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Analysis and research of cruise ship safety at Wusongkou International Cruise Ship Terminal

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ANALYSIS AND RESEACH OF CRUISE SHIP SAFETY AT Wusongkou International Cruise Ship Terminal

By

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DECLARATION

I certify that all the materials in this research paper that is 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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Date: Jun 28, 2018

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ABSTRACT

Title of Dissertation: **Analysis and research of cruise ship safety at Wusongkou International Cruise Ship Terminal**

Degree: **MSc**

Cruise ship touring is becoming a new fashion in China, more and more Chinese like to choose this tour method. However, how to ensure the safety of cruise ship is consider as a challenge. When people discuss about the cruise ship economic, but the safety doesn't obtain sufficient attention. This paper attempts to find the risk factors and conduct the analysis of cruise ship safety.

In this paper, author chooses WSKICT as the research objects, because it's the largest cruise terminal in China, and Shanghai is the biggest city. The author gives a detailed description about this cruise ship terminal including its geographical location, surroundings.etc.

With the FSA, the author conduct a series of investigation to determine the risk factors. In succession, the risk factors are analyze and classified as two main factors. A clear risk factors framework is established and introduced, through this, people can easily understand the risk factors.

In accordance with the risk factors, this paper utilizes the AI technology and fuzzy mathematics to conduct the risk assessment. A lot of membership function images are presented in this paper.

With these steps, the author proposes some suggestions. These suggestions cover all the aspects as much as possible. The decision-makers can choose to adopt depend on the practical situation.

KEY WORDS: Safety, natural environment, fairway environment, cruise ship manoeuvre, hazard identification, risk analysis

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LIST OF ABBREVIATIONS

ABB	Asea Brown Boveri Ltd.
AI	Artificial Intelligence
AIS	Automatic Identification System
BSF	Baoshan Fairway
BSSf	Baoshan Sub Fairway
CCDMZ	China Cruise Development Model Zone
CJK	Chang Jiang Kou
CJDP	Chang Jiang Deep Water
CSC	China Changjiang National Shipping Corporation
DP	Dynamic Positioning
DW	Deep Water
E	East
ENE	East/North East
ESE	East/South East
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
FIS	Fuzzy Inference System
FMEA	Failure Mode and Effect Analysis
FSE	Fuzzy Synthetic Evaluation
FSA	Formal Safety Assessment

GT	Gross Tonnage
IMO	International Maritime Organization
MSA	Maritime Safety Administration
MSC	Maritime Safety Committee
N	North
NE	North East
NNE	North/North East
NNW	North/North West
SPSS	Statistical Product and Service Solution
WSKICT	Wusongkou International Cruise Ship Terminal

CHAPTER 1

INTROUCTION

1.1 Background

cruise ship originates from Europe, which is initially used for transferring the mails, modern cruise have become a kind of comprehensive tour product which includes transportation, entertainment and leisure, accommodation, catering, gymnasium, and shopping centre. Nowadays, cruise ship touring is not only considered as the symbol of elite life, but also a popularity of vocation style in the new era. As a dramatical economic growing nation, a large number of Chinese are attracted by this kind of new tour mode, and choose the cruise ship to enjoy their tour life (Li, 2010). Meanwhile with the accumulation of funds and continuous infrastructure development, Shanghai, a pioneer city of China economy over the decades, which is ready to lead the new touring tendency as well. (Jiang, 2006). To comply with this trend, the city government of Shanghai decides to become the home port of cruise ship and develops two important cruise ship terminal, one is located the bank of Huangpu River, another one is built at the mouth of the Huangpu River, which is called Wusong Internal Cruise Ship Terminal (WSKICT).

WSKICT is considered as the key component of the strategy of Shanghai international cruise ship centre, which is the important infrastructure of China Cruise Development Model Zone (CCDMZ) as well. Since the opening of ports in 2010, annual passenger throughput has been increasing year by year. The annual berthing is far more than expected, and the berthing of both vessels has become the norm. In 2014, for the first time, the scale surpassed that of Singapore cruise port and ranked first in Asia Pacific, and its international status was further enhanced (Chen et al, 2012). With cruise ships such as Royal Caribbean Cruises, Costa Crociere, Norwegian Cruise line, Princess Cruises, MSC Cruises, Star Cruises, Cunard Cruises, and Tianhai Cruises competing in the layout of WSKICT, the number of cruise liners has increased. The problem of insufficient berthing capacity highlights the restrictions on the construction and development of Shanghai Cruise Tourism Development Experimental Area. Owing to the reason aforementioned, WSKICT starts to enforce the succession construction of the terminal extension to relieve the pressure of cruise berthing. It will extend 380 meters towards the upstream on the basis of phase 1 of WSKICT, and extend 446 meters towards down stream, two new large-scale berthing will be newly built. After construction, the total length will be as long as 1600 meters, two 200,000 GT berth and two 150,000 GT berth can be arranged, in other words, in total 4 large berth can be used.The front waters of WSKICT are narrow, and the ships' density in the waters is high (Xu, 2015). Ship entering and leaving the Huangpu River & the Changjiang River will meet in this waters, therefor the traffic flow is complicated. After the completion of the terminal follow-up project, it will inevitably increase the frequency of multiple cruise berthing at the same time, which also increases security risks.

1.2 Objectives of research

This dissertation will investigate the surrounding navigation environment, make full use of existing navigation resources and management techniques, and ensure the safe operation of ships. On the basis of an in-depth assessment of the cruise ship berthing and departure, we will analyze the berthing technology of large cruise ship, study the boundary conditions and the relevant security measures for the cruise ship on arriving and departure the berth, further to provide a theoretical basis and reference for the safety of arriving and leaving berthing of large international cruise ship at WSKICT.

1.3 The main research contents of this dissertation

This paper will will focus on the following parts, 1) Analysis and utilization of surrounding navigation resources. 2) Simultaneous berthing risk assessment for multiple vessels at WSKICT. 3) Optimization of detailed manoeuvre measures of large cruise for berthing and departure at WSKICT 4) Defining boundary conditions (tide,wind, current, vessel manoeuvre performance, tug boat and manning) 5) The related research of safety precautions. (Maritime precautions, traffic flow organization, emergency plan etc.) 6) improvement of WITC competitive power.

1.4 The research ideas and methods

To complete this research, the related shipping entities and companies were visited, meanwhile, Shanghai Baoshan MSA supplied great help as well. At WSKICT, the information including surrounding navigation environment, historical meteorological condition, traffic flow,berthing process of large cruise ship and navigation data were collected, besides, WSKICT also instructs the present condition,operation process and the follow-up projects. In the Shanghai pilot station, pilotage norm and hazard assessment were obtained, Baoshan MSA and Wusong VTS gives amounts of suggestions with respect to management experience. And then combine with the information, this paper use the fuzzy mathematics and AI technology to model and conduct calculation. Finally, these high risk combinations are listed in the after mentioned chapter.

CHAPTER 2

The Current Navigation Environment Of WSKICT

2.1 WSKICT General Situation

2.1.1 Geographical location and boundary

WSKICT is located at the coastal line of Wusongkou, Baoshan district of Shanghai, south to the Baoshan sub fairway, geographical coordinate boundary: E121°29′53″～121°30′45″， N31°24′18″～31°24′51″. It is approximately 2km southeast of Wusongkou. The phase 1 of the terminal construction is located in the middle section of the breakwater. The follow-up project will be expanded from both sides of the existing project to both sides (Baidubaike, 2018). WSKICT location is shown in Figure 2.1

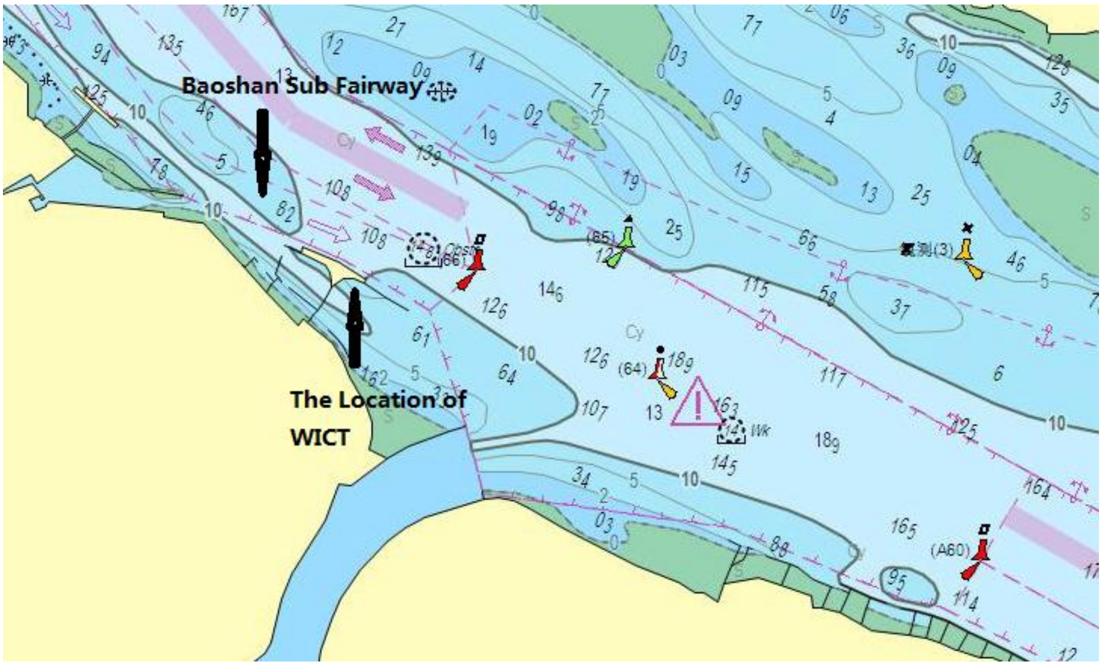

Figure 2.1 WSKICT Geographical Location

Source: Chuanxun Net (Modified by the Author)

2.1.2 WSKICT Layout

The current WSKICT is divided into two parts, which are upstream terminal (west part) and downstream terminal (east part). Upstream terminal is 420 meters long, it's designed for berthing 200,000 GT cruise ship, as to downstream terminal, which is 354 meters long, only 100,000 GT can get alongside this berth. Customer platform is set up between terminal and approach bridge, meanwhile, customer platform becomes a connection junction between these two above mentioned construction unit. On the basis of the present estimation, the target annual number of cruise berthing at the WSKICT is 450, actually, in 2017, it has be greatly exceeded. The peak number of berthing ship is 55-60 when it's in the peak month of boom season, and the demand number for berthing is 14-15 per week during the peak month (WSKICT, 2018). Therefore, it is necessary to arrange 4 cruise berths for WSKICT before it can reasonably meet the berthing demand of the target year.

To meet the continuous rising berth demand, the extension project becomes the primarily task for WSKICT. In accordance with the construction plan ,two new cruise ship berths will be accomplished, in other words , there will be 4 large-scale cruise ship berths in the future, the total length of new terminal is approximately 1600 meters. Upstream terminal is extend to 800 meters as equal as the length of downstream terminal.these two new berths and the two old berths will form a group of three home port berth plus one port of call. With these professional berth group, four ships between 150,000-200,000 GT can get alongside at the same time. The Integrated berthing group is two 200,000 GT ships plus 150,000 GT ships, 1600 meters is sufficient length for mooring the cruise (WSKICT, 2018). A 200,000 GT can satisfy the berthing demand of the various cruise of port of call.The future WSKICT layout plan is shown in the Figure 2.2

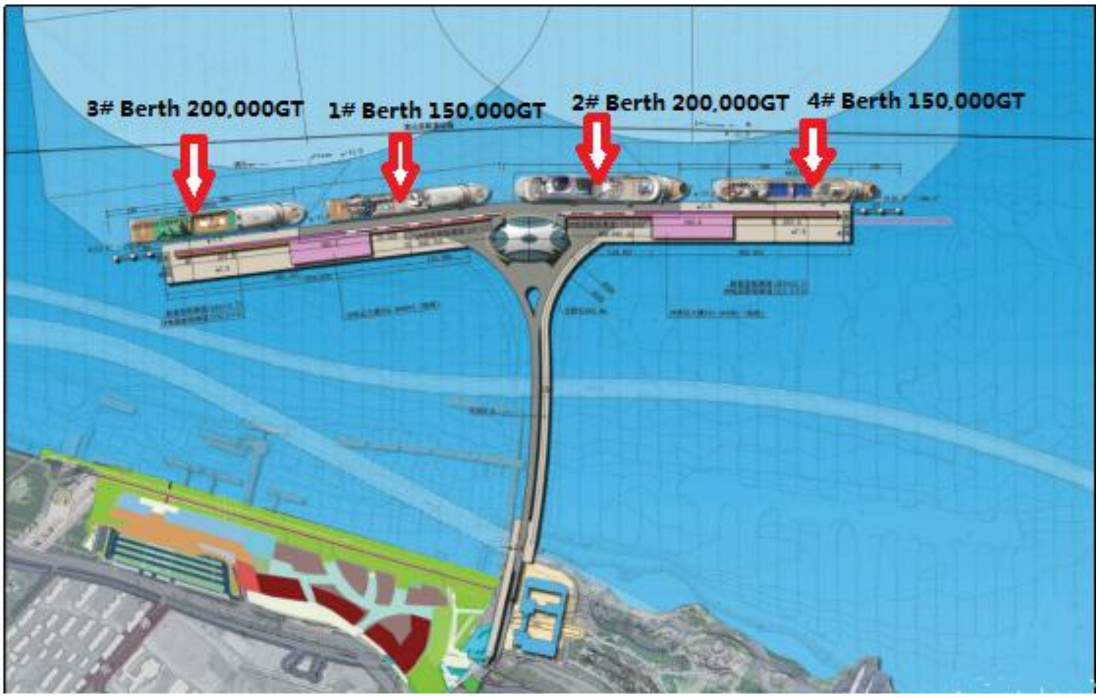

Figure 2.2 WSKICT Berth Layout Plan After the Extension Project

Source: WSKICT (Modified by Author)

Two turning waters are set up at WSKICT and both occupy the Baoshan sub fairway. The dimension of cruise berth in the upstream section of the turning waters: the transverse width is twice the designed cruise ship length, which is 720m, in addition,the longitudinal length is three times the designed cruise ship length, which is 1080m; the dimension of cruise ship berth in the downstream section of the turning waters : the transverse width is twice as long as the designed cruise ship length, 680m, and the longitudinal length is three times as long as the designed cruise ship length,1020m. The configuration of the both berths are demonstrated in Figure 2.3

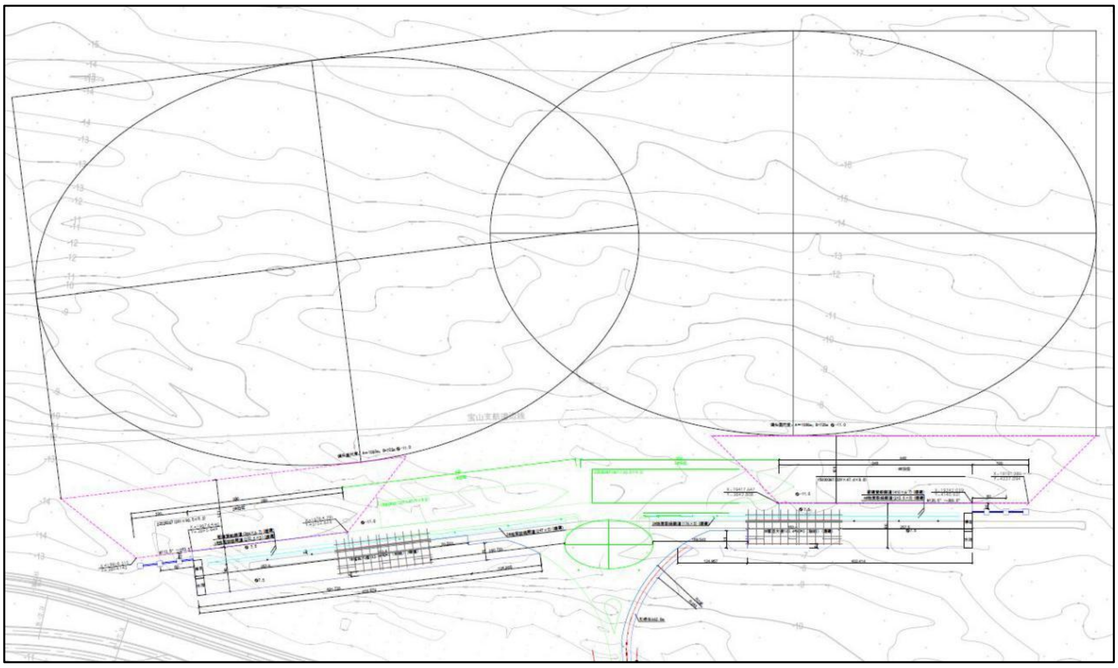

Figure 2.3 The Mooring Waters and Turning Waters of New-built Two Berths

Source: WSKICT

2.2 Fairway and Anchorage

2.2.1 Fairway

The WSKICT is located at the intersection waters of the Changjiang River and the Huangpu River. Between the Wusongkou precautionary area and the Baoshan precautionary area, multiple routes are crossing nearby. The waters near the project is the section of Shanghai Changjiang River with the largest traffic density, the most complex navigation environment, and the accident-prone waters (Zeng, 2014). Nearby routes include: Baoshan fairway, Baoshan sub fairway, and the deep water fairway extension of the Changjiangkou (CJK). The location is show in the Figure 2.4.

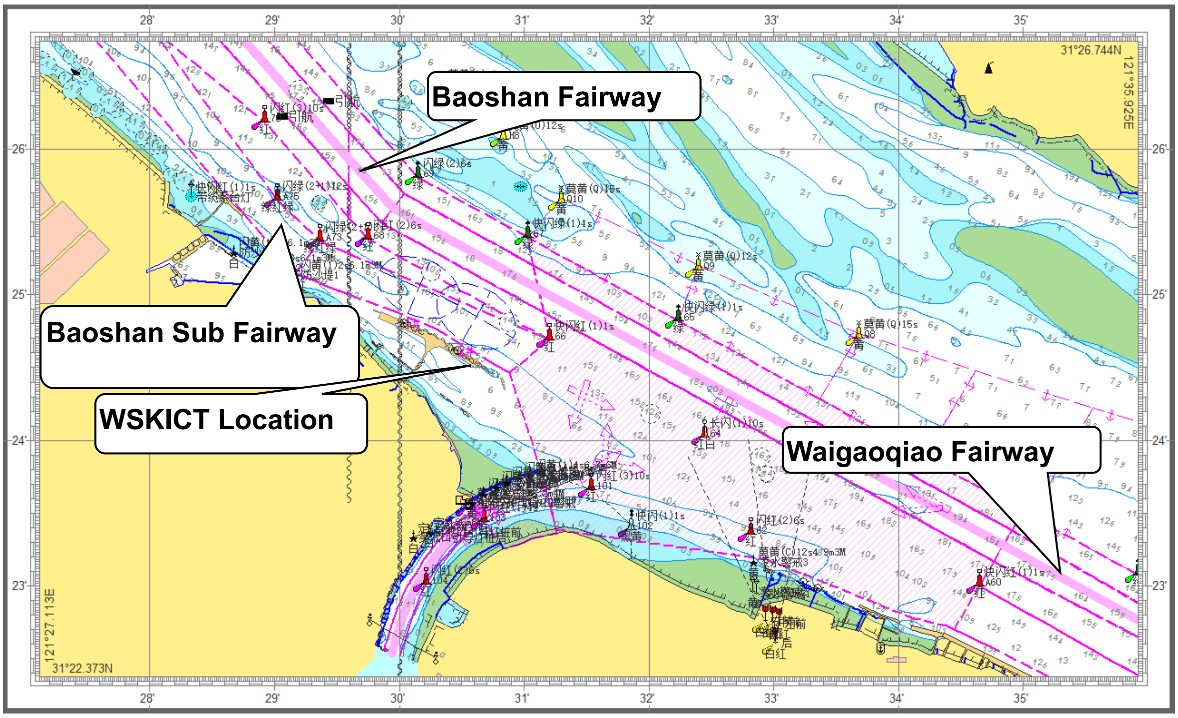

Figure 2.4 The Fairways in the Vicinity of WSKICT

Source: WSKICT (Modified by Author)

In the vicinity of WSKICT, several fairways are critical for the safety of the cruise ship berthing and departure at the terminal. They are introduced as follows:

1) Baoshan Fairway: In the case of a double fairway, both sides of the fairway separation line are the inward and outward fairways of the extension section of the deep water fairway. From the west boundary line of Wusongkou precautionary area (66/67 light buoy link line) to the eastern boundary line of Baoshan preccaution area, the total length of the fairway is 3.35 nautical miles, with a width of 0.1 nautical miles and 0.15 nautical miles respectively, and a depth of more than 12.9 meters for large ships sailing in and out of the Changjiang River (Chen, 2010).

2) Baoshan Sub Fairway: from the west boundary line of the Wusongkou precaution area to the eastern boundary line of the Baoshan precautionary area, the fairway has a total length of 4.0 nautical miles, a width of 300 to 600 meters, and a depth of more than 6.3 meters, for small ships which sail in and out the Changjiang River along the coast.

3) the Extension Section of Changjiangkou deep water Fairway: The deep water fairway extension section is located in the Waigaoqiao fairway, Baoshan fairway, and Baoshan North fairway. The DW is used for indicating deep water fairway on the chart, and the boundary line is marked by the AIS virtual navigation mark. The Waigaoqiao, Baoshan, and Baoshan North fairways boundaries are marked by lateral mark. The total length of the deep water fairway extension section is about 25 nautical miles, in addition, the bottom width is 350 meters to 460 meters. The depth of the bottom width of the deep water fairway extension section is 12.5 meters below the theoretically lowest tide level (Chen, 2010). The center line of the deep water fairway extension section separates the Waigaoqiao fairway, Baoshan fairway and Baoshan North fairway into inward and outward traffic lane.

The inward fairway of WSKICT needs to cross the Wusongkou precautionary area, Baoshan fairway and Baoshan sub fairway when approaching the terminal. When crossing the above mentioned waters, it will have a greater impact on normal sailing ships. If the cruise ship turn around in front of the berth, the impact on the Baoshan sub fairway is even greater and there is a potential danger of vessel collision.

2.2.2 Anchorage

Owing to the hazardous traffic flow, the authority has to set up a variety of fairways in accordance with the traffic separation scheme nearby the WSKICT, accordingly, anchorage, as a kind of important functional waters, which supply the place to the vessel so as to anchoring, waiting for tide, avoiding hurricane, provision and so on. Therefor, several anchorages are established around WSKICT.All the anchorages are shown in the Figure 2.5. These anchorages include Wusongkou anchorage, Baoshan north anchorage, Baoshan south anchorage. 1) Wusongkou anchorage, which is the nearest anchorage from the WSKICT. It's made up of 10 sub anchorages, and these sub anchorages are numbered from the downstream to the upstream. It undertakes general functions as an anchorage, such as anchoring, provision, avoiding hurricane and so on, meanwhile, the vessel's continuous anchoring period can't exceed 72 hours (Zeng et al, 2016). 2) Baoshan North anchorage, which is used for large-scale vessel, and Its general functions are similar with the Wusongkou anchorage, in addition, the crew relieving usually are completed in this anchorage. A emergency special anchorage is established in the Baoshan North anchorage. In the same way, vessel continuous anchoring period of time can't exceed 72 hours, but the emergency special anchorage can't exceed 24 hours. 3) Baoshan South anchorage, similarly, it possesses the function as well as the Wusongkou anchorage, at the same time, vessel continuous anchoring period of time can't exceed 72 hours.

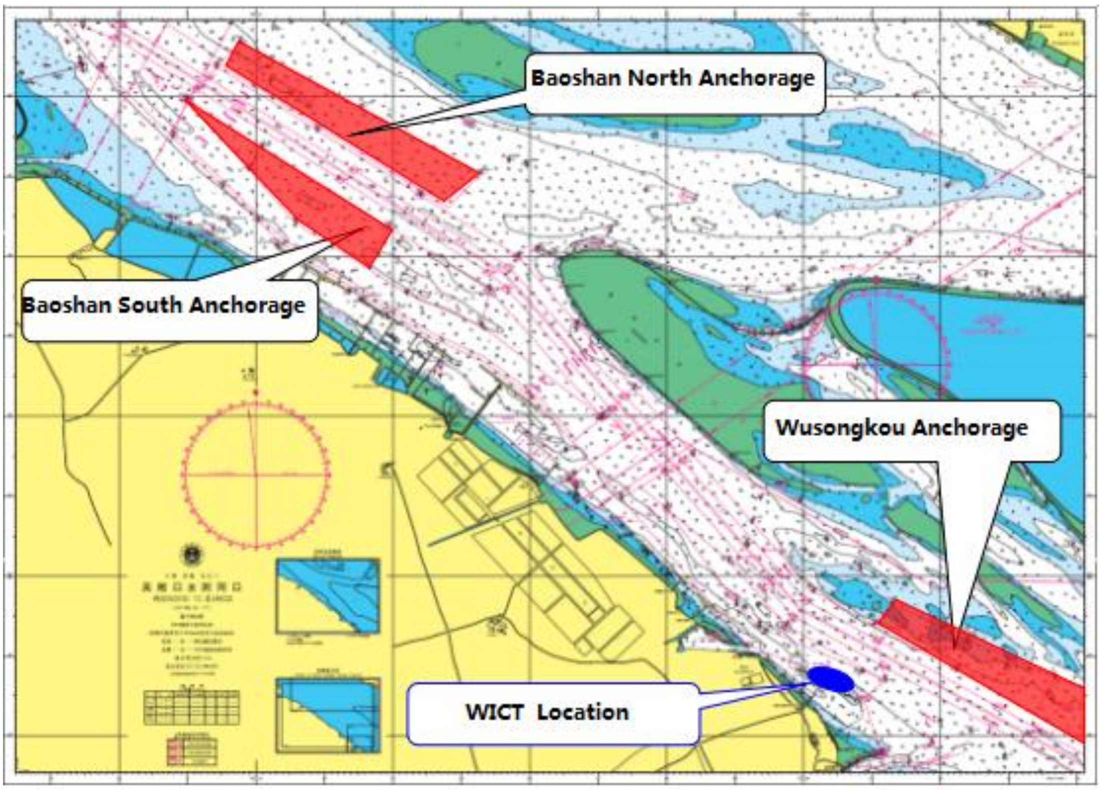

Figure 2.5 The Anchorages in the vicinity the WSKICT

Source: Baoshan MSA (Modified by Author)

2.2.3 Other Hydraulic Facilities and Cargo Ship Terminals

There are a variety of hydraulic facilities and wharf near the WSKICT, the nearest hydraulic facility is China Changjiang National Shipping Corporation (CSC) vessel base, moreover, along the coast of Baoshan district there are around 7 cargo ship terminals belonging to the Baoshan Steel Corporation. As these terminals, everyday lots of vessels will sail in the fairways near the WSKICT, which may affect the navigation safety of cruise (Baoshan MSA, 2018).

2.3 Meteorology and Hydrology

2.3.1 Meteorology

Based on the statistical results of meteorology observation data from Baoshan Meteorological Station in Shanghai over the past 10 years, a brief analysis of the climate conditions in the region was conducted as a climate background of the WSKICT.

2.3.1.1 Basic Features

The climate feature of this region is shown in the following table 1.

Table 2.1 Climate eigenvalue In the WICT region

Item		Eigenvalue
Temperature	Annual maximum temperature	39.7℃（2003.8）
	Annual minimum temperature	-9.4℃（1967.1）
	Average temperature over years	17.1℃
	Monthly average maximum temperature over years	28.5℃（July）
	Monthly average minimum temperature over years	4.9℃（January）
Rainfall	Average rainfall over years	1160.7mm
	Average rainfall days over years	119.1d
	Annual maximum rainfall over years	1435.6mm（1999）
	Annual minimum rainfall over years	755.6mm（2003）
	Day (24 hours) maximum rainfall over years	174.2mm（2001.8）
	1 hour maximum rainfall over years	52.3mm（2001.8）
	Rainfall≥5.0mm Days	49.5d
	Rainfall≥10.0mm Days	29.1d
	Rainfall≥25.0mm Days	9.2d
Humidity	Average relative humidity over years	75%
	Average maximum yearly relative humidity over years	77%（1998 and 1999）
	Average minimum yearly relative humidity over years	70%（2005）
Fog	Annual fog day over years	12.6 d
	Maximum fog days over years	20.0 d（1997and1998）
	Minimum fog days over years	3.0 d（2005）

Thunderstorm	Average thunderstorm days over years	23.7d
	Maximum thunderstorm days over years	31 d（1998）
	Minimum thunderstorm days over years	16 d（2004）

Note: The source is compiled by author based on the collected information from the Baoshan Meteorological Station

2.3.1.2 Wind

The winds in this region have obvious seasonal characteristics. In winter, winds of NE and NW are prevalent and SE winds prevail in summer. For the whole year, the ESE wind (frequency 9.3%) dominated, followed by E wind (frequency 8.8%) and ENE, NNE wind (frequency 8.6%). The strong wind direction is ENE, and the maximum wind speed is 16.0m/s (Baoshan Meteorological Service, 2018).The prevailing wind is demonstrated in Table 2.2

Table 2.2 Prevailing Wind

WindSpeed	≥6Level	≥7Level	≥8Level
Average gale days over years	44.1d	11.2d	2.2d

Note: The source Compiled by author based on the collected information from the Baoshan Meteorological Station

2.3.2 Hydrology

2.3.2.1 Tidal Level Datum

In this paper, the Wusong Zero Point is considered as the datum, the relation of the datum in this region is shown in the Figure 2.6.

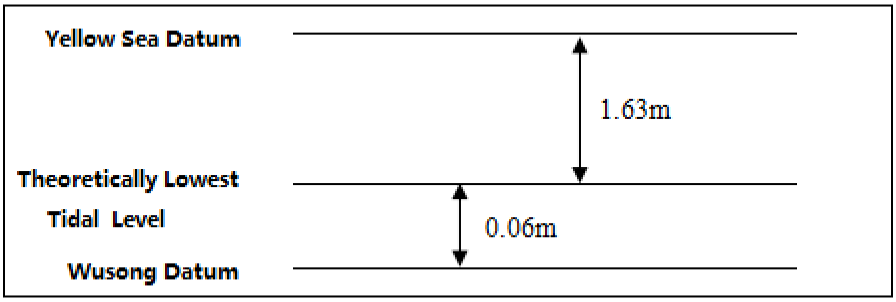

Figure 2.6 Local Datum Relation

Source: Baoshan Meteorological Station

2.3.2.2 Tidal Characteristic

The Changjiang River estuary is a medium sensible tidal estuary. The tidal feature belongs to the regular shallow semidiurnal tide. The tide level rises two or two at a time, and the phenomenon of diurnal inequality in the tide is relatively obvious, especially the difference in the high tide level. The average duration of the flood tide of the WSKICT waters costs about 4 hours and 20 minutes, and the ebb tide lasts about 8 hours. The annual maximum tidal level of the WSKICT waters is often the result of the combination of astronomical tide and typhoon. According to the statistics of the tides in Wusong, Changxing, Waigaoqiao, Shidongkou, and Hengsha hydrology stations at the upstream and downstream of WSKICT waters, and all the statistics are updated to 2005.

2.3.2.3 Current

WSKICT is located in the Changjiang River estuary, where the tide flood current and the tide ebb current play a significant role. The movement of current present a reciprocating flow pattern. According to tide current analysis, the tide current pattern coefficient F of the WSKICT waters is 0.21. Because of the influence of the estuary topography and runoff jacking, the tidal wave deformation is significant, and the shallow sea component currents and residual current are relatively large, and the ebbing current duration is much longer than the flood current duration. The current nature of the waters belongs to the regular shallow semidiurnal tide. As for the tide current velocity, the ebbing velocity is faster than the flood velocity, in addition, according to the distance from far to near the shore, the tide current velocity is going lower and lower. General direction of flood current at the maximum velocity is northwest, the ebb tide direction is generally southeast. According the statistical information of wave, the normal wave direction of WSKICT waters is ESE, and the frequency is 21.7%, as for strong wave, its direction is N~NNW, the frequency of wave height beyond 0.6m is around 8.86%, but the frequency of wave height beyond 1.0m is merely 0.14%, wave height beyond 2m is very rare, none -wave is 16.2%.

2.3.3 The Analysis of Traffic Flow

2.3.3.1 General Situation of the Statistics of Traffic Flow

Owing to numerous small vessels in the WSKICT waters, the statistics is a relatively hard job. Thanks to the information from the Baoshan MSA, the analysis can be conducted successfully. The data from Baoshan MSA covers the three main fairway: Baoshan fairway (BSF), Changjiang deep water fairway (CJDP) extension section , Baoshan sub fairway (BSSF). The data shows the total quantity of vessels sailing in the aforementioned fairways in 7 days, see the Table 2.3. and Figure 2.7.

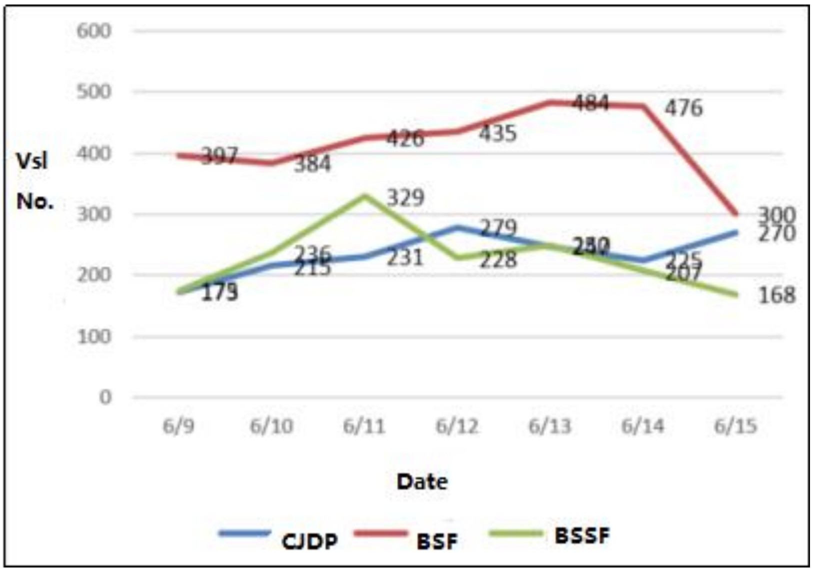

Figure 2.7 The Variation of Vessel No. in 7 days

Source: Baoshan MSA (Modified by Author)

Table 2.3. Data Statistics of Vessel No. in 7 days

Item	BSF	CJDP	BSSF
Average	417	238	236
Total	6135		

Source: Baoshan MSA (Modified by Author)

According to the data, average 417 vessels sail in the BSF everyday , and maximum value is 484, followed by CJDP, which is 238 each day, maximum value is 279. The last one is BSSF, which is 236, but the maximum value is 329, in other words, the variation of vessel No. is the most drastic. As a matter of fact, this is a characteristic of BSSF, because most of small vessels with two seafarers, which are commonly seen in Changjiang River, sail in BSSF. Through the data analysis, a phenomenon is found that the vessel quantity transiting the fairway in daytime is more than the one in nighttime, especially in 11am, the number reach the peak, and in 5 am the number is minimum, see the Figure 2.8.

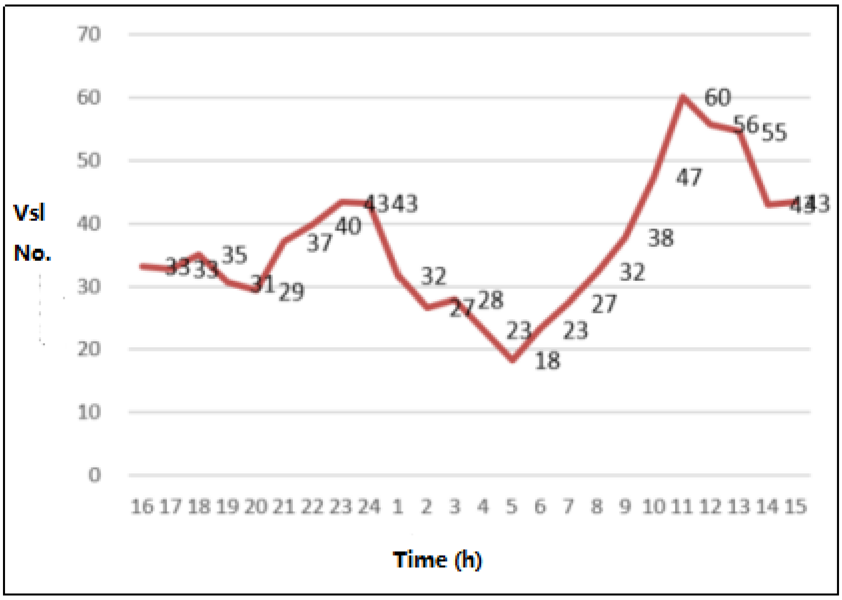

Figure 2.8 The Distribution of Vessel No. at each hour

Source: Baoshan MSA (Modified by Author)

In addition, the length of vessel sailing in CJDP is the longest in the three fairways, as for the shortest length of vessel is the one sailing in the BSSF, see the table 2.4.

Table 2.4 The Distribution of Vessel Length In the Main Fairways

Vessel Length (M)	≦25	25-50	50-100	100-150	150-200	200-250	250-300	>300
BSF	52	498	1529	421	141	14	9	5
CJDP	32	178	471	307	461	72	41	4
BSSF	11	832	586	21	5	2	1	7

Source: Compiled by author based on the information from Baoshan MSA

2.2.3.2 Variation Regulation of Traffic Flow

Through the analysis above, most vessel sailing in front waters of WSKICT are median and small size, considered these two types of vessel are affected easily by the tide current. In particular, small vessels entering and leaving the Huangpu River usually like to follow the tide, furthermore, the time that small vessels entering and leaving the Huangpu River have close relation with the tide time. With the related information, the variation regulation is found as follows: 1) At 0-1 hours before and after the first low tide of the day, the number of vessels on the BSSF reaches the peak of the day. 2) Meanwhile, the vessel number in BSF increases obviously. 3)But in CJDP, vessel number has no remarkable variation with the tide.

2.2.3.3 Correlation analysis between the tide and the vessel number in three main fairway

For the purpose of saving fuel, small vessels of Inland river usually utilize the tide to assist their own navigation, the BSSF is a prescriptive route for the entry of small upstream vessels into the Huangpu River. Vessel types are complex, and the density of ships in the peak hours of each day is relatively large. There are also a few ships that do not follow the traffic separation scheme. This has brought huge safety risks to large-scale cruise ship.

Pearson Correlation Analysis is used for analyzing the relation between two continuous variables, it is often used in economic sector. For this paper, this method is suitable to analyze the relation between the tide and vessel number (Baidubaike, 2018). Its formula is as follows:

$$r = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{X_i - \bar{X}}{s_X}\right)\left(\frac{Y_i - \bar{Y}}{s_Y}\right)$$

Therein, the range of the correlation coefficient r: $-1 \leq r \leq 1$, $r > 0$ for positive correlation, $r < 0$ for negative correlation, $r = 0$ for no linear relation, $r=0$ for no linear relation $0 < |r| < 1$ for existence of different degree of linear correlation, and the closer to1 $|r|$ is, the closer the linear correlation between the two variables; $|r|$ is closer to 0, indicating that the linear correlation between the two variables is weaker.Generally can be divided into three levels: $|r|<0.4$ is a low linear correlation; $0.4 \leqslant |r|<0.7$ is a significant linear correlation; $0.7 \leqslant |r|<1$ is a highly linear correlation (Baidubaike, 2018).

The Pearson correlation corresponds to the correlation coefficient r, which reflects whether the two are positive correlation or negative correlation, and whether they are close or not close. The greater the absolute value of this number is, the closer they are. If negative, it means that these two are negative correlation.

Furthermore, with SPSS software, the relation between the vessel number in BSSF and tide variation data is analyzed, r is -0.587, Sig equals 0.00. Significant (bilateral) Sig is related to the judgment of significance, if Sig <0.05 indicates that the correlation is statistically significant, which is, the two are really correlated. If it is >0.05, the correlation is not significant, which is, they are not correlated. Therefor, it means the relation between the vessel number in BSSF and tide variation data is significant correlation, and is negative correlation. In other words, when low tide comes, the vessel inward the Huangpu River is in the maximum value. This proves the ratiocination, due to save the fuel oil, small vessels usually choose the low tide time to sail and follow the tide to enter the Huangpu River. By this method, they can draw support from tide.

In the same way, for BSF, the correlation coefficient is merely -0.386, it indicates that relation between the vessel number in BSSF and tide variation data presents non-significant negative correlation. This shows that the variation trend of BSF vessel number follows the variation trend of BSSF vessel number, but the increase or reduction of vessel number in the BSF is not significant as same as the BSF.

As for CJDP, the correlation coefficient is -0.121,it proves that the relation between the vessel number in CJDP and tide variation data is correlated. Meanwhile, it shows the tide variation hardly affects the vessel number in the CJDP.

2.3 Manoeuvring Characteristic of Large Cruise Ship

Large cruise ship has their own manoeuvring characteristic which is different with the ordinary commercial vessel, these characteristics are as follows:

2.3.1 Windage Area

Windage area of cruise ship is large. Due to the huge superstructure of a large cruise ship deck, the wind pressure and wind-induced drift during wind movement are relatively large. When the wind reaches a level 4 or above, it has a significant impact on the cruise ship.

2.3.2 Structure

The bridge is mostly located on the bow. But the ship's rotation center is often located behind the bridge, the judgment of the ship's angular velocity and distance from the shore is different from that of the aft-engined ship. It takes a long time for adapting to the manoeuvring of this type of ship.

2.3.3 Propulsion System

Excellent manoeuvring performance, large cruise ships generally use electric propulsion, and the propulsion system uses pod propulsor with bow thrusters or conventional electric propulsion with both bow and aft thrusters, providing powerful propulsion and flexible steering capabilities (Li et al, 2014). When such a large cruise ship operates on berthing and departure, under normal conditions, it can operate on its own without tugboat assistance. Regarding the Propulsion System, due to the big difference in 2.4, this paper will give a detailed description.

2.3.4 Manoeuvre Performance

High movement inertia and short emergency brake distance. Large cruise ships have huge tonnage and high inertia, but the main engine power of cruise ships is relatively large, and they are mostly propelled by pod propulsor. Therefore, the emergency brake distance is relatively short compared to that of commercial vessels with the same tonnage.

2.3.5 Blind Area

The blind area in front is small but when going astern the blind area is large. When the ship is going astern, due to the relative high level of superstructure behind the bridge, the operator outside the bridge could only observe the situation at one side of the ship, however, the stern and other side are completely obscured.

2.4 The Introduction of Pod Propulsor

Marine electric propulsion is the use of propulsion motors to propeller directly or indirectly to propel the vessel forward. Pod propulsor is a new type of ship electric propulsion system developed in recent years, it is a hot spot in the research and development of ship propulsion system (Ma et al, 2007).

The design concept of the Pod propulsor originated from the icebreaker and was first proposed by the Kvaerner masa-Yard and ABB companies in Finland. In the late 1980s, the Finland MSA first proposed the development of Pod propulsor in order to meet the needs of icebreakers sailing in ice areas with higher performance. It was requested that the propulsion of motors be provided in all directions; and then, ABB prototype program proposed by Azipod was manufactured by Kvaerner Masa Shipyard (Zhang et al, 2008). Since then, the countries concerned have conducted more in-depth studies to apply such propulsor to various of vessels.The Pod propulsor is shown in Figure 2.9. Besides, another propulsion method is the traditional electric propulsion system. It still uses the traditional propulsion equipment, which is, the motor is connected with the propeller through the transmission shaft. Most cruise ship berthing at WSKICT usually use electric propulsion system or Pod propulsor(Hou, 2015).

Figure 2.9 Pod Propulsor

Source: http://image.so.com (Modified by author)

2.5 Traditional Manoeuvre Solution of Berthing and Departure

Large cruise ships generally rely on their passage plans to determine the ETA or ETD at WSKICT. There are few considerations for tide currents,however, large flood with a tide difference of 2.75 to 3.66 meters between high tide and low tide or larger tide current must be treated with caution. The berthing and departure operation of ships have the following four conditions respectively.

2.5.1 Berthing Operation

When cruise ship tries to berth at WSKICT, normally it will be affected by flood tide and ebbing tide, in general, it is decomposed into the 4 situations.

1) During the time period of flood tide, the cruise ship gets alongside against current at appropriate time. This method is a normal way for berthing, the starboard side of the ship gets alongside.The cruise ship crosses the main fairway through the waters between No. 66 light buoy and No. 68 light buoy, and then turns left. Finally, the cruise ship gets alongside against the current after turning around. In this situation, when crossing outward fairway, the cruise ship must find enough space, in addition, communicate and coordinate with other ships in the correct way. See Figure 2.10.

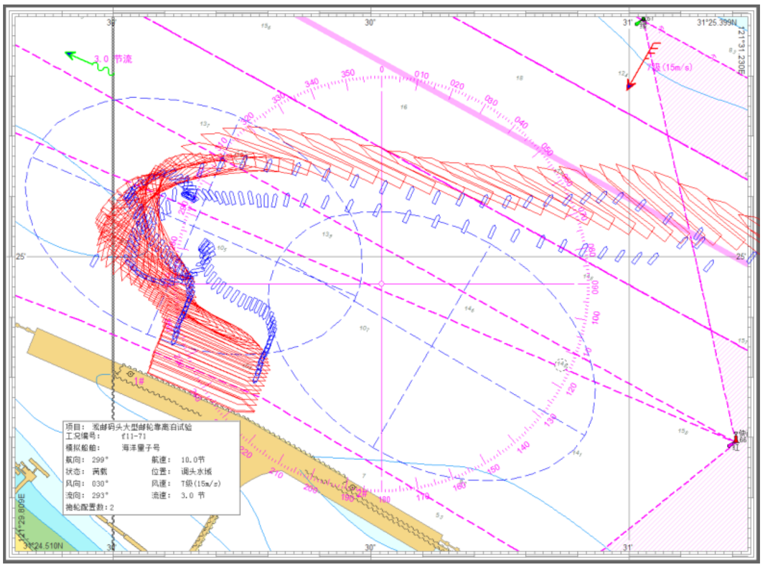

Figure 2.10 The First Berthing Method

Source: Baoshan MSA

2) During the time period of flood tide, the cruise ship gets alongside with current at appropriate time. Vessel gets alongside the port side, it is recommended to cross the main fairway at the downstream of No.66 Light buoy when getting alongside the berth No.2 and berth No.4. But if the berth No.1 and berth No.3, the cruise ship should cross the main fairway at the upstream of No. 66 Light buoy, which may be the best option, and then berth with current. The cruise ship should avoid berthing with current during the period of fastest flood tide or fastest ebb tide. When the cruise ship crosses the fairway and enter into the inner side of the light buoy link line, especially near the berth, due to the current pressure on the port side, the vessel direction should be adjusted to be parallel with the berth at a proper time. However, the starboard side should avoid keeping at a small angle with the stern. With this method, the adverse effects of the current on the cruise ship will be minimum. At the same time, the cruise ship should maintain a sufficient distance to No. 66 light buoy or the shoal near the berth. See Figure 2.11.

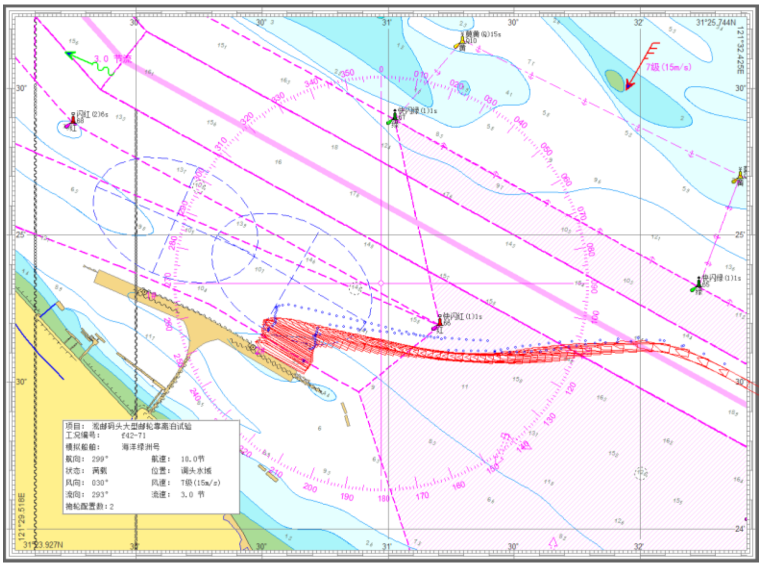

Figure 2.11 The Second Berthing Method

Source: Baoshan MSA

3) During the period time of ebb tide, with the flood tide, the cruise ship can get alongside with tide at appropriate time. Under this method the cruise ship need to turn around by the starboard side, and then alongside with current. Before berthing, the cruise ship should cross the main fairway at the upstream of No. 66 light buoy, and then turn around at the upstream of the berth, finally the cruise ship carries out berthing with current. There are 2 points that should be paid attention. i) Avoid prematurely completing turnaround, which may cause vessel position too far from the berth. It is difficult for berthing when the starboard side receive the current. ii) The cruise ship should pay attention to the shallow water area at the upstream of the link line between upper corner of the berth and No.68 light buoy. See Figure 2.12.

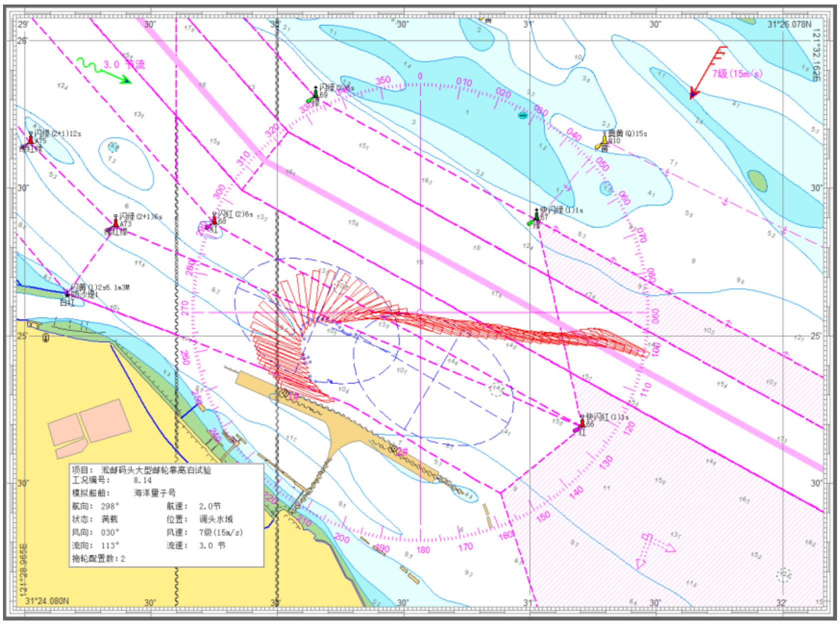

Figure 2.12 The Third Berthing Method

Source: Baoshan MSA

4) During the period time of ebb tide, the cruise ship can get alongside against current. This method is the normal way for berthing and the ship's port side gets alongside. If berthing at berth No.2 or berth No.4, the cruise ship should cross the main fairway at the downstream of No.66 light buoy. But if berthing at berth No.1 or berth No.3, the cruise ship should cross the main fairway at the upstream of No.66 light buoy, and then berth against the current. See Figure 2.13

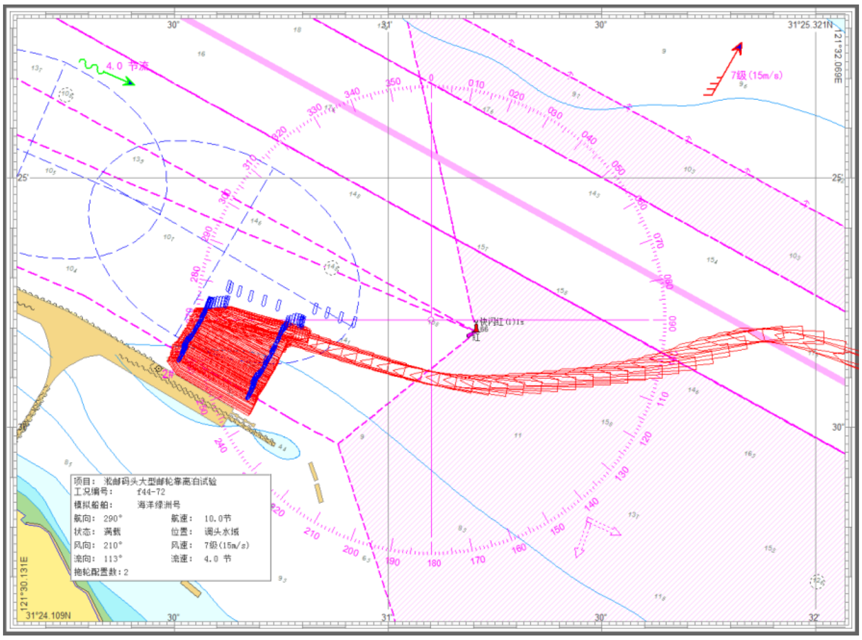

Figure 2.13 The Fourth Berthing Method

Source: Baoshan MSA

When arriving at the waters for turnaround, the cruise ship should maintain a sufficient transverse distance with the berth. After using the main engine, rudder, lateral thruster, and tugboat to assist in completing the turnaround operation, a sufficient transverse safety distance to the berth must be maintained before berthing operation. The cruise ship should not turn around while berthing.

2.5.2 Departure Operation

It’s similar with the berthing operation, the departure operation are divided into 4 situations as well.

1) The cruise departure at flood tide against current. This method is the normal way of departure. The ship's starboard side gets alongside, and departure directly against the current. Generally, ship’s bow departed from the berth at first, and then the cruise ship start to speed up for navigation in the fairway when there is a sufficient transverse

distance between the ship and the berth. Regarding this method, the following points should be taken notice of: Depart from berth No.1 and berth No.3, it is recommended to pass by the starboard side of light buoy No.66 for entering the main fairway. But if departure from berth No.2 and berth No.4, the cruise ship should pay attention to the poor water depth located in the link line between the down corner of WSKICT and light buoy No.66. See Figure 2.14.

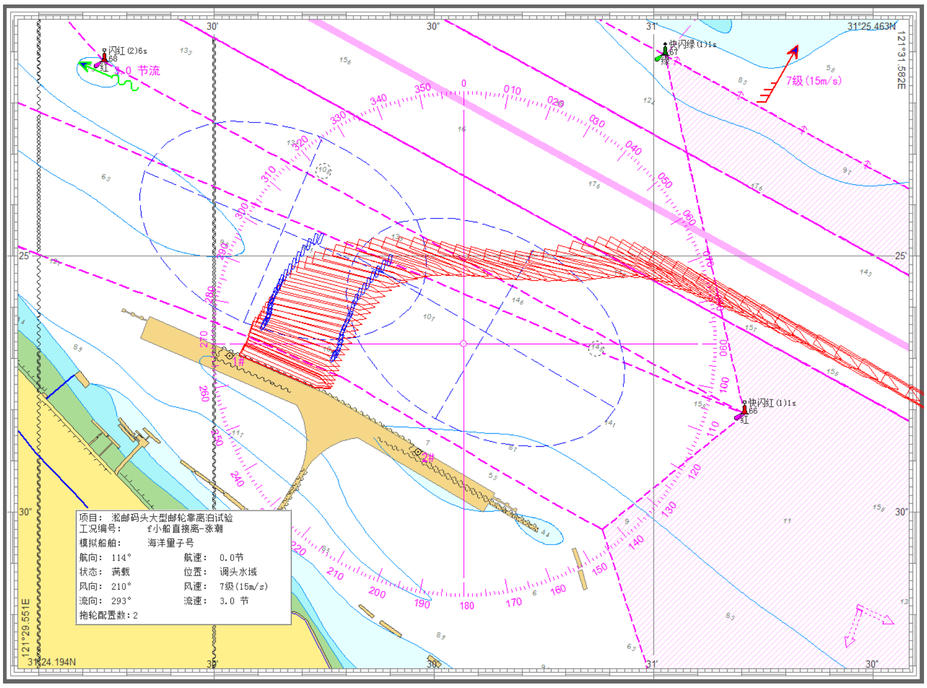

Figure 2.14 The First Departure Method

Source: Baoshan MSA

2) The cruise ship departure at ebb tide with current. The method is to directly depart from the berth with the current. The ship's stern should depart primarily, for ensure that the inner side of the ship always receives the current and gradually increases the drift angle. At the same time, it must also avoid the ship's forward rush drastically.After the ship can move transversely to obtain sufficient transverse distance (same as the ship's length), and then speed up for entering into the fairway. The cruise ship should avoid departure from the berth with the current in fastest flood

tide or fastest ebb tide. In the process of the cruise entering into the main fairway, owing to the effects of ebb tide current, the ship will drift to the downstream side, and it may easily cause navigational hazards when there is heavy traffic around the ship. After departure from the berth No. 2 and berth No.4 departing, it is recommended that the cruise ship passes by the light buoy No. 66 on the ship's port side for transiting the main fairway. But the cruise ship takes notice of the poor water depth located in the link line between the down corner of WSKICT and light buoy No.66. See Figure 2.15.

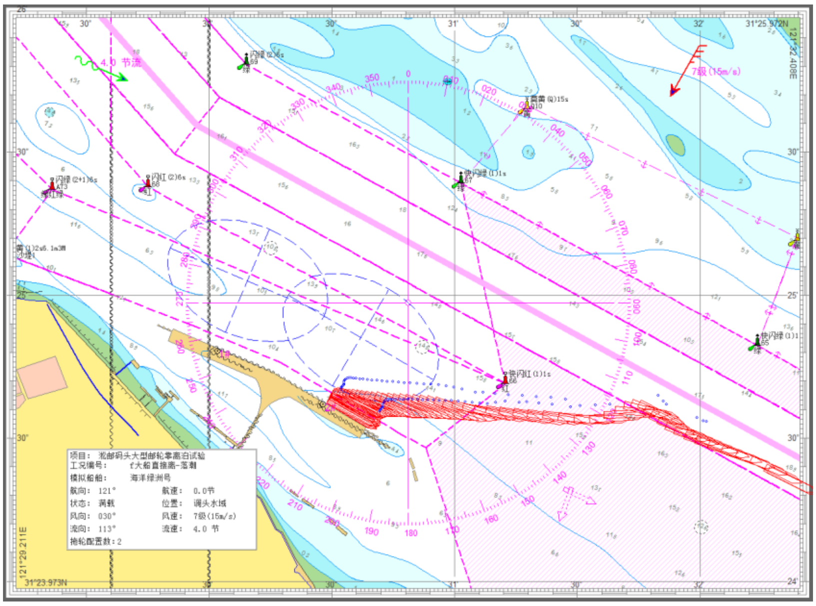

Figure 2.15 The Second Departure Method

Source: Baoshan MSA

3) The cruise ship departure at flood tide with current. This method is that the cruise ship should turn around for departure from the berth with the current. The ship’s stern should departure firstly, for ensure that the vessel always receives the current at the inner side of the cruise ship, and then gradually increases the drift angle. At the same time, the cruise ship must avoid the ship's forward rush drastically. In addition, the ship can move transversely to obtain enough transverse distance, which is at least 100 meters, and then turns the left. After turnaround, the cruise ship enters into the main fairway against the current. The cruise ship should avoid departure from the berth with

the current in fastest flood tide or fastest ebb tide. When carrying out this operation at the berth No.1 and berth No.3, the cruise ship should pay attention to the shallow water area at the upstream of the link line between the upper corner of WSKICT and light buoy No. 68. The cruise ship shoul avoid the impact of the flood tide current, or it may drift to shallow water further to cause grounding. See Figure 2.16.

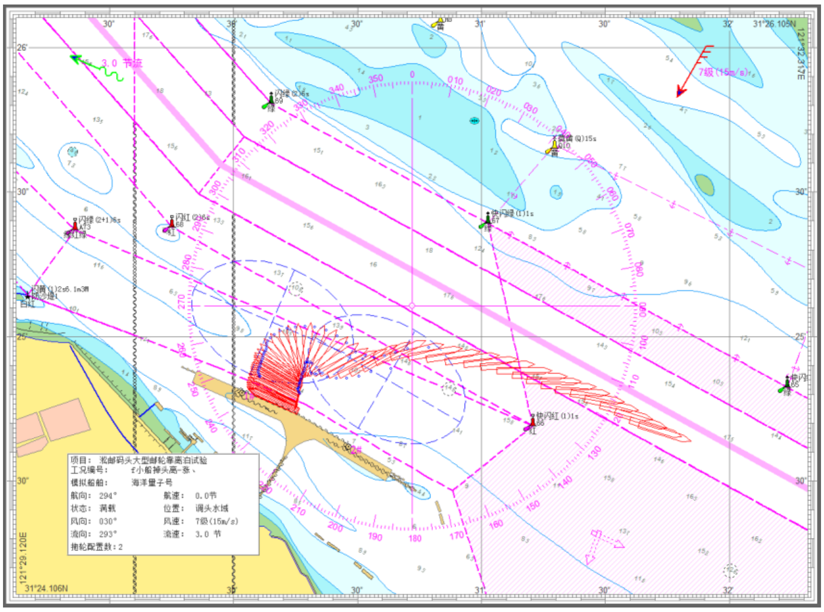

Figure 2.16 The Third Departure Method

Source: Baoshan MSA

4) The cruise ship departure at ebb tide against current.. This method is the normal way of departure. The ship's port side gets alongside, departure from the berth against the current and turn right. After turnaround, the cruise ship enters into the main fairway with the current. The cruise ship should pay attention to the influence of drift caused by current and effects from other ships; Depending upon the specific circumstances at that time, the cruise ship can decide to pass which side of light buoy No.66. But the cruise ship should take notice of the poor water depth in the link line between the bottom corner of WSKICT and the light buoy No. 66. See Figure 2.17.

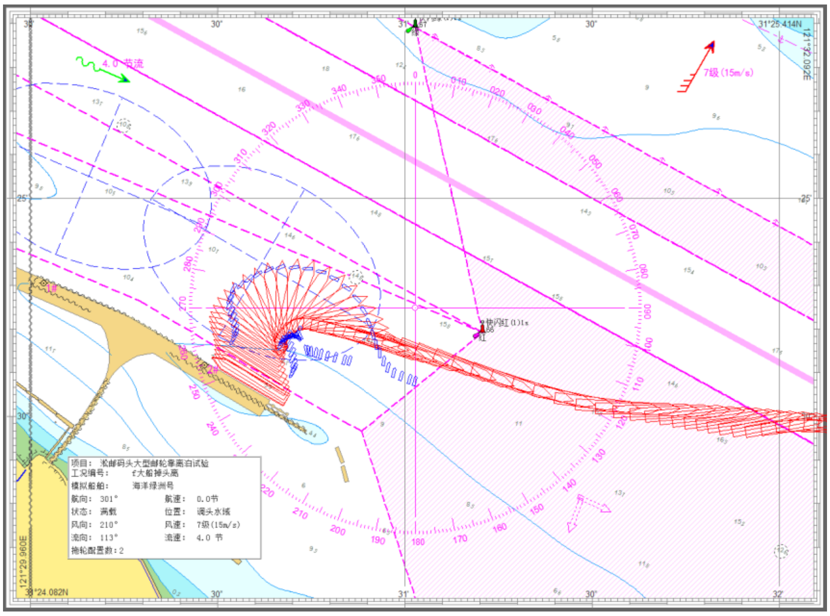

Figure 2.17 The Fourth Departure Method

Source: Bashan MSA

2.6 Summary

In this chapter, the author introduces the geographical location of WSKICT, the fairways nearby it, traffic flow, and point out the characteristics of the traffic flow. According to the related statistics and Pearson correlation analysis, the characteristic of vessel number variation can be easily explained. According to the analysis, it shows that the variation of tide affects significantly the vessel number in BSSF, the affection is relative smaller for the vessel number in BSF, as for the CJDP, the variation of tide almost has no any affection. In succession, manoeuvre characteristics of large cruise ship are listed, these characteristics is significantly different with the ordinary commercial ship, besides, the Pod propulsion system, a common propulsion system fitted on the large cruise ship, whose characteristics are show. This chapter can be the basis for the following research.

Chapter 3

Hazards Identification

3.1 Basic Knowledge of FSA

In 1988, a huge offshore oil drilling platform explosion accidents happened in British, the fire caused a great loss of human lives and property. For avoiding the similar catastrophe, the related parties of British established corresponding regulations, which stipulated all the parties should prepare for the safety case. Safety case is a kind of document which contains the measures that prevents the potential risk may lead to the accidents. Safety case is the prototype (Wu, 2013). Afterwards, on the basis of safety case, FSA was developed and proposed by the British MSA at the 62th Maritime Safety Committee (MSC). The big difference between FSA and Safety case is that FSA doesn't merely applied to the vessel but all the aspects of maritime safety. Therefor, IMO encourage their member states to use FSA for the purpose of maritime safety. FSA usually consists of 5 steps, hazards identification, risk analysis, risk control options, cost-benefit assessment, recommendations for decision-making (Zhao, 2005). The specific steps can been seen in the Figure 3.1

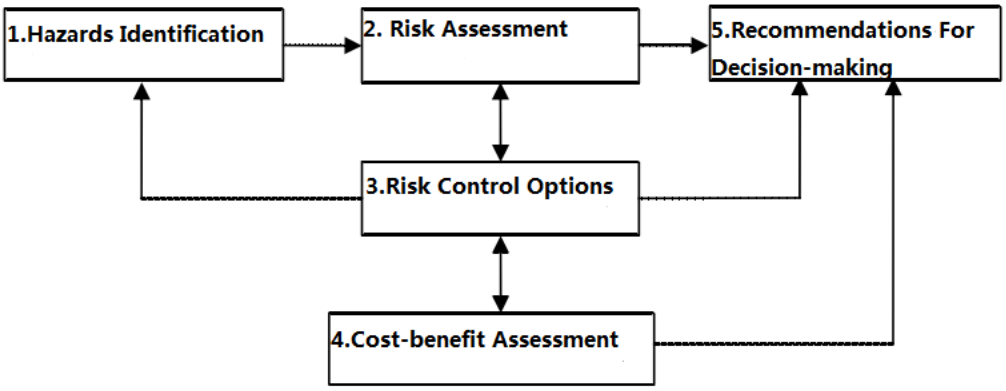

Figure 3.1 Flowchart of FSA

Source: www.baidubaike.com.cn (modified by author)

3.2 Method for Identification of Hazards

In this step, scientific and reasonable method need to be used to identify the potential risk source. Lots of methods can be used for the identification of hazards, such as brainstorming, fault tree analysis, event tree analysis, failure mode and effect analysis (FMEA). etc. Fault tree and event tree is used for qualitative analysis and quantitative analysis on the basis of accidents historical statistics, these methods lack of initiative of hazards resource. As for brainstorming method, the experts discuss and look for the potential hazards resources forwardly, it’s less restricted by the historical statistics (Qin et al, 2005). Therefor, this paper chooses the brainstorming to conduct the resource identification.

3.3 The Investigation Process of Risk Resource

To discover the risk source of cruise ship for berthing and departure at WSKICT, the author find the related experts, after discussion over again and again, experts gives their own views and difficulty analysis regarding the berthing and departure operation. The difficult analysis is listed as follow:

3.4 Difficult Points of Berthing and Departure

With the completion of the renovation and expansion of the second phase of WSKICT, there may also be extreme situations where two cruise ships or three or four cruise ships get alongside at the terminal in a day. The increase in demand isn't consistent with the heavy traffic and safety normal operation within the fairway. Therefor, it requires a comprehensive, scientific and cautious analysis of the operation difficulty of the cruise ship in relation to berthing and departure, so as to avoid the occurrence of cruise ship safety incidents.

3.4.1 Small manoeuvre space

The water surrounded by the four-point connection line, the four points are as follow: light buoy No. 68, light buoy No. 66, down corner of WSKICT, upper corner of WSKICT. This water is the core area where the cruise ship conduct departure and turnaround operation(See Figure 3.2). Due to the long-term existence of shoal and poor water depth in the upstream of the area, the downstream is the only way for many small vessels entering and leaving the Changjiang River and the Huangpu River. The ships' density is very large, and turning area cannot be matched when WSKICT is expanded. When several ships berth,departure or turn at the same time, This situation may greatly increase the spatial congestion extent, and the chance of collision danger will also greatly increase. Therefore, the limitation operation permission should be restricted to the fact that the two ships should turn,berthing or departure at the same time, and they must not berth or departure from the adjacent berths so as to avoid too close distances further to increase risks.

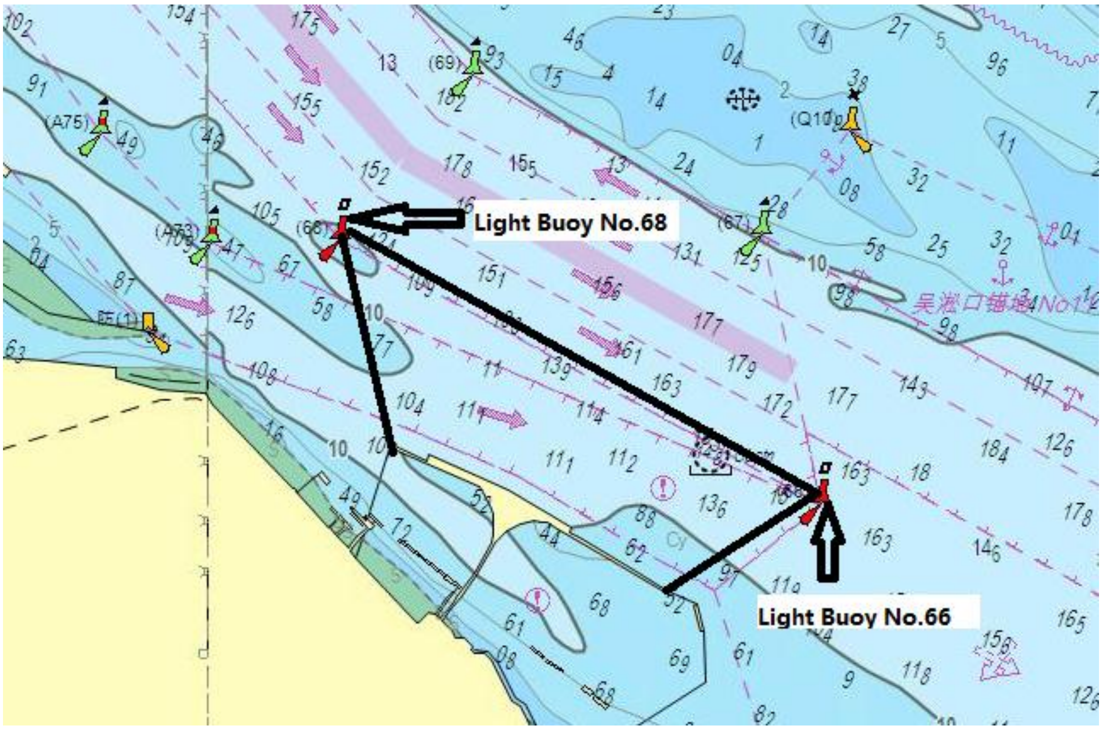

Figure 3.2 Core Area of WSKICT

Source: Chuanxun net (modified by author)

3.4.2 Tide Current

According to the present design, it can be seen that the berth No.2 and berth No.4 are basically the same as the main fairway course (300° /120°). The shore is mainly characterized by reciprocating current, and the advection duration time is short; there is a certain angle between berth No.3 and the main fairway, in addition, the current direction is slightly changed. The peak value of current velocity is generally appeared 1.5 hours after the current direction changes, and the daily current velocity is around 2 knots even up to 3 knots (summer flood season). The cruise ship can better control its own position when against the current or with the current, but it is susceptible to cross-current when the ship is turning around. The cruise ship is prone to cause drifts by current when the current is rapid. Therefore, it is necessary to avoid that large cruise ship berths or departs during fastest flood tide or fastest ebb tide.

3.4.3 Turning Waters

The turning water area of the cruise ship coincides with the BSSF. As the analysis in chapter 2.2.2.3, since small and medium vessels entering and leaving the Huangpu River and the Changjiang River usually navigate with tide currents, the traffic flow of small vessels is particularly intensive during two hours before the Wusong low tide and within two hours after the low tide. The detailed situation are presented as follows:

1) Yellow sand vessel with heavy load leaving the Changjiang River: these vessels normally will turn near light buoy No.66 for entering into the Huangpu River. Generally, it starts two hours before the Wusong low tide, and its peak time is from one hour before Wusong low tide to half an hour after Wusong low tide. Its characteristic: large ships' density, ships navigates in parallel row, more width of fairway are occupied, deep draft, slow speed.

2) The yellow sand vessels without load leaving the Huangpu River and sail towards the upstream of Changjiang River, they may choose to cross the BSSF through the water between light buoy No.64 and light buoy No.66 for entering into the BSF. It normally starts at one hour before Wusong low tide, Its peak time is from half an hour before Wusong low tide to one hour after Wusong low tide. Its characteristics are the following points: large ships' density, smaller space is left to other ships, large wind area of unloaded, slow speed after leaving the Huangpu River, the vessel usually choose to cross the water between light buoy No.64 to light buoy No.66 to sail inward the Changjiang River, slow crossing speed.

3) The time period in which the two intensive ship flows superimposed on the cruise ship is: 1 hour before the Wusong low tide and 1 hour after; the dense area may affect the cruise ship: the waters between the light buoy No. 64 and light buoy No.68 (including the main fairway, BSSF, WSKICT front water). If two large cruise ship berthing or departure at the same time occurs because of the requirements of cruise ships' punctuality, the scope of occupied waters will vary greatly. Furthermore, the duration time of berthing & departure operations will also be elongated. This will inevitably cause traffic conflicts with the intensive ship flow, and increase the difficulty and risk of berthing and departure.

3.4.4 Weather

The local weather is complex and changeable. In summer and autumn, it may experience thunderstorms or typhoons. It is often hazy in the winter and spring season. When it is poor visibility caused bad weather such as heavy snowstorms, drizzles, swift fog, and frontal fog, it will brings about great danger on the berthing and departure operation of the cruise ship.

3.4.5 Special Berthing Requirements For Berthing

The special berthing requirements of some ships, such as embarkation and disembarkation equipments of "Quantum of the Seas" the starboard side, so it has always been required to berth on the starboard side, which not only limits the effective use of the tide, but also brings about the risks and difficulties due to turnaround against the tide and berthing with the tide.

3.4.6 Wind

It is more difficult to conduct berthing and departure operation in windy day. The cruise ship has strong power, but its wind area is very large. When the leaning abeam wind reaches level 8 or above, the combined force of the main engine, rudder, thruster, and tugboat is not enough to counteract the comprehensive influence of the wind and current. Consequently when the blowing-in winds 8 or above at the abeam, large cruise ships should suspend the berthing and departure operation.

3.4.7 Manoeuvre Performance

Differences in operation performance of cruise ships with different propellers and power configurations. The manoeuvre of pod propulsion systems such as “Azipod” is obviously better than that of “double rudders”; the safety of berthing and departure for cruise ships with traditional rudder and main engine combination configurations is stronger than that of cruise ships with only stern thruster.

3.5 The Risk Analysis of Vessel Berthing and Departure

As above mentioned difficulty points, experts list all the difficulty points during the berthing and departure operation, and then experts analyze the risk and propose the several types of risk as below:

3.5.1 Manoeuvre Performance and Structure Characteristics

The super large cruise ship is better than the traditional cargo ship in terms of ship manoeuvre performance, but it also has obvious unfavorable features, such as:

1) The superstructure is huge, the clearance height is high, and the lateral area is large, so the windage area is large (larger than the wind area of a container ship of the same size).

2) The turning center of the ship is generally 1/5 to 1/3L away from the stempost. Obviously, the turning center of the cruise ship is behind the bridge. This is very different from the maneuvering habits of the aft-engine vessel.

3) Because the bridge of the cruise ship is at the bow and the superstructure is high, it is easy to look out at the bow. However, the blind area on ship's both sides are large, especially in the stern direction. Hence, It is difficult to look out on ship's both sides and stern direction.

4) Huge Inertia of the movement: large cruise ship has huge tonnages, therefor, It's when starting and braking.

3.5.2 Meteorology

Meteorology factors usually are various, in this section, meteorology can be decomposed into the below points:

1) Poor visibility: Poor visibility is mainly affected by fog, heavy rain, and heavy snow in Shanghai Port, The longest fog days in Shanghai Port are 40 days, and the average number of fog days over the decades are 28 days. In March and April of each year, it is a foggy season. Advection fog is characterized by long duration and wide range (Xu, 2014). This period is also a peak season for a large number of cruise ships which will berth at WSKICT. The poor visibility not only causes a great impact on the punctuality of the cruise ship, but also it causes a great risk to the safety of the cruise ship.

2) Gale: The winds in Shanghai Harbor experienced seasonal changes, with more NE or NW winds in winter, and more SE winds in summer. The mean wind force greater

than 8 are about 15 days (Shi et al, 2015). The factors that produces gale including: Firstly, the cold air in winter passing southwards; Secondly, the Jianghuai cyclone in the spring near the Changjiang Estuary enters into the sea; Thirdly, the typhoon in summer; In addition, small-scale weather such as thunderstorms, and tornadoes. All above factors cause the gale in Shanghai.

3) Tides and Trends: The index that defines the tidal size of the Shanghai Port is the tidal range. In other words, that is the difference between the high tide height and the low tide height in the same tide. Therein, the trends that produced by the large flood (usually appearing around the first day or the fifteenth day of each month of the lunar calendar) where the tidal range is between 2.75 m and 3.66 m will bring certain risks to the berthing and departure operation of large cruise ships(Shao, 2015). In addition, the super large flood with a tidal range greater than 3.67 m (generally occurring during the flood season or storm surge) causes the risk to the berthing and departure operation.

3.5.3 The Tide and Water Depth

The water depth of the fairway and the terminal should be bounded by the -10m isobath. There are shallow water areas with variable depths at the upstream of WSKICT(the link line between the upper corner of berth No. 3 and light buoy No. 68). The water depth at the downstream of the terminal (berth No.4) is poor. When the tide is fastest ebb tide, the cruise ships usually get alongside at berth No. 4; when the tide is fastest flood tide, the cruise ship usually gets alongside at berth No.3. Especially when the two cruise ships operate together, it's difficult to arrange the berth properly for both ships.

3.5.4 Traffic Flow

Since the overlap of the cruise ship turnaround area and the BSSF, when the cruise ship crosses the fairway for berthing or departure from the WSKICT, at the same time, the vessels loaded the yellow sand transit the above mentioned waters nearby WSKICT. On these above mentioned occasions, There are many risks, such as position adjustments between ships (eg, overtaking), crossing situation at the fairway interchange, collision accidents caused by intensive vessel flow and so on.

3.5.5 Unexpected Risk

The risk of berthing and departure operation due to various accidents and emergencies, such as the sudden gale, own ship or the other ships are not under command, interrupting the navigation order when encountering the dense fog and so on.

3.6 The Analysis Result

Through the analysis, experts induce the above key points, and propose a terse framework to sum up the risk factors. The safety of cruise ships entering and leaving Shanghai Port is usually affected by their own conditions, natural environment and traffic environment. In natural environment, visibility, wind and current play a significant role, in addition, the influence of fairways and ship traffic flow in traffic environment is prominent. Overall, the risk factors are mainly affected by the external environment, the cruise ship own condition will not be considered as the main factor. The dynamic risk that the cruise ship may suffer will be classified as two main factors, and each main factor contains several sub factors. As shown in Figure 3.3.

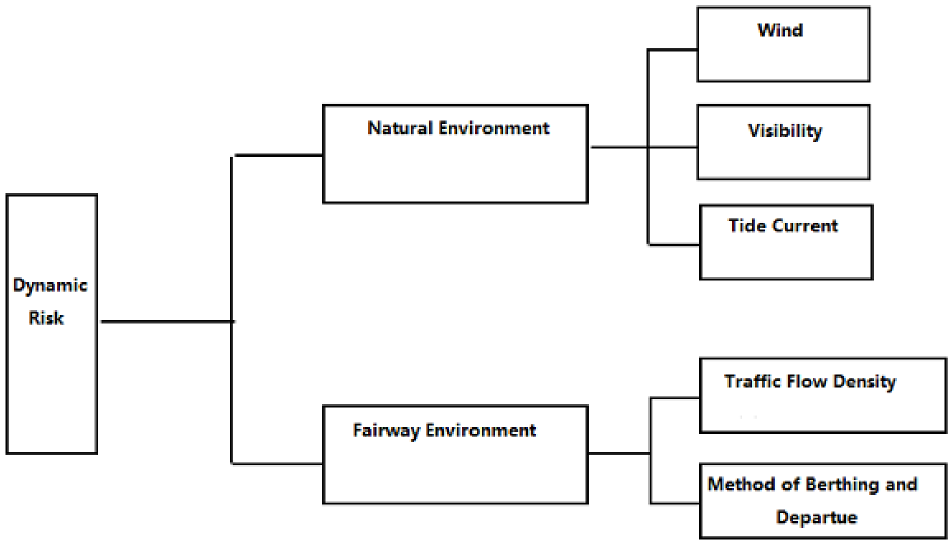

Figure 3.3 Risk Analysis Framework

Source: Compiled by Author

Therein, the wind in the analysis framework mainly refers to the impact of wind force on the ships' berthing and departure operation at the berth; the visibility refers to the visible distance to the ship; the tide mainly refers to the impact of the ebb tide and flood tide of the ship's four kinds of manoeuvre modes; traffic flow density refers to the influence of ship flow in the fairway when the ship's cycling; the method of berthing and departure operation primarily must consider the situation that both vessels conduct berthing and departure operation.

3.7 Summary

In this chapter, the tasks of risk identification and analysis are completed, these can be the basis of risk assessment. With the help of experts, firstly, this chapter ascertains the difficulty points of berthing and departure operation. Secondly, continue to analyze the risk factors on the basis of the difficulty points. At last , the risk framework is completed, through this framework, the risk can be easily understood and is beneficial for the study of next chapter.

CHAPTER 4

Risk Assessment Of Berthing and Departure Operation

According to the risk factors proposed last chapter, the cruise ship is mainly affected by the fairway environment and the natural environment, and these two aspects are in dynamic statues with the external conditions, it has uncertainties, and cannot be accurately quantified in the risk assessment. Fuzzy Synthetic Evaluation (FSE) is a kind of important method for coping with this kind of dynamic risk (Li et al, 2009). In this paper, to easily understand the risk evaluation, on the basis of FSZ, fuzzy inference in artificial intelligence (AI) theory is introduced, and use a fuzzy inference system (FIS) to achieve a dynamic quantitative assessment of the cruise ship berthing and departure risk.

4.1 Basic Knowledge of Fuzzy Synthetic Evaluation (FSE)

In 1965, American expert Pro.L.A. Zadeh proposed the concept of fuzzy sets theory for expressing the uncertainty of objects. After continuous development, FSE theory is improved and perfected(Liu, 2018). The FSE is a kind of synthetic evaluation method on the basis of fuzzy mathematics. According to the membership theory of fuzzy mathematics, this synthetic evaluation method transform the qualitative evaluation into quantitative evaluation, in other words, with the help of fuzzy mathematics, this method can make a synthetic evaluation for the object that may be restricted by various of factors. It usually has the characteristics including clear result, strong systematicness, owing to these characteristics, this method can settle these problems that is fuzzy and difficult to be quantitative, suitable for the settlement of various of uncertain problem(Ouyang, 2009). Generally, it can be divided into 5 steps. First step, determination of FSE index. FSE index is the basis of synthetic evaluation, if the evaluation index is not suitable, it may affect the accuracy of synthetic evaluation(Li, 2007). Determination of index should absorb industry information or the related law and regulations widely. Second step, determination of the relative weight vector. Third step, determination of judgement matrix, usually use suitable membership function to determine the judgement matrix. Fourth Step, the combination of judgement matrix and weight.

Fuzzy Inference System (FIS) is applied to artificial intelligence (AI) to settle kinds of uncertainty problem. Its theory basis is from the fuzzy mathematics, and it's a kind of study method of FSE as well(Huang, 2011). Fuzzy inference is similar with the human mentality process, therefor it contributes the settlement of uncertainty problem. The fast growing AI technology applies this kind of technology to simulate the human brain. In this paper, with FIS of AI, the calculation process can be transformed into function image. Owing this, the model can be easily understood.

4.2 FIS-based Dynamic Assessment Model

In line with the analysis in the last chapter, experts find these factors that may affect the safety of cruise ship, now, with the help of AI , the membership function of all the factors are determine, and then the through these functions, the FIS model is determined, furthermore, the dynamic risk can be better understood and find the reasonable suggestions. Since the analysis of last chapter, the factors are decomposed into two types of main factor, and the process is listed as follow:

4.2.1 Natural Environment

4.2.1.1 Wind

The wind is quantified according to the wind level, and its universe is defined as the range between [0,12], which is represented by three fuzzy subsets of “low”, “average”, and “high”. Parameters which is lower than the lower limit of the domain are treated in accordance with the lower limit of the universe, and the parameters which is higher than the upper limit of the universe are treated in accordance with the upper limit of the universe. When the wind force is below level 3, it has no effect basically. When the wind force exceeds the level 6, it begins to have a significant effect. Figure 4-1 shows the triangular membership function:

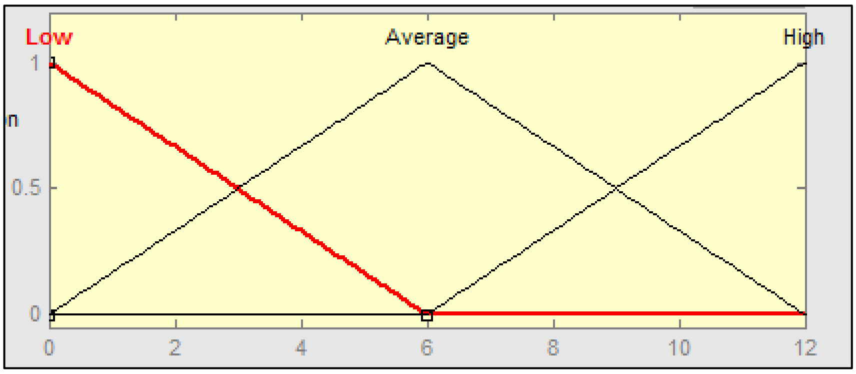

Figure 4.1 Wind Membership Function Model

Source: Compiled by author

4.2.1.2 Visibility

The visibility (nautical) universe is defined as the range between [0,5], and is represented by the three fuzzy subsets of "bad", "general", and "good", as shown in Figure 4.2.

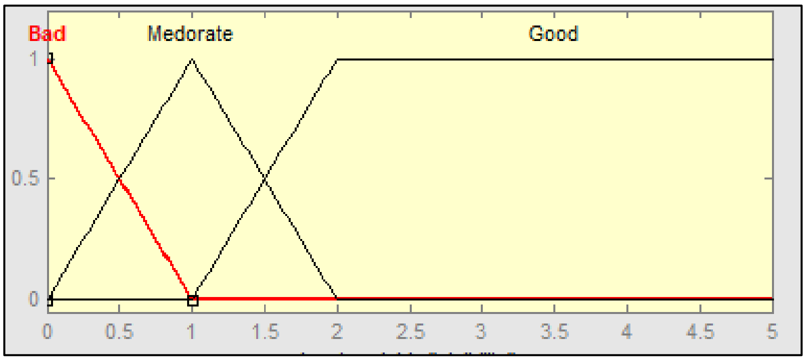

Figure 4.2 Visibility Membership Function Model

Source: Compiled by Author

4.2.1.3 Tide

According to a tidal cycle, it can be divided into two parts: fastest flood and fastest ebb, high water stand and low water stand. When they are fastest flood and fastest ebb, it has a greater impact on ship's manoeuvre. But the high water stand and low water stand are less affected, the universe is defined as [0, 1], use these two fuzzy subsets "fastest flood and fastest ebb" and "high water stand and low water stand," as shown in Figure 4.3.

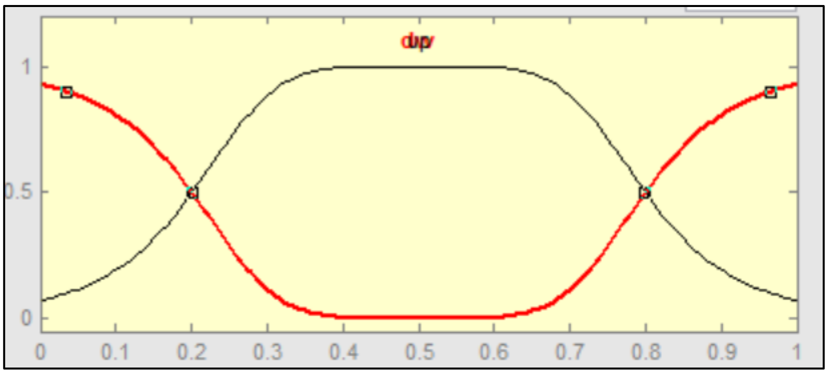

Figure 4.3 Tide Membership Function Model

Source: Compiled by author

4.2.2 Fairway Environment

4.2.2.1 Traffic Flow Density

The number of ship is used as an indicator to measure traffic flow density. The universe is defined between [0,80] and is represented by three fuzzy subsets of "small", "meddle", and "large", as shown in Figure 4.4.

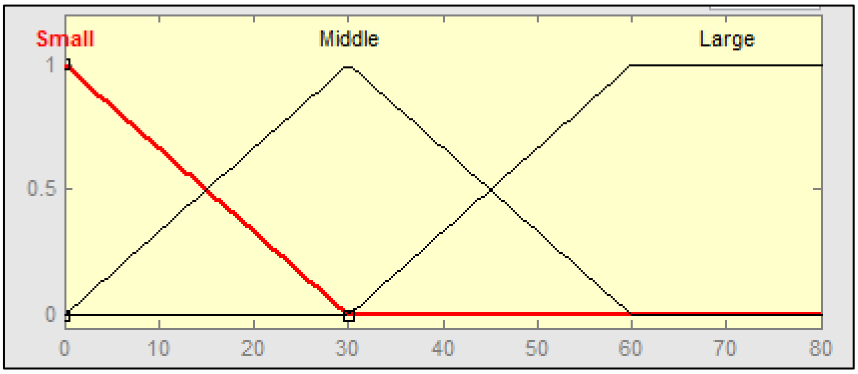

Figure 4.4 Traffic Flow Membership Function Model

Source: Compiled by author

4.2.2.2 The Method of Berthing and Departure

According to the plan of WSKICT, it is divided into two ways: single ship berthing and double ships berthing.Therein, the second method has a larger impact, the impact is relative small when a single vessel berths. The universe is defined as [0,1] and is represented by two fuzzy subsets of "single ship" and "double ships". As shown in Figure 4.5.

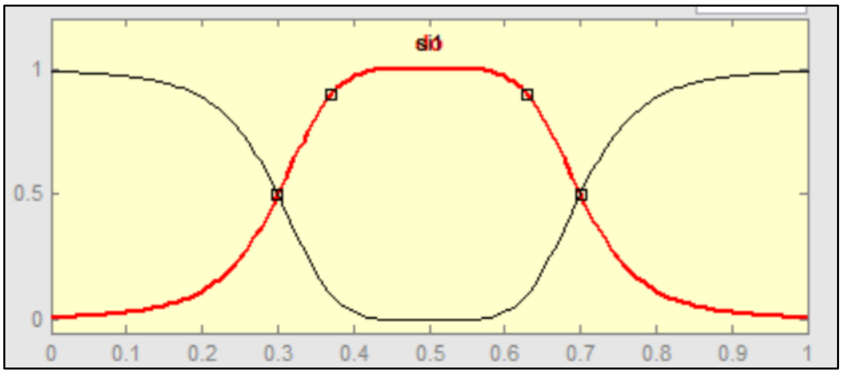

Figure 4.5 The Method of Berthing and Departure Membership Function Model

Source: Compiled by author

4.2.2.2 Integrated FIS Model

Integrate the fuzzy models of the above four factors, we take wind, visibility and tide factors as natural environment factors, for designing the FIS inference rules, and finally obtain the integrated reflection of the natural factors. In addition, the traffic flow density and berthing & departure method are taken as the fairway environment factors, in accordance with the inference rules. Integrated reflection are obtained, then the natural factors and the fairway environment factors will be integrated and taken as output. The universe is defined between [0,10], and the three fuzzy subsets "low risk", "average", and "high" are represented as shown in Figures 4.6 and 4.7.

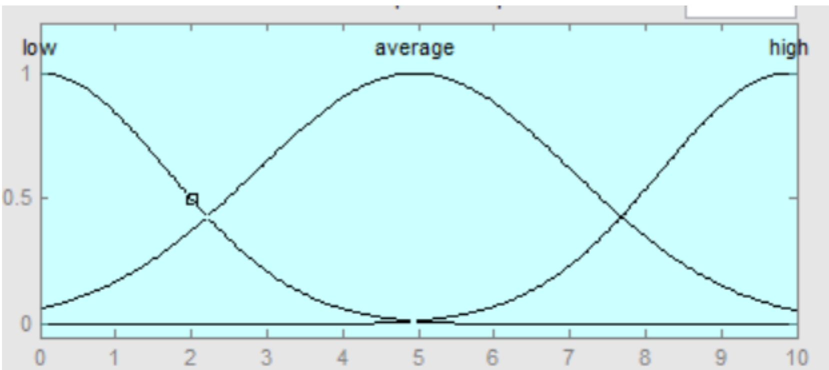

Figure 4.6 Overall Dynamic Risk Membership Function Model

Source: Compiled by author

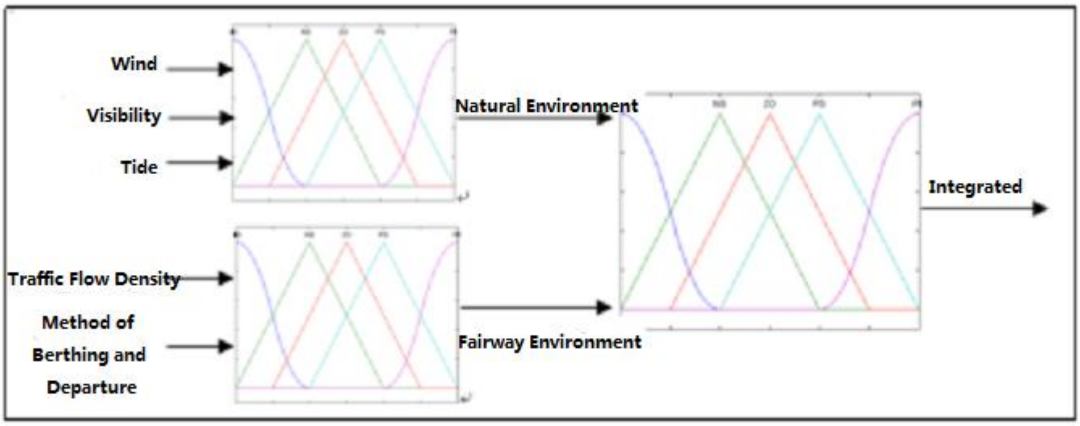

Figure 4.7 Integrated FIS Model System Structure

Source: Compiled by author

4.2.3 Assessment Effect Analysis

Since berthing and departure operation environment is in a dynamic change, the degree of risk will also change. Based on the established fuzzy inference system model and the actual environmental conditions, the risk factors are quantified with the above-mentioned membership function models and brought into the software to yield a synthetic risk output value, and determine the risk level that meets the prevailing circumstances. Dependent upon the current berthing and departure conditions of WSKICT, when various factors are in good condition and the risk level is in general risk, at this time, the quantified risk value universe is 4.63. This result biased towards general risk in the assessment model. As shown in Figure 4.8.

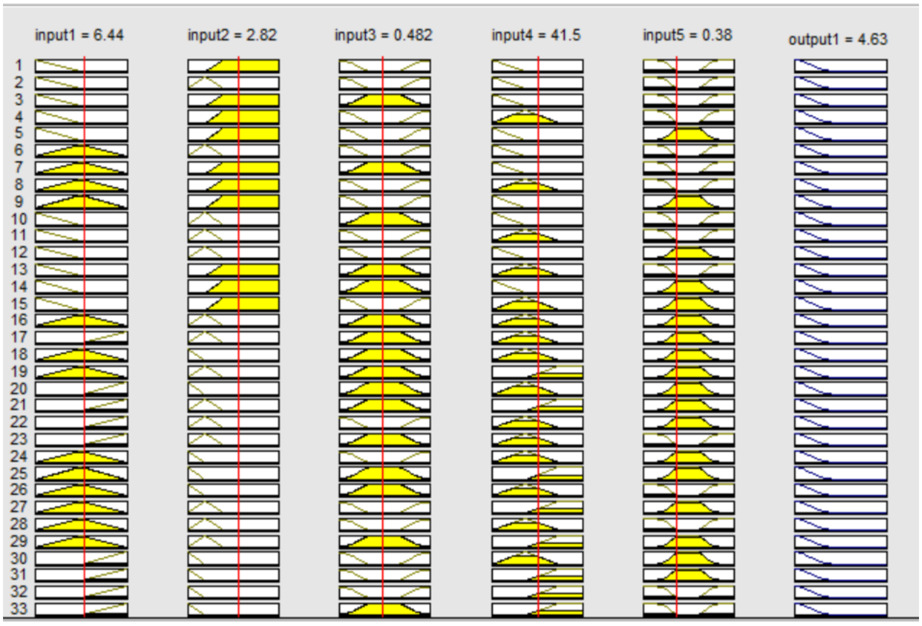

Figure 4.8 The Quantitative Result of Risk Assessment

Source: Compiled by author

When the risk components of the model change, the corresponding degree of risk will change. Since each risk component is ambiguous, it cannot be accurately quantified. Therefore, according to the model design, the combinations that may pose high risks are listed as follow(See Table 4.1)

Table 4.1 High Risk Combination

Wind	**Visibility**	**Tide**	**Traffic Flow Density**	**The Method of Berthing and Departure**
Large	General	Fastest Flood Fastest ebb	Middle	Single Ship
Large	General	Fastest Flood Fastest ebb	Middle	Double Ship
Middle	General	Fastest Flood Fastest ebb	Large	Double Ship
Middle	Poor	Fastest Flood Fastest ebb	Large	Double Ship
Small	Poor	Fastest Flood Fastest ebb	Large	Double Ship

1) While double ships are berthing at the same time, the universe value is in the high risk interval assuming that there is any situation where wind force is greater than or equal to 7, visibility is poor, fastest flood, fastest ebb or intensive traffic flow, at this time, Under the above-mentioned situation, the berthing of double ships should be avoided.

2) While the visibility is poor or the wind force is greater than or equal to 7 and the traffic flow near WSKICT is intensive, the universe values are in the high-risk interval. The cruise ship should navigate with particular caution and pay attention to avoid collision.

3) While the wind force is greater than or equal to 7 and the tide is fastest flood & fastest ebb, the universe value is in the high-risk internal, and berthing and departure should be avoided as far as possible.

Therefore, when vessels conduct berthing and departure operation, each influence factor should be considered so as to comprehensively assess the degree of risk, and the cruise ship should be cautious for the occurrence of adverse conditions of two or more influence factors which may cause high-risk conditions.

4.3 Summary

In this chapter, the author use the method of mathematics to model and analyze the risk, through this method, the uncertain risk can be quantitative and be easy to find the risk combination, furthermore, it can supply the reference to the decision makers. Therefor, the related measures can be taken to ensure the safety of cruise ship to the maximum extent.

Chapter V

Measures For the Safety of Cruise Ship

After a series of discussions and analysis, some measures are proposed to be taken for ensure the safety of cruise ship, these measures cover many different aspects, and give some emergency plans to cope with the emergency situations. At last , this chapter gives some recommendations on the management and training level.

5.1 Safety Precautions

In order to effectively protect the safety of berthing and departure of large cruise ships at WSKICT, the following measures and recommendations are proposed:

1) While encountering unexpected poor visibility, the U-turn or berthing and departure operation should be suspended in time. The cruise ship should decisively select the safe waters to anchor or waiting for mooring, wait until visibility improves, and obtain permission from the MSA before resume the relevant operation.

2) The cruise ship encountered unexpected gale. As the normal tugs assist, the effective dragging force is usually 40 to 50 tons. Once the wind force exceeds level 8, the actual effect of the tug falls below 70% as the wind becomes larger. When the wind force abeam is so large that the cruise ship can't overcome the comprehensive influence of the wind and current only by the ship's own power (engine power, rudder, lateral thruster) and tugboat assistance, it is necessary to suspend the berthing and departure

operation in time, then wait until the wind force falls and resume the operation. As for typhoon attacks in summer and autumn, cruise ships at WSKICT should be evacuated to ensure the absolute safety of personnel and property.

3) When the cruise ship is in the process of berthing and departure operation, then encounters accidents or emergency situations, such as main engine is out of control, visibility drop rapidly caused by sudden heavy snowfall or heavy rain. etc. The cruise ship should take effective measures such as anchoring to avoid further deterioration of the situation further to suspend ongoing operations. At the same time, the cruise ship should promptly notify nearby ships, and then wait for accidents to be eliminated. Once eliminating unexpected situations and the cruise ship recovers the normal airworthiness, the cruise ship can resume the berthing and departure operation.

4) Due to the punctuality of berthing and departure operation for cruise ships, it is sometimes difficult to avoid encountering intensive traffic flow while passing the waters near WSKICT. As a result, the risk of navigation increases when the cruise ship departure from the berth and turnaround. At this time, MSA can organize the traffic flow on the scene, MSA patrol boat and tugboats can guide, coordinate and handle emergency situations nearby the waters. With these measures, ample waters can be made. When the cruise ship crosses the fairway, tugboats at the upstream and downstream of fairway can remind the vessels which is transiting the fairway. VTS should release the information in relation to the berthing and departure operation in time. Meanwhile, for the safety of cruise ship, " China Coastal Tide Tables (Shanghai, Hangzhou Bay)" should be referred by the MSA, pilot and seafarers. The specific plan should be accomplished so as to reduce the threaten from the traffic flow in the BSSF.

5) The master of a large cruise ship has sufficient navigation experience and is well

aware of the operational performance of the cruise ship. Pilots and masters should be more closely communicate with each other and respect each other. Pilots should initiatively inquire about the operation characteristics of the ship before implementing the pilotage operation. In particular, more and more large cruise ships adopt pod electric propulsion systems. Pilots should acquire relevant knowledge further to understand the characteristics of such power systems. Be aware of its advantages and limitations. At the same time, the pilotage plan, the relevant conditions of the port, especially the wind and the current, should be actively informed to the captain, and they should cooperate closely and ensure safety in the process of berthing and departure so that they can successfully complete the operation.

6) When leaving or arriving at WSKICT at night, the light signal (search and rescue lights, Morse light, etc.) should be placed in a suitable position and ready for use. When the relevant small vessel is not able to communicate successfully, the sound and light signals are used to warn earlier.

5.2 Emergency Plan

As we know, there may be various emergency situation on board, therefor, the necessary emergency plan should be completed, especially for the cruise ship with plenty of tourists on board, the related parties should not ignore the establishment of emergency plan and guide the related persons to implement the plan.

5.2.1 Emergency Situation

The emergency situations that may be faced by large cruise ships in the inward & outward navigation, berthing and departure operation are mainly the following:

5.2.1.1 Meteorological

Poor visibility, such as fog, thunderstorms (storms), and heavy snow, affect visibility and normal look-out. Blowing in (out) wind which is more than level 8 from abeam and so on.

5.2.1.2 Ship Traffic Conditions

Due to the restrictions on the ultra-wide crossing of the Changjiang River estuary deep water fairway, the slow speed of inward vessels has caused that cruise ships are not able to sail normally in accordance with the approval time. There are many outward vessels and inward cruise ships are forced to wait at the Changjiang River estuary.

5.2.1.3 Ship Density

About one hour before and after the local low tide, the number of vessels near WSKICT is close to the peak value, the density was high, and the navigation order is disorderly, which was not beneficial to the safe passage, crossing and turning of the cruise ship.

5.2.1.4 Terminal

When a cruise ship berths in accordance with the berth plan, cruise ship berthing at the terminal will not be able to depart due to human factors (disease or death, delays in embarkation or disembarkation, etc.), mechanical factors (vessel mechanical malfunctions) or other factors (supply, refueling, etc.). As a result, inward cruise ships encounter the situation where there are no berths.

5.2.1.5 Other Situations

Other temporary or mandatory traffic regulations (collisions, oil pollution, or military exercises) that may result in the impediment of the cruise ship’s navigation, failure to properly berth or depart at the port, even failure to out of port properly.

5.2.2 Measures to be taken for Emergency Situation

Although the emergency situations are various, the main situation can be decomposed into three kinds of situation, these three kinds of situation are listed as follow:

5.2.2.1 The cruise ship for berthing

1) For temporary or sporadic, It's usually short duration and the area impacted is relative small, the result can be clearly judged, such as personal embarkation or disembarkation delays, bunkering delay. whilst the traffic flow is intensive the ship should not enter the area to cross or turn, etc., Under the premise of not affecting the normal navigation of trailing vessels, the cruise should navigate at appropriate slow-speed in the deep water fairway of the Changjiang River estuary; after passing by Yuanyuansha light vessel, a reasonable speed reduction is required, or make space for the trailing vessel to overtake(Bai et al, 2016). Whilst passing through the sufficient fairway waters, the cruise ship can be scattered to wait for the time. Until the berth is clear or the traffic flow of the waters in the vicinity of the terminal is not too intensive, the cruise ship can sail towards the terminal in the main fairway, and then conduct turnaround, crossing or berthing operation successively.

2) In case of poor visibility, ship collisions, or such as containers falling down into the river, the unclear time required for repairing the cruise ship machine, in addition, the

situation in the future cannot be judged and estimated. Under these occasions, the cruise ship can choose the appropriate anchorage (such as No.6 or No.7 Wusong Anchorage) to anchor. In the anchorage or in the waters near the berths which doesn't affect the berthing and departure operation of the cruise ship, the dynamic positioning (DP) system can be used to accurately control the position of the ship to wait for the berth. With this measure, it can avoid to affect the other ship's normal navigation.

3) In the event of shipwrecks and container falling down along the waters of the cruise terminal, which will affect the safe use of the waters, the cruise ship should choose the backup wharf to berth. If the whole Shanghai port is blocked, the cruise ship should choose Yangshan port to berth for avoiding tourists' emotional fluctuation(Zou, 2008). At the same time, the related parties can start emergency plan to connect land transportation, and ensure the normal passenger's embarkation and disembarkation.

5.2.2.2 The cruise ship for departure

1) If the duration is short, and the area impacted is relative small. Such as it encounters the heavy rain or heavy snow in a sudden when cruise ship departure from the berth, or whilst departure it is the peak time of local traffic flow. etc. Under these occasions, the cruise ship can choose to wait for the end of these events, so it can depart or sail in a clear and safe environment.

2) If the duration is long, and the area impacted is relative large. Such as it encounters the visibility change in the Changjiang estuary deep water fairway, inward fairway is blocked. Under these occasions, the cruise ship at the terminal should suspend the departure plan. As for the cruise ship which is sailing, it should apply for the appropriate waters from VTS in time, For example, the cruise ship can arrive at the

Yuanyuansha anchorage, and anchor to wait for the end of the event. Once these events end, the cruise ship can resume the departure plan or sail towards the Changiiang estuary.

5.2.2.3 The corresponding measures based on the characteristic of emergency situation

1) As for the events that can be clearly estimated, such as personnel embarkation & disembarkation, or cargo loading & discharging delay. etc. The operators of the cruise ship can establish or adjust the pilotage plan in accordance with the practical situation, and report to the pilot station, VTS, the WSKICT or other relevant parties.

2) There is no timetable for the repair of mechanical faults, no obvious improvement in visibility, no timetable for the opening of the port, and if there is any maritime accidents in the waters in the vicinity of the terminal or the collision waters where the loss is unknown and the extent of the impact on the navigation fairway is unknown. Under these occasions, the relevant parties should be informed in time in order let the ship to wait until the navigating environment is accurately conducted a safety assessment(Xia, 2007). A pilotage or manoeuvre plan shall be formulated, especially the related parties should prohibit blindly berthing or sailing just for the purpose of keeping the punctuality of the cruise ship.

3) The number of passengers in a cruise ship is so large that improper handling in emergencies can easily lead to adverse social impacts or group incidents. When the related parties judge and make decisions, it is imperative to ensure the tourists' safety and avoid haste movements. Therefore, all parties concerned should formulate detailed emergency plans separately, and establish a good exchange mechanism to guarantee

the smooth berthing and departure of cruise ships on the premise of ensuring the safety of cruise ships.

4) In view of the special nature of personnel transportation on cruise ship, sudden changes in the port or fairways may seriously affect the normal operation of the cruise ship. Arrangements should be made. For example, the cruise ship should go to the appropriate waters for anchoring. By means of this, the cruise ship can wait for the change of navigation environment or the stable situation, then adopt the next action (sailing, berthing or departure operation). This emergency anchorage should be located in the waters that the cruise ship may transit, in addition, this water should ensure the normal navigation or safety of anchoring when in low tide level. These anchorages include Baoshan north anchorage, Wusong anchorage (No.6 or No.7), Yuanyuansha triangle anchorage, or Changjiang River estuary No.3 anchorage.etc (Yang, 2016).

5) When severe acute illness on board the ship are life-threatening or other situations that may lead to casualties, the cruise ship need to berth and the patient should be saved immediately, but other rescue traffic methods (helicopters or rescue boats) are unable to get involved in the rescue. Therefor, all the related parties should ensure the safety of patients, "green emergency route" should be set up. The related parties must fully guarantee that the cruise ship will sail into the port under the most rapid and safe condition further to berth at a suitable berth to facilitate personnel's rescue(Liu, 2015).

5.2.3 The Notice of Manoeuvre When Berthing and Departure

Large cruise ship should pay attention to the below points when berthing and departure at WSKICT:

1) The cruise ship should keep good communication with other ships, and coordinate the preventing collision relationship between ships, and pay close attention to the effects of the relevant ships on the operation of own ship.

2) During the process of coasting or turnaround, the cruise ship should pay close attention to the drift and deflection caused by the wind and current. Observe the vertical and horizontal reference objects, besides, control them in time with the main engine, rudder, thruster and tugboat.

3) Before berthing and departure,the cruise ship should confirm that patrol boat and tugboat have been ready for escorting.

4) Engine should be used properly, and keep certain power in advance, and avoid using engine frequently.

5) If the wind force is greater than 7,the wind velocity is greater than 17m/s, besides, the influence of the wind velocity is greater than the current velocity. Under this occasion, the pilot may select to berth by port or starboard side according to the actual situation.

6) The cruise ship follow the correct angle of departure, the angle dimension which depends on the effects of the external force and the need of subsequent operation. The cruise ship should not form a large angle to the terminal in a short period during the initial period of berthing.

7) When encountering the strong blowing in wind, but the cruise ship is departing from

the berth. Under this occasion, before letting go the tugboat, the cruise ship should keep sufficient transverse distance to the terminal.

8) When encountering the blowing in wind, but the cruise ship is berthing. The dual anchor should be ready at the ship's bow.

5.2 Recommendation

Beside the measures for the practical operation level, the below advice are proposed for the management level of the related parties, decision makers can take these advice and enforce them from the top level, these measures may prevent and reduce the risk factors basically. The advice are listed as followed:

1) Pilots will carry out relevant knowledge update training. They will be proficient in manoeuvring the 220,000 GT cruise ship through ship simulators or on board learning. If possible pilots can board the cruise ship at the last port, in order to better understand and cooperate with the cruise ship bridge team In addition, the pilot can fully communicate the ship's navigation and berthing plans with the bridge team for ensuring the safe operation of the cruise ship.

2) It is recommended that the 220,000 GT cruise ship and two large cruise ships should choose relative better working conditions to conduct the relevant operation in the early stage of berthing and departure. At the same time, the cruise ship take notice of the fastest flood and fastest ebb. The cruise ship should avoid them as much as possible, especially when berthing with the current. After all the related parties are familiar with the relevant manoeuvre methods, and pilots and master perform a good cooperation, then they can gradually improve working conditions to ensure the safe operation of the 220,000 GT cruise ship and the safety of two cruise vessels berthing

at the same time.

3) In view of poor water depth at the upstream of the berth No.3 and the downstream of the berth No.4, it is recommended that the WSKICT should conduct a sweep survey for the depth of the terminal front waters as soon as possible, and dredge the shallow points to ensure smooth berthing and departure.

4) In view of the importance of berthing and departure safety of cruise ships, it is recommended that the cooperation of cruise companies, ports authority, MSA, and pilot station should be strengthened so as to improve emergency response plans. If emergency events occur, it is possible to study and explore the plans for the settlement of tourists on shore.

Chapter VI Conclusion

Due to the importance of cruise ship safety, the related subjects is getting more and more attention from the public and the authority. In this paper, the author firstly makes a overview of the development trend of cruise ship, and then focus on the WSKICT in Shanghai, China. The paper points out the fierce development of cruise ship industry in China. In succession, this paper introduce the geographical location, and meteorology & hydraulic information, fairway information.etc. In addition, with Pearson correlation analysis, summarize the relation between tide and vessel number in three main fairways. In the chapter III, through the hazards identification and analysis, the author find the risk factors. Besides the author give a risk analysis framework, from the figure, the risk factors can be easily understood. All the relations among the risk factors are presented clearly. Then in chapter IV, the author utilizes the fuzzy mathematics combined with FIS theory of AI to obtain the membership function of each risk factor. At the end of this chapter, the author gives the FIS model and lists the high risk combination including kinds of risk factors, furthermore, the author explains these combinations. Finally, in chapter V, the author supplies a lot of suggestions, the suggestions which not only include the manoeuvre level, but also include the management level. These suggestions form a complete suggestion chain. Although the author has done a lot of work to collect information, obtain expert suggestions and analyze available information as much as possible, the author may still ignore some information. The analysis in this paper can't avoid some mistakes due to the insufficient information and non-perfect technology (AI technology still have space to improve). Besides, some other emergency situation can't be considered completely, for example, the fire accident, flooding.etc. Each emergency situation can be a subject to be researched. However, this paper restricted by the word counts, many situation can't be covered, these subjects maybe left to solve in the future.

Through the paper,the author believes that the safety of cruise ship can be ensure in the future, as long as the related parties can establish sufficient and reasonable measures, and implement it carefully. After all, as the economic growth of China, cruise ship will play a more important role, so the related research will be more and more as well. This paper is just a initial attempt, the author hopes more and more people and parties can pay attention to the cruise ship industry, and finally create a safe and comfortable environment for all of the tourists in the future.

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