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Research on risk analysis of seaplane in Sanya Port and countermeasures

Lei Gao

WORLD MARITIME UNIVERSITY

Dalian, China

RESEARCH ON RISK ANALYSIS OF SEAPLANE IN SANYA PORT AND COUNTERMEASURES

By

Gao Lei

China

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DECLARATION

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

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the university.

(Signature): Gao Lei

(Date)： 01 July, 2014

Supervised by： Dr. Bu Renxiang

Professor of Dalian Maritime University

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and took care of my little daughter Yoyo, here I really want to express my thanks to them for their understanding, supports and encouragements.

ABSTRACT

Title of Research paper：**Research on Risk Analysis of Seaplane in Sanya Port and Countermeasures**

Degree： **MSc**

As a famous international tourism city known as the oriental Hawaii, Sanya located in the extremely south of China, is richly endowed by nature to develop seaplane industry in, in particularly under the background of construction of Hainan international tourism island. Like the cruise ship and yacht industry, seaplane will also become the new highlight and flourish the development of tourism economy in Hainan. However, seaplane industry is in the initial stage in Hainan even in China, the vacancy of research on seaplane security make it significant for us to develop polices and measures in seaplane management and then protects and promotes seaplane industry in Sanya port.

The thesis gives a general introduction on seaplane, seaplane industry at home and abroad, changes happened in recent years and marine tourism in Sanya port.

Also, it studies the marine traffic environment of Sanya Port and traffic environment of seaplane navigable waters, through analyzing the traffic track and flow, points out that the traffic flow in Sanya Port, mainly is relatively large, and the traffic track lines near the seaplane center are mixed and disorderly, it will seriously affect the seaplane navigation safety.

Based on the statistics of maritime incidents during the last five years, it summarizes accidents characteristics happened in Sanya Port by qualitative analysis, and analyzes the root causes of maritime accidents and the objective issues facing the seaplane industry faced with by PHA research.

Moreover, it spells out 9 factors relevant to the safety of seaplane by AHP and classifies the different results caused by these factors. Above all, the thesis presents the safety countermeasures for promoting and protecting seaplane industry in Sanya port and finally obtains a conclusion that it is capable for us to control and reduce the risks relevant to the safety of seaplane by developing appropriate policies and measures.

Despite the navigable conditions in Sanya port are complex and not mature for seaplanes conducting entertainments. It is sure that people can overlook the charming South China Sea and enjoy the charming island by seaplane some day, if we promote the healthy development for seaplane industry by taking actions such as strengthening management, improving navigable environment, creating better conditions and providing good safety measures.

KEYWORDS: seaplane, safety, risk analysis, countermeasure

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LIST OF ABBREVIATIONS

AHP	Analytic Hierarchy Process
AIS	Automatic Identification System
CFR	Code of Federal Regulation
COLREGS	Convention on the International regulation for Preventing Collisions at Sea, 1972
HSE	Human being--Ship--Environment
ICAO	International Civil Aviation Organization
INF	Information
MSA	Maritime Safety Administration
NAS	Navigation Aids and Services
PHA	Preliminary Hazard Analysis
SMS	Safety Management System
STCW	Standards of Training, Certification and Watchkeeping
USCG	United States Cost Guard
USDCAD	United States and Canada

Chapter 1

Introduction

1.1 Background

After nearly 30 years' constant and steady development, China's social economy level has enhanced, providing a favorable macroeconomic conditions for people's outdoor leisure and tourism activities. As a new way of travelling different from the conventional counterpart, seaplane has gradually aroused the concern of Chinese people. The civil seaplane industry is an emerging industry in China, the first domestic seaplane project was started in Sanya city Hainan province in August 2012, henceforth, China's first civil seaplane company has officially entered the phase of operation on January 25, 2014.

Seaplane can navigate on the surface of vast river, lake and sea waters, with its relative good safety, and the low spending on the taking-off and landing auxiliary facilities, therefore, it is widely used in entertainment, transportation, fire disaster relief, and many other fields. With the constant improvement of the economic level, the quantity of civil seaplane programs are increasing, issues like navigation safety and maritime supervision of seaplanes are receiving increasing attention from Chinese people. Seaplanes have a dual characteristic of planes and ships, when sailing on the water, seaplanes are just like any other ships, they are subject to all the restrictions and privileges of other vessels and conduct their operations accordingly,

therefore, they should receive the jurisdiction of the maritime sector; Once flying out of the water, they are considered to be planes and subject to the civil aviation department regulation.

As a booming industry in China, the development of civil seaplane is in its initial stage, although the Sanya government has launched “the low-altitude tourism development planning of Sanya (2012-2022)” in August 2013, to schematize the layout of seaplane project and service facilities in Sanya. However, researches on the maritime regulatory of the domestic seaplane are not sufficient and perfect, therefore, to carry out the seaplane maritime supervision research is necessary.

1.2 Research Contents

According to the introduction of some experts, in the United States, Canada, Australia, Russia and some European countries and regions, seaplanes and relevant industries have been developed well and become popular as water leisure projects and transport. Compared with these countries and regions, seaplanes in China have not formed industry chain, they are lack of management measures and relevant services, so the seaplanes’ marine safety management is almost vacant, hence it is impossible to study how to improve the safety management measures of seaplanes based on the insufficiency of historical data. Seaplanes need some certain activity waters, when sailing on the water, they are considered to be vessels. However, water areas are not opened only for seaplanes, therefore, it is necessary to research the vessel traffic system besides seaplanes themselves, this paper studies the traffic environment in the system, and then researches the potential risk factors based on the analysis of the accidents in Sanya Port, and gains the decision-making advice to ensure seaplanes’ security through analyzing the risk factors affecting the safety of seaplanes. In this paper, the following contents are displayed which studied by the author.

(1) It studies the navigable environment adaptive to seaplane development by PHA at the basis of the statistics analysis of maritime incidents during the last five years

(3) It analyses the potential risks of marine environment in Sanya port and the objective issues facing seaplane industry.

(4) It spells out 9 factors relevant to the safety of seaplane by AHP and classifies the different results caused by these factors.

(5) It proposes the safety countermeasures for promoting and protecting seaplane industry in Sanya port.

The purpose of the thesis is to improve the navigation safety of seaplanes, ensure the maritime traffic safety, establish the position and role MSA plays in seaplane safety administration, so that prefect the maritime supervision mechanism of seaplanes.

The research result of this thesis has an important referent significance to enhance the security of the seaplane taking-off, landing, sailing and berthing, strengthen the effective management for seaplanes, improve the safety of the port and promote the seaplane industry development.

Chapter 2

Overview on Seaplane and Its Current Development

2.1 Overview of Seaplane

Seaplane, also called hydroplane. As the Wikipedia explained, a seaplane is a powered fixed-wing aircraft with the capability of taking off and landing (alighting) on water. The definition of seaplane in the World English Dictionary is that any aircraft that lands on and takes off from water. According to the "Convention on the International Regulations for Preventing Collisions at Sea 1972"(hereafter referred to as GOLREGS), the definition of seaplane is that any aircraft designed to maneuver on the water.

2.1.1 Types of Seaplanes

Commonly，seaplanes are divided into three categories based on their designed ways of contacting with water surface: Flying Boat, Amphibian, and Floatplane. Most civil seaplanes are designed into Flying Boat and Floatplane.

1) Flying Boat

Flying Boat is a common design approach of large seaplane, the fuselage of which contacts with the water surface directly, no buoys mounted under the fuselage, but some models are installed auxiliary buoys under both their wings. Another derived type of Flying Boat is called ground effect aircraft, which generally are not included in the classification of the Flying Boat.

2) Amphibian

Amphibious aircraft refers to subclass that can add wheels or have wheels itself, and take off or land directly on the airfield. This kind of seaplanes can be operated in the water and on land as well if needed, so it's called Amphibian.

3) Floatplane

Floatplane is more commonly used by small aircrafts equipped with one or two buoys under the fuselage, separating the fuselage from the water, some are equipped with small auxiliary buoys under both side of the wings, in order to avoid overturning.

Compared with larger Flying Boats, Floatplanes are more commonly used in marine tourism. Such models are generally designed with 2-6 seats, suitable for individuals, and couples of families to enjoy the air experience; nevertheless, some are designed with 20 seats or less and suitable for small groups of sightseeing.

2.1.2 Characteristics of Seaplanes

1) Dual identities

Seaplanes have a dual identity of aircraft and ship. In 1967, the ICAO redefined the aircraft as any machines that relied on the adverse effects of the air, not from the adverse effects of the air to the earth, but obtained the support from the atmosphere. When flying in the air, the lift force of a seaplane comes from the air pressure difference between the up-surface and down-surface of its wings, and it conforms to the definition of aircraft, but when navigating and berthing on the water, it falls into the ship. The double identities of aircraft and ships make the safety management of the seaplanes stretch across the fields of the sky aviation and water sailing, involving double standards of maritime organization and civil aviation organization.

2) Convenient seadrome

Although seaplanes need civil aviation airdrome as stipulated in The International Civil Aviation Covenant Annex 14, or the marine airfield is far different from the land airdrome. Without the runway, taxi-track, buffer zone and so on, a water field with only 1500-2000 meters long and 60 meters wide can be used as a seadrome. At the same time, the seadrome does not need any maintenance; so the construction cost of it is very low, less than 1/10 of the land airdrome construction fees.

3) No need special air and sea traffic services

Due to the low flight level, slow speed and short distance, the seaplane completely relies on the driver's visual flight when flying in the air, so it does not need to be monitored by air traffic services. Similarly, when navigating on the water, seaplanes also adapt visual navigation rules, actually in the practical operation, they demand drivers with stricter visibility, if the visibility reduces poor, the seaplane are not permitted to fly or sail, as well as in the night.

4) Low environmental pollution

Because of the small volume, small engine power, when sailing on the water, the noise of seaplanes generated is far less than any other marine engine. Secondly, seaplanes use aviation kerosene or diesel as fuel, these low polluted oil can volatile and decompose rapidly by the wind and sea current when spilling out, additionally the fuel volume of a seaplane carried is limited, so the pollution caused by it is far less compared with the vessel.

5) Good safety

Due to the flexible maneuverability of seaplane, adapting visual navigation rules, and not flying or sailing in the night or in the condition of poor visibility; the traffic accident rate of seaplanes is very low. In the past few decades, the accident rate of seaplane is zero in Canada where the seaplane is used more frequently in the world. Most

international recorded seaplane accidents did not happen during the water activity.

2.2 Current Development Situation in China and Abroad

Figure 2.1- Distribution of seaplane base/clubs around the world
Source: http://www.kchance.com/Text_details.asp?id=1633

Seaplane tourism project is more popular in Europe and America regions, mainly distributed in three areas: North America, Europe and Australia. Seaplanes in North American mainly concentrate in USDCAD around five great lakes and coastal areas. According to the statistics, there are more than 103 seaplane bases only in Alaska in the United States, and the registered pilots amounted to 10016 people. Not only seaplanes are used in marine tourism activities, but also as an idiomatic transport between Canada cities like Vancouver, Victoria and Seattle of US. In European, seaplane tourism focused on the west coast of Europe and Mediterranean area, for instance, Como seaplane club, located in northern Italy, is the largest seaplane club in Europe. Seaplane bases in Australian were mainly grounded on east coast. In addition, the seaplane tourism is developed earlier in holiday resorts such as Maldives and Dubai earlier as well.

Competent administrative authorities in these regions and countries are generally similar. When flying in sky，the competent authority of seaplane in almost all

countries is civil aviation department, and when sailing on water surfaces， seaplanes are administrated by transport department or maritime sectors. For instance， in US，seaplanes are managed by the US Department of Transportation and Federal Aviation Administration besides USCG is responsible for rescue and accident disposal. In Canada，the Transports Canada takes the responsibility of managing seaplanes when they sailing on waters. In US and Canada, a lot of relevant developed laws and regulations are formulated for protecting seaplanes' safety, and the port facilities and security services system for seaplanes are more completed. For example, the US Department of Transportation and Federal Aviation Administration jointly issued Seaplane Safety for 14 CFR Part 91 Operators, Seaplane Pilots' Model Code Of Conduct –Version 1.1, and so no; at port of Vitoria in Canada, the local authority even designated special exclusive area and channels for seaplanes, and made traffic schemes for them, the port facilities and services which are considerably convenient too.

The aquatic resources in China are very abundant. The coastline is up to 18000 kilometers, and nearly 1500 rivers whose drainage area exceed 1000 square kilometers, besides many large lakes, the application prospect of seaplane is considerably promising. However, the seaplane industry in China is still in its initial phase.

In recent years, seaplane tourism projects are introduced in some lake tourist districts, such as Shahu Lake in Ningxia province, Qiandao Lake in Zhejiang and many other lakes. However, most of them are small scales and without approval of relevant departments, so-called seaplanes in some districts are just the ground effect aircraft actually. At present, the seaplane business in Shenzhen has made breakthroughs, especially the new airdrome terminal has been completed and opened in March 2010, and seaplanes routes of pan-pearl river delta region were

opened up including Hong Kong, Macau, and Guangzhou, 10 DHC-6 twin otter planes were put into operation. It is understood that the spending is 2400 RMB from Shenzhen to Macau by seaplanes, and only needs 15 minutes, and the attendance is considerably high. In 2013, Hainan has passed “the low-altitude tourism development planning of Sanya (2012-2022)”, which is the first domestic low tourism special planning, with the aim to construct Sanya international seaplane center, and the first real civil seaplane project in China.

However, the seaplane industry in China is still in its initial stage, researches on pier site selection, construction, services and security system, and maritime administration are so incomplete, furthermore, laws and regulations system on seaplanes is not perfect and systematic, and the actual supervision is relative lacking

2.3 Chapter Summary

This chapter briefly introduced the definition, main types and characteristics of seaplanes, and then overviewed the current development situation of seaplanes in China and abroad.

Commonly，seaplane can be divided into three categories: Flying Boat, Amphibian, and Floatplane, most of civil seaplanes are designed into Flying Boat and Floatplane. Seaplane has such five characteristic namely: dual identity, convenient seadrome, low cost in air and marine traffic services, low environmental pollution and, good safety.

The development of seaplane industry is unbalanced in the world. In United States, Canada, Australia, Russia and some European countries and regions, seaplanes and relevant industries have been developed well and become common as water leisure projects and transport, the relevant laws and regulations, security service system, port facilities and, related industrial chains are more developed. However,

compared with these countries and regions, the development of seaplanes in China is relatively lagging far behind, research on pier site selection, construction, security services system and, management experiences are almost blank, as well as laws and regulations system on seaplanes.

Chapter 3

Sanya International Seaplane Center

Sanya international seaplane center, located in Sanya bay, directly faces the corner of Xinfeng Street, and 380 meters far from the land. The total designed construction area of this seaplane center is about 60,000 square meters; it was funded and will be built by Meiya Aviation Holdings CO., Ltd., the first approved seaplane operator in China. The center's construction projects includes aviation complex building, aviation exhibition and security center, tourist service center and VIP private plane/yacht club, etc., at least 20 seaplane berths after completion. The company has officially entered the phase of operation on January 25, 2014. Now it has built a temporary seaplane pier on the planning area.

3.1 Designed Representative Seaplane Type

Figure 3.1- The designed representative seaplane type
Source: Meiya Aviation Holdings CO., Ltd.

As shown in figure 3.1, the designed representative seaplane type of Sanya seaplane center is Triumph-waterway (C208-675), most seaplanes operated in the

future will be this type, and piers are also designed according to this type or similar types.

Table 3.1 illustrates the main size data of this seaplane type.

Table 3.1- The principal dimensions list of C208-657 seaplane

NO.	Content	Unit	Size	Note
1	Length of Cabin	ft/m	12.7 / 3.8	Internal measurement
2	Height of Cabin	ft/m	4.3 / 1.3	
3	Width of Cabin	ft3/m3	5.2 / 1.6	
4	Cabin volume	ft/m	254 / 7.2	
5	Carrying	person	10	
6	Total length	ft/m	38.9/11.9	External measurement
7	Wingspan	ft/m	52.1/15.9	
8	Total height	ft/m	16.3/5.0	

source: Meiya Aviation Holdings CO., Ltd.

Table 3.2 shows the main performance data of C208-675 seaplane type.

Table 3.2 - The main performance data list of C208-657 seaplane

No.	Content	Unit	Parameter
1	Maximum cruising speed	kn / km/h	162 / 300
2	Maximum range	n mile / km	790 / 1463
3	Climb rate on sea level	fpm / mpm	1,110 / 338
4	Full service ceiling	ft / m	2,000 / 6,096
5	Takeoff taxiing distance on sea level	ft / m	1,920 / 585
6	Distance of obstacle over 15m high	ft / m	3,015 / 919
7	Stalling speed	kn / km/h	59 / 109
8	Land running distance on sea level	ft / m	1,045 / 319
9	Landing distance from 15m high	ft / m	1,936 / 590

source: Meiya Aviation Holdings CO., Ltd.

According to Table 3.1, Table 3.2 and the maneuvering characteristics of this type of seaplanes, the requirements of take-off and landing area are as follows:

1) Area for landing and taking off need at least 750m*60m;

2) The width of marine taxiway must be up to 38m, and 45m will be preferred;

3) The distance of obstacles on both sides must be at least 15.9m；

4) The depth of water need to be up to 1.8m.

3.2 General Layout of Sanya International Seaplane Center

3.2.1 Terminal Layout

The construction of terminal contains fixed bridge, fixed platform, floating bridge and floating boarding station. The layout of terminal is illustrated as Figure 3.2.

The length of fixed bridge is 165m (150 in water and 15m on land), with 3 meters' wide; the size of fixed platform is 50 meters' long and 6 meters wide. Both fixed bridge and platform are adopted concrete-filled steel frame structure, surrounded by handrails. Track piles are used for the lower foundation, distance between piles is 4.5 meters, and the surface of fixed platform is laid by anticorrosive wood blocks. The elevation of fixed bridge and platform is +4.22 meters (calculated from the local theoretical lowest tide).

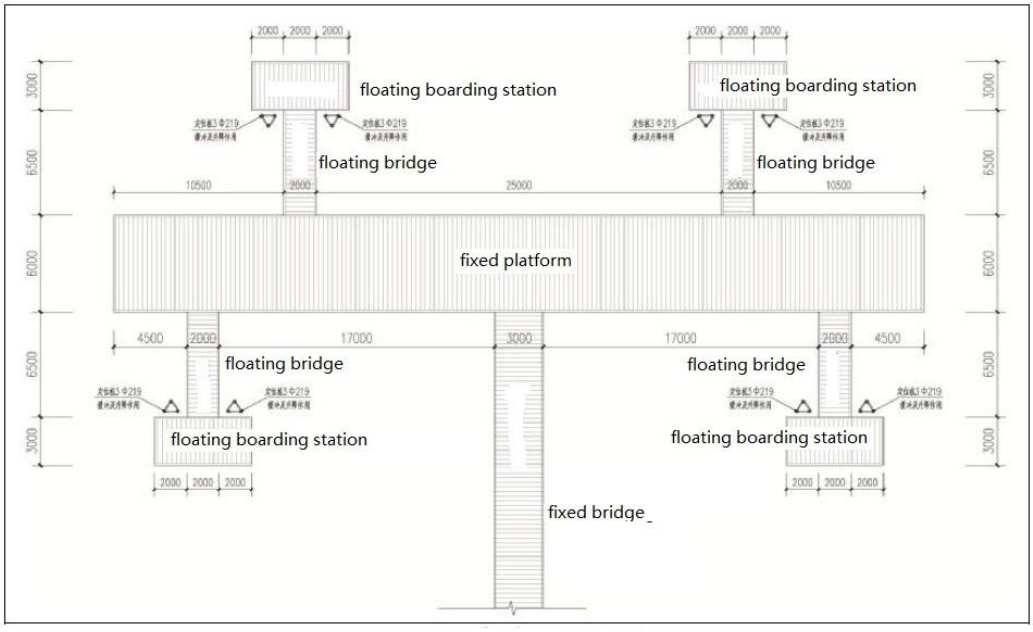

Figure 3.2 - Terminal layout

source: Meiya Aviation Holdings CO., Ltd.

3.2.2 Layout of Taking-off and Landing Area

The seaplane center water area is designed with a runway and slide channel, the sizes and positions of the center are shown in Figure 3.3.

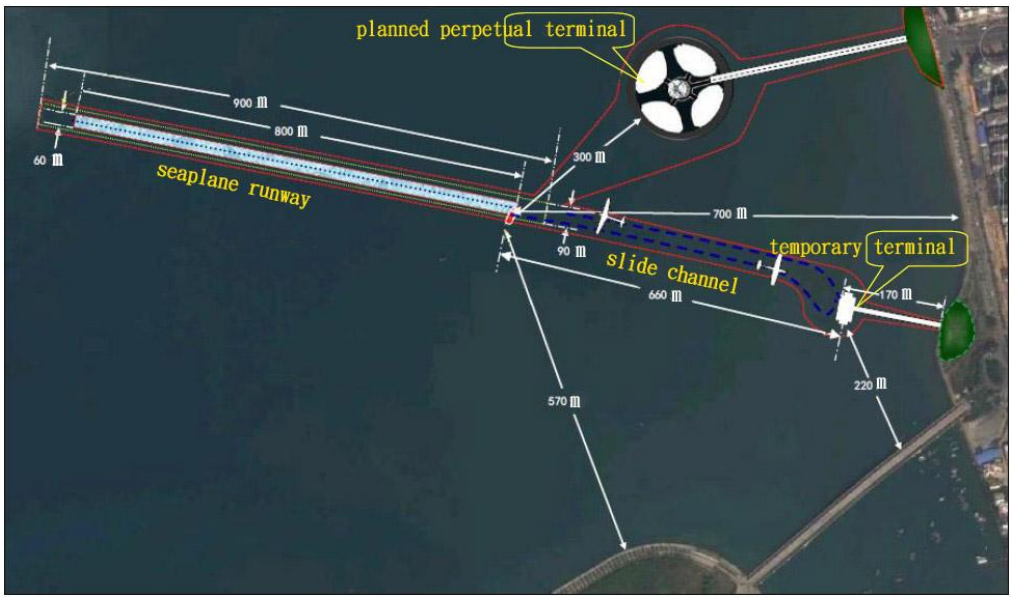

Figure 3.3 - Layout of taking-off and landing area
source: Meiya Aviation Holdings CO., Ltd.

3.2.3 Blue Print and Position of Sanya International Seaplane Center

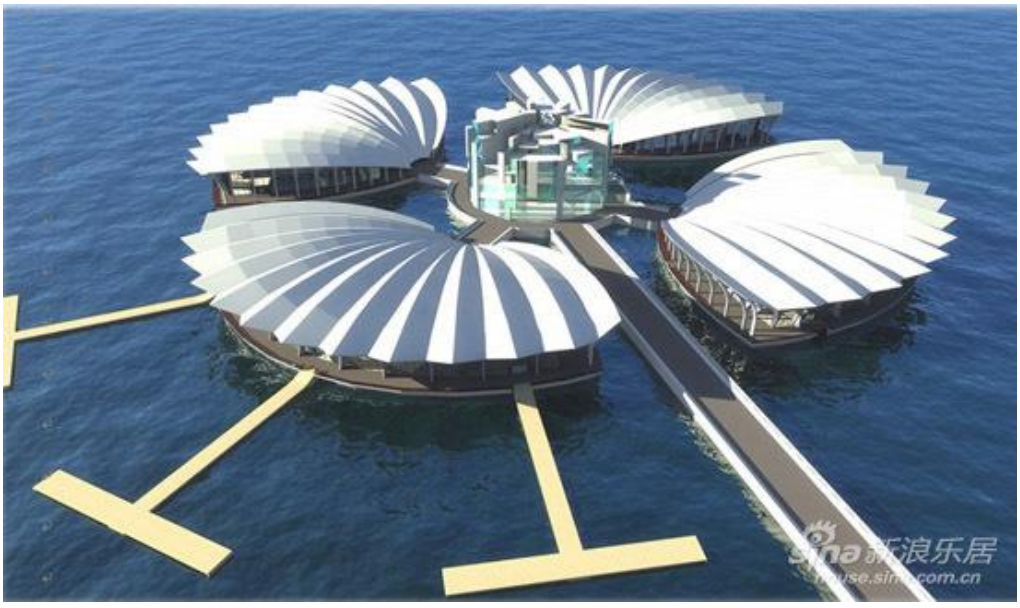

Figure 3.4 - The blue print of Sanya International Seaplane Center
source: Meiya Aviation Holdings CO., Ltd.

Figure 3.5 - The position of Sanya International Seaplane Center
source: Meiya Aviation Holdings CO., Ltd.

3.3 Marine Traffic Environment of Sanya Port

3.3.1 Natural Environment

Sanya Port is located in the extremely south of China, 18° 14'06" N,109° 29'58" E, the length of coastal line is about 40 km，and it is divided into inner harbor and outer harbor two parts by the ligature between Baipai beacon light and Little Green Island. The outer harbor is nearly 145.56 km^2，about 6-30m deep, with the capability of berthing 10,000 tonnage vessels. The inner harbor is about 3.22 km^2 , the only entrance to inner harbor is located between Baipai and Little Green Island，the depth is about 5-9m. The whole Sanya Port provides 7 berths，including two 5,000-ton berths， two 3,000-ton berths, one 1500-ton berths and two 500-ton berths.

(1) Wind

The winds appear primarily as eastern wind and northeast wind, the occurrences of

the two winds are 13.2% and 13.6% respectively, the largest average wind speed is ENE wind, about 4.2m/s, and the second is NE and SSE wind, about 3.8m /s.

Sanya Port is one of the most severely affected areas by the typhoon, which mainly occurs from May to November, and the largest recorded speed of typhoon is 45m/s. According to the statistics from 1949 to 1987, there were 99 typhoons hit this area, 2 per year on average, in the most case, the occurrence of typhoon is 6, typhoons landed from Sanya city and Lingshui county had a strong impact on this sea area, and the total number of it is 20, 0.5 per year on average.

(2) Rainfall

The average annual rainfall is 1254.7mm, and the rainy season mainly begins from May to October, the volume of rainfall in these six months is 1200.8mm, accounting for 95.7% of the whole year.

(3) Fog

There was no record illustrating the fog influencing this project area.

(4) Tide

The tide of this project area is irregular diurnal tide, in one month, the occurrence of the diurnal tide is about 14 days, and the semidiurnal tide comes about 11 days. The average high tide level is 1.29m, and the average low tide level is 0.43m, so mean range of tide is 0.86m.

(5) Current

The current primarily appears as rectilinear current, the strength of the tide current is relatively stronger, but the maximum velocity does not exceed 1.5 knots. The tide current near the seaplane center project trends to be a characteristic of a rotational flow, whose main shaft closes to the north and south.

(6) Wave

According to the observation and statistics, the stormy wave's frequency was 87%, and the ground swell's rate was 78.8%, the average height of wave was 0.48m, and the highest wave was 4.0m. The wave in this area often appears in the south, the frequency is 16.08%, and the following shown as SSE, SE, SSW, SW, the frequencies are 13.99%, 12.83%, 11.56% respectively.

3.3.2 Traffic Environment of Seaplane Navigable Waters

Although the seaplane center is not located in the main channel of Sanya Port; however, for conducting research on the traffic flow on the main channel, it has a reference value to study the traffic situation around seaplane center and analyze the interplay between the traffic flow and seaplanes. So we select the ligature between point A(18°14'09''N,109°28'46''E) and point B (18°13'50''N,109°28'53''E)at the outside end of the main channel as a tracking observation section on AIS, positions of point A, point B and the seaplane center are as shown in Figure 3.6.

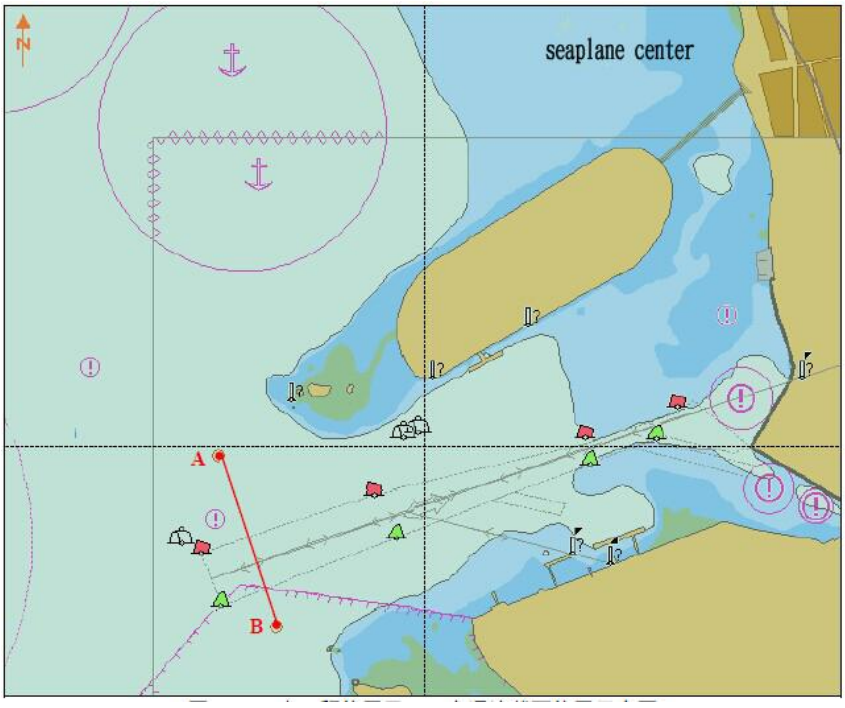

Figure 3.6 Track observation section and the position of seaplane center
Source: Sanya MSA

The AIS track gate diagram and traffic flow statistics in 2011 are as shown in Figure3.7, which are similar with those in 2012 and 2013. The selected section is at the outside end of the main channel, so it can reflect the overall traffic flow conditions of Sanya Port. The volume of the traffic flow on this section in 2011 is 2982, not including the fishing vessels without AIS installations and cargo ships less than 300 gross tonnages, and the number presents an increasing trend in the following two years owing to the policy of International Tourism Island promoted the development of ports in Hainan.

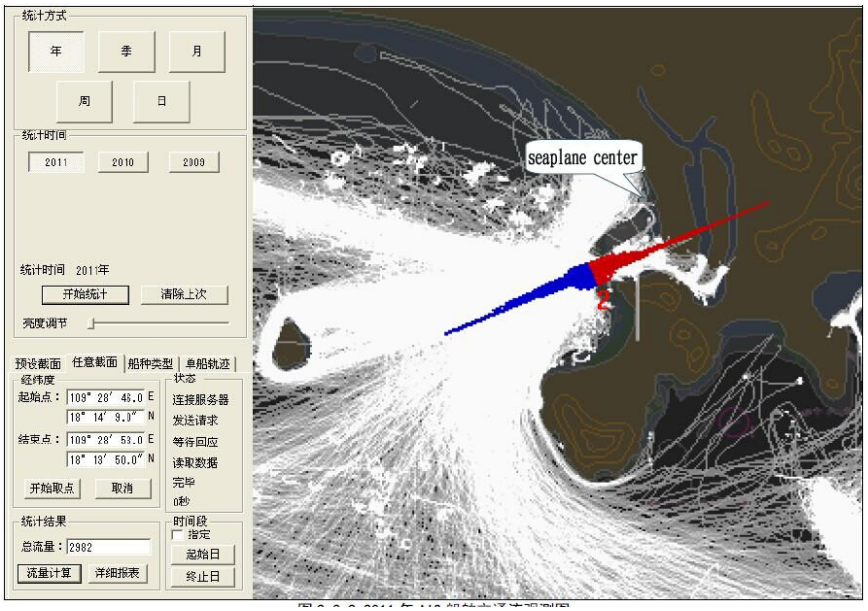

Figure 3.7 AIS track gate diagram in Sanya Port in 2011
Source: Sanya MSA

Figure 3.8 is the pie chart of traffic flow Composition of Sanya Port in 2011, as can be seen from the pie chart, non-transport ships like fishing vessels with AIS installations accounted for more than three quarters of the vessel traffic flow, and there are still plenty of small fishing boats and cargo ships without AIS installations are not recorded. The following are passenger ships and cargo ships, occupying 13% and

9% respectively. And the passenger ships are increasing in recent years because of the improved tourism environment and the emerging duty-free stores in Hainan. The proportion of other ship types like oil tanker and dangerous cargo ships was very small. The regularities of the vessel traffic flow in 2012 and 2013 are very similar with that in 2011.

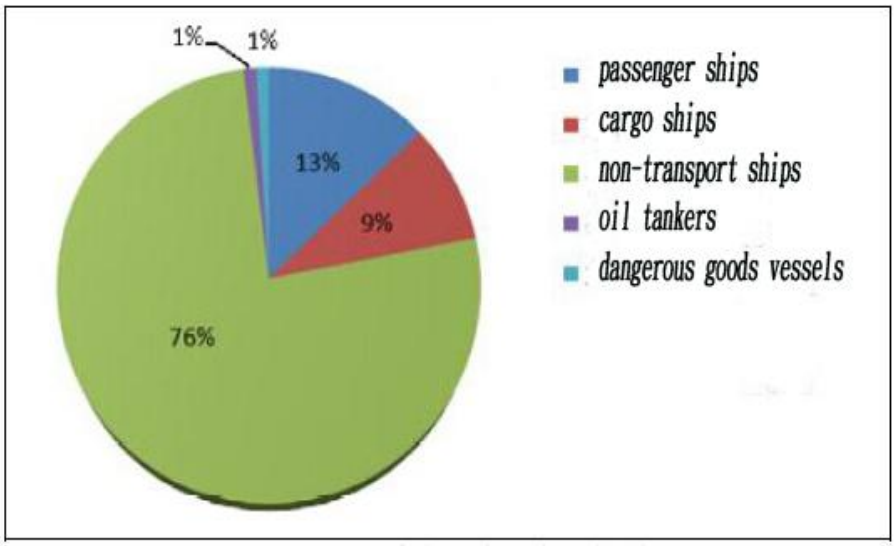

Figure 3.8 Composition of traffic flow of Sanya Port in 2011
source: Sanya MSA

Through the above analysis，the traffic flow in Sanya Port is relatively large. The track line of considerable ships presents a repetitiveness and irregular rings，most of these vessels are fishing vessels, marine sightseeing passenger ships, cruises and yachts, etc.. Most cargo ships often sails along the main channel of Sanya Port. On the contrary, the traffic flow near the seaplane center is relatively small, the track lines are mixed and disorderly, in the majority with sea sightseeing boats and small fishing boats, it will serious affect the seaplane navigation safety.

3.4 Chapter Summary

Chapter 3 gives a brief introduction on designed representative seaplane type of

Sanya International Seaplane Center, draws out the requirements of taking-off and landing areas for seaplanes; then generally presents the general layout of Sanya International Seaplane Center, including the terminal layout, taking-off and landing area layout, the blue print and basal position of Sanya International Seaplane Center.

Also, this chapter introduces the marine traffic environment of Sanya Port, including natural environment, such as wind, rainfall, fog, tide, current, wave etc., and traffic environment of seaplane navigable waters, through analyzing the traffic track and flow, points out that the traffic flow in Sanya Port, mainly composed of fishing boats, sightseeing passenger ships, cruise and yachts, is relatively large, however, the traffic track lines near the seaplane center are mixed and disorderly, it will seriously affect the seaplane navigation safety.

Chapter 4

Risk Analysis of Seaplane in Sanya Port

Seaplane industry is an emerging industry to Sanya and even the whole China, the safety issue of it is an eternal topic. Although it is feasible to develop seaplane industry in Sanya due to the objective conditions like technology, economic and social aspects. However, as a leisure project, a certain risk also exists when seaplanes are sailing on water, therefore, it's necessary to put forward special requirements on safety.

4.1 Risk Factors Affecting the Safety of Seaplanes Based on Accident Analysis

When sailing on the water, a seaplane used as a vessel, so the marine traffic environment of a seaplane is very similar with other vessels in the same water, therefore, we can analyze the accidents statistics of other ships in Sanya Port, an then popularize it on seaplanes, in case of no accidents data of seaplanes. Next, we study the navigable environment adaptive to seaplane development by PHA on the basis of the statistics analysis of maritime incidents during the last five years.

4.1.1Preliminary Hazard Analysis

PHA (Preliminary Hazard Analysis) is often used to generally analyze the system riskiness before a launching project, try to avoid adopting unsafe techniques, risky materials, applications and process from the aspect of the safety system project. The analysis steps are as follows:

Step 1, analyze the potential systematic risks according to the accidents;

Step 2, confirm the possibilities of hazards;

Step 3, identify the converting conditions, and research the trigger conditions from risky elements to accidents;

Step 4, find out the risk factors.

4.1.2 Marine Traffic Accidents Statistics and Root Analysis

According to materials from Sanya MSA, 21 marine accidents in the past five years happened in Sanya Port and nearby waters; the total number is not so huge relatively. However, the consequences and society impacts are serious, severe accidents which caused ship sunk or people lost /death, accounts for nearly 1/4 of the total number. The marine accidents statistics of Sanya Port from 2009-2013 are as shown in Table 4.1.

Table 4.1- Accidents statistics of Sanya from 2009-2013

No.	Cause	Quantity of referred ships	Proportions in the total number
1	Failure to alert	14	35.29%
2	No answer on steers and rudders	5	12.61%
3	Failure to watching	21	51.68%
4	Improper emergency operation	15	37.61%
5	Un-unified intention when meeting	5	13.66%
6	Tackles	6	14.92%
7	Influence of wind and wave	7	17.44%
8	Collision avoidance of a third party	2	5.88%
9	Violation of the navigation principle	21	53.15%
10	Bad visibility	11	26.68%
11	Adventure overtaking	8	19.33%
12	Fatigue	2	4.62%
13	Failure to adopt safe speed	9	21.85%

14	Other causes	9	23.53%

4.1.3 Qualitative Analysis on Accidents Characteristics

Through the qualitative analysis on accidents statistics, the potential risk mainly includes:

(1) Collision and contact damage are the main two types of accidents, accounting for more than 75% of the total in the past five years. For instance, when navigating, berthing and carrying out operations in Sanya Port, some small vessels especially fishing boats or often reverse navigation, overtake other ships boldly, without watching on the VHF security channel, or anchoring or berthing anywhere as they like, which seriously impact the navigation environment of Sanya Port, and are prone to cause the collision and contact accident.

(2) “Human factor” represented as the failure of manipulation is the main cause of marine traffic accidents. Some seafarers are not familiar with the port, including the channel, wave, current, wind and so on, lacking of sailing experience and potential risk estimation, in the case of emergency, they may adopt improper measures, so the accident occurred.

(3) The marine accidents present strong seasonal characteristics. Through the marine accident statistical analysis from 2009 to 2013, the second half of the year is the marine traffic accident prone season, accounting for more than 2/3 of the total annual accident occurred throughout the whole year, especially in the fourth quarter, the accidents often accounted for over 65% of the four seasons. Because this period is the typhoon, storm, wind and other bad water season, it often easily leads to marine traffic accidents.

(4) Accidents happened in Sanya Port have a grater social influence. Compared with the other harbors, Sanya Port has a larger number of cruise ships, yachts, and

passenger ships, most passengers and yacht players are elites from all sectors of the community, once the accident happened, these environmental elements will have a high degree of social concern and social influence.

4.1.4 Root Cause Analysis

The root causes of maritime accidents in Sanya Ports are as follows:

4.1.4.1 Low Quality of Small and Medium Ships' Crew

A large number of seafarers from small and medium-sized ships are equipped as flow individual crew, most of them have not received the systematic on-job training s, and lack of the necessary knowledge and emergency ability training, they know little about the basic knowledge and sailing skills, and just handle the ship with their experiences, especially fishing vessels' crew, they poorly understand the navigation rules and the local regulations even know nothing about the related regulations at all. Phenomenon such as weakness of legal concept, overloading, manning shortage, breach of navigation rules and illegal mooring, evading supervision often happen. Frequent operation mistakes, failure to use the navigational facilities, and keep good sailing habits and adopting wrong operations will lead to frequent dangers and accidents in case of emergency.

4.1.4.2 Poor Condition Ships

Angering ships, small ships with poor facilities and frequent failure are more easily to cause accidents. In recent years, along with the transformation of the state-owned large shipping companies' operating strategy, the shipping market of Sanya Port is occupying a large number of individual ships gradually. In order to maximize the profits, many individual operators purchase overage and aging ships to operate, which are equipped with poor navigation equipments, and lack of maintenance, even worse, some of them are lack of navigational data, as a result,

the unilateral liability accidents are increasing. Generally speaking, the serious ships' defects and lacking of equipments are becoming one of the most important hidden risks of marine traffic accidents.

4.1.4.3 On/under Water Constructions Affect the Navigable Environment

In the background of promoting Hainan international tourism island construction, Sanya has devoted herself to building an international tropical costal tourist city in recent years, the city constructions have been developed continuously, the continual artificial island projects, yacht piers, cruise home harbor, submarine cables and other major on/underwater construction works also bring some negative impacts and difficulties objectively to the navigation environment of Sanya Port which is under a big pressure itself. Key projects such as Phoenix international cruise terminal, Pphoenix artificial island project, and Longwan peninsula yacht pier etc. have had a great effect to the navigable waters nearby, the channel has been adjusted repeatedly, sometimes even the local traffic control has been implemented, therefore, the difficulty of ship maneuvering has been increased, to cause the officers passing these waters great psychological pressure and tension of impatience, and lead to operation and judgment errors. These key marine engineering projects induced marine accidents objectively.

4.1.4.4 Numerous Ship Violations

From the analysis of accidents statistics, we can know that, more than a half of these accidents in the past five years were caused by violation of related regulations, leading to three ships lost and six people missing. Some accidents were caused by strain capacity, failure of watching, illegal overtaking, optional mooring, or reversed navigation, meanwhile, some were caused by infirm mooring or navigation in bad weather, and led to sinking or people lost.

4.1.5 Hazard Elements

From the research of preliminary hazard analysis, it can be generalized that the main hazard elements are as follows:

(1) The impact of wind, wave, tide, unfamiliar with the harbor or uncontrollable ships led to collisions and contact damage accidents;

(2) Complicated traffic situation shaped by dense traffic, navigation orderliness, and the impact of wind, wave, tide, led to accidents;

(3) Dragging anchor caused by wave, wind, tide and poor condition of anchorage, led to grounding and collisions;

(4) Difficulties and limited maneuvering of ships caused by the impact of dense traffic and deficiency of channel, led to collisions;

(5) The changing of navigation environment caused by the key on/underwater construction projects, increased the difficulty of maneuvering of ships, aroused officers' psychological pressure and tension of impatience, and then gave rise to operation and judgment errors.

(6) Poor ship condition itself, shortage of manning, low quality of seafarers, and violation of sailing rules resulted in rock running, grounding and collision.

4.2 Objective Issues Facing the Seaplane Industry

4.2.1 Complex Activity \Area

The marine traffic environment of Sanya port is relatively complex, busy shipping, various ship types, the navigation environment is under a large pressure, and greatly influenced by the weather, especially typhoon. At present, there is no exclusive activity area for seaplanes, but just a temporary seaplane terminal, the navigational

Aids and channel for seaplanes are not set, the outer bound of the planning seaplane center is overlapping with No.4 anchorage ground and the traditional routes of fishing boats and yachts, once the seaplane center is launched, mutual influences between seaplanes, fishing boats, yachts and ships mooring in the No. 4 anchorage will make chaos to the navigational environment. What's more, till now the Sanya Port's VTS has not be established, and the harbor facilities and security services system for seaplanes are not developed neither.

4.2.2 Inadequate Seaplane Industrial Development Policies

Without water area, good industrial development policies, the development of seaplane industry would be impossible to achieve. As we known, government plays an important role in developing seaplane industry, it is necessary to make the local government fully aware of the motivation the seaplane industry providing for the economic development, and push them to develop industrial policies to support the development of seaplane industry.

Relevant policies such as low-altitude airspace opening, seaplane market opening, and marine tourism exploiting and safety management of seaplanes are appealed to be formulated, and these policies will arouse the interests of investors and attract them to invest to built social infrastructure and pave the way for developing seaplane industry.

4.2.3 Vacant Maritime Safety Administration

Developing seaplanes should be the highlight of Sanya city, but should not based on the premise of affecting the maritime transportation, therefore, the interact contradiction between seaplanes and other ships should be solved primarily. Maritime safety supervision and management of seaplanes are the key issues to ensure seaplane safety. However, at present, the maritime administration of

seaplanes' safety and water management are almost vacant, including measures for registration, traffic order management, training, examination and certificate of seaplane pilots, etc. Once Sanya seaplane international center completes and the seaplanes reach a certain amount, issues like seaplane pilot certification, seaplane pollution preventing, safety navigation and service, search and rescue would be definitely occur. How to manage to solve these problems and urge to establish a safety management mechanism is worthy to profoundly study as early as possible.

4.3 Chapter Summary

Based on the statistics of maritime incidents during the last five years, this chapter summarizes accidents characteristics happened in Sanya Port by qualitative analysis, and analyzes the root causes of maritime accidents and the objective issues facing the seaplane industry.

Through the qualitative analysis on accidents statistics, the main characteristics of maritime accidents in Sanya Port are:

1) Two main types of accidents are collision and contract;

2) "Human factor" represented as the failure of manipulation is the main cause of maritime accidents;

3) The maritime accidents present strong seasonal characteristics, because the bad weather comes more frequently in the second half of the year;

4) Accidents happened in Sanya Port have a greater social influence.

The root causes of maritime accidents in Sanya Ports are as follows:

1) Low quality of small and medium ship's crew;

2) Poor condition ships;

3) On/under water constructions affect the navigable environment;

4) Numerous ship violations.

And three objective issues facing the seaplane industry are concluded in this chapter

by PHA research, namely complex activity area for seaplanes in Sanya Port, inadequate seaplane industrial development policies and, the vacant maritime safety administration.

Chapter 5

Identification the Risk Factors Affecting Seaplane Safety

The affecting degree of seaplane safety rests with hundreds of factors which belong to the comprehensive reflection of many kinds of elements. How to select the evaluation index is a key point to evaluate the impact of seaplane safety. In this paper, the author valuates the selected indexes throughout experts' consultation, investigation, researches of scholars in this field and related management experience, and with the consideration of the ship navigation environmental analysis, to make sure that the selected index can reflect the seaplane safety as far as possible, and provide recommendations for the management and decision-makers.

5.1 Risk Indexes Identification

5.1.1Marine Traffic System

Within the marine traffic system, it includes three elements named human being, ship and environment, which interact with each other. Marine traffic environment system is the subsystem of the marine traffic system. The interrelations of the three elements are as shown in figure 5.1.

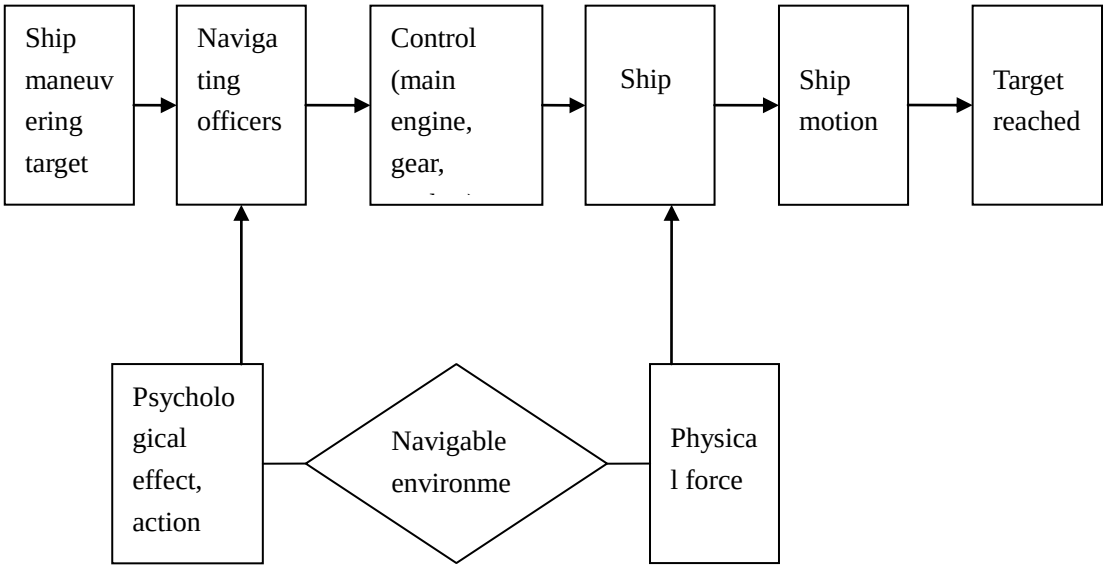

Figure 5.1- The chain system composed by human beings, ship and environment

In the study of marine traffic, ship behavior refers to the similar behavior modes and rules of the ship group. The operator is the subject of the ship's behavior, and the ship is the object of ship maneuvering, to some extent, ship's behavior is the navigator's behavior. However, ship's behavior depends not only on the navigator's consciousness, thinking, decision-making and handling skills, but also on the ships' characteristics and the environment surrounded. The navigator's handling decision process is as shown in the following figure.

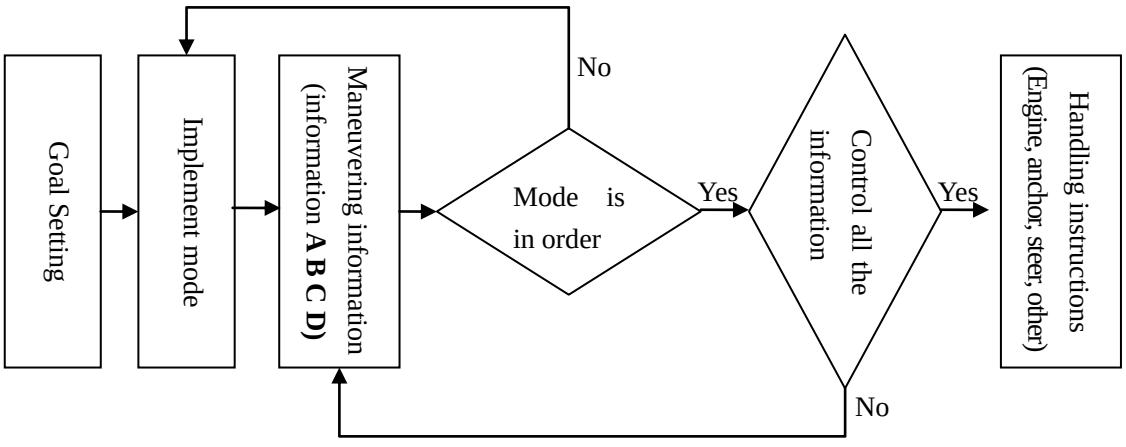

Figure 5.2- Decision-making process of maneuvering a ship

In Figure 5.2, information A and information B are environmental information in the navigable area and route. To be specific, information A refers to the environmental information which affect the ship behavior directly, such as wind, wave, tide, current and water flow, etc.; information B means other environmental information except for information A, e.g. trends of other ships, navigational aids, visibility, obstruction, laws and so on. In addition, information C and D are the ship related information. Information C refers to the dynamic information of the ship, such as speed, direction, position, swing and so on. Information D means the static information of the ship, like the ship size, characteristic of main engine, maneuverability, loading condition etc.

Comprehensively anglicizing, the main ingredients of vessel traffic system in Sanya Port are as follows:

1) Traffic state: ship density, volume of traffic, ship size and type, traffic order, working vessels and their condition;

2) Route: navigable width, cross state, curvature, field of view;

3) Navigable aids and services: navigation mark, information services;

4) Management situation: laws and regulations, administration, control;

5) Hydrometeorology: wind, wave, vision distance, current, illumination, tide and so on.

These ingredients have different influence on ships' behavior, if without consideration of marine navigators and the ship maneuverability itself. The route condition impacts on the process of navigators' judgment and decision-making by the water space limitations, and hydrometeorology, traffic state, navigable aids and services, and the management situation affect navigators by the limitation of action choices. Therefore,

it is necessary to carry out safety analysis on the marine traffic environment subsystem.

5.1.2 Identification of Risk Indexes

Based on the comprehensive analysis of the mutual relationships between human—ship—environment in the marine traffic system, and throughout the initial consultation of the competent authority, shipping experts and seaplane operators opinions and investigations, the author of this paper has generalized 9 main risk factors affecting seaplane safety for risk indexes, they are human factor(the quality of seaplane pilots), seaplane condition, company management(seaplane operator), traffic density, traffic order, navigation Aids and services, Maritime Safety Administration, natural environment, and the total seaplanes respectively; and introduced the AHP method into the risk analysis and identification to make further investigating.

5.2 Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions, based on mathematics and psychology. It was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It is a new method which effectively combines with data, experts' opinions and analyst's judgments, and also a systematic analysis method with quantitative and qualitative analysis.

AHP users break down the complex system into different elements by analyzing the factors and their mutual relationships harbored in the system, and sub classify these elements into different levels, so as to form a hierarchical analysis model objectively. And then judge the various elements of each level relatively to its previous level elements of a pair wise comparison; obtain the comparison of the relative importance

of scale, and establish a judgment matrix. That is to say，once the hierarchy is established, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. During making the comparisons, the decision makers can use concrete data about the elements, but they typically make their judgments about the elements' relative meaning and importance. And then get the order of importance of the element on all levels relative to its previous level of element, to establish the relative weight of the weight vector. In the final step of the process, numerical priorities are calculated for each decision alternatives，to get the combination weight of all the elements in the hierarchy relative to the general systematic goal，sort the alternatives according to final weight, and provide the basis for selecting the optimum solution for decision-making.

The implementation steps of AHP are as follows：

Step1: Confirm the issue. It includes identifying the systematic goal，clearing the range of the problem，and knowing the elements and their mutual relationships in the system.

Step2: Establish hierarchical structure model.

Step3: Establish the judgment matrix. The user systematically evaluates its various elements by comparing them to one another two at a time, to get the relative comparison importance degree, and examine the consistency of the judgment matrix.

$A=(a_{ij})_{nxn}$ (i,j=1,2…n)，

$a_{ij}=W_i/W_j$ (i,j=1,2…n)，

obviously, $a_{ij}=1/a_{ji}$ $a_{ii}=1$, (i,j=1,2…n)，

Table 5.1- Definition of the judgment scale

Judgment scale	Definition
1	Equally important
3	Slightly important
5	Obviously important
7	Strongly important
9	Extremely important
2,4,6,8	Between the two adjacent scales

Step4: Level simple sequence. Calculate S_j, S_j is the vertical sum of each row in matrix A，

$S_j = \sum_{j=1}^{n} a_{ij}$ (i,j=1,2…n)，

Anorm is a new normalized matrix divided by S_j， if Anorm=$\{A_{ij}*\}$， that

$a_{ij}*=a_{ij}/S_j$ (i,j=1,2…n)，

calculate the transverse average W_i of Anorm matrix，obtain the weight of Level simple sequence W, that

$wi=\frac{\sum_{i=1}^{n} a_{ij}*}{n}$ (i,j=1,2…n),

and that $W=[w_1, w_2, w_i,..., w_n]^T$.

Step5: Examine the consistency. Calculate the largest Eigen values of judgment matrix. That,

$\lambda_{max} = \frac{\sum_{i=1}^{n} (Aw)_i}{nw_i}$ $\lambda_{max} \geq n$,

CI is the consistency index, then,

CI=（λmax - n）/（n -1）

CR is the random consistency ratio, then,

CR=CI/RI, when CR＜0.1,the consistency of the matrix is satisfied.

Table 5.2- The value of RI

Matrix order	2	3	4	5	6	7	8	9	10
RI	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.52

5.3 Analysis on the Importance of the Main Factors Affecting Seaplane Safety

5.3.1 Experts Investigation

In order to calculate the weightiness of the 9 main risk factors affecting seaplane safety, the author of this paper has delivered 20 questionnaires to 9 MSA officers, 5 captains and chief engineers from shipping companies, 3 seaplane drivers and managers, and 3 professors from marine university. The detail of the questionnaires can be found in appendix 1.

5.3.2 Manipulation and Analysis of the Data

Table 5.3 shows the statistical result of the expert investigations on factors affecting seaplane safety.

Table 5.3- The statistical result

A	Human factor	Seaplane condition	Company management	Traffic density	Traffic order	NAS	MSA	Natural conditions	Total seaplanes
Human factor	1.00	5.75	2.50	4.00	4.25	5.00	4.00	3.25	4.50
Seaplane condition	0.18	1.00	0.34	3.00	0.88	3.00	0.23	3.75	4.00

Company management	0.42	3.25	1.00	3.50	3.25	3.25	3.75	3.75	4.00
Traffic density	0.27	0.33	0.30	1.00	0.38	2.25	0.20	0.34	3.75
Traffic order	0.26	1.25	0.34	3.00	1.00	3.25	0.47	3.75	4.25
NAS	0.22	0.33	0.34	0.54	0.34	1.00	0.47	4.00	4.00
MSA	0.27	4.5	0.31	5.0	3.00	3.00	1.00	4.00	4.00
Natural conditions	0.34	0.31	0.31	3.25	0.31	0.27	0.27	1.00	3.25
Total seaplanes	0.27	0.34	0.31	0.33	0.28	0.27	0.27	0.51	1.00

The element of judgment matrix A is a_{ij}, it can be illustrated as follows:

$$A=\begin{Bmatrix} 1.00 & 5.75 & 2.50 & 4.00 & 4.25 & 5.00 & 4.00 & 3.25 & 4.50 \\ 0.18 & 1.00 & 0.34 & 3.00 & 0.88 & 3.00 & 0.23 & 3.75 & 4.00 \\ 0.42 & 3.25 & 1.00 & 3.50 & 3.25 & 3.25 & 3.75 & 3.75 & 4.00 \\ 0.27 & 0.33 & 0.30 & 1.00 & 0.38 & 2.25 & 0.20 & 0.34 & 3.75 \\ 0.26 & 1.25 & 0.34 & 3.00 & 1.00 & 3.25 & 0.47 & 3.75 & 4.25 \\ 0.22 & 0.33 & 0.34 & 0.54 & 0.34 & 1.00 & 0.47 & 4.00 & 4.00 \\ 0.27 & 4.5 & 0.31 & 5.0 & 3.00 & 3.00 & 1.00 & 4.00 & 4.00 \\ 0.34 & 0.31 & 0.31 & 3.25 & 0.31 & 0.27 & 0.27 & 1.00 & 3.25 \\ 0.27 & 0.34 & 0.31 & 0.33 & 0.28 & 0.27 & 0.27 & 0.51 & 1.00 \end{Bmatrix}$$

5.3.3 Calculation of Level Simple Sequence

The calculating sheet of the feature vectors are shown in table 5.4.

Table 5.4- The calculating sheet of the feature vectors

A	Human factor	Seaplane condition	Company management	Traffic density	Traffic order	NAS	MSA	Natural conditions	Total seaplanes	Wi	Awi	Awi/Wi
Human factor	1.00	5.75	2.50	4.00	4.25	5.00	4.00	3.25	4.50	0.27	3.00	11.10

Seaplane condition	0.18	1.00	0.34	3.00	0.88	3.00	0.23	3.75	4.00	0.09	1.00	11.10
Company Management	0.42	3.25	1.00	3.50	3.25	3.25	3.75	3.75	4.00	0.19	2.10	11.10
Traffic density	0.27	0.33	0.30	1.00	0.38	2.25	0.20	0.34	3.75	0.07	0.50	7.70
Traffic order	0.26	1.25	0.34	3.00	1.00	3.25	0.47	3.75	4.25	0.10	1.10	11.10
NAS	0.22	0.33	0.34	0.54	0.34	1.00	0.47	4.00	4.00	0.06	0.60	10.00
MSA	0.27	4.50	0.31	5.00	3.00	3.00	1.00	4.00	4.00	0.15	1.60	10.07
Natural conditions	0.34	0.31	0.31	3.25	0.31	0.27	0.27	1.00	3.25	0.06	0.40	7.00
Total seaplanes	0.27	0.34	0.31	0.33	0.28	0.27	0.27	0.51	1.00	0.03	0.30	10.30
											$\sum$	90.10

W=[0.27 0.09 0.19 0.07 0.10 0.06 0.15 0.06 0.03]^T , and W_a=0.11. W is the weight of all elements in this hierarchy, and W_a erarchyis the average of W.

5.3.4 Consistency Examination

$$\lambda_{max} = \frac{\sum_{i=1}^{n} (Aw)_i}{nw_i} = 10.01$$

CI is the consistency index, then,

$CI = (\lambda max - n)/(n-1) = 0.126$

CR=CI/RI,=0.09＜0.1

It can be concluded that the consistency of matrix A is satisfied.

5.3.5 Risk Identification

Through analyzing the importance of risk factors affecting seaplane safety, we can understand the concern rate we should give to each factor in the safety management of seaplanes, and accordingly take appropriate measures to minimize risk with limited resources and forces. It is the important basic work of the safety management

of seaplanes.

From the calculation weight results, the 9 main factors affecting seaplane safety can be divided into three categories, as shown in table 5.5, factors in the first category have a large influence on seaplane safety, the influence of the second category factors is medium, and the factors which affect seaplanes slightly fall into the third category.

Table 5.5 - Risk factor classifications

Category	**Influence degree**	**The main factors**
First	Large	Human factors: $W=0.27>W_a$ Company management: $W=0.19>W_a$ MSA: $W=0.15>W_a$
Second	Medium	Traffic order, seaplane conditions, traffic density
Third	Small	NAS, natural conditions, total seaplanes

5.4 Chapter Summary

Based on the comprehensive analysis in chapter 3 and chapter 4,and the research on the mutual relationships between human—ship—environment in the marine traffic system, and throughout the initial consultation of the competent authority, shipping experts and seaplane operators opinions and investigations, the author of this paper has generalized and chosen 9 main risk factors affecting seaplane safety for risk indexes, they are: human factor(the quality of seaplane pilots), seaplane condition, company management(seaplane operator), traffic density, traffic order, navigation Aids and services, Maritime Safety Administration, natural environment, and the total seaplanes respectively; made 20 questionnaires and introduced the AHP method to calculate the weightiness of the 9 risk indexes, for further investigating.

According to the calculation results of weightiness, the 9 risk indexes can be divided into three categories, human factors, company management and MSA gained the

largest weight and fell into the first category, they had a large influence on seaplane safety; traffic order, seaplane conditions and traffic density come into the second category the influence of which is medium, followed by the third category including NAS, natural conditions and total seaplanes which affect seaplanes relatively slightly.

Chapter6

Countermeasures of Protect the Safety of Seaplanes

As an emerging marine tourism project sailing in particular waters, seaplane has its own particularities, but safety is the eternal theme for marine management. Compared with other larger and more mature harbors like Hong Kong, Shenzhen, Qingdao and Dalian, Sanya has its own limitations in harbor facilities and marine traffic environment; However, as a frontier city in the construction of Hainan international tourism island, developing seaplane tourism project has a great significance in promoting a new city planning and the development of tourism industry.

In order to develop seaplane industry，it is necessary to promote scientific industrial policies，as well as establish and improve the supporting policies of marine management，aiming to provide good marine environment and supporting facilities for the sailing, berthing, leisure and entertainment. Furthermore，it will be better to deal with three relationships skillfully，namely the relationship between developing the seaplane travelling and the commercial shipping，the relationship of combining the developing the seaplane industry and promoting the development of tourism，and the relationship between developing the seaplane industry and boosting the economic development.

The issue is how to promote and protect the safety of seaplanes, making the seaplane industry becomes the impetus of building international tropical costal tourist city. According to the characteristics of Sanya Port and the analysis from chapter 4 to

chapter 5, the author believes that Sanya Port should make efforts from next several aspects.

6.1 Classification Risk Control

The accident occurs in a series of events through a combination of many hazard factors, leading to the consolidated consequences of human injuries and economic property losses. In order to ensure seaplane security, risk mitigation measures must be taken to reduce the probability or impact of a risk, alleviate the risk or avoid the risk entirely.

6.1.1 Risk Control for the First Category Factors

(1) For human factor. Since the Herald of Free Enterprise casualty happened in March 1987, governments of all IMO parties have increasingly recognized that, the maritime traffic safety level was too hard to improve, the main cause is that human factor in ship maneuvering and management is neglected. Seaplane is a marine entertainment and leisure project approaching Chinese people; however, due to the special risks of seaplanes, higher requirements are proposed to seaplane pilots and other related employees. Therefore, the quality of seaplane pilots must be improved by more rigid education, training, assessment, and throughout more strictly controlling the access of seaplane pilot certificate. At the same time, strengthen the dynamic supervision and management by research and develop correspondent rules, regulations, standards, guidance and handouts, to make effort to reduce the risk caused by human error.

(2) For the company safety management. The competent authority should push and guide the seaplane operators or companies to establish their own safety management system, implement the ISM audit timely, to alleviate or eliminate the risk from insufficient company safety management.

(3) For safety supervision. Risks can be lowed down by strengthening the safety supervision and regulating the seaplanes' activities.

6.1.2 Risk Control for the Second Category Factors

(1) The risk caused by traffic order can be alleviated. Replying on the scientific and technological progress, the competent authority can adapt and innovate in management tools, to build a new marine safety supervision system, take effective measures in the key waters，and strengthen the on-site supervision，finally, to improve the marine traffic order gradually. The actual effects of measures should be evaluated and adjusted regularly by using multi-level and multi-factor comprehensive evaluation method, in order to reduce the risk.

(2) Seaplane condition. The competent authorities should rationally determine the suitable seaplane models for Sanya Port，and strictly control the access by special inspection improve the communication and navigation method，strengthen daily safety inspection，detect and correct defects in time，to ensure that the seaplane condition is good，and the risk can be eliminated.

(3) Traffic density. Although the traffic density of Sanya Port shows an increasing tendency from 2010 due to the Hainan international tourism island policy; however, the risk can be cut down by reasonable traffic origination and guidance.

6.1.3 Risk Control for the Third Category Factors

(1) Navigation Aids and services. Security authorities continues to improve the normal rate of navigation Aids, providing high quality INF services, including ship sailing INF, search and rescue information, potentially dangerous information, the risk can be lowered as far as possible.

(2) Natural conditions. The seaplane companies or operators should be required to

strengthen the sailing management，develop and improve the emergency response mechanism to avoid risks.

(3) Quantity of seaplanes. The market demand and high price determine that the amount of seaplanes will be not too much，the impact of seaplane quantity is smaller than other factors. To control the total seaplanes reasonably can cut down the risk.

According to the above analysis， it is no doubt that the risks affecting the seaplane safety can be reduced and controlled if the safety management is strengthened and reasonable countermeasures are implemented.

6.2 Recommendation for Safety Management of Seaplanes

Based on the characteristic of seaplane sailing and safety management, combination with domestic and foreign researches, recommendations are given as follows:

6.2.1 Measures for safe sailing and collision avoiding

When sailing on the water, including taking-off and landing, seaplanes should comply with the related regulations in COLREGS.

(1) Responsibilities when meeting other vessels

As prescribed in Rule 18 in this Convention, A seaplane on the water shall, in general, keep well clear of all vessels and avoid impeding their navigation. In circumstances, however, where risk of collision exists, she shall comply with the Rules of this part.

(2) The exhibitions of lights and shapes are required

In Rule 31, it says that where it is impracticable for a seaplane to exhibit lights and shapes of the characteristics or in the positions prescribed in the Rules of this part she shall exhibit lights and shapes as closely similar in characteristics and position as is possible.

Meanwhile, relevant provisions of The International Civil Aviation Covenant should also be complied with.

6.2.2 Special Training and Examination on Seaplane Pilots

Seaplane pilots should have all equipments of maritime collision avoiding, lifesaving, fire fighting and relevant laws and regulations besides holding the pilot competency certificate. In order to obtain these competent certificates issued by maritime authorities, they must participate in the maritime safety training, which is a kind of special training for seafarers organized by maritime authorities, only in this way, can they engage in a seaplane driving business in designated waters. The specific provisions of special training, examination and certification should be complied with “The Procedures of People’s Republic of China of Special Training, Examination and Certification for Seaplane Pilots”, STCW and other regulations.

6.2.3 Special Inspection for Seaplanes

As a special ship safety management, when inspecting on seaplanes, MSA officer should focus on the maritime safety, collision avoiding and search and rescue, for instance, lights and shapes, security and emergency communications, emergency position indicating marks, lifesaving, fire fighting and related equipment.

Oil pollution equipments can not be considered as a focal point of checking, because seaplanes use aviation kerosene or diesel oil for fuel, and seldom produce residual oil and grease. However, because they transport passengers, seaplanes can also generate a certain amount of garbage, whose disposal should be checked according to annexes of MARPOL Convention.

6.2.4 Seaplane Activities shall be Controlled

The safety management of seaplanes should be harbored into Sanya Port maritime

traffic management system, because its special operation of taking-off and landing will affect other passing vessels, so that the seaplane's activities should be controlled more strictly. It must get permission from MSA before taking-off and landing; seaplanes pilots are required to watch and listen to the VHF traffic channel when sailing, berthing all the time or, before landing and after taking-off in a certain altitude.

Visual aviation and navigation rules should be implemented strictly. Because ships sailing on water surface use plane radars, it's difficult for them to discover seaplanes when they taking-off and landing, so a seaplane is recommended to perform visual aviation and navigation rules, in case of poor visibility, she can not take-off and land.

6.2.5 Intensify the Source Management for the Seaplane safety

MSA can introduce the management experience on Ropax companies into seaplane company management, urging the seaplane operating companies to establish SMS, and audit them regularly. Meanwhile, MSA should supervise and help seaplane companies to develop and implement internal documents such as on-duty system, procedures of seaplane operations etc., making them to keep smooth communication between seaplanes and MSA.

6.3 Other Suggestions

6.3.1 Define Exclusive Activity Waters for Seaplanes

In order to reduce the risks of collision between seaplanes and vessels, it is feasible to designate a specific activity area for seaplanes. For instance, based on full assessment, the No. 4 anchorage can be adjusted to a different location and part of the outer harbor waters of Sanya Port in the north of Phoenix Island can be designated as the excusive water area for seaplanes. When taking-off and landing, traffic control can be carried out to prevent other vessels entering the area, if necessary, MSA can be requested to conduct field maintenances.

6.3.2 Establish and Develop the Seaplane Security Service System

With the completion of Sanya international seaplane center and the increasing marine traffic flow, it is necessary to consider the construction of Sanya Port VTS, setting seaplane service tower, so that collect the relevant advisory INF of seaplane development, establish security INF database and INF releasing platform, and provide INF such as meteorological INF, navigation environment, marine accidents, dynamic ship INF, to optimize the traffic organization, improve navigation efficiency, providing security services and navigational suggestion for seaplanes.

Developing government-enterprise-seaplane tri-level emergency distress plans can improve the emergency response capabilities. Maritime authorities should urge and guide seaplane operating companies and seaplanes pilots to establish maritime safety emergency plan, and conduct emergency drill regularly.

6.3.3 Establish and Improve the Management System and Regulations for Seaplanes

In the long run, as a special ship, seaplane will exist in China for a long period, maritime safety issues refer to company management, navigation rules, traffic management, ship management, seaplane pilot management; Moreover, research and rescue need to be regulated by corresponding laws and regulations, therefore, lots of works and research should be done by maritime authorities to formulate management regulations for seaplane maritime safety, and solve the problems systematically.

6.4 Chapter Summary

According to the characteristics of Sanya Port and based on the analysis from chapter 4 to chapter 5, the author posed some classification risk control countermeasures for controlling risk factors of each category , recommendations and

some other suggestion to promote and protect seaplane safety and impel the healthy development of seaplane industry.

Recommendations for safety management of seaplanes are:

1) When sailing on water, including taking-off and landing, seaplanes should comply with GOLREGS, especially when meeting other vessels and exhibiting lights and shapes.

2) Seaplane pilots should be specially trained and tested to obtain competent certificates issued by maritime authorities.

3) MSA should implement a special inspection for seaplanes in maritime safety, collision avoiding, search and rescue, etc.

4) Activities of seaplanes should be controlled strictly.

5) MSA should intensify the source management of seaplane safety to urge seaplane operating companies to establish their own safety management system and ensure that the SMS is fully implemented.

Other suggestions, including defining exclusive activity waters for seaplanes, establishing and developing the seaplane security service system and, establishing and improving the management system and regulations for seaplanes, can also help to protect the safety of seaplanes.

Chapter7

Conclusions and Outlook

7.1 Main Conclusions

There come some conclusions after analysis.

(1) The research has analyzed the potential risks of marine environment in Sanya port.

(2) It analyses the objective issues that the seaplane industry faces from the view of seaplane safety security. It spells out 9 factors relevant to the seaplane safety by AHP and classifies the different results caused by these factors by calculating their own weights.

(3) It proposes the safety countermeasures for promoting and protecting seaplane industry in Sanya port from safe sailing and collision avoiding, special training and examination, special inspection for seaplanes, seaplane activities control, seaplane company management and other aspects. Finally, it comes to a conclusion that the risk affecting the seaplane safety can be reduced and controlled if the safety management is strengthened and reasonable countermeasures are implemented.

7.2 Shortages of the Thesis

This thesis takes Sanya Port for example, the analysis result may show a parent original characteristic.

Because seaplane is an emerging industry in China, there is no specific data in seaplane accidents. So it is impossible to conduct risk analysis research on seaplane accidents directly because there is no specific data in accident, therefore, the analysis result on existing vessels is a lacking of such quantitative analysis. After further development and gaining the data statistics, we can continue to study.

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Appendix 1

Questionnaire

Dear experts:

I am a student of the World Maritime University in Dalian program, I have made this questionnaire for writing my master's thesis----Research on the Risk Analysis of Seaplanes in Sanya Port and Countermeasures, earnestly requesting you to finish this questionnaire with your profound experience and knowledge, and give your precious opinions and recommendations. Thank you for your help and supports.

Based on the initial consultation and investigation, the 9 main factors affecting seaplane safety are generalized in the following table 1, please systematically evaluate the elements by comparing them to one another two at a time, and fill the result according to the explanations in table 2. For instance, if you consider that the element "human factor" in the transverse row is strongly important compared with the element "seaplane condition" in the vertical line, please fill 7 in the blank, conversely, fill 1/7 in the blank crossed by transverse element "seaplane condition" and vertical element "human factor".

Table 1- The importance of factors affecting seaplane safety

	Human factor	Seaplane condition	Company manageme	Traffic density	Traffic Order	NAS	MSA	Natural conditions	Total seaplanes
Human factor									
Seaplane condition									
Company management									
Traffic density									
Traffic order									

NAS									
MSA									
Natural conditions									
Total seaplanes									

Remarks:

[1]. NAS means Navigation Aids and Services

[2]. MSA means Maritime Safety Administration

Table 2- Direction of filling table 1

Judgment scale	Definition
1	Equally important
3	Slightly important
5	Obviously important
7	Strongly important
9	Extremely important
2,4,6,8	Between the two adjacent scales

Table 3- Questions canvassed

	Questions canvassed
1	What other factors do you think can affect seaplane safety? What's their importance?
2	What respect should be focused on to promote the development of seaplane industry in Hainan?
3	What's your opinion on ensuring the safety of seaplanes?