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WORLD MARITIME UNIVERSITY

Dalian, China

Research on the Maritime Safety in Qiongzhou Strait

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A research paper submitted to the World Maritime University in partial
Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

2014

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DECLARATION

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

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

Signature:LI Jiakuan.....

Date:10th July 2014.....

Supervised by:SHI Guoyou.....

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The paper's research is under the guidance of Professor SHI Guoyou. He gave lots of useful suggestions in my writing process. His strict attitude in research, deep academic background, and diligent spirit in working influence me a lot, and will also inspire me in my future study and work. Please allow me to express the greatest respect for him.

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Thank the assessors who will take their precious time from their busy schedule to check my paper. Due to my limitation in knowledge, it is impossible to eliminate all mistakes in my paper, and I would be glad to receive advice from assessors and do my best to improve it.

At last, I shall say thanks to my family who always stand by my side. During the writing process, I receive great support and encouragement from my wife April. Thank all of you sincerely.

ABSTRACT

Title of Research paper: Research on the Maritime Safety in Qiongzhou Strait

Degree: **MSc**

This research paper is a study of ro-ro passenger transport in Qiongzhou Strait. Maritime Safety has draw more and more attention of public in recent years. As one branch of maritime transport, ro-ro passenger transport is of great importance in Qiongzhou Strait. Considering the potential huge risk and tremendous cost in human life and property, it is necessary to research and analysis the contributing factors which may lead to accidents.

A brief look is taken at present achievement of human factor in the marine field. By introducing SHELL model, the research paper investigates the details in ro-ro passenger transport which should be pay attention to. Several measures toward reducing the risk in ro-ro passenger transport are provided accordingly

KEYWORDS : Qiongzhou Strait, ro-ro passenger transport, human factors, SHELL Model

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LIST OF ABBREVIATIONS

IMO	International Maritime Organization
MSA	Maritime Safety Administration
RO	Recognized Organization
RoPax	Ro-Ro Passenger

Research on the Maritime Safety in Qiongzhou Strait

1. Introduction

November 24, 1999, Da Shun, a ro-ro vessel in Shandong Yantai-Dalian Ferry Co., Ltd., carrying 304 passenger and 61 cars from Yantai Port to Dalian, capsized at 23:38, the accident caused 290 deaths and direct economic losses of about 90 million yuan. There were 312 people on board the ship including passengers and the crew, only 22 people survived. At 8:58 on April 16, 2014, a passenger ship (SEWOL) which was carrying 476 people sank in southwest waters of South Korea due to flooding, up to May 15, 2014 morning, 172 people were rescued, 281 people confirmed dead, 23 people were still missing.

These tremendous accident have arose public concern widely. As the most dominating transport component in Qiongzhou Strait, ro-ro passenger transport is benefit from the economic development around Qiongzhou Strait region. Meanwhile, the risk raised by the increasing transportation density in this area is climbing too. It is very necessary to study the feature of ro-ro passenger transport and grasp effective method to ensure the transport's safety. This paper is trying to analyze the human factor in ro-ro passenger transport from details in four aspects, and reduce the risk from administration, company, and operational level. SHEL model is applied as the main research method.

2. Introduction to Qiongzhou Strait

As one of the three largest channels in China, Qiongzhou Strait, is clamped between the Hainan Island and Leizhou Peninsula of Guangdong Province. Qiongzhou Strait is about 80 km long, the average width is 29.5 kilometers (straight distance in the narrowest point is only 18 kilometers), and the average depth is 44 meters (maximum depth is 114 meters). The entire water area of Qiongzhou Strait is 2300 square kilometers. The Qiongzhou Strait is a most important traffic connection which connects Hainan Island and the continent. According to *The United Nations Convention on the law of the sea*, the Qiongzhou Strait is the water of our country, as well as an international channel. With the continuous development of China's opening to the outside world, especially with the great development of West China Exploration and the rapid economic construction of Hainan province, the traffic density in Qiongzhou Strait saw a great increase. According to observation data, the number of ships passing the Strait is about 300 a day on average, not to mention many small fishing boats. There are many shallow water areas in the channel, and the complex traffic flow due to several port located along the coast in both side of the Strait, makes the areas accident-prone. In addition, many fish gear are located illegally in the water, worsening the navigable environment, and posing a great threat to the safe operation of ships. (LI Tao, 2013)

In order to strengthen the safety management of the waters, safeguards the ships navigation security, improve transport efficiency, prevent traffic accidents and protect the water environment, the Ministry of Transportation approved the establishment of Qiongzhou Strait Vessel Traffic System in the "Ninth Five-Year" period, referred to as Qiongzhou Strait VTS. Qiongzhou Strait VTS includes a center and three radar stations. The center is located in Haikou, and four radar stations are located in the

south of the channel, namely Yubaojiao radar station, Baishamen radar station, Mulantou radar station and Xinhai radar station. Xinhai radar station is the latest one which is constructed because of the operation of Yuehai Railway. The main function of the Qiongzhou Strait VTS are: (1) monitoring traffic flow through radar as well as AIS, with tracking, recording and replaying functions; (2) use the VHF communication system to contact with the ships, multi - channel recording and playback function; (3) radio direction finder has the function of determination and identification of the ship's position when it is using the VHF. The system was officially opened on June 1, 2002, to accept ships' reports, and implement formal management upon the water.

3. Ro-ro passenger vessels transportation in Qiongzhou Strait

3.1 The development of ro-ro passenger vessels transportation

Since 1980s, the ro-ro passenger vessels transportation in Qiongzhou Strait has experienced a rapid development. Today, it transports 700,000 cars and 5,000,000 passengers every year. The ro-ro passenger transport plays an active role in enhancing the regional logistics and communication. However, due to the special features of ro-ro passenger vessels, relevant navigation safety issues become more and more vital, arousing extensive concern in the shipping field. In the last few years, maritime accidents including collision, grounding, fire and capsizing of car often take place, which cause serious threat to Strait transportation safety. Therefore, in order to effectively prevent the maritime accident in Qiongzhou Strait, we shall look into the factors which affect the maritime safety in Qiongzhou Strait, and conduct useful measures so as to reduce and eliminate the hazards of maritime safety in Qiongzhou Strait.

In the last decade, the quantity, tonnage and size of ro-ro passenger vessels in Qiongzhou Strait are increasing again and again (see Table 1,2 Figure 1,2)which calls for new requirements for the supervision of safety of ro-ro passenger vessels. To carry out the analysis of ro-ro passenger vessels in Qiongzhou Strait, generic data should be considered first. Up to 2012, there were 59 ro-ro passenger vessels operated in the Qiongzhou Strait(see table), there were 20 vessels whose GRT(Gross Tonnage) was more than 3000, 14 vessels were in the 1001~2999 category, 25 vessels were below 1000 GRT, accounting for about 40% of the total number of ro-ro passenger vessels; There were 22 vessels whose age was younger than 10 years, 9 vessels whose age were between 10 to 14 years, the rest 28 vessels were over 15 years, accounting for about 47% of the total number of ro-ro passenger vessels. The hull structure, technical conditions of aged ro-ro passenger vessels, and the poor capacity of small ro-ro passenger vessels and some open type ro-ro passenger vessels in resisting wind and wave, constitute potential risks in transportation safety.

Table 1 The quantity of ro-ro passenger vessels from 2003 to 2012

YEAR	03	04	05	06	07	08	09	10	11	12
VESSELS	40	43	43	43	44	45	47	50	55	59

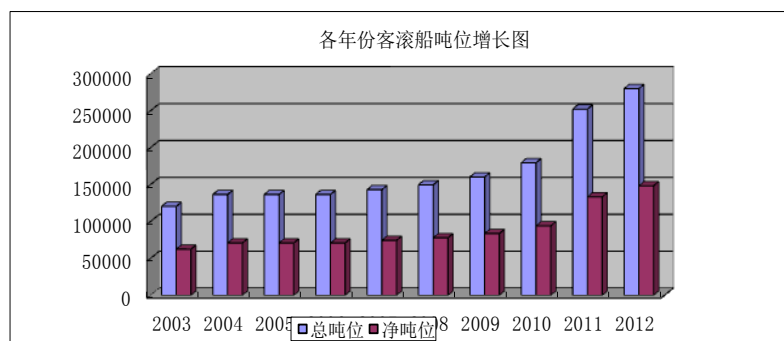


Figure 1 Tonnage of ro-ro passenger vessels from 2003 to 2012

Table 2 Wind force resistance grade of ro-ro passenger vessels

	6	7	8	Total
2003	9	29	2	40
2004	9	31	3	43
2005	9	31	3	43
2006	9	31	3	43
2007	9	31	4	44
2008	9	31	5	45
2009	9	33	5	47
2010	9	33	8	50
2011	9	33	13	55
2012	9	34	16	59

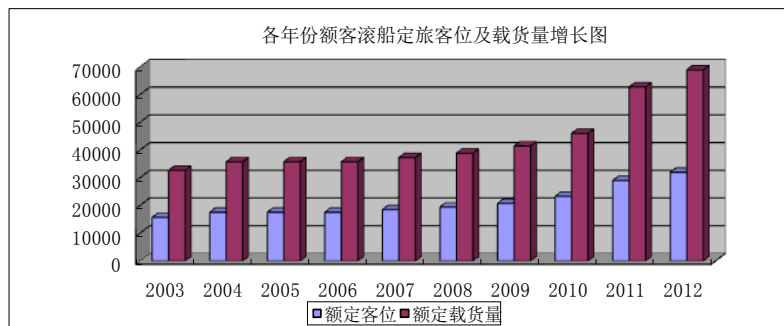


Figure 2 Transportation capacity of ro-ro passenger vessels

3.2 Accident analysis

At present, the potential danger existing in the traffic mode of Qiongzhou Strait water is increasing. The main factors are as follows:

(1) Different types of ships including fishing boat, bulk carrier, container ship and so on, are sailing across the route of ro-ro passenger ship. It constitutes very complex

traffic flows which cover a huge area. The frequency of meet between ships also climbs significantly.

(2)The wind, wave and fog make the navigation circumstance more and more difficult. The average wind force is 3.0m/s. The highest wind force (4.6m/s) is in April, the lowest wind force (2.5m/s) usually occurs in August or September. The flow speed in east Qiongzhou Strait can reach 7 kn; the flow speed in the middle of Qiongzhou Strait is about 3-5 kn; the flow speed in west Qiongzhou Strait is no more than 2 kn. Fog usually happen from December to March, 25% of accident in Qiongzhou Strait are directly influenced by poor visibility.

(3)The rapid development in traffic density especially the VLCC and various types of ships which carry dangerous cargo, increase the risk of traffic safety in this area.

Take accidents in Qiongzhou Strait between 2007-2011 for example,

2007: 7 accidents include 7 minor accidents (7 collision). Financial loss is 646,000 Yuan (RMB).

2008: 11 accidents include 1 very serious accident, 1 moderate accident and 9 minor accidents (5 Collision, 3 Impact, 2 Fire/explosion, 1 Grounding). Financial loss is 1,200,000 Yuan (RMB). 1 person missed, 1 ship sank.

2009: 8 accidents include 2 very serious accidents, 1 moderate accident and 5 minor accidents (4 Collision, 1 Impact, 2 Grounding). Financial loss is 720,000 Yuan (RMB). 1 person missed, 1 ship sank.

2010: 11 accidents include 11 minor accidents (9 Collision, 1 Impact, 1 Grounding). Financial loss is 1,920,000 Yuan (RMB). 1 ship sank.

2011: 13 accidents include 2 very serious accident, 2 moderate accident and 9 minor accidents (6 Collision, 1 Impact, 1 Fire/explosion, 1 Grounding, 3 Flooding). Financial loss is 16,180,000 Yuan (RMB). 1 casualty, 1 ship sank.

From these data, we can get the conclusion: the safety issue in Qiongzhou Strait is

becoming serious year by year. In this five-year, during the 50 accidents in total, 31 accidents are collisions. It counts for 62%. Collision is the most common type that ro-ro passenger ship would possibly experience, so it is necessary to study the characteristic of the collision accident. From the visibility aspect, 15 collisions are under the poor visibility, 16 collisions are under good visibility. Worth-noting is that, in the 9 collisions which ro-ro passenger ship involved in, 7 collisions are in good visibility. Apparently, there are other factors that ro-ro passenger ship should concern. Considering the time, 15 collisions are in the 0000-0800 period, 12 collisions are in the 0800-1600 period, only 4 collisions are in the 1600-2400 period. This result is consistent with a census held by IMO fatigue factor research team. They investigated 60,000 seafarers in Baltic Sea, and found out seafarers feel very tired and in extremely fatigue status during 0000-0400 and 1300-1500 period.

4. Human factors

4.1 The research in human factors

Human factors was first proposed as a concept in 1930s, American scientist Heinrich pointed out that the root cause which lead to accident is Human factors. It has aroused great concern in aviation and was applied in research. As the science develop, human being's activities spread to every corner of the world. Due to the limitation of science, technology and human's inherent capability, accident in different domain occurs from time to time. Gradually, human factors are adopted as a special concept to describe the main cause of accident in many domains. But there are varieties of definitions in Human factor due to the difference in culture, domain and understanding.

Human factor is acknowledged by America in 1957, Human Factors Association was

found in this year and organize the first conference. In Europe, the similar professional area focused in human factors called Ergonomics in this period (Michael Maddox, 1998). Human Factors theory was first utilized by aviation realm in China. The representative view in these theories includes Hain rule, Murphy's Law and accident chain principle. MEDA procedure and human factor investigation method in Hewlett-Packard Company are the main operational methods (WU Mei, 2005).

4.2 Human factors in shipping

Shipping has been a high risk industry from the very beginning dated back to thousand of years ago. When ships are sailing on the sea, the tough hydrographic conditions such as flow, reef, narrow channel effect, bad weather conditions such as fog, typhoons and other factors, will hazard the navigation, and in some cases, may lead to terrible accident. Since ships are usually far away from the land, external rescue resource is not available, so mostly ships will have to rely on themselves. Therefore the consequences of accidents often turn out to be very serious, causing not only loss of life and property, but also serious pollution of the environment and ecology.

Many agencies including Japan Coast Guard, Germany Bremen Shipping Economic Research Institute, Australian Department of Transportation have made specific accident statistics and research. Although all of data they use are from different sources, the conclusions are the same, that is about 80% of the accidents are due to human factors.

What is human factor? At present there is no international uniform interpretation. Human factors include the positive and negative factors, defined by IMO as: A departure from acceptable or desirable practice on the part of an individual or group that can result in unacceptable or desirable results. In the maritime domain, human

factors refer to its negative effects. In June 23, 1997, IMO published human factors unified terminology, and it divided human factors into six categories:

(1)Human error; (2)Diminished human performance; (3)Marine environment; (4)Safety administrations; (5)Management; (6)Mental action. (LIU Zhengjiang, 2004)

4.3 The characteristic of human factors in ro-ro passenger ship accident

In the maritime domain, human factors are related to sense of responsibility, mental status, physical condition, ability and knowledge. Human factors and other relevant factors have coordinated relationship. Therefore, human factors depend on various components in the particular people and certain environment. Understand the nature of human factors to overcome the negative effects of human factors is essential. According to the definition and characteristics of human factors, human factors have the following properties:

①Lag. Human is the main promoter of ro-ro passenger transport development. The level of related science and technology in ro-ro passenger transport experiences a rapid development, but the level of required operator's own inherent qualities is relatively too slow to match it. That is why 80% of risk in ro-ro passenger transport comes from the human factors.

②Implied. Human factors exist in the human's own internal side, it hidden in human or human organization as the micro form. So with the characteristic of human factor is implicit and difficult to grasp. We can observe it through external action performance of the implicit human factors.

③Universality. Human factors present in human social systems, and exist in every corner where human involve. In ro-ro passenger transport, human factors exist in various departments, every stage and each chain, its impact is universal.

④Unity. In ro-ro passenger transport security system, it contains human, hardware, environmental and software, the most important is the human factor involved in shipping companies, maritime authorities, crew training institutions, and many crew participants. In this system, human is the dominant component, human factors and human is inseparable, they are united within human themselves.

⑤Empirical. Development of human history depends on the experience, human experience provides a reliable guarantee for all activities engaged in, human factors in the field of passenger transport is also inseparable from the application of experience, empirical reflects human skills accumulation.

5. SHEL model appliance in ro-ro passenger transport

5.1 Introduction to SHEL model

SHEL model was first proposed in 1972 by Professor Edwards, and then revised by Professor Hawkins. This model is now widely used in the framework of human factors research. The name of SHEL model consists of the following four words' initial letters: Software (S), Hardware (H), Environment (E), Liveware (L). Liveware, which is the center of the model, is considered to be the most important part of the system. The relationships between liveware and other components are four interfaces of the model: L-S interface, L-H interface, L-E interface, L-L interface. The relationship between the various interfaces is uneven, which means that each interface does not completely match each other. It indicates that, it should be very careful in considering the various elements of the system; otherwise it will lead to system crashes and accidents. (Frank H Hawkins, 1993)

SHEL model has not been widely used in the maritime field. But in aviation, this famous human factor analysis model has been included in many university textbooks,

and has been widely applied as a typical factor model in accident analysis in the aviation domain.

5.2 Human factors risk assessment system based on SHEL model

In the ro-ro passenger transport areas, a majority of accidents are caused by human factors. Meanwhile, ro-ro passenger transport safety management system is based on human control in decision-making. As the most positive and most active factor in ro-ro passenger transport safety, human is also the most difficult factor to handle, so human factors become the bottleneck in enhancing the ro-ro passenger transport safety level. Human factors in ro-ro passenger transport are composed by human (Liveware) and the same interaction interfaces mentioned above. SHEL model can therefore take advantage of the scientific analysis human factors in ro-ro passenger transport in all aspects, find reasons from the source and take preventive measures to minimize the risk of accidents caused by human factors.

In this human factors risk assessment system:

(1) L factor (L): refers to the element associated with the individual in ro-ro passenger transport. As an organism, a human being has his own ability, but also has its own limitations. Human's behavior is subject to the influence of character, physiology, psychological and psychosocial aspects. There is health condition, fatigue, drug use, alcohol and illusion in the physiological aspect. There is perception, attention, emotions, attitudes, personality, ability and other factors in the psychological aspect. There is work, family, social, human-machine pressure in the psychosocial aspect. Personnel involved in the system are often very extensive. It includes not only direct maritime operator (such as the master, crew, pilot, etc.) of the ship, but also includes the personnel in the ship design, construction, survey, and management services and maritime security operation.

(2) Liveware-Software interface (L-S): the relationship between people and software. For example, whether the required information in ro-ro passenger transport is sufficient and reasonable; ro-ro passenger transport-related regulations, systems, rules, protocols, standard operating procedures, habits and customs, do they meet the requirements of ro-ro passenger transport safety management?

(3) Liveware-Hardware interface (L-H): The relationship between human and the physical part of the system mainly refers to the relationship between the crew and the ship or cargo, such as: the design of the ro-ro passenger vessel, equipment maintenance conditions, overloading situation, lashing status of vehicles and cargo on board the ship, cargo stowage situation. Fundamentally speaking, the hardware design should be human-centered, the development, equipment shall aim at promoting safety, improving efficiency, and simplifying the operation. As the operator, human shall make himself adapt to the hardware.

(4) Liveware-environment interface (L-E): The relationship between people and environment (including the social environment and family environment). For instance, whether the sailing environment of ro-ro passenger vessel would limit the participant's behavior in ro-ro passenger transport or affect their judgment.

(5) Liveware-Liveware interface (L-L): Activities between people and others in the system is the relationship of leadership, management, communication and cooperation among people. For example, the management of master, the cooperation of the crew, the safety management of the passengers on a ro-ro passenger vessel; shipping safety management, coordination between department, and information management in the shipping company; supervision and monitoring authorities in charge of ro-ro passenger transport safety and so on. Effective coordination is the key point to improve efficiency of ro-ro passenger transport and reduce the risk in ro-ro passenger transport safety.

6. Ro-ro passenger transport human factors Risk analysis

6.1 L factor

6.1.1 Personality and psychological factors

The personality and psychology of the crew and safety-management personnel is the fundamentals to ensure ro-ro passenger transport safety. Personality and psychological factors affects human potential in various forms, thus affecting the entire population and the achievement of organizational goals, which has a huge impact on ro-ro passenger transport safety. The indicators include four major areas (professional ethics qualities, personality traits, psychology quality, and safety awareness).

(1) Professional ethics qualities refers to the quality of professional ethics passenger transport spirit of love and dedicated personnel for employers to provide excellent service employee spirit, team spirit and sense of humanity, to win glory for the motherland and the nation's sense of ownership for the survival of mankind and the protection of the marine environment mission and other aspects. As the superstructure, professional ethics would have an effect on people's behavior subjective initiative. Thus the quality of professional ethics directly affects the size of the risk of ro-ro passenger transport.

(2) Personality traits measure the impact of crew's main character traits on ro-ro passenger transport risks incurred. Studies have shown that accident prone personality traits are: emotional impulse, easily excited, grumpy, tired of work, no patience, panic, do not calm, action stiff, slow and inefficiency; deal with rash.

(3) Psychological quality affects crew's resilience and attitude in tough environment. Psychological quality can directly affect the applications of theory, calmly deal with

an emergency situation, in order to make the right judgments, and take effective measures to carry out self-rescue or support, minimize the loss and risks; People who have poor psychological quality will use negative attitude to deal with danger. According to the ro-ro passenger transport accident statistics, there is a higher proportion of incidents which are caused by psychological qualities in the previous incident. Although the crew have qualified certificates and meet ro-ro passenger transport navigation requirements, due to the absence of necessary emergency response capabilities, disastrous consequences of ship occur. In summary, the psychological qualities not only determine the performance of routine work, but also determine the level of emergency response capabilities.

(4) Security awareness is the sub-consciousness accumulated by professional knowledge, understanding of safety knowledge, experience, daily knowledge, respect for life and so on. Security awareness ensures respect and effectively implementation of safety regulation. In particular, as a special group of ro-ro passenger transport, the safety quality of passenger plays an important role.

6.1.2 Professional quality factors

(1) Seafarer's navigation knowledge and skills. It measures the comprehensive capabilities of seafarer when they conduct the operation on board based on certain navigation education background and own experience they obtained. This factor can be evaluated from academic, sailing experience and English language level. Only by having sufficient sailing knowledge and professional skills can the crew effectively prevent the ro-ro passenger accidents caused by human factors, and accomplish the rescue and remedy job after the accident.

(2) The quality of managers in shipping company concentrates in the knowledge and capability in safety management. Managers must master the knowledge of safety management in order to fundamentally solve the security risks, ensure the safe

operation of ro-ro passenger transport safety. Safety management capability refers to the judgment toward the whole company's status and the ability to control the overall situation of the company, including the ability to make decisions, planning ability, creativity, judgment, training and motivation.

6.1.3 Physiological factors

Physiological factor is the most basic factor to ensure safety of the crew to perform their duties. The paper focused in the health condition and fatigue.

(1) Health condition mainly measures the physical health of the crew and vigorous status. As a high-risk business, sailing is work-intensive, not only requires the crew to withstand prolonged continuous work, but also requires the crew to bear changing climate caused by different navigation area. Thus physical health of the crew will certainly pose a direct impact on their job security, even though the crew has undergone medical research before obtaining the corresponding certificate of competency, but since medical examination is not complete and sudden illness is difficult to avoid, and change in the health of the crew is inevitable. In addition, poor living conditions on board, the depression emotion and a variety of complex reasons often lead to the occurrence of disease, so the health condition of the crew is the most basic and the most important content in physiological factors.

(2) Another aspect we should measure is the degree of fatigue of the crew during the voyage. Frequent mooring, loading and unloading drive the seafarers in ro-ro passenger ship in danger of exhausting. Lack of manning make the situation worse. In the long work process, Seafarers are likely to become fatigue due to the heavy pressure and lack of rest. the seafarer's physiological manifestations of brain fatigue include slow sensation, non-accurate action, and reduced sensitivity, the psychological manifestations of brain fatigue include inattention, slow thinking, slow response and feelings of irritability. These phenomenons often easily lead to

accidents. So fatigue is a status that reduces people's working efficiency, slow down the reaction of the body and mind, and weaken the ability to make a reasonable judgment, the result will inevitably lead to increasing unsafe behavior, decreased quality of ship maneuvering, the slows down of collision avoidance reaction, leading to increased accidents. Currently, the fatigue has become recognized as a leading risk factor in ro-ro passenger transport.

In ro-ro passenger transport of Qiongzhou Strait, insufficient manning is the most serious problem. Although the seafarers on board the ship meet the minimum manning requirement, it is obviously not enough for ensure the crew's rest hour due to many kind of task they have to do. Frequent berthing occupies the crew lots of time for loading and unloading especially in the busy holiday.

6.2 L-S interface

6.2.1 Factors of shipping company

In the L-S factors, rules and regulations, education and training, departmental organization structure are the three aspects that the shipping company should concern

(1) Rules and regulations measures establishment and implementation conditions of the rules and regulations in shipping companies. In order to standardize ship operating management, shipping companies need to establish a corresponding security administration rules and regulations, and need to develop a series of relevant quality system documents such as operation procedures, working standards, operation rules.

(2) Education and training measures validity and integrity of the crew and staff education and training system, this indicator mainly checks safety education cycle, the development of safety lecture, whether the safety training is conducted, evaluation mode of safety training, whether the safety training has model exercises

and comprehensive plans. Education and training is the most effective way to improve the quality of managers and seafarers, and also is the most important risk controlling aspect of human factors in ro-ro passenger transportation. Perfect education and training system can not only raise the crew and staff's awareness of safety in production and self-consciousness of abiding by rules and regulations, but also can strengthen the crew's ability to identify and handle emergency situations, and help to maintain and manage ship equipment. Thus education and training determines high or low risk of human factors in ro-ro passenger transportation.

(3) The departmental organization structure measures department settings and organizational structure related to safety, each department and position's responsibility and correlations. Reasonable setting in departmental organization structure, scientific division of departmental organization functions, smooth relationship and efficient coordination of safety management system, are the foremost guarantee to reflect security policy effectively for the company.

6.2.2 MSA factors

MSA factors mainly focus on policies and regulations, rules and regulations, organizations and methods of management.

(1) Policies and regulations, rules and regulations used to measure integrity, coordination, maneuverability, practicalness of related policies and regulations, rules and regulations in ro-ro transport. In order to protect safety of life and property at sea in ro-ro transport, and protect the water area environment, IMO and China's relevant departments promulgated a number of policies and regulations. But ro-ro passenger transportation has some special laws compared with other forms of transportation, in our country relevant professional regulations are very limited at present. To the company engaged in transportation, it lacks unified strict legal definition enterprise qualification, personnel quality, safety management and navigational requirements.

Moreover, whether these policies and regulations play a role in reducing ro-ro accident relies on the coordination and implementation. As a ro-ro passenger transport safety management authority, MSA has the duty to formulate and organize implementation of safety supervision and management of ro-ro transportation, provides peer security. Thus, incomplete policies and regulations as well as rules and regulations related to ro-ro transportation have a great impact on our country's security management.

(2) Organizations and methods of management mainly measure the reasonableness of the maritime safety administration and correctness of management methods. The operation and management center of VTS (Vessel traffic management system) is an administrative and law-enforcing department by which the competent authority directly exercises their safety management functions of water traffic in accordance with national laws and regulations.

6.3 L-H interface

6.3.1 Ships factors

Whether the structure and equipment of the ship is safe or not plays an important role in human factors risk assessment of ro-ro passenger transport. Ship factor system is the most dynamic and active component except human. It is the leading force in the economic benefits of the entire waterway transport system. Eliminate the hidden dangers of ship is of great significance in human factors risk control in ro-ro passenger transport. Ship design, equipment maintenance conditions and drainage system quality will determine the risk of ro-ro passenger vessel in some degree.

(1) Ship Design measures the integrity and reliability of the ro-ro passenger vessel and its equipment. It is vital to make sure the ship and its equipment are designed and constructed scientifically, otherwise, there must be many hazards and potential risks

in the ro-ro passenger transport. At present, some ro-ro passenger vessels operating in Qiongzhou Strait have the following design shortages:

①Lack of internal transverse bulkheads. Overall design of ro-ro passenger vessel is to make the vehicle get in from one end of the ship and get off from the other end, so complete transverse bulkhead installation is a major obstacle, especially in the upper deck. Despite the SOLAS Convention requires ro-ro passenger vessel must install watertight door or bulkhead so as to separate the cabin below the freeboard deck , but the huge car deck can be quickly immersed in the water, and also allows the fire spread quickly. ②The loading door at the bow and aft is a potential weakness. After several years of use, these doors are almost damaged or distorted. When the doors are treated as a loading springboard, the situation is more serious. ③Low freeboard. Since the access doors installed on a ro-ro passenger ship usually is vary close to the waterline. When the ship experiences a sudden heel or trim caused by the movement of goods would, if the water reaches the limit and the door is not closed, the water will flush into the ship and make the ship more difficult to keep balance and even lead to capsize. Therefore, television surveillance and a water leakage detection system shall be arranged to provide an indication to the navigation bridge and to the engine control station of any leakage through inner and outer bow doors, stern doors or any other shell doors which could lead to flooding of special category spaces or ro-ro spaces. (SOLAS, 2012)

(2) Equipment maintenance conditions. Equipment and facilities in the long-term use, will inevitably making the reliability decline by aging, insufficient design margins, incorrect use environments, undetectable defects, human error and abuse. Reasonable strategy of maintenance on equipment and facilities should be taken in order to maintain stable condition in ensuring ro-ro passenger transportation safety. Even the newest, the best modern equipment can not achieve its intended performance without

human's management and maintenance.

(3) Drainage system is also a risk factor that must be considered. Ro-ro passenger ship has relatively poor stability. In this situation, the problem caused by drainage system becomes particularly important since it can easily interact with other factors and triggered accident.

6.3.2 Factors of goods

If the goods in ro-ro passenger ship were not stowage and lashing properly, it is easy to make the goods deregulate from its original position. In addition, the crews do not know exactly the cargo condition in the vehicles, this problem becomes more serious. A heavy-loaded cargo could force other near by units also moves. It can easily result in leakage of dangerous material. In extreme situation it will jeopardize the hull and the ship's structure.

(1) Stowage of the goods is an important part of ro-ro passenger transport. Incorrect stowage not only directly leads to increased loading time, but also resulted in the risk of fire and explosion due to excessive contact and friction with each other. Therefore, it is necessary to organize proper loading under the control of well trained and experienced crew.

(2) In ro-ro passenger transport process, due to lack of safety knowledge, negligence or lack of professional personnel training and other reasons, make lashing vehicles adverse effects in the cabin, can not meet the safety of navigation requirements on vehicles lashing. In addition there are also the vehicle placed unreasonable, without placing such a well-planned, space utilization is very low, and can easily result in unreasonable placed collision between vehicles, leading to fires and other accidents.

6.4 L-E interface

6.4.1 Ship environmental factors

Ship environment mainly includes internal work environment and crew's living environment.

(1) The internal work environment mainly measures the impact caused by the internal work environment for the crew, and thus the impact on ro-ro transport risks. The internal work environment related to safety and health of the crew, and so related to safety and benefit of the ro-ro transport, therefore we need to take technical and organizational measures to improve the poor environment that endanger the safety and health of the crew in working process, prevent casualty accident and occupational hazard, and protect the safety and health of the crew in working process.

(2) The crew's living environment measures the effect caused by the living environment on board for the crew. The crew's living environment includes living facilities guarantee, crew communication, collective activities etc. As the living space is small on board, single crowd, fixed roles, insufficient exercise, lack of fresh vegetables, violation of biological rhythm, plus long separations from society and family, the crews life is dull, boring, lack of stimulation and information. Living in such an environment, people are easily easily irritated and annoyed. Therefore, healthy and comfortable living environment can relieve crew's negative emotion, improve work efficiency, eliminate unsafe behavior, and then to reduce or prevent the occurrence of ro-ro accidents.

6.4.2 Navigation environmental factors

Navigation environment includes environmental judgment and traffic density.

(1) Environmental judgment measures the accuracy that the officer judging the environment during the voyage of ro-ro passenger ship. As it is free to choose route when the ship sailing on the sea, correct environmental judgment is the foundation of ship's safty traffic, if the driver choose the sea area where the waterway is narrow

and the depth of flow is insufficient for the reason of incorrect environmental judgment, the ship handling will be harder, and easily lead to accident.

(2) The traffic density measures how busy the traffic is in maritime space for ro-ro passenger ship, and traffic density etc. Traffic density makes the ship off course because of frequent avoidance from other ships, also makes ship handling harder in ship collecting area, and easily lead to accidents.

6.5 L-L interface

6.5.1 The seafarer factors

Seafarer factors directly affect the level of risk of ro-ro passenger transport, the quality plays a decisive role in the accident's occurrence or not.

(1) The management level of master measures master integrated management ability such as sailing experience, operational capability, safety awareness and the ability to respond in emergencies. Master on board as the main managers of the work, has significant impact on safety navigation of the vessel. Many of the ro-ro passenger incidents indicate that the master's performance in emergency situation will lead to totally different results in ship's safety.

(2) The management level of officer measures officers' function as exemplary roles to the crew. Excellent professional skill and standardize operation and strong sense of safety awareness and good attitude will enhance the spirit of the crew and promote work quality. It is very important to have a high level officer team in order to achieve the purpose of safe operation and management.

(3) How to carry passenger safety management to ensure passenger safety is an important issue related to people's life and property and the country's reputation, as well as the primary responsibility of the employees in ro-ro passenger transport service.

6.5.2 Ship operator's factors

IMO pointed out in the ISM Code, about 80% accidents at sea are related to human factors. In addition, about 80% of the accidents associated with the human factors are management-related. From the statistics, it shows that about 80% of the accidents which are management-related are caused by the ashore management of shipping company. Thus, shipping companies (ship operators) are the major force in risk control of the ro-ro passenger transport. The level of effect and the capability of management of shipping company directly determine the degree of the risk of ro-ro passenger transport. There are four aspects of the ship operator that should consider as follows: security control, implementation of the rules and regulations of the company, the coordination between departments, the communication channels and information management.

(1) Security control of the company measures the quality of ship safety inspection system, the degree of implementation and corrective action after discovery of defects in the implementation. The company should arrange a special safety inspector for all ships, the master is required to check the inspection records of the crew, and the crews are supposed to check the equipment which are under their duty in accordance with the requirements of the ISM. For security management, a routine work is to investigate security situation of the ship with the form of inspection and internal audit periodically. It has two purposes: first, know the security situation of the ship through inspection and obtain first-hand information in time for existing non-conformities, so as to propose corrective measures according to the requirements to effectively implement; Second, do some preparatory work in order to response external safety survey, such as safety management system (SMS) external audits, safety inspection by the competent authorities (MSA), provide necessary resources and support onshore depending on the specific circumstances, in order to better

safeguard the safety of ro-ro passenger vessel operation.

(2) Implementation of the rules and regulations of the company. In order to speed up the job and improve economic efficiency, illegal actions often occurred, in addition, blind optimism and carelessness make the crew easily violate the regulation. These kinds of behavior are prone to cause accidents. At present, there is a paper work phenomenon in ro-ro passenger transport. For example, the company's SMS document provides a safe working procedure; however, in practice, the crews follow the traditional practices or other procedure. There is no related record even if they do the work according to the same requirement regulated by SMS. The traditional management model can not be improved in a short time, which increases the difficulty in controlling the risk of human factors in ro-ro passenger transport.

(3) Keep improving the departmental coordination by effective management of shipping is a long-term work. Only in this way can make various departments, all aspects, each individual cooperate together organically, ensure that individuals' motivation is in accordance with organizational goals, ensure that individual behavior is safe and effective, therefore, the overall cohesion and combat effectiveness could be strengthened, and unsafe behavior caused by management factors could be reduced.

(4) The communication channels and information management refers to the connection between ship and shore base, the degree of communication between various departments and each work position, the effectiveness of information transfer, diversity of main method of information evaluation, the smoothness of information transmission channels, records of information and materials. Information communication is a very important management function. Companies must have smooth channels of communication and efficient information management scheme, to ensure that safety information between various departments and positions can be

delivered fast, accurately and effectively. And, after the security information is received, relevant departments should properly recorded, processed and feedback in time to improve the operational efficiency of safety management.

6.5.3 Authority factor

Shipping authority mainly refers to the Maritime Safety Administration (MSA), China Classification Society(CCS) and other relevant departments, which carry out supervision and inspection upon ro-ro passenger company according to ro-ro passenger transport-related laws and regulations.

(1) The quality of ship safety inspection assessment conducted by authorities is important. In the supervision process, MSA and other safety authorities should use their skills and professional knowledge to take safety inspection and safety assessment, so the accident can be prevented before it occurs.

(2) The main responsibility of MSA is to ensure the safety of maritime navigation and prevent marine pollution. But there are also weakness and drawbacks in management which need to be improved and rectified. Poor management in actual situation will make the full-scale safety supervision is impossible, which is also one cause of the accident.

7. Recommendations of human factors risk control in ro-ro passenger transport

7.1 Establish a scientific and practical training system and improve the seafarer's quality

7.1.1 The situation of seafarer's quality

The quality of crew will directly determine the level of risk from human factors in ro-ro passenger transport. In recent years, ro-ro passenger transport team has

expanded rapidly, but the overall quality has declined. Therefore, crew training and evaluation system should be further improved.

It is worth noting that psychological quality training especially capability training in emergency shall be strengthened. At present, although ro-ro passenger transport authority(MSA) put emergency response capabilities assessment into the scope of supervision and inspection structure, but does not specify the contents and the way to check the emergency response capabilities. Seafarers who obtain the related competent certificates do not prove that they have the appropriate emergency response capabilities. Therefore, an effective evaluation system of emergency response capabilities needs to be set up as soon as possible. Meanwhile, it may be combined with ro-ro passenger safety drills and crew special training.

In addition, members of the holder and ro-ro ship management confusion about the certificate issuance, making the personal qualities of the investigation not true and reliable, so that there is a potential risk in safety management. We must strengthen the crew examinations, assessments, special training, and certification system, put forward special training programs and measures which are suitable for the specific ro-ro passenger transport conditions in our country, and improve seafarers training with related educational institutions together.

7.1.2 Recommendations on education and training of law enforcement personnel

From the view of the competent authority, it can effectively avoid the phenomenon of loose enforcement and impunity, national and local ro-ro transport safety laws and regulations can be properly implemented by the way of improving the quality of law enforcement personnel.

First, raise education levels. although a level of education is not the unique determinant of its level of business, the average level of educated people in law enforcement self-discipline, adaptability and the ability to handle the emergency

event to be higher, general law enforcement officers should have college education background or above.

Second, strengthen the professional knowledge training. According to the characteristics of safety management in ro-ro passenger transport, it's helpful to implement systematic and planned training to the law enforcement officers with the safety knowledge and skills, and is a good way to further enhance the level of business and legal awareness of law enforcement officers.

Third, emphasize moral cultivation. Moral culturing is to enable law enforcement personnel with a strong self-discipline and dedication, which will help avoid interference from external forces and resist the temptation of material, so they can better enforce laws and regulations.

The fourth is to strengthen incentives. On the basis of the implementation of safety regulation, establish appropriate and effective incentive mechanism, strengthen the sense of responsibility of law enforcement officers and stimulate their enthusiasm and initiative to do the work of safety supervision.

7.2 Strengthen safety management and ensure good coordination and cooperation

7.2.1 Strict safety control of shipping companies

Security control mainly reflected the idea of "advance prevention, process control and evaluation after", the potential risks and the possible loss should be reduced as low as it could be.

(1) Security control before sailing

Safety checks before sailing is an important part of risk control in ro-ro passenger transport, designed to find potential risks and minimize the risk of transport. In addition, master should remain real-time communication with safety and technical supervision department of the company. Once in danger, port authorities, security

technology supervision department of shipping company, ship could solve the problem together. Safety technical supervision department should send personnel to safety monitoring before sailing, mainly doing the job of site supervision and hull ship loading operations, and sampling equipment and production safety inspection records submitted to the technical supervision department.

(2) Navigational safety control

In ro-ro passenger voyage, the well organized operation is one of the effective means of transportation risk control to prevent accident.

①Berthing operation: Master should be aware of the weather, data of flow, the port requirements, and develop operational deployment and security measures. First mate and second mate who are responsible for bow and stern respectively should organize the job accordingly. They should always report the distance of bow and stern away from the port and other safety conditions to the master.

②Chart work: Master is fully responsible for chart work by checking the chart work and providing guidance; Officers on duty should seriously operate, report to master in time when identifying problem, and give suggestions actively. Use different instruments and methods to observe the ship's position timely and estimate ship track depending on the area of navigation. Mark signs, labels and symbols completely and clear on the charts and logbooks according to requirements.

③Management of Ships sailing Data: Second officer is in charge of maritime books, responsible for proper management, corrections, updates of maritime books and data, which is under the supervision and inspection of the master. Before sailing, second officer should develop navigation plan approved by the master based on voyage orders and put the chart required in the voyage in order and prepare for utilizing.

④Watch keeping and shift: Whether sailing or moored, ship implemented people on duty around the clock. Officer deck, rating deck, officer engine, rating engine on

duty should conscientiously perform watch-keeping duties, not allowed to leave their jobs while on duty and the transfer must be in accordance with regulations in the workplace and shift with informing all necessary changes.

⑤Emergency training and drills: the master is in charge of arranging crew training and regular exercises based on the job tasks provided by the "emergency deployment table". Third vice-master is responsible for developing a variety of emergency and assisting the master to perform drills and training. Content of emergency drills and exercises includes: understanding the emergency signal and emergency duties, rescuing, fire fighting, abandon ship drills, emergency steering drills, spill drills, and so on.

(3)Safety controls after voyage

①Preparation, testing and precautions before arrival: master should make the safety measures and plan of enter the anchorage at night or in poor visible distance. The master is responsible for equipment testing before arriving, arranging special personnel responsible for the inspection, testing and maintenance. Second officer shall prepare the latest version charts in large scale as soon as possible before entering the harbor and anchorage ground, and pay attention to correct the situation and ensure effectiveness and accuracy. It can reduce the risk of ground in shallow water.

②Anchoring process: Require the crew to improve accountability, choose the right anchorage, determine the appropriate anchoring methods and the anchor chain length, and correctly operate the anchoring and watch keeping when the ship is anchored according to the regulation. In the anchoring process, chief mate, officer on duty and able seafarer deck should take the initiative to actively cooperate with the master, release anchor chain, throw and grasp it properly, and record the anchor position according to the master instructions. After throwing properly anchor, pilots and

sailors on duty should keep watching, frequently check the anchor position to prevent the anchor from moving, and monitor dynamic anchorage around the ship, carefully recorded.

③Safety record: At the end of the voyage, the ship master should faithfully record the voyage related matters based on the situation and truthfully and promptly report to the Security Technical Supervision Department; Security Technology Department should check the inspection records and the master's records, and send personnel on board to verify the relevant circumstances when find discrepancies or considered necessary.

7.2.2 Strengthen management of safety supervision authorities

MSA should strengthen ro-ro passenger transport safety supervision in accordance with the relevant national regulation and local provision, combined with the characteristics of China's passenger transport, in-depth study of effective management and supervision methods and tools, and support research departments to develop effective supervision and management system to strictly control the permission of ro-ro passenger operation; strengthen the management of crew by improving the system of crew examinations, assessments, special training, and certification; should propose a special training program suited to the conditions of passenger transport and measures, and strengthen the training crew combined with relevant educational institutions together; should timely report the issues found in the inspection to the competent authorities and inform the local authorities in charge, to solve the problem immediately, leaving no troubles.(WU Kunjun, 2013)

Ship Inspection Department is the country's marine technology administrative body responsible for the implementation of supervision and inspection of the ship, and ensuring the technical conditions of safety navigation. For safe transport of the ro-ro passenger vessel, it should study and formulate regulations which is suitable for

actual survey, ship classification, shipping documents, vessel inspection fees and normative standards of ship construction, tonnage measurement, load line, maximum passenger, various navigational safety equipment, machinery and equipment, and so on. All regulations and normative standards should be promulgated after the approval of the Ministry of Transportation. Inspect the construction, repair and operation of the ship, issue certificates of seaworthiness and use various machinery and equipment when the technical conditions of the ships meet the requirements. The conclusions of ship survey should communicate with industry authorities to solve the inherent technical deficiencies of the ship's, not to make the Qiongzhou Strait become a market of old ships from foreign country.

7.3 Rational using of hardware and reduce the potential risk

Due to the particularity of freight on ro-ro passenger transport, the risk of L-H field also has the particular control objectives, mainly in the following requirements:

①The ro-ro passenger vessel shall not transport vehicles or goods that do not comply with the relevant provisions of the State; ②The carrying capacity of a ship stowage vehicle shall comply with the approved vehicle cabin, loading scales and lasing the vehicle according to the lasing Manual; ③water line of the ro-ro passenger vessel, shall not exceed the approved load lines; ④Cargo distribution of the ro-ro passenger vessel should be strictly controlled to maintain balancing; ⑤Loading spaces of the ro-ro passenger vessel shall be marked with a clearly marked vehicle loading position, and vehicle loading position numbering; ⑥Passenger tank and the maximum passenger number shall be indicated in the apparent position of the ro-ro passenger vessel.

In order to achieve the above risk control objectives, the following specific measures should be taken: ①Every ship should achieve cargo lashing before sailing according

to the seaworthy requirement including wind force conditions. ②Securing vehicles and goods should be suitable for the intended route of the ship; ③Ships should consider carrying capacity of their vehicles tanks, securing capacity and set up limitation on total weight and size of the carrier vehicle unit. ④Category vehicle spaces must installed longitudinal bulkhead or column after approved by RO(China Classification Society); ⑤Port Terminal and shipping companies should establish a team of professional lashing; ⑥Cargo loaded on the vehicle must be symmetrical; ⑦For obvious poor condition of the vehicle, shall refuse the loading on board; ⑧Crew should view the proposed shipment of vehicles. Poor condition of the vehicle, improperly loaded vehicles should be adjusted the load, or be refused the loading on board. ⑨It should be stated clearly in the view when there are special requirements for loading position of the vehicle; ⑩Establish system of inspection staff.

To enhance passenger safety risk control, it's generally realized in the form of ban: ①no oversell of tickets in ro-ro passenger ship; ②carrying passengers forbidden in crew accommodation, vehicle cabin, safe passage of the ro-ro passenger ship,

7.4 Establish sound organizational structure and management functions

Establishing sound organization and scientific safety management function of distribution is an important part of safety management. Risk control department of human factors involved in numerous shipping companies should be based on the system design requirements, in accordance with the strict, coordinated, efficient, streamlined, uniform principles, adjusting the internal organization, and equipped with competent staff, while clearly subordinate agencies relations and coordinated manner, establish a sound risk control system operation mechanism and scientific allocation of risk control management functions.

Also, it's essential to pay attention to coordinating control functions related departments, namely establishing accountability and a clear relationship between the organizational structures, management mechanisms to achieve efficient operations through coordinated control of various departments. Clear management objectives and responsibilities of the various departments within the company would optimize the organizational structure and make it run smoothly. For the company's safety management, the company should establish clear responsibilities, supervision and effective management mechanism.

Security Management Office is responsible for developing, auditing and improving corporate security management system in accordance with the ISM rules, which establishes the corporate security management framework in general.

Security Technology Supervision Department is responsible for the technical supervision of safety management and supervision of the daily operation of the ship, under the jurisdiction of which, maritime surveillance room (Marine, climate environmental monitoring, fire, regular rescue, ship and shore labor safety), Ship Technical Department (ship pollution prevention, pollution emergency, certificates), Communications and Navigation Centre (to ensure communication, Support) and crew Comprehensive Management Office (arrange crew training and seafarer auditing), provide their own technical support in the management of the ship respectively. Shipping Department and the Control Room are responsible for the arrangement of ship operation and ship dynamic monitoring. They're supposed to be on continuous watch keeping and to ensure smooth communications, to organize emergency drills and rescue, manages the routine operation of the ship.

8. Summary and Conclusions

The overall trend of ro-ro passenger ship transport in Qiongzhou Strait will keep on developing, which inevitably poses a great challenge. Human factor in maritime realm is a complex issue which involves ship design, ship survey, ship operator, ship management and ship supervision. Beside focusing on the human factor in the ro-ro passenger industry, from the supervisor (Hainan Bureau, MSA)'s point of view, many aspects need to be considered in order to improve the scheme of safety management in Qiongzhou Strait, such as clear the navigation area which is now invaded by illegal fishing net; evaluate the risk of substandard ship which may affect the ro-ro passengers ship transport; carry out effective measures to regulate the Vietnamese commercial trade ships which often violate the rule of navigation due to the quality of seafarers on board, and so on. (WANG Shu, 2009)

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Appendices

Appendix 1. Five types of accident for RoPax vessels.

1.Collision: events where two vessels accidentally come into contact with each other. This may lead to sinking, grounding or to a fire on the vessel, but these are counted as collisions if this was the cause. This definition includes collisions between two ships under way, and also events sometimes known as “striking”, where a moving ship strikes another ship at a berth.

2.Grounding (incidents classified by LMIU as “wrecked/stranded”): cases where a vessel comes into contact with the sea bed or shore, including underwater wrecks. If the ship is struck fast, this is known as “stranding”. If the ship sinks, this is sometimes known as “wreck”.

3. Impact (incidents classified by LMIU as “contact”): cases where a vessel comes into contact with objects other than ships, the sea bed or the shore. This includes impacts on berths, bridges and offshore platforms. It is known by LMIU as “contact”.
4. Other flooding (incidents classified by LMIU as “hull damage” or “foundered”): cases where water enters a ship for reasons other than collision, impact or grounding (treated separately). Some of these events are included by LMIU under the category “hull/machinery damage”. If the ship sinks, this is known by LMIU as “foundering”. The “other flooding” category is also taken to include weather damage, cargo shifting and intact instability events which would lead to flooding if the ship were to sink.
5. Fire/explosion: cases where fires and/or explosions occur for reasons other than collision, impact or grounding (treated separately).