Port is S=1

The better speed ratio in Shanghai Port is 0.8≤S<1

The normal speed ratio in Shanghai Port is 0.67≤S<0.8

The bad speed ratio in Shanghai Port is 0.5≤S<0.67

The worst speed ratio in Shanghai Port is S<0.5 S>1

According to the South Passage and the other Channel, the standard S is similar to the North Passage

3.1.4 Analysis of Deviation Angle

The deviation angle is the included angle of ship heading and channel course. In the open water area, particular in the ocean, deviation angle is without consideration and navigation track such as S-shape or straight-shape are both accept. However in the narrow channel, like the channel of the Shanghai Port, a vessel must sail in a certain course. If the deviation angle is much big, it will affect the safety of vessel due to ship grounding or collision with other vessels. From the opinion of pilots with senior experience over 20 years pilotage in Shanghai Pilot Station and opinion from crews whose ship always berth in Shanghai Port. Suppose θ= deviation angle, Due to the limited width of Channel in Shanghai Port, vessels are safe if their ship heading is parallel to the channel, θ=0.it means excellent.

If 0<θ≤2 °degree, it means good.

If 2 °< θ≤4 °degree, it means normal.

If 4 °< θ≤9 °, it means bad.

If θ>9 °, it means worse.

3.1.5 Analysis of Ship Condition

Usually, we always have a sentence that the vessel is in a good condition. But it is difficult to define the condition whether it is good or not. In order to do the risk assessment of water area in the Shanghai Port, this sub-factor can be replace by another sub-factor, ship stability. Vessels always are affected by waves, typhoon and external forces when they sail in the ocean or channel and berth in the port. If external force eliminates, they can return to the original position of equilibrium. It means the stability is good. Suppose C= ship stability.

If C=1, the ship stability is good

If C=0, the ship stability is bad

3.1.6 Analysis of Ship Type

Ship Type is still an important factor due to a huge impact of safety of life, environment and economy. For example, LNG belongs to the highly flammable and explosive substances, when LNG vessel voyages in the channel, it always gets high concern. And oil pollution always damages the ecological environment and causes huge economic losses. According to the type of vessel, namely cruise ship, LNG ship, oil ship, super standard ship, Ro-Ro ship, bulk-cargo ship, container ship and general-cargo ship. According to the statistics of losses caused by accidents, compared to the general-cargo ship and bulk-cargo ship, LNG ship, oil ship and cruise ship will create incalculable loss. The container ship, ro-ro ship and super standard ship are in the second place.

3.1.7 Analysis of Cargo Type

According to the nature of the goods, it is divided into general cargo which is combined with cleaning goods, fragile goods, smell goods, dust cargo, pollution cargo and special cargo which is combined with perishable goods, dangerous goods, long pieces goods and high-price goods. In order to do the risk assessment of water area in the Shanghai Port, the standard is according to the International Maritime Dangerous Goods Code (IMDG Code) because it is accepted as an international guideline to the safety transportation or shipment of dangerous goods or hazardous materials by water on vessel. If the goods are defined dangerous goods in IMDG Code, it means dangerous to the water area of Shanghai Port and vice versa.

3.2Analysis of Environment Factors

Due to the geography of Shanghai Port, the environment factor has impact on the safety of water area in Shanghai Port. The water environment is included with traffic rate and water depth. Meanwhile the meteorological environment is included with tide, wind and fog.

3.2.1 Analysis of Traffic Rate

Due to the development of vessels, we will find the size of vessel is much bigger than before and the tonnage is much larger as well. Though the shipping industry in not better than before, the traffic rate of the Shanghai Port increase from 2010 to 2014

Table1-Total Number of Ship Statistics from 2010-2014 of North Channel

Year Water Area	2010	2011	2012	2013	2014
North Passage	48353	48784	48695	51262	45080

(Source: Shanghai MSA, 2015)

And definition of traffic rate is the total number of vessel in the unit area in one moment. Suppose ρ= N/WL(N=total number of vessel, L=the length of channel, W=the width of channel). According to the actual situation of Shanghai Port. However, this ρ cannot represent the actual traffic rate of Shanghai Port.

Suppose K=separation distance of each vessel, L= the length of ship

s= occupied area=$\sum_{i=1}^{n} \pi[\left(\frac{L}{2}\right) + K]^2$

Suppose the definition of water area which length is 1n.m. and width is 1n.m.

Suppose the average length of vessel is 200 meters and separation distance of each vessel is 0.3n.m. , In the area of 1n.m^{2,} the maximum idealized number of vessel is about 9.

ρ= N/WL=9/1=9

s= occupied area area=$\sum_{i=1}^{n} \pi[R]^2/1$ =3.14*(200/2+0.3*1852)^2=0.3935m^2. In the 1n.m^{2,} the number of vessel in the 1n.m^{2,} ρ≈2 vessels.

In the result, K=2/9, if K>2/9, the traffic rate is so high, the situation of water area is dangerous

K≤2/9, the situation of water area is safe.

3.2.2 Analysis of Water Depth and Tide

The tide rang of the Shanghai Port is defined as follows

Table 2-The Tide Rang of Shanghai Port

Size of Tide	Tide Range
Super small	Under 0.91meters
Small	0.92-1.83 meters
Medium	1.84-2.74meters
Maximum	2.75-3.66meters
Super Maximum	Above 3.67meters

(Source: Zhao R.H., 2011)

The features of tide in the Shanghai Port:

The tide of the Shanghai Port is irregular semidiurnal tide which have two tide and ebb except in the day of spring tide and the significant different tide height.

The characteristic of the tide in the Shanghai Port, 1, the height of tide is higher at night and lower in the daytime in summer,

2, the height of tide is higher in the daytime and lower at night in winter,

3, the spring tide is high in summer and low in winter,

4, the super maximum tide range occurs in tidal surge and super small in neap,

5, the higher astronomical tide level is on the rainy day and smaller on the cold day,

6, the higher spring tide is in the Southeast windy day and lower in the Northwest windy day,

7, the maximum tide rang in low pressure day and small in higher pressure day.

From the characteristic tide of Shanghai Port, it is significant that the tide affects the Shanghai Port seriously. When doing the risk assessment of the Shanghai Port, it is obvious that water depth and tide should be considered together in this study. Suppose E= (the height of tide +the depth of chart)/the draft of vessel.

In the Shanghai Section of Yangtze River:

The depth of chart of North Passage is 12.5 meters. The maximum height of high tide is 5.4m and minimum height of low tide is 2.5meters in Shanghai Port. Until now, the maximum draft of vessel voyaging in North Passage is 13.5meters.According to the Yangtze River Estuary (12.5meters) Deepwater Channel Navigation Safety Management Measure (In Temporary) Article 4. Under Keel Clearance, Under Keel Clearance should not be less than 12% of the ship's draft. In order to meet this Article 4, the minimum depth of tide is 2.62 meters when the draft of vessel is 13.5 meters.

E=$(2.62+12.5)/13.5$=1.12， it is the minimum standard.

E=$(5.4+12.5)/13.5$=1.32, it means the best condition with the high tide.

If E>1.32, it means better

If 1.12<E≤1.32 degree, it means normal

IF E≤1.12, it means worse

In the South Passage:

In the South Passage, the depth of chart of the South Passage is 5 meters. So far, the maximum draft of vessel voyaging in the South Passage is 9 meters. And the Under Keel Clearance in the South Passage for every vessel is 0.7 meters

E=$(4.7+5)/9$=1.07, it is the minimum standards.

E= $(5.4+5)/9$=1.16, it means good condition with the high tide.

In the result of Shanghai Section of South Passage,

If E>1.16, it means good

If 1.07<E≤1.16, it means normal

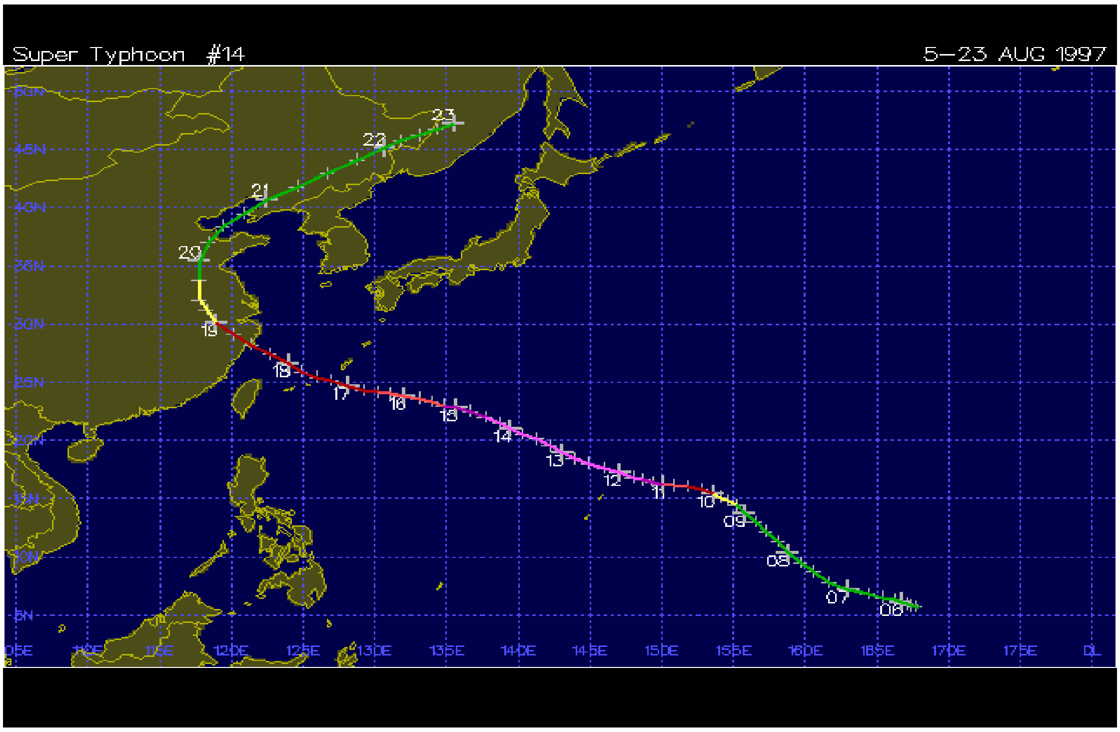
IF E≤1.07, it means bad

3.2.3 Analysis of Typhoon

Due to the geographical position, Shanghai Port is seriously affected and attacked by typhoon. The wind is so strong and often associated with cold air to produce heavy rainfall in September. The average wind speed is 3.0m/s and maximum wind speed 30.0m/sec. And storm tide which is a disaster natural phenomena on which is the combination of typhoon and astronomical tide.

On Aug 18, 1997, Shanghai Port struck from the Typhoon, Winnie, which maximum wind was 60 m/sec and minimum pressure is 920 hpa. The heavy rainfall reached 152.1mm and tide of Huangpu River increased by 24 to 50 cm and meanwhile the tide of Wusong area reached 5.98 meters which was higher than warning line of 1.18 meters.

Figure 20-Typhoon No.9711(Winnie)



(Source: BBS of Typhoon Cyclone Section, 2011)

And in order to describe wind factor, the scale of wind is describe by Beaufort Wind Force Scale. Purpose F= Beaufort Wind Force Scale .According to the actual situation in the estuary of Yangtze River,

If F=0 it means excellent.

If 0<F≤2, it means good.

If 2<F≤4, it means normal.

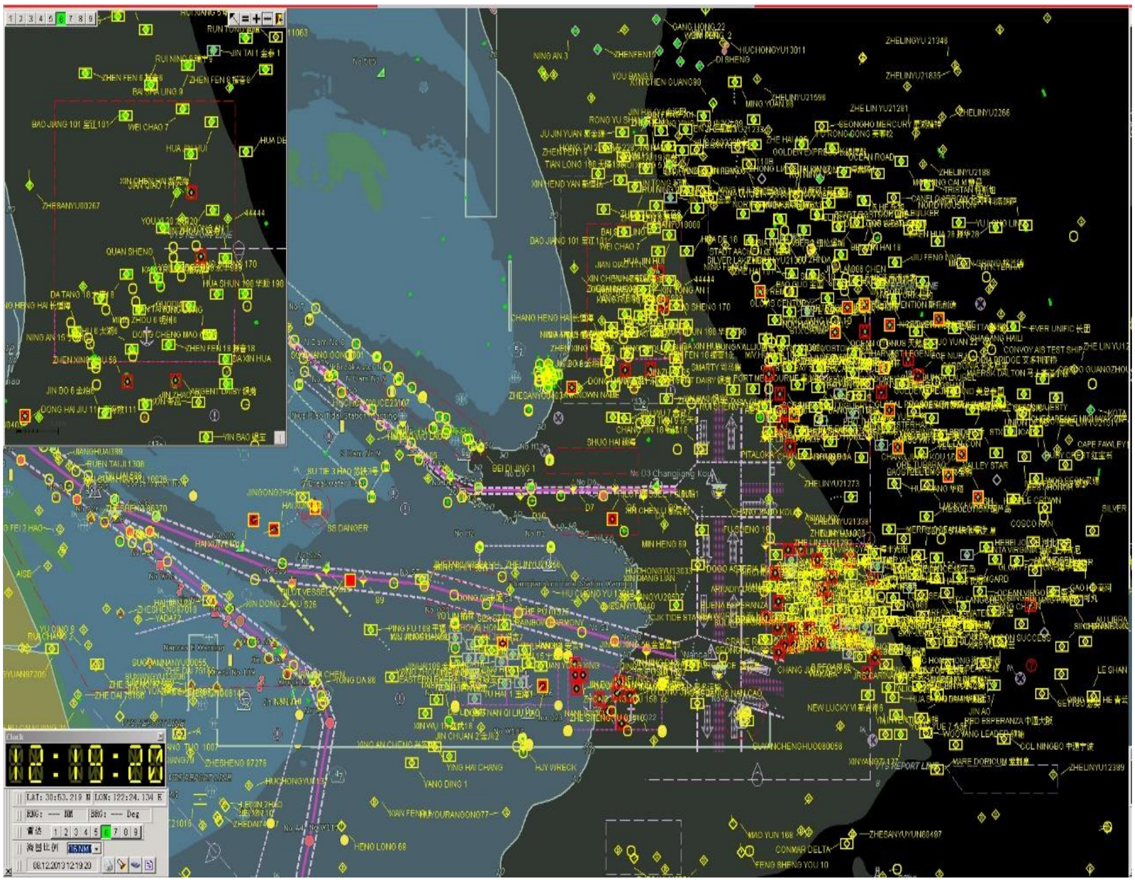
If 4<F≤6, it means bad.

If F>6, it means worse

3.2.4 Analysis of Visibility

Visibility is another problem which affects the safety of international cruise in Shanghai Port. The reason for bad visibility is fog and haze which will cause the suspending sailing for about 50 days of each year in the Shanghai Port. According to the Yangtze River Estuary (12.5meters) Deepwater Channel Navigation Safety Management Measure (In Temporary), the North Passage will be suspended to the vessels which are not in the channel when the visibility is less than 1000 meters. If the visibility is in the distance from 500 to 1000 meters, dredgers in the channel should work with care. When the visibility is less than 500 meters, no ship can voyage in the channel and all the vessels should choose appropriate place for anchorage. From Figure 19, when the visibility is so poor in the shanghai Port, all the vessels are suspended.

Figue21-VTS Record of Estuary of Yangtze of poor visibility



(Source: Shanghai MSA, 2013k)

Suppose V=the distance of visibility. Generally, the visibility is so good when the weather is fine, being over 15 n.m. If 5n.m$<V\le 15$ n.m., it means good. If $1<V\le 5$ n.m.,

it means normal If 500m<V≤1 n.m., it means bad If V≤500m, it means worse.

3.3 Analysis of Human Factors

US Coastguard defines it as 'human and organizational influences on marine safety and maritime system performance'.''(Alert, issue NO1, Oct. 2003) In fact, human being will be influenced by stress, experience and training and duty

3.3.1 Analysis of Knowledge Level

Due to the limitations imposed by characteristic of shipping industry, in the earlier period, most crew members working on board do not have special training in navigation, particularly in developing countries. However, with the development of the global shipping trade, vessels are not only voyaging in the inland area, but also more cargoes are transported by ocean vessels from one country to another. As increasing number of people receive systematic training in the training institutions and more and more persons enter into the colleges and some maritime universities to accept theoretical studies and practical operation. But the number of people is far from meeting the needs of huge talent market, which results in the uneven level of knowledge. Sometimes, the lack of knowledge will affect the operation of vessel, and sometimes it will endanger the safety of vessels. Knowledge means the level of professional knowledge mastered by the crew. Due to the restriction of industry, seafarers do not have high degree generally. Suppose K= the overall knowledge level in a ship.

If 80% crew member in the same ship have graduated from technical colleges or universities, it means excellent.

If 70≤K<80%, it means good.

If 50≤K<70%, it means normal.

If 30≤K<50%, it means bad.

If K<30%, it means worse

3.3.2 Analysis of Rest Time

In the MLC 2006, Regulation 2.3 Hours of work and hours of rest, including the maximum hours of work and minimum hours of rest and Guideline B2.3 Hours of work and hours of rest. Meanwhile in the STCW, Chapter VIII Standards regarding watchkeeping, Section A-VIII/1 *Fitness for duty. Paragraph Two. All persons who are assigned duty as officer in charge of a watch or as a rating forming part of a watch and those whose duties involve designated safety, prevention of pollution and security duties shall be provided with a rest period of not less than:*

.1 a minimum of 10 hours of rest in any 24-hour period; and

.2 77 hours in any 7-day period (STCW, IMO).

paragraph three. *The hours of rest may be divided into no more than two periods, one of which shall be at least 6 hours in length, and the intervals between consecutive periods of rest shall not exceed 14 hours* (STCW, IMO).

And now, many accidents are caused by fatigue of crew who cannot get enough rest on the board.

Suppose S=1, it means crew in the vessel can get enough rest time according to the STCW and MLC 2006.

S=0, it means crew cannot get enough rest.

Crew who cannot get enough rest on board will affect the safety of vessel everywhere.

3.3.3 Analysis of Work Experience

Work experience is always defined as the knowledge accumulated from a long time work. The employers are willing to employ the people who have much work experience because these people can deal with unexpected problems more calmly and address these issues successfully. Compared to the graduates who entered community just now, these employees deal with the problem conferred with the actual situation. And board is a place where more experience is need, crew may deal with more unexpected problems. For example, the cadet are always very nervous when they enter Huangpu River for first time due to the numbers of the small boats. However, the experienced crew member will stand by the engine and rudder earlier and estimate dangerous situation before their boat arrives.

Suppose E= a span time of work

If people work for $E \geq 5$ years, it means better and they can do better in their position a

If people work for $3 \leq E < 5$ years, it means good.

If $2 \leq E < 3$ years, it means normal.

If $1 \leq E < 2$ years, .it means bad

If $E < 1$ years, it means worse.

3.3.4 Analysis of the Crew's Mental State

Crew many lose the ability of interpersonal communication due to a long time living in a small space and far away from their families. The mental health will be affected and cause many adverse effects and even endanger the safety of ships. In the face of a dangerous situation, crew who have mental illness are likely to feel nervous and lose calmness. They cannot solve the problem in a good mental condition and sometimes small problems could result in a disaster. In order to measure the psychology of crew, the evaluation criterion is the time span on board, S=a time span on board. This information is from the crew who have been working for over 5 years. Considered the limited time on board of each year is 12 month, Most of them think:

It means best when $11.5 < S \leq 12$ months

It means good when $11<S\leq 11.5$ months

It means normal when $2<S\leq 4$months

It means bad when $1<S\leq 2$months $4<S\leq 7$months

It means worse when $0<S\leq 1$month $7<S\leq 11$month

3.4 Analysis of Management Factors

3.4.1 Analysis of Reporting Time of Dynamics of Vessel

Since a vessel sails on the ocean where people cannot completely know about. Sometimes an external factor will change the plan of the vessel. And a good plan will greatly reduce the consumption the maximum saving for the oil funds to shipowners. In the channel of the Shanghai Port, some vessel deliberately reduce speed in the channel due to the undetermined plan which affects the vessel who follows and it affect other vessels voyaging in Shanghai Port as well. In order to measure the impact from the dynamics of vessel.

Suppose T=the reporting time of dynamic plan.

If the vessel can declare plan more than 24 hours in advance by call or by VHF to Wusong VTS, it means good.

If $14<T\leq 24$ hours, it means good.

If $8<T\leq 14$hours, it means normal.

Generally, the shortest period of time is 4 hours for a vessel to pass through completely the North Passage and the South Passage. If Wusong VTS cannot get the report from vessel 4 hours in advance. The vessel cannot voyage in the channel. Therefore

If $4<T\leq 8$hours, it means bad.

If $T\leq 4$hours, it means worse.

3.4.2 Analysis of Compliance of International Conventions and National Laws

Each place has its own rule, just as the car running on the road. Drivers will be fined for violating the traffic rules. Usually, if all the vessels voyage with complying the rules, the rate of accident would be very low. From the investigation of accidents in the Shanghai Port, about 70% vessels which violate the rule of overspeed and voyaging in the opposite route easily have collision with others. Therefore fine is another standard to measure the safety of vessel and if the vessel often receive the fine from Shanghai MSA, it is bad for the safety of the Shanghai Port due to the potential pitfalls. Suppose L= frequency of receiving a fine and the vessel is a liner. It is good to the safety of water area of the Shanghai Port if crew always comply with the law and never have any fine from Shanghai MSA over 5 years. It means they are excellent in compliance with law.

If they get the fine in the time of $2<L\leq5$ years, it means good.

If they get the fine in the time of $1<L\leq2$ years, it means normal.

If they get the fine every year, $0.5<L\leq1$ year, it means bad.

If they get more than two fines in the same year, $0<L\leq 0.5$year, it means worse.

3.4.3 Analysis of Retention of PSC and FSC

According to the Procedures for Port State Control, 2011,(Resolution A.1052(27),), it provides guidance on the conduct of Port State Control inspections and affords conduct of these inspections, the recognition of deficiencies of a ship, its equipment, or its crew, and the application of control procedures. Meanwhile, the vessels also receive some guidance on the conduct of Flag State Control inspections. According to the result of inspections, if the vessel gets the notice of retention, it means she is unsafe to the Shanghai Port. And if they are not retarded by Shanghai MSA, it means the vessel is temporarily safe.

3.4.4 Analysis of Technology of Pilotage

When an international vessel voyages into the Shanghai Port, the first person she will meet is a pilot of Shanghai Pilot Station. According to the rules of Shanghai Pilot Station, the quality of pilotage will affect the safety of international vessels. Because the Shanghai port is a very busy port, Shanghai pilots always feel fatigued due to their heavily workload. The second reason which will influence the pilot is the environment which has been supposed. When typhoon passes the Shanghai Port, the pilot ship will change the anchorage in the buoy light No.D20, and the international vessel have to voyage by themselves from buoy light No.D3 to buoy light No.D20 which is not familiar to them. The third reason which will influence the safety of international vessel when they have pilots on board is noncooperation of the captain. Some captains think that they can berth the vessel by themselves though they are not familiar with the dock according to Maritime Law of the People's Republic of China, Rule 39, the responsibility of captain on management and piloting has not been discharged when pilots are on board. Meanwhile in On-Duty Rules of Seamen of the People's Republic of China (2012) Rule 44, the responsibilities of management and pilotage are not relieved when the vessel is piloted by pilot (Ministry of Transport of the People's Republic of China,2012). In order to measure the level of pilotage, the best way is to calculate the number of accidents caused by the pilot. In the Shanghai Pilot Station, the different levels of pilots drive different types of vessel and ship size. Suppose P =the period of time of no accident,

If the pilot does not have accident in the period of time, $P>10$years, it means best.

If the pilot does not have accident in the period of time, $5<P\leq 10$years, it means good.

If the pilot does not have accident in the period of time, $3<P\leq 5$years, it means normal.

If the pilot does not have accident in the period of time, $1<P\leq 3$years, it means bad.

If the pilot does not have accident in the period of time, $P\leq 1$year, it means worst. This pilot must retake the certification training.

3.5 Analysis of Other Factors

3.5.1 Analysis of Engineering Working

Due to the back siltation of North Passage and in order to maintain the depth of water in 12.5meters, the engineering ships which is in charge has to work day and night in the Shanghai Port, And they always work in the North Passage near the Yuanyuansha Precautionary Area which is the aggregation of the North Passage and South Passage. However, sometimes it affects the safety of Shanghai Port, because these engineering ships come and go from working areas and mud areas which ares far from the channel. These construction operations will easily affect the vessel normally voyaging in the channel. From the view of

Suppose C=the period of time

If the engineering vessel voyages across channel in the period of time, $C>2$hours, it means better.

If the engineering vessel voyages across channel in the period of time, $1.5<C\leq2$hours, it means good.

If the engineering vessel voyages across channel in the period of time, $1<C\leq1.5$hours, it means normal.

If the engineering vessel voyages across channel in the period of time, $0.5<C\leq1$hours, it means bad.

If the engineering vessel voyages across channel in the period of time, $0<C\leq0.5$hour, it means worse.

3.5.2 Analysis of Distance of Fishing vessel from Channel

The finishing nets is another reason which will affect the safety of Shanghai Port, particularly in April and May. Many small fishing vessels always voyage in channels and cross the channel in the front of large ships which may increase the risk of large vessels. Many crews and pilots fed back these problems to Shanghai MSA. However, this situation cannot be completely solved. In order to measure this risk, the distance of fishing vessels from channel is an evaluation criterion.

Suppose D=the distance of fishing vessel from edge of channel.

If D<50 meters, it means very dangerous. Propellers are surely be spiraled by the concentrated fishing net.

If 50<D≤150meters, it means the safety condition is bad and easily be spiraled.

If 150<D≤200meters, it means the inbound and outbound vessel will not be affected by finish nets.

If 200<D≤300meters, it means good.

If D>300meters, it means better. The inbound and outbound vessel are certainly not affected by fishing nets.

3.5.3 Analysis of Time of Traffic Control

Shanghai is famous for its beautiful lights in Shanghai Bund to the foreign tourists. And it always has water programs in the important festivals in the Shanghai Port and sometimes the channel is so crowded as to result in accidents. The longer time of traffic control will affect the safety due to the increasing number of vessels in the channel.

Suppose T=the span time of traffic control.

If the time of traffic control T≤ 30minutes, it means the condition is excellent.

If the time of traffic control 30<T≤60minutes. It means the condition is good.

If the time of traffic control 60<T≤120minutes, perhaps, the safety condition still keep

control.

However, if the time of traffic control $120<T\leq180$minutes, the condition is out of control

If the time of traffic control $T>180$minutes, the worse condition will happen.

3.5.4 Analysis of Appearance of Patrols

The law enforcement inspection of Shanghai MSA will increase the safety of Shanghai Port. Just like the traffic policeman standing in the crossroad, crew will obey the rule when they find patrols in the certain line of waterways.

Suppose Q= whether it is a patrol in the certain line of waterways and 1=Yes, 0=No.

If Q=1, this water area is safe.

If Q=0, this water area is unsafe.

CHAPTER 4

CALCULATION

4.1Suppose of Factors Set and Evaluation Set

Suppose the domain U= { $u_1, u_2,\ldots, u_n$ } in which U_i (i=1,2,…,n)denotes a set of evaluated factors(i.e., the North Passage, South Passage); V= { v_1, $v_2,\ldots, v_n$ } in which v_j (j=1,2,…,m) denotes a set of evaluation grades which can be described as 7 degrees. V= { v_1, $v_2,\ldots,$ v_n } = { -3, -2,-1,0,1,2,3, } .The numbers ,-3,-2,-1,0,1,2,3 which are the fuzzy numbers actually represent the fuzzy concepts as best, better, good, normal, bad, worse, worst.

4.2 Suppose of relative weight

In order to define the relative weight, the method used in this study is applied according to the analytic hierarchy process, AHP of Saaty purposed. Meanwhile the AHP method is a tool for multi-criteria group and analyzing complex decisions. The Shanghai Port is divided into different parts according to the different channels and the sub-criterion is according to the vessel, environment, human and management.

Suppose K= { A_1,A_2,…, A_n } , A_n(n=1,2,…,n)

Construction of Judgement Matrix

$$K=\begin{matrix} A_1/A_1 & A_1/A_2 & \cdots & A_1/A_n \\ A_2/A_1 & A_2/A_2 & \cdots & A_2/A_n \\ \vdots & \cdots & \cdots & \vdots \\ A_n/A_1 & A_n/A_2 & \cdots & A_n/A_n \end{matrix}$$

Because it compares to itself, so that A_n / A_n=1. And Saaty's nine-point scale should be used according to Table X.

Table 3. Definition of Saaty's nine-point

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated improtance	An activity is favored very strongly over another, its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it
Reciprocals of above	If activity i has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit

(Source: Saaty, 1977)

Table 4. The Scale of Judgement of Matrix

Judgment Scale	Definition
1	Factor A_i is the same important to Factor
3	Factor A_i is more important to Factor
5	Factor A_i is much more important to Factor
7	Factor A_i is strongly more important to Factor
9	Factor A_i is extremely more important to Factor
2,4,6,8	For compromise between the above values
Reciprocals of above	If Ai/Aj=a_{ij}, so a_{ij} =1/ a_{ij}

(Source: Saaty, 1977)

A_{kp} represents the Judgement of Matrix, K=1,2,…,n; P=1,2,…n.

$$\overline{a_{ij}}^{k} = \frac{1}{n}\sum_{p=1}^{n} a_{ij}^{(k)(p)} \quad (4\text{-}1)$$

and $a_{ij}^{(k)(p)} is$ the element of Judgement of Matrix

4.3 Calculation Procedures of Consistent Matrix Analysis

In order to satisfy the consistent conditions. The calculation procedures are so follows

Suppose Judgement of Matrix, A=$(a_{ij})_{m*m}$,

$$G=\begin{Bmatrix} \frac{a_{i1}}{\sum_{i=a}^{m} a_{i1}} & \cdots & \frac{a_{im}}{\sum_{i=1}^{m} a_{im}} \\ \vdots & \cdots & \vdots \\ \frac{a_{m1}}{\sum_{i=1}^{m} ai1} & \cdots & \frac{a_{mm}}{\sum_{i=1}^{m} a_{im}} \end{Bmatrix} \quad (4\text{-}2)$$

The vector W,

$$W= [w_1 \quad w_2 \quad \cdots \quad w_m]^T = \left[\frac{1}{m}\sum_{j=1}^{m}\left(a_{1j}/\sum_{i=1}^{m} a_{ij}\right) \quad \cdots \quad \frac{1}{m}\sum_{j=1}^{m}\left(a_{mj}/\sum_{i=1}^{m} a_{ij}\right)\right]^T \quad (4\text{-}3)$$

W*A =H

$H = A_{m*m} * W_{m*1} = [h_1 \quad h_2 \quad \cdots \quad h_m]^T$ (4-4)

H/W=H'

$H = \left[\frac{h_1}{w_1} \quad \cdots \quad \frac{h_m}{w_m}\right]^T, \sum H/\text{m} = \lambda_{max}$ (4-5)

$\lambda_{max} = \frac{1}{m}\sum_{i=1}^{m}\frac{h_i}{w_i} \quad (h_{i,}w_i \textit{ is the component of vector of } H' \textit{and } W)$ (4-6)

In the APH, the Judgement of Matrix A_k meets $a_{ij}{}^k>0$, $a_{ij}{}^k * a_{ji}{}^k=1$, $a_{ii}{}^k=1$.

If any i, j is true, it is consistent judgment matrix. Meanwhile it means consistency if $a_{ij}{}^k * a_{j1}{}^k = a_{i1}{}^k$.

But it cannot come true in the real cases, it must measure the consistency of Judgement of Matrix.

Due to the concept of Matrix, if the reciprocal matrices meets the constancy, λ_{max}=m
The result of deviation degree can be estimated by$(\lambda_{max} - \text{m})/(\text{m} - 1)$ and$\lambda_{max} \geq \text{m}$

CI (Consistency Index) $= \frac{\lambda_{max} - m}{m-1}$ (4-7)

When $CR = \frac{CI}{RI} \leq 0.01$, (4-8)

It means the Judgement of Matrix conforms to meet the consistency.

The acceptable value of the CR depends on the size of the matrix. If the CR value is equal to or less than the specified value, this indicates that the evaluation within the matrix is acceptable and close to the ideal values. However, if the CR is higher than acceptable value, evaluation process must be improved. Improvement is achieved in a joint meeting of research participants.

Table 5-Mean Consistency Index

Matrix Order	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.50
Matrix Order	11	12	13	⋯						
RI	1.51	1.54	1.60	⋯						

(Source: Jovanovic´, Filipovic´ & Bakic´,2015,pp.225-235)

4.4 Calculation of Relative Weight and Procedures of Consistent Matrix Analysis of Different Channels of Shanghai Port

4.4.1 Calculation of Five Factors

Table 6-Pairwise Comparisons Matrix of Five Factors

Different Factors		Vessel B1	Environment B2	Human B3	Management B4	Others B5
Vessel	B1	1	6/5	6/9	6/5	6/4
Environment	B2	5/6	1	5/9	5/5	5/4
Human	B3	9/6	9/5	1	9/5	9/4
Management	B4	5/6	5/5	5/9	1	5/4
Others	B5	4/6	4/5	4/9	4/5	1

(Source: Completed by the author)

$TR_i = (\prod_{j=1}^{4} a_{ij})^{1/4}$

TR_1= [1* (6/5)*(6/9)*(6/5)*(6/4)] $^{1/5}$=1.0757

TR_2= [(5/6)*1*(5/9)*(5/5)*(5/4)] $^{1/5}$=0.8964

TR_3= [(9/6)*(9/5)*1*(9/5)*(9/4)] $^{1/5}$ =1.6135

TR_4= [(5/6)*(5/5)*(5/9)*1*(5/4)] $^{1/5}$=0.8964

TR_5= [(4/6)*(4/5)*(4/9)*(4/5)*1] $^{1/5}$=0.7171

Wi=Tri/Σ^4 TR_i

$\Sigma^4 TR_i$ = TR_{1+} TR_2 +TR_{3+} TR_{4+} TR_5=1.0757+0.8964+1.6135+0.8964+0.7171=5.1990

$w_{1=}$ $TR_{1/}\Sigma^4 TR_i$ =1.0757/5.1990=0.2069

$w_{2=}$ $TR_{2/}\Sigma^4 TR_i$=0.8964/5.1990=0.1724

$w_{3=}$ $TR_{3/}\Sigma^4 TR_i$=1.6135/5.1990=0.3103

$w_{4=}$ $TR_{4/}\Sigma^4 TR_i$=0.89645.1990=0.1724

$w_{5=}$ $TR_{5/}\Sigma^4 TR_i$=0.7171/5.1990=0.1379

Calculation of the eigenvalue, λ_{max}

$\lambda_{max} = \sum_{i=1}^{4} \frac{(Bw)i}{4w_i} = \frac{1}{4} \sum_{i=1}^{4} \frac{\sum_{i=1}^{4} a_{ij} w_j}{w_i}$

$$B_w = \begin{pmatrix} 1 & 6/5 & 6/9 & 6/5 & 6/4 \\ 5/8 & 1 & 5/9 & 5/5 & 5/4 \\ 9/6 & 9/5 & 1 & 9/5 & 9/4 \\ 5/6 & 5/5 & 5/9 & 1 & 5/4 \\ 4/6 & 4/5 & 4/9 & 4/5 & 1 \end{pmatrix} \begin{pmatrix} 0.2069 \\ 0.1724 \\ 0.3103 \\ 0.1724 \\ 0.1379 \end{pmatrix} = \begin{pmatrix} 1.0345 \\ 0.8621 \\ 1.5517 \\ 0.8621 \\ 0.6897 \end{pmatrix}$$

$\lambda_{max} = \frac{1}{4}\left[\frac{1.0345}{0.2069} + \frac{0.8621}{0.1724} + \frac{1.5517}{0.3103} + \frac{0.8621}{0.1724} + \frac{0.6897}{0.1379}\right] = 5.0000$

The consistency ratio (CR) is calculated as CR = CI/RI. RI value is the random consistency index. Table X1shows the values for the RI of the matrix dimensions of 1–10.

Table 7-Random consistency Index

N	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

（Source: Jovanovic´ et al,2015,pp.225-235)

$CI = \frac{\lambda\,max - n}{n-1} = \frac{5-5}{5-1} = 0$

$CR = \frac{CI}{RI} = \frac{0}{1.12} = 0 < 0.1$

4.4.2 Calculation of Vessel Factors

$W_{Ship\ Age}$=0.1428
$W_{Ship\ position}$=0.1111
$W_{Ship\ speed}$=0.1541
$W_{Deviation\ Course}$=0.1948
$W_{Ship\ Conditon}$=0.1632
$W_{Ship\ Type}$=0.0942
$W_{Cargo\ Type}$=0.1398

4.4.3 Calculation of Environment Factors

$W_{Traffic\ Rate}$=0.3478
$W_{Water\ Depth\ and\ Tide}$=0.3043
$W_{Typhoon}$=0.1739

$W_{Vissibility}$=0.1739

4.4.4 Calculation of Human Factors

$W_{Knowledge\ Level}$=0.2500
$W_{Rest\ Time}$=0.2083
$W_{Work\ Experience}$=0.2500
$W_{Psychology}$=0.2917

4.4.5 Calculation of Management Factors

$W_{Reporting\ Time\ of\ Dynamics\ of\ Vessel}$=0.2273
$W_{Compliance\ of\ Interantional\ Conventions\ and\ National\ Laws}$ =0.2727
$W_{Rentention\ of\ PSC\ or\ FSC}$=0.1818
$W_{Technique\ of\ Pilotage}$=0.3182

4.4.6 Calculation of Other Factors

$W_{Engineering\ Work}$=0.1591
$W_{Distance\ of\ Fish\ Vessel\ from\ Channel}$=0.1738
$W_{Time\ of\ Traffic\ Control}$=0.2534
$W_{Appearance\ of\ Patrols}$=0.2228

4.5 Definition of Degree of Membership

4.5.1 Definition of Degree of Membership of Vessel

4.5.1.1 Ship Age

Table 8-Degree of Membership of Ship Age

	-3	-2	-1	0	1	2	3
0≤A≤5years	0	0	0.2	0.6	0.8	0	0
5≤A≤10years	0	0	0	0.2	1	0.4	0.2
10≤A≤15years	0	0	0.2	0.8	1	0.2	
15≤A≤20years	0.2	0.4	1	0.6	0.2	0	0
A>20years	1	0.6	0.2	0	0	0	0

(Source: Completed by the author)

4.5.1.2 Ship Position

Table 9-Degree of Membership of Ship Position of Inbound Vessel

	-3	-2	-1	0	1	2	3
1/2D≤B<2/3D	0	0	0	0.8	1	0.4	0
2/3D≤B<5/6D	0	0	0	0	0.8	1	0.4
5/6D≤B≤D	0.2	0.8	1	0.6	0	0	0
B<1/2D or B>D	1	0.8	0	0	0	0	0

(Source: Completed by the author)

Table 10-Degree of Membership of Ship Position of Outbound Vessel

	-3	-2	-1	0	1	2	3
0≤B<1/6D	0.2	0.8	1	0.6	1	0	0
1/6D≤B<1/3D	0	0	0	0	0.8	1	0.4
1/3D≤B≤1/2D	0	0	0.8	1	0.4	0	0
B<0 or B>1/2D	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.1.3 Ship Speed

Table 11-Degree of Membership of Ship Speed

	-3	-2	-1	0	1	2	3
S=1	0	0	0	0	0	0	1
0.8≤S<1	0	0	0	0	0.8	1	0.2
0.65<S≤0.8	0	0	0.2	1	0.2	0	0
0.6<S≤0.65	0.2	1	0.4	0	0	0	0
S≤0.65 or S>1	1	0	0	0	0	0	0

(Source: Completed by the author)

4.5.1.4 Deviation Couse

Table 12-Degree of Membership of Deviation Course

	-3	-2	-1	0	1	2	3
θ=0	0	0	0	0	0	0	1
0<θ≤2°	0	0	0	0	0.8	1	0

2°< θ≤4 °	0	0	0.2	1	0.4	0	0
4 °< θ≤9°	0.6	1	0.2	0	0	0	0
θ>9 °	1	0	0	0	0	0	0

(Source: Completed by the author)

4.5.1.5 Ship Stability

Table 13-Degree of Membership of Ship Stability

	-3	-2	-1	0	1	2	3
Good	0	0	0	0	0.2	1	0.8
Bad	1	0	0	0	0	0	0

(Source: Completed by the author)

4.5.1.6 Type of Ships

Table 14-Degree of Membership of Ship Type

	-3	-2	-1	0	1	2	3
Cruise	1	0	0	0	0	0	0
LNG	1	0	0	0	0	0	0
Oil	0.6	1	0	0	0	0	0
Super Standard	0.6	1	0	0	0	0	0
RO-RO	0.4	1	0	0	0	0	0
Bulk-Cargo	0	0.4	1	0	0	0	0
Container	0	0.8	1	0	0	0	0
General-Cargo	0	0.4	1	0	0	0	0

(Source: Completed by the author)

4.5.1.7 Type of Cargo

Table 15-Degree of Membership of Type of Cargo

	-3	-2	-1	0	1	2	3
In (IMDG Code)	1	0	0	0	0	0	0
Out (IMDG Code)	0	0	0.2	1	0.8	0	0

(Source: Completed by the author)

4.5.2 Definition of Fuzzy Set on Degree of Membership of Environment

4.5.2.1 Traffic Rate

Table 16-Degree of Membership of Traffic Rate

	-3	-2	-1	0	1	2	3
0<K≤2/9	0	0	0	0	0.8	1	0
K>2/9	0.2	1	0.8	0	0	0	0

(Source: Completed by the author)

4.5.2.2 Water Depth and Tide

North Passage

Table 17-Degree of Membership of Tide of North Passage

	-3	-2	-1	0	1	2	3
E≤1.12	1	0.8	0	0	0	0	0
1.12<E≤1.32	0	0	0.2	1	0.6	0	0
E>1.32	0	0	0	0	0..8	1	0.2

(Source: Completed by the author)

South Passage

Table 18-Degree of Membership of Tide of South Passage

	-3	-2	-1	0	1	2	3
E≤1.07	1	0.8	0	0	0	0	0
1.07<E≤1.16	0	0	0.2	1	0.6	0	0
E>1.16	0	0	0	0	0..8	1	0.2

(Source: Completed by the author)

4.5.2.3 Wind

Table 19-Degree of Membership of Typhoon

	-3	-2	-1	0	1	2	3
F=1	0	0	0	0	0	0	1
0<F≤2	0	0	0	0	0.8	1	0.2
2<F≤4	0	0	0.2	1	0.8	0	0
4<F≤6	0	0.8	1	0.8	0	0	0
F>6	0.8	1	0.2	0	0	0	0

(Source: Completed by the author)

4.5.2.4 Visibility

Table 20-Degree of Membership of Visibility

	-3	-2	-1	0	1	2	3
V>15n.m	0	0	0	0	0	0	1
5<V≤15 n.m.	0	0	0	0	0	1	0.8
1<V≤5 n.m.	0	0	0	0.8	1	0.2	0
500m<V≤1 n.m.	0	0.8	1	0.2	0	0	0
V≤500m	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.3 Definition of Fuzzy Set on Degree of Membership of Human Factor

4.5.3.1 Knowledge Level

Table 21-Degree of Membership of Knowledge Level

	-3	-2	-1	0	1	2	3
K≥80%	0	0	0	0	0	0.8	1
70≤K<80%	0	0	0	0	0.8	1	0.2
50≤K<70%	0	0	0.2	1	0.6	0.2	0
30≤K<50%	0	0.8	1	0.2	0	0	0
K<30%	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.3.2 Work Experience

Table 22-Degree of Membership of Work Experience

	-3	-2	-1	0	1	2	3
E≥5years	0	0	0	0	0	0.8	1
3≤E<5years	0	0	0	0	0.8	1	0.2
2≤E<3 years	0	0	0.2	1	0.6	0	0
1≤E<2 years	0	0.8	1	0.2	0	0	0
E<1 year	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.3.3 Rest of Hours

Table 23-Degree of Membership of Rest of Hours

	-3	-2	-1	0	1	2	3
Meet Conventions	0	0	0	0	0.8	1	0
Not Meet	0.2	1	0.8	0	0	0	0

(Source: Completed by the author)

4.5.3.4 Crew’s Mental State

Table 24-Degree of Membership of Crew’s Mental State

	-3	-2	-1	0	1	2	3
11.5<S≤12 months	0	0	0	0	0	0.8	1
11<S≤11.5 months	0	0	0	0	0.8	1	0.2
2<S≤4months	0	0.2	0.6	1	0.8	0	0
1<S≤2months or 4<S≤7months	0.2	0.8	1	0.2	0	0	0
0<S≤1month or 7<S≤11moth	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.4 Definition of Fuzzy Set on Degree of Membership of Management Factor

4.5.4.1 Reporting Dynamic of Vessel to VTS

Table 25-Degree of Membership of Dynamic of Vessel Reporting to VTS

	-3	-2	-1	0	1	2	3
T>24 hours	0	0	0	0	0	0	1
14<T≤24hours	0	0	0	0	1	0.8	0
8<T≤14hours	0	0	0	0.8	1	0	0
4<T≤8hours	0	0.2	0.6	0.8	0.2	0	0
T≤4hours	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.4.2 Compliance of International Conventions and National Law

Table 26-Degree of Membership of Compliance of Law

	-3	-2	-1	0	1	2	3
L>5 years	0	0	0	0	0	0	1
2<L≤5years	0	0	0	0	1	0.8	0
1<L≤2years	0	0	0.2	1	0.2	0	0
0.5<L≤1year	0	1	0.8	0	0	0	0
L≤0.5year	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.4.3 Retention of PSC or FSC

Table 27-Degree of Membership of Retention of PSC or FSC

	-3	-2	-1	0	1	2	3
Retention	1	0	0	0	0	0	0
Not Retention	0	0	0.2	0.8	1	0.2	0

(Source: Completed by the author)

4.5.4.4 Technology of Pilotage

Table 28-Degree of Membership of Technology of Pilotage

	-3	-2	-1	0	1	2	3
T>10 years	0	0	0	0	0	0	1
5<T≤10years	0	0	0	0	0	1	0.6
3<T≤5years	0	0	0.2	1	0.8	0	0
1<T≤3years	0	0.4	1	0.8	0.2	0	0
T≤1year	1	0.8	0.2	0	0	0	0

(Source: Completed by the author)

4.5.5 Definition of Fuzzy Set on Degree of Membership of Other Factors

4.5.5.1 Engineering Working

Table 29-Degree of Membership of Engineering Work

	-3	-2	-1	0	1	2	3

C>2hours	0	0	0	0	0	0.8	1
1.5<C≤2hours	0	0	0	0	0.8	1	0.2
1<C≤1.5hours	0	0	0.2	1	0.6	0	0
0.5<C≤1hours	0	1	0.8	0.4	0.2	0	0
0<C≤0.5hour	1	0.8	0.2	0	0	0	0

(Source: Completed by the author)

4.5.5.2 Distance of Fishing Vessels from Channel

Table 30-Degree of Membership of Distance of Fishing Vessels from Channel

	-3	-2	-1	0	1	2	3
D>300meters	0	0	0	0	0	0.8	1
200<D≤300meters	0	0	0	0	0.4	1	0.8
150<D≤200meters	0	0	0.2	1	0.6	0	0
50<D≤150meters	0	1	0.8	0.4	0.2	0	0
D≤50 meters	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.5.3 Time of Traffic Control

Table 31-Degree of Membership of Time of Traffic Control

	-3	-2	-1	0	1	2	3
T<30 minutes	0	0	0	0	0	0	1
30<T≤60minutes	0	0	0	0	0.8	1	0.4
60<T≤120minutes	0	0	0.2	1	0.6	0	0
120<T≤180minutes	0	1	0.6	0.4	0.2	0	0
T>180minutes	1	0.8	0	0	0	0	0

(Source: Completed by the author)

4.5.5.4 Appearance of Patrols

Table 32-Degree of Membership of Appearance of Patrols

	-3	-2	-1	0	1	2	3
In Channel	0	0	0	0	0.2	1	0.8
Not In Channel	0.8	1	0.2	0	0	0	0

(Source: Shanghai MSA, 2015)

4.6 Risk Evaluation Model of water area in Shanghai Port

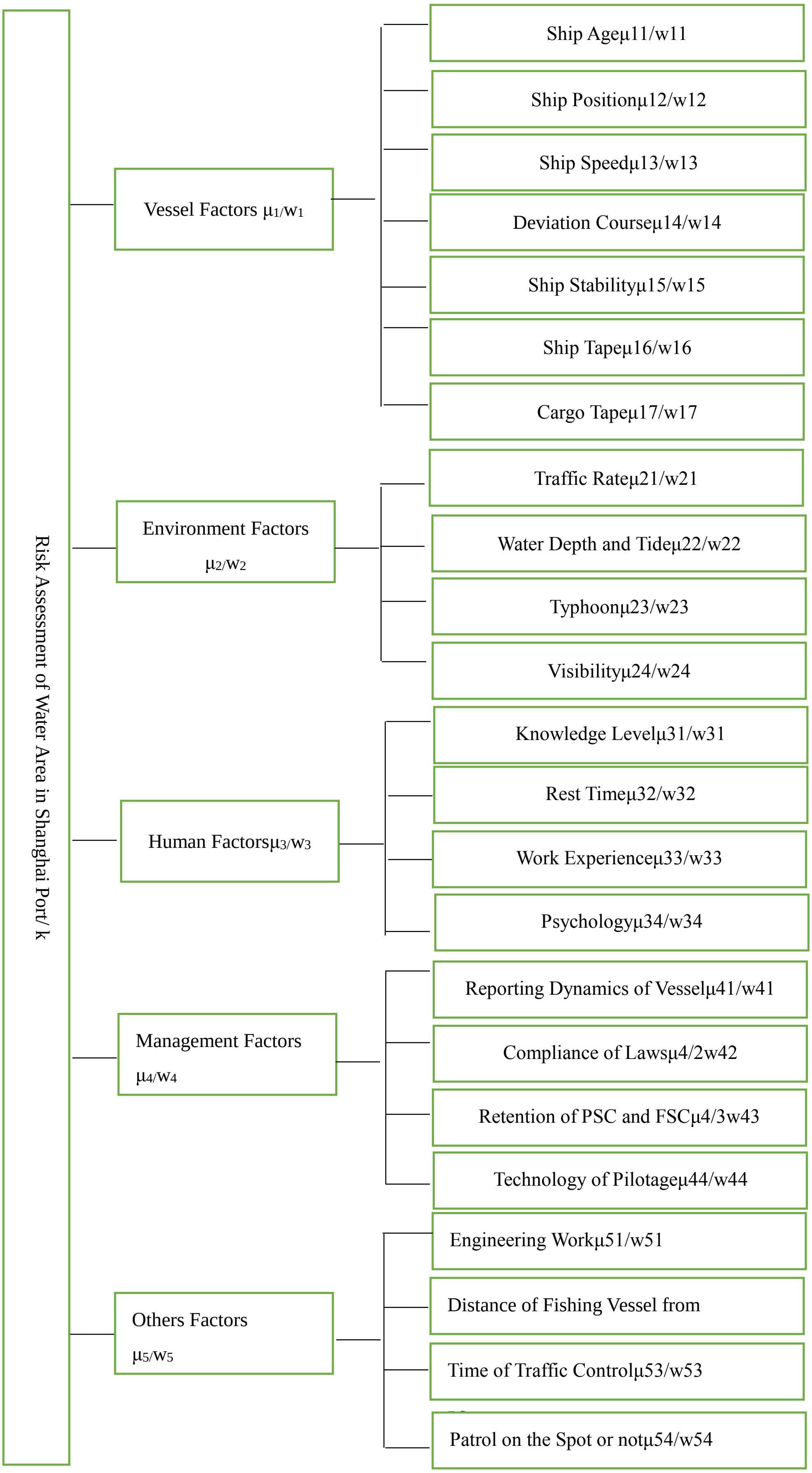
Factor Set μ= (μ_1, μ_2, μ_3, μ_4, μ_5), μ_1= (μ_{11}, μ_{12}, μ_{13}, μ_{14}, μ_{15}, μ_{16}, μ_{17}), μ_2= (μ_{21}, μ_{22}, μ_{23}, μ_{24}), μ_3= (μ_{31}, μ_{32}, μ_{33}, μ_{34}), μ_4= (μ_{41}, μ_{42}, μ_{43}, μ_{44}), "w" represents the weight.

$$\begin{cases} \mu_R(\mu_1) = w_1 * R_1 \\ \mu_R(\mu_2) = w_2 * R_2 \\ \mu_R(\mu_3) = w_3 * R_3 \\ \mu_R(\mu_4) = w_4 * R_4 \\ \mu_R(\mu_5) = w_5 * R_5 \\ w_1 = [w_{11} \quad w_{12} \quad w_{13} \quad w_{14} \quad w_{15} \quad w_{16} \quad w_{17}] \\ R_1 = [\mu_R(\mu_{11}) \quad \mu_R(\mu_{12}) \quad \mu_R(\mu_{13}) \quad \mu_R(\mu_{14}) \quad \mu_R(\mu_{15}) \quad \mu_R(\mu_{16}) \quad \mu_R(\mu_{17})]^T \\ w_2 = [w_{21} \quad w_{22} \quad w_{23} \quad w_{24}] \\ R_2 = [\mu_R(\mu_{21}) \quad \mu_R(\mu_{22}) \quad \mu_R(\mu_{23}) \quad \mu_R(\mu_{24})]^T \\ w_3 = [w_{31} \quad w_{32} \quad w_{33} \quad w_{34}] \\ R_3 = [\mu_R(\mu_{31}) \quad \mu_R(\mu_{32}) \quad \mu_R(\mu_{33}) \quad \mu_R(\mu_{34})]^T \\ w_4 = [w_{41} \quad w_{42} \quad w_{43} \quad w_{44}] \\ R_4 = [\mu_R(\mu_{41}) \quad \mu_R(\mu_{42}) \quad \mu_R(\mu_{43}) \quad \mu_R(\mu_{44})]^T \\ w_5 = [w_{51} \quad w_{52} \quad w_{53} \quad w_{54}] \\ R_5 = [\mu_R(\mu_{51}) \quad \mu_R(\mu_{52}) \quad \mu_R(\mu_{53}) \quad \mu_R(\mu_{54})]^T \end{cases} \tag{4-9}$$

Suppose the result of risk assessment is k,

$$\begin{cases} k = w * R \\ w = [w_1, w_2, w_3, w_4, w_5] \\ R = [\mu R(\mu 1) \ \mu R(\mu 2) \ \mu R(\mu 3) \ \mu R(\mu 4) \ \mu R(\mu 5)]\ T \end{cases} \tag{4-10}$$

Figure22-Environment Tress of Water Area in Shanghai Port



(Source: Completed by the author)

CHAPTER 5

APPLICATION AND COMPLICATAION OF COMREHENSIVE ASSESSMENT OF SHANGHAI PORT

5.1 M.V.MINGLI and M.V. BABUYA

June 4, 2015, inbound M.V. MINGLI. Length 295 meters, Width 46meters, Draft 10.6 meters, Total Tonnage 94710 tons. Net Tonnage 59,527, Dead-weight tonnage 180050 tons, horsepower 25,370HP. Flag Nation, Hong Kong. Meanwhile, outbound M.V. BABUYA Length 180 meters Width 23 meters, Draft 6.50 meters, Design Speed 19.5 knots, she voyaged from LNG dock to Malaysia.

Analysis:

Inbound vessel MINGLI voyaged to Ningbo Port along Yangtze River and transferred Yangtze pilot in the Baoshan Channel. In the Shanghai Section, the vessel which is constructed in 2006 voyaged from the estuary of the Yangtze River where shanghai pilot boarded on vessel. Weather condition is not well. The wind is about 4-5F and tide condition of Hengsha is (0044 414, 0823 093, 1221 354, 2005 083). Besides there was an accident in Wusongkou Precautionary Area. Meanwhile M.V. BABUYA voyaged form LNG dock to Malaysia successfully in South Passage.

5.2Calculation M.V MINGLI in North Passage

Figure23-Event Tree of M.V. MINGLI in North Passage

	Sub-Factor/Weight	worst	worse	bad	normal	good	better	best
Vessel /0.2069	Ship Age/0.1428	0	0	0	0.2	1	0.4	0.2
	Ship Position/0.1111	0	0	0	0	0.8	1	0.4

	Ship Speed/0.1541	0	0	0	0	0.8	1	0.2
	Deviation Angle/0.1948	0	0	0	0	0	0	1
	Ship Stability/0.1632	0	0	0	0	0.2	1	0.8
	Type of Ship/0.0942	0	0.4	1	0	0	0	0
	Type of Cargo/0.1398	0	0	0.2	1	0.8	0	0
	Traffic Rate/0.3478	0	0	0	0	0.8	1	0
Environment /0.1724	Water Depth and Tide/0.3043	0	0	0.2	1	0.6	0	0
	Wind/0.1739	0	0.8	1	0.8	0	0	0
	Visibility/0.1739	0	0.8	1	0.2	0	0	0
	Knowledge Level/0.2500	0	0	0	0	0.8	1	0.2
Human /0.3103	Work Experience/0.2083	0	0	0	1	0.8	1	0.2
	Rest Time/0.2500	0	0	0	0	0.8	1	0
	Psychology/0.2917	0	0.2	0.6	1	0.8	0	0
	Reporting Dynamic of Vessel of VTS/0.2273	0	0	0	0	0	0	1
Management/0.1724	Compliance of International Conventions and National Law/0.2727	0	0	0	0	0	0	1
	Rentition of PSC and FSC/0.1818	0	0	0.2	0.8	1	0.2	0
	Technology of Pilotage/0.3182	0	0	0	0	0	0	1
	Engineering Working/0.1592	0	0	0.2	1	0.6	0	0
Other /0.1379	Distance of Fishing Vessel from Channel/0.1738	0	0	0	0	0.4	1	0.8

	Time of Traffic Control/0.2534	0	1	0.6	0.4	0.2	0	0
	Appearance of Patrols/0.2228	0.8	1	0.2	0	0	0	0

(Source: Completed by the author)

The result of North Passage is (0.0246, 0.1395, 0.1878, 0.3334, 0.4921, 0.4104, 0.2775)

The biggest number is 0.4921, the North Passage was safe.

5.3 Calculation M.V MINGLI in the Waigaoqiao Channel, the Baoshan Channel and the Baoshan North Channel.

Figure24-Event Tree of MINGLI in the Waigaoqiao Channel, the Baoshan Channel and the Baoshan North Channel

	Sub-Factor/Weight	worst	worse	bad	normal	good	better	best
Vessel /0.2069	Ship Age/0.1428	0	0	0	0.2	1	0.4	0.2
	Ship Position/0.1111	0	0	0	0.8	1	0.4	0
	Ship Speed/0.1541	0	0	0	0	0.8	1	0.2
	Deviation Angle/0.1948	0	0	0	0	0	0	1
	Ship Stability/0.1632	0	0	0	0	0.2	1	0.8
	Type of Ship/0.0942	0	0.4	1	0	0	0	0
	Type of Cargo/0.1398	0	0	0.2	1	0.8	0	0
Environment /0.1724	Traffic Rate/0.3478	0.2	1	0.8	0	0	0	0
	Water Depth and Tide/0.3043	0	0	0	0	0.8	1	0.2
	Wind/0.1739	0	0.8	1	0.8	0	0	0
	Visibility/0.1739	0	0.8	1	0.2	0	0	0
Human /0.3103	Knowledge Level/0.2500	0	0	0	0	0.8	1	0.2

	Work Experience/0.2083	0	0	0	1	0.8	1	0.2
	Rest Time/0.2500	0	0	0	0	0.8	1	0
	Psychology/0.2917	0	0.2	0.6	1	0.8	0	0
Management/0.1724	Reporting Dynamic of Vessel of VTS/0.2273	0	0	0	0	0	0	1
	Compliance of International Conventions and National Law/0.2727	0	0	0	0	0	0	1
	Rentition of PSC and FSC/0.1818	0	0	0.2	0.8	1	0.2	0
	Technology of Pilotage/0.3182	0	0	0	0	0	0	1
Other /0.1379	Engineering Working/0.1592	0	0	0	0	0	0.8	1
	Distance of Fishing Vessel from Channel/0.1738	0	0	0	0	0	0.8	1
	Time of Traffic Control/0.2534	0	0	0	0	0.8	1	0.4
	Appearance of Patrols/0.2228	0	0	0	0	0.2	1	0.8

(Source: Completed by the author)

The result of the Waigaoqiao Channel, the Baoshan Channel and the Baoshan North Channel is (0.0120, 0.13388, 0.1938, 0.2634, 0.4636 0.4676, 0.3441) The biggest number is 0.4676， so these channels were safer.

5.4 Calculation M.V. BABUYA in the South Passage

Figure25-Event Tree of M.V.BABUYA in the South Passage

	Sub-Factor/Weight	worst	worse	bad	normal	good	better	best
	Ship Age/0.1428	0	0	0.2	0.8	1	0.2	0

	Ship Position/0.1111	0.2	0.8	1	0	0	0	0
	Ship Speed/0.1541	0.2	1	0.4	0	0	0	0
	Deviation Angle/0.1948	0	0	0	0	0	0	1
Vessel /0.2069	Ship Stability/0.1632	0	0	0	0	0.2	1	0.8
	Type of Ship/0.0942	1	0	0	0	0	0	0
	Type of Cargo/0.1398	1	0	0	0	0	0	0
	Traffic Rate/0.3478	0.2	1	0.8	0	0	0	0
Environment /0.1724	Water Depth and Tide/0.3043	0	0	0.2	1	0.6	0	0
	Wind/0.1739	0	0.8	1	0.8	0	0	0
	Visibility/0.1739	0	0.8	1	0.2	0	0	0
	Knowledge Level/0.2500	0	0	0.2	1	0.6	0.2	0
Human /0.3103	Work Experience/0.2083	0	0	0.2	1	0.6	0	0
	Rest Time/0.2500	0.2	1	0.8	0	0	1	0
	Psychology/0.2917	1	0.8	0	0	0	0	0
	Reporting Dynamic of Vessel of VTS/0.2273	0	0	0	0	1	0.8	0
Management/0.1724	Compliance of International Conventions and National Law/0.2727	0	0	0	0	0	0	1
	Rentition of PSC and FSC/0.1818	0	0	0.2	0.8	1	0.2	0
	Technology of Pilotage/0.3182	0	0	0	0	0	0	1
Other /0.1379	Engineering Working/0.1592	0	1	0.8	0.4	0.2	0	0
	Distance of Fishing Vessel	0	1	0.8	0.4	0.2	0	0

	from Channel/0.1738							
	Time of Traffic Control/0.2534	0	1	0.6	0.4	0.2	0	0
	Appearance of Patrols/0.2228	0	0	0	0	0.2	1	0.8

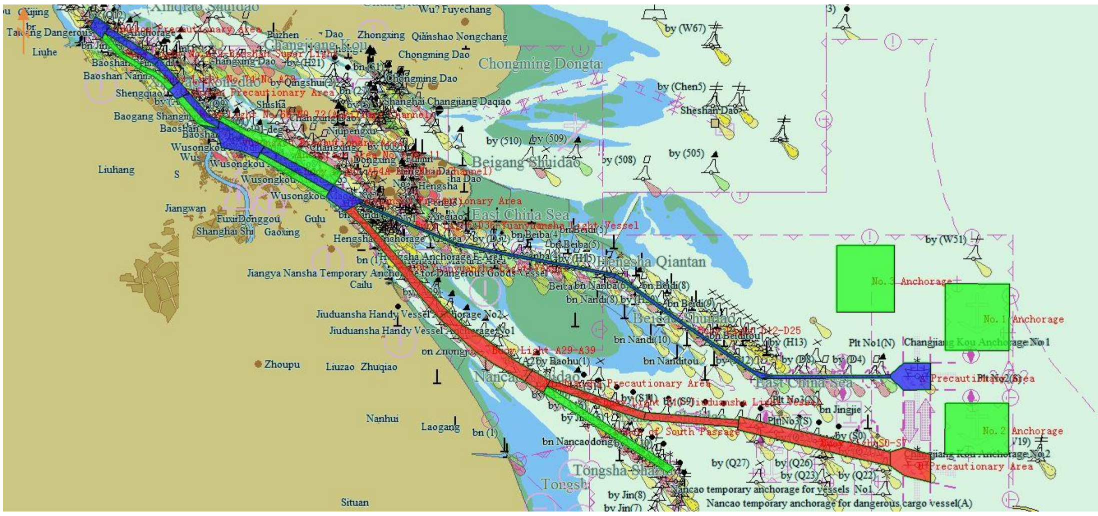
(Source: Completed by the author)

The result of the South Passage is (0.1774, 0.3891, 0.3145, 0.3057, 0.2459, 0.2011, 0.1938) The biggest number is 0.3891. Therefore the South Passage was more dangerous.

5.5 Risk Assessment of M.V.MINGLI and M.V. BABUYA in Shanghai Port

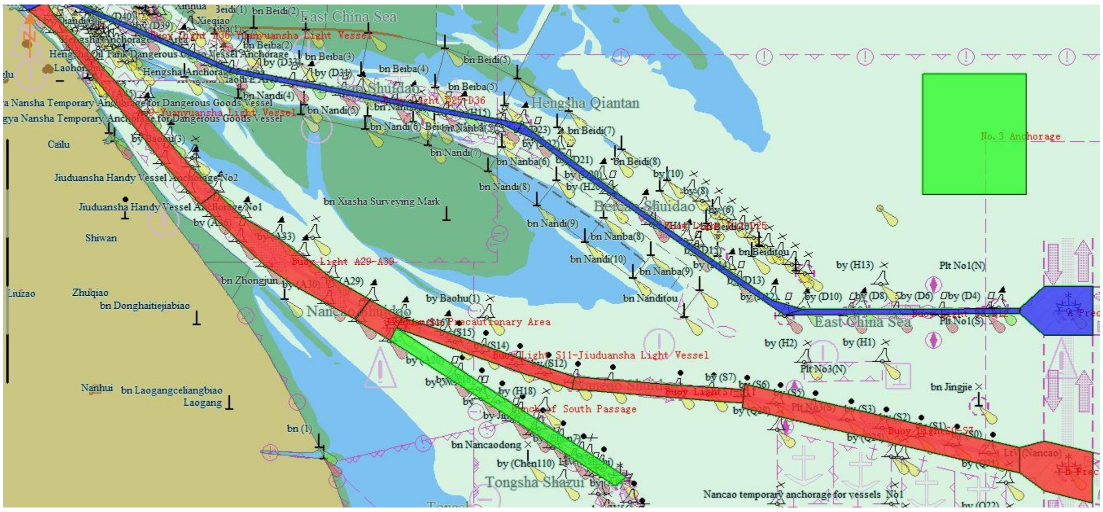
Suppose: Blue means safe, purple means safer and green means safest. Yellow means dangerous, red means more dangerous and brown means the most dangerous. The result of risk assessment of M.V.MINGLI and M.V.BABUYA in the Shanghai Port which represents in Figure 25, Figure 26 and Figure 27.

Figure 26-Risk Assessment of M.V. MINGLI and M.V.BABUYA in Shanghai Port (A)



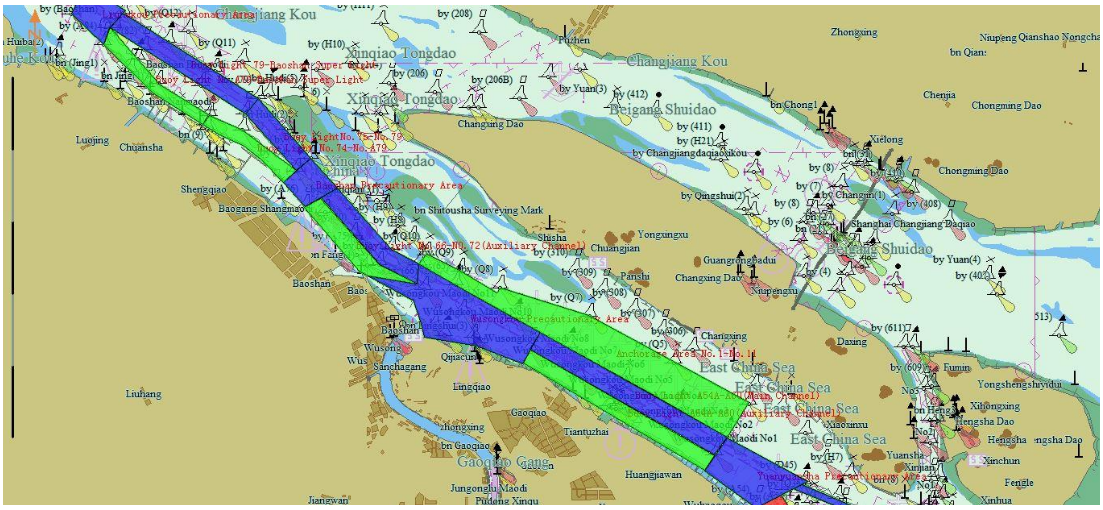
(Source: MSA China and Modified by author, 2015a)

Figure27-Risk Assessment of M.V. MINGLI and M.V.BABUYA in Shanghai Port (B)



(Source: MSA China and Modified by author, 2015b)

Figure28-Risk Assessment of M.V. MINGLI and M.V.BABUYA in Shanghai Port(C)



(Source: MSA China and Modified by author, 2015c)

CHAPTER 6

CONCLUSION

In the past study, it is obvious that scholars always focus on one aspect, such as tide, weather, Yangtze Estuary Deepwater Channel of the Shanghai Port. Few studies focus on the entire water area in Shanghai Port. However, the study of risk assessment of water area in the Shanghai Port is seriously important. The reason is that Shanghai MSA, particular Wusong VTS can find the problems in the channel as soon as possible. They can analyze the dangers of fairway in advance and make a judgement of risks. Rescue operations are able to be taken as early as possible when the accidents happen. The risk assessment of water area in the Shanghai Port is not only in the theoretical knowledge but also in the actual situation. The mode is made by Fuzzy Comprehensive Evaluation Method (FCEM) and the actual example is used to test the mode with an various of assessment factors though the assessment factors cannot cover all the aspects. The authentic assessment mode of water area in the Shanghai Port in this study is based on the vessel, human, environment, management and the other factors. In addition, the reliability will not be affect due to the different degree of assessment factor.

In order to regulate and control the risk of water area in the Shanghai Port, the major factor is human factor which leads to the 90% of the accidents according to the incomplete statistics. Knowledge level and work experiences of crew are determined by the ship company when they arrange personnel transfer. Meanwhile if crew have the rest of hours according to the international conventions, such as MLC 2006, Regulation 2.3 and STCW, Chapter VIII, fatigue problem can be improved effectively. However crew mental factor in human factor compared to knowledge level and work experiences are more difficult to control because of the uncertainty. In the result that psychology, unlike physical illness, is the most important factors in the human factors and it will indirectly alter personality and emotions. If mental illness cannot be well treated, it will largely affect the emotion of crew and it will affect the safety of navigation under bad circumstances.

In the environment factors involved in traffic flow, water depth and draft, typhoon and visibility are changeful factors and these factors are difficultly to control as an old Chinese saying goes, human, in face of the nature, is too small. The environment factors affecting the safety of water area in Shanghai Port cannot be controled completely. The only thing Wusong VTS of Shanghai MSA do is to reduce the impact from these risks. In these two factors of management and other factors, most of them are involved with the other projects, namely PSC and FSC, pilotage, engineering working, reporting time to VTS. Compared to the uncontrollable factors, these factors can be controlled in good condition and in maximum extent, reduce the impact of water area in Shanghai Port.

In the last factor, vessel factor, ship age, speed, position, deviation course, ship type and cargo type, all these factors will influence the water safety of Shanghai Port and it is impossible to prevent all the dangers. But the circumstances of water area in Shanghai Port may be predicted by the risk assessment mode and the impact of dangers may be minimized as much as possible.

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APPENDIX

QUESTIONNAIRE

Please order different factors according to the important level

1,Human 2,Vesel 3 Environment 4 Management or 5 the others

Please tick some reasons which you think important in Shanghai Port

	1, Habit	__		1, VTS Service	__
	2, Psychology	__	Management	2. Pilot Service	__
	3, Expereience	__		3, Ship Owner Service	__
Human	4, Knowledge	__		4, Rentation or not	__
	5, Age	__		1, Fishing Vessel	__
	6, Gender	__		2, Traffic Control	__
	7, Responsibility	__		3, Engineering Work	__
	1, Length	__	Others	4, Unexpected Situation	__
	2, Width	__		5,	__
	3, Draft	__		6,	__
Vessel	4, Stability	__		7,	__
	5, Age	__		…	__
	6, Vessel Type	__			
	7, Nationality	__			
	1, Weather	__			
	2, Wave	__			
Environment	3, Tide	__			
	4, Visibility	__			
	5, Traffic Rate	__			

If you have any advice, please take down.

Thank you for your cooperation

(Source: Completed by the author)