8-28-2016

Practical research on human factor problems in maritime casualty investigation of China

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PRATICAL RESEARCH ON HUMAN FACTORS PROBLEMS IN MARITIME CASUALTY INVESTIGATION OF CHINA

By

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The People's Republic of China

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

(Maritime Safety and Environmental Management)

2016

DECLARATION

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

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

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ACKNOWLEDGEMENTS

I am sincerely thankful to Dalian Maritime University for providing me with this opportunity to study in this MSEM program in Dalian. I appreciate Mrs. Wang Yanhua, Mr. Zhao Jian, Mr. Bao Junzhong and all staff and faculties of this program, who offer me great help and support me to achieve master degree during my study life in the university.

I am deeply grateful to my supervisor Prof. Fu Yuhui, for guiding me final dissertation by offering me plenty of valuable information and advice. His rich knowledge and rigorous research attitude impress me a lot and will have influence on me in my future position and the whole life. Thanks to teacher in Foreign Language Institute who made linguistic review for my final dissertation.

I also appreciated all my classmates in Dalian Maritime University, who give me a lot of inspiration of dissertation writing and help me with daily study. They also make me spend a meaningful and unforgettable period during this program.

Last but not least, I am sincerely thankful to my beloved parents who always encourage me and support me during my study life to make me filled with great determination to finish my postgraduate studies successfully.

ABSTRACT

Title of Dissertation: **Practical Research on Human Factor Problems in Maritime Casualty Investigation of China**

Degree: **MSc**

With the thriving of shipping industry, accidents happen more frequently than before. In almost all shipping countries, administration concerned tends to use maritime casualty investigation as a tool to deal with marine accidents under the requirements of IMO. Most of marine accidents are caused by human errors, therefore, human factors play a crucial role in the maritime casualty investigation, which is appealed by IMO all the time. With the intention of learning lessons from the accident, the investigators investigate marine accidents by using a variety of methods to collect the information and carry out analysis. After investigation and analysis process, reasons for the accident will be found and some measures will be taken to prevent similar accidents from happening again. However, not all countries can perform their duties of investigation well. China is an obvious example, which has shortcomings in its maritime casualty investigation system. Due to the national condition of China, the characteristic and the goal of investigation is not the same as the requirements of IMO. What's more, the organization structure and the quality of investigators cannot make the investigation meet the basic requirements. China's maritime casualty investigation only focuses on the responsibility judging and reason finding, which hardly concerns human factors. Under this condition, in order to improve the investigation, especially the human factors, China can refer to the advanced experience and methods of other developed shipping countries. For example, China can improve the quality of education and apply the advanced accident-related theory and models. There are many accident-related theories and models, which can be used to deal with different types of accidents. For marine accidents, SHEL model and Hybrid model are the most popular models, which both concern the human factors and may serve the investigation process in different ways. SHEL model can facilitate the collection of the information concerning human factors in the maritime casualty investigation, and Hybrid model

can help identify the accident process by analyzing the causes of five different layers. By using these two models, China's investigation will get much fruition in terms of the analysis of human factors, which will absolutely improve the quality of China's investigation in return and make it better satisfy the requirements of IMO. The serious sinking accident of Orient Star in Yangtze River of China in 2015 can also be analyzed by using SHEL model and Hybrid model to find out how human factors contributed to this accident. However, only referring to the advanced theories and models of other developed shipping countries is not enough for China. In order to improve the investigation fundamentally, China should gradually change its organization structure and characteristic of investigation.

KEY WORDS: maritime casualty investigation, human factors, shortcomings, national conditions, accident theories and models, SHEL model, Hybrid model

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LIST OF ABBREVIATIONS

COLREG	Convention on the International Regulations for Preventing Collissions at Sea
IMO	International Maritime Organization
MARPOL	The International Convention for the Prevention of Pollution from Ships
MCI	Maritime Casualty Investigation
MEPC	Maritime Environment Protection Committee
MLC	Maritime Labor Convention
MSA	Maritime Safety Administration
MSC	Maritime Safety Committee
SHEL	Software, hardware, environment and liveware
SOLAS	Safety of Life at Sea

CHAPTER 1

Introduction

1.1 Maritime casualty investigation–A challenge for China

With the advent of economy globalization, the shipping industry is continuously booming. However, the number of maritime accidents is increasing, too. No country can ensure that its fleets of merchant vessels and fishing vessels are capable of getting rid of the unexpected accident all the time. (Pu, 2009) Therefore, in order to fulfill the related conventions, such as SOLAS, MARPOL, MLC and etc., the administration should take some effective measures to prevent the accident from happening again. Maritime casualty investigation is among the most effective measures. In China, maritime casualty investigation also plays an important role in shipping industry. Early in the 1990s, related administration in China started to advocate the importance of maritime casualty investigation. In 1997, IMO Assembly passed the Resolution A.849, namely the International Code of Maritime Casualty Investigation, which had a big impact on the maritime casualty investigation in China. There is no denying that the maritime casualty investigation in China has developed a lot in the past 20 years, however, China falls behind compared with other countries and cannot meet the requirements of IMO. IMO requires that, based on the human factors, the investigation should find out reasons, learn lessons, take measures and prevent similar accidents from happening again. In China, the investigation focuses on the reasons and ascertain of responsibility, especially the latter one, without concerning about the human factors.

1.2 Objective of the research

The primary purpose of this research is to illustrate the shortcomings of China's

maritime casualty investigations and to give practical recommendation of improving China's maritime casualty investigation on human factors by applying accident-related theories and models. In order to make this dissertation convincible and concrete, the serious sinking accident that happened last year will be introduced, which will be analyzed by using accident theories and models on human factors.

1.3 Methodology

Before doing this dissertation, relevant literature was widely browsed, including IMO conventions, requirements, regulations, codes, documents and circulars, journal articles, books, thesis, resources on the websites. A variety of administrations concerned have been inquired to achieve dependable advice and opinions, including Maritime Safety Administration, Fishery Administration and shipping companies. Furthermore, numerous tables and statistical figures are introduced into the dissertation, which provide essential datasets for the research and help improve the reliability of this research. At last, an actual example of serious accidents is introduced in order to make the recommendation of applying relevant methods more convincible and concrete.

1.4 Structure of dissertation

This dissertation consists of six chapters, including introduction and conclusion. Chapter two illustrates the status quo of China's maritime casualty investigation by introducing its history and development. After that, the shortcomings of China's maritime casualty investigation are mentioned. Chapter three focuses on the issue of human factors in maritime casualty investigation. After the history of human factors in maritime sector has been introduced, the importance of human factors is mentioned. Then the imperfection of China's maritime casualty investigation on human factors is put forward and some measures are advised. Chapter four continues the issue of

accident theories and models mentioned in the last part of the previous chapter. In this chapter, a variety of accident theories and models are introduced, especially two popular models in maritime sector on human factors. Then the contents and merits of these two popular models are mentioned. In order to make the statement more convincible and concrete, an actual example of sinking accidents is introduced. Finally, the last chapter draws the overall summaries and conclusions.

CHAPTER 2

The status quo of maritime casualty investigation in China

2.1 The development of maritime casualty investigation in China

The main target of maritime casualty investigation is to confirm the reasons for the accident, so that some effective measures can be taken to prevent similar accidents from happening again. The lessons from the investigations can be used to amend the international conventions, which also help prevent accidents happening in the future. For some reasons, such as the lack of understanding of maritime casualty investigation and lack of training for investigators, China, as well as other contracting parties of IMO never carries out necessary investigation for the accidents that happened within their jurisdiction areas before the 1990s. China is a big shipping country, which has a large scale of ocean shipping fleets covering most of the sea area in the world. In addition, China is also a big coastal country due to its enormous territory. Along the long coastal line, there are many ports, which involve a large amount of trade in the world. Therefore, shipping activities of China is very frequent. That is to say, there may be many more shipping accidents falling on Chinese vessels or within China's territory. With the development of China's shipping industry, related administration starts to realize the seriousness of the accident and pay attention to the maritime casualty investigation. In the 1990s, maritime casualty investigation in China was mainly conducted by harbor superintendence agencies or fishery administrations. The accident scene was hard to protect and the clues may be lost in a second. Human testimony and material evidence could be easily changed even destroyed, which made it difficult to find out the true reason of accident. In 1997, IMO integrated the previous codes and regulations, which are related to maritime casualty investigation, and passed the International Code of Maritime Casualty Investigation. This code had a big impact on maritime casualty investigation of each contracting parties. China was also greatly influenced. Before passing of the new code, maritime investigation in China was quite different from other countries. Some big

shipping countries pay much attention to the maritime casualty investigation, and the investigator are prepared all the time. They can be hurried to accident scene immediately after the accident. In addition, these countries have relatively complicated and complete investigation system. Compared to these countries, China fell behind a lot. However, with the passing of International Code of Maritime Casualty Investigation, China was provided with an opportunity to be in line with the international standards. In 2000, Maritime Safety Committee and Maritime Environmental Protection Committee of IMO promulgated the MSC. 953 and MEPC. 372 Circular, namely various reports of maritime casualty investigation, which cover the details of almost every kind of accidents. After that, China adopted the reports in these circulars. However, the essence of China's maritime casualty investigation was different from the other countries until 2010. In that year, the Casualty Investigation Code, which was passed in 2008, started to be effective. It was also added into the new chapter of SOLAS Convention. This new code regulated the characteristic of maritime casualty investigation in detail, which facilitated the integration of investigation spirit in the world. After that, related administration in China changed their ideas. Instead of judging the responsibilities, it focused more on the reasons of accident, which prevent similar accidents from happening again. Up to date, the Casualty Investigation Code has been implemented for six years; however, China's maritime casualty investigation still has long way to go to be consistent with the requirements in Code. The administration should pay enough attention to this issue and should take the national condition of China into consideration, in order to complete the maritime casualty investigation system of China.

2.2 The shortcoming of maritime casualty investigation in China

2.2.1 Why China has shortcomings in maritime casualty investigation

Although IMO has stipulated the regulations of maritime casualty investigation, due to different levels of development of each country and national condition, some countries cannot meet the requirements of IMO to some extent; in other words, they

may have their own system of maritime casualty investigation, which surely has some shortcomings. China is an obvious example for this problem. It is a big shipping country with the shipping industry thriving continuously, and thus a relatively high safety standard of sea area is needed. However, given China's national condition and existing system of maritime affairs, the safety environment is difficult to achieve. China is a developing country, which is fundamentally different from other developed countries. Something in developed countries is hard to realize in China. Meanwhile, China is also a big shipping country. This is an interesting combination. China, as a country to be both developing country and big shipping country, will inevitably encounter some challenges and shocks, which hardly exist in developed countries.

2.2.2 The main shortcoming of China's maritime casualty investigation

The primary shortcoming of China/s maritime casualty investigation is its characteristic, namely the goal of investigation. In China, the goal of maritime casualty investigation is only to find out reasons and judge responsibilities, especially the latter one. It is different from the requirements of IMO, which emphasize on the lessons learned from the accident and taking measures to prevent the similar accident from happening again. In China's investigation reports, there are only general conditions of ships and water areas, the accident timeline, loss and injury and the reason of the accident for each accident. The lessons are seldom mentioned in the report, and not to mention the measures to be taken to prevent the accident happening again. What's more, the reasons in China's reports focus more on vessels and external conditions, rather than the internal human factors and the combined effect of all aspects. And as we know, more than eighty percent of maritime accidents are caused by human errors, the human factors in maritime casualty investigation are supposed to be the most important consideration. However, in China's investigation, human factors are usually ignored. It is because the main goal of China's investigation is to judge responsibilities, analyzing human factors will not serve this goal and may need

more budgets. This kind of investigation, which was designed in the 1980s, can surely cut down the cost, but it contradicts the basic purpose of maritime casualty investigation and is not consistent with the public demands for procedural justice and rights protection in the current society. The reason for China's investigation shortage is the development situation, compared to the developed countries. China can use the maritime casualty investigation system of developed countries for reference to cover the shortage of its own system. Due to this shortcoming, China's maritime casualty investigation can go deep into the area of human factors. Not enough expenditure and attention have been paid into the investigation work. For example, the maritime casualty investigation of Ro-Ro ship Dashun only concerned the general accident scenario and some direct causes, such as overloading of cars, unsafe securing of cars, bad weathers, etc. Apart from these, information collection part, human factors analysis part, causes of all dimensions, lesson learning part and prevention measures part are not mentioned in this investigation report.

2.2.3 Other shortcomings of China's maritime casualty investigation

China's maritime casualty investigation also has some other shortcomings. First, the organizations concerning maritime casualty investigation is not independent. In China, Maritime Safety Administration is responsible for nearly all maritime accidents except military accidents. Harbor superintendence agencies or fishery administration are responsible for fishing vessel accidents and State Council is responsible for serious maritime accident. (Liu, & Fu, 2007) None of them is an independent organization, which is specialized in maritime casualty investigation. Maritime casualty investigation in these organizations is only a composition sector. That means not enough human resources and material resources even attentions will be allotted to this affair. In addition, different organizations in charge of different types of accidents also bring obstacles to the integration of maritime casualty investigation system of China. On the other hand, if the organization concerning maritime casualty investigation is

operating as an independent organization, the basic purpose of maritime casualty investigation can be achieved more easily, since the resources and attentions can be ensured. Meanwhile, setting up a check-and-balance mechanism of the rights will facilitate the impartiality of maritime casualty investigation. What's more, an independent organization will lessen the resistance, which may be caused by the limitation of each superior administration, when carrying out the investigation.

Second, the people in charge of maritime casualty investigation are less experienced and with less expertise. Carrying out maritime casualty investigation needs relative high capability and professional knowledge, and rich experience is also indispensable. As a result of organization structure of maritime casualty investigation in China, the investigation sector is merged in the maritime organization, when recruiting people, the detailed requirements for investigation position will not be listed. What's more, the internal member exchanging is usually conducted, which means many investigators are usually not experts of this area and they have little experience. (Zhang, 2009) They cannot carry out detailed analysis for accidents, but only can find out reasons on the superficial level. Under this situation, investigators used to imitate the previous reports and not to find the deep reason, such as human factor, let alone applying the related accident model to analyze the accident. Although this mode can facilitate the working passion and improve the expanding ability, it will seriously hamper the quality of maritime casualty investigation in China.

Third, the scope of China's maritime casualty investigation is relatively narrow. In China, existing legislation only concerns maritime traffic accident investigation now. Therefore, maritime casualty investigation in China only refers to investigation of traffic accidents, not covers the ship pollution accident, pirate attack accident or personal injury accident. That is why the investigation in China hardly mentions human factors. However, in western developed countries, the investigation is consistent with IMO A.849 Resolution, not only containing traffic accidents, but also cover personal injury and pollution accidents (Zhang, 2009). Apart from this,

investigations in China are usually on-scene investigation but lack of preliminary and subsequent analysis. This is also because of the narrow scope of the investigation, only concerning traffic aspects, which imitates the solution to the road traffic accident.

CHAPTER 3

The human factors problems in maritime casualty investigation

3.1 The history of human factors in maritime sector

According to the research, more than 80% of maritime accidents are related to human factors. The history of human factors can date back to the 1930s. At that time, Heinrich, an American engineer, first brought out the concept of human factors and its importance in accidents (Xia, 2004). Then, more and more maritime safety workers and maritime enterprises started to research the human factor in maritime affairs. At first, the research focused on the quantitative statistics and analysis of maritime accidents and extracted the information related to human factors. Then, IMO also initiated the research on human factors. IMO published some regulations and standards concerning human factors, such as ISM Code and anti-fatigue measures. IMO also published some model courses, such as Maritime Investigator Model Course to emphasize the importance of human factors in maritime accidents. However, human factors aspect is the most flexible aspect in maritime affairs and the easiest one to be ignored. Although IMO and related workers all pay much attention to human factors, due to its complexity, trivialness and flexibility, the human factors are easily neglected in actual investigation. Apart from this, in China, as a result of some shortcoming of maritime casualty investigation mentioned above, there are more resistances for the deep research of human factor problems in investigation.

In maritime field, the actual manifestation of human factors is different from many other fields, because of the specificity of maritime affairs. In maritime field, the behavioral agents concerning human factors are crew members. The specific manifestation of human factors can be divided into four aspects. First is physical aspect, such as stamina, flexibility, memory, physical strength and etc. Second is mental aspect, such as aloneness, anxiety, lazy, repression and etc. Third is intelligent aspect, such as degree of education, logical capability, insight and etc. Fourth is

ability aspect, such as manipulative ability, communicative ability, working experience, coordinated ability and etc. (Zhou, 2007). Human factors are like a double-edged sword, which can have both positive and negative impact on shipping. Human's creativity, judgment and potential can facilitate the maritime affairs; at the same time, the fluctuation of emotion can bring disastrous consequences.

3.2 Why human factor is important in maritime casualty investigation

In maritime analysis and prevention of accidents, maritime casualty investigation plays an important role by feeding back information. The goal of maritime casualty investigation is to find out the reasons in all dimensions of accidents, such as major and minor causes, subjective and objective causes, direct and indirect causes, by investigating all stages of accident, such as primary stage, developing stage and loss stage. In IMO Maritime Investigator Model Course, the human factors chapter states that human factors play a vital role in the primary stage of accident. Therefore, from the angle of accident chain, human factors should be paid the most attention, because it concerns the first stage of the whole accident. An accident can be prevented in high possibility in the primary stage. Therefore, in 1999, IMO passed Resolution A.884, namely the guidelines for investigation of human factors in marine casualties and incidents, which emphasizes the importance of human factor in maritime casualty investigation and provided investigators with detailed investigating methods and procedures. From the angle of causes, as mentioned above, more than 80% of maritime accidents happened as a result of human factors. Therefore, research on human factors is the key to prevent the similar accident happening again. What's more, the behavioral agent of maritime affairs is human; if the investigation is conducted from the angle of human, the complex causes and combination effects can be more easily revealed. For instance, in SHEL Model of maritime casualty investigation, human is the central part of the model, and this model analyzes the accident by finding out the relationships between human and each other parts. In Hybrid Model,

human factors permeated in each layer of the model; in other words, each level of this model analyzes the accident based on human factors. In short, human factors are very important in maritime casualty investigation.

3.3 The reasons of the imperfection of human factor aspects in China's maritime casualty investigation

3.3.1 The goal of China's maritime casualty investigation

Since human factors are so important in maritime casualty investigation, why human factors are hardly involved in China's maritime casualty investigation? This may be related with the imperfection of China's maritime casualty investigation system due to the national condition. The major reason is the goal of China's maritime casualty investigation. Apart from this, the organization structure and quality of investigator also lead to imperfection of human factors.

The goal of China's maritime casualty investigation is mainly to judge responsibilities; in other words, it aims to find out which ship or person should be responsible for the accident and pay indemnity. However, the goal of maritime casualty investigation stipulated by IMO is to find out reasons from all dimensions and take measures to prevent the similar accident happening again. Obviously, there is a conflict between China's investigation and IMO's investigation. When judging responsibilities, the only thing to do is to refer to the related code or regulation to judge who have violated the code or regulation. For example, two ships are crossing on their track. Ship A is on the port side of Ship B. Ship A steer forward and finally collides with Ship B. In this case, Ship A should take full responsibility, because it obviously violates the Article related to crossing situation in COLREG 1972. In COLREG 1972, Rule 15 states that: When two power-driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and

shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel. (COLREG 1972, IMO) After judging the responsibility of Ship A, nothing else will be done. For example, there is no need to find out why Ship A steers forward and not alters its course or whether these two ships communicated before the collision. In addition, no prevention measures will be given to prevent the similar accident happening again. Although the case mentioned above is so simple and in actual situation, there should be some other procedures when judging responsibilities. This is really the epitome of China's maritime casualty investigation now. There are few prevention measures and little research on human factors. However, in the regulation of IMO, there are many other things to do even in this simple accident. For example, the timeline of whole accident will be straightened out, the detailed scenario of the accident will be reproduced, evidence will be gathered, and the status of crew members and ship company will be investigated. All in all, the investigation focuses on multiple reasons for the accident, applying the accident model to analyze the accident causes and bring out prevention measures. Among them, human factors permeate every aspect; no investigation can be conducted without considering human factors. But in China, as a result of omitting these procedures for investigation, the human factors are easily ignored.

3.3.2 The structure of China's maritime casualty investigation sector

China's organization structure for maritime casualty investigation is also a reason for the imperfection of human factors aspect. As mentioned above, the organizations, which concern maritime casualty investigation in China, are under the supervision of superior administration and they are separated in different superior organizations due to the characteristics of the accidents. For example, in China, most of the accidents are investigated by the sector under Maritime Safety Administration. Before respecting the requirement and spirit of maritime casualty investigation of IMO, the investigation sector should first obey the requirement and meet the interests of

Maritime Safety Administration and there will be much resistances for investigators to deeply research the human factors of accidents. In addition, the investigators themselves have no motivation for the extra work of researching, because they had only payment for the work of judging responsibilities. What's more, this affair is not just in the charge of Maritime Safety Administration. As mentioned above in Chapter 1, the fishery administration and State Council also carry out investigation for specific accident, which leads to a situation that there is not a uniform regulation and spirit for maritime casualty investigation in China. Each organization has its own pace and behavior, which is obviously of no help for researching into human factors.

3.3.3 The quality and knowledge background of investigator

The quality and knowledge background of investigators is also a reason for the imperfection. Unlike other developed shipping countries, the quality of investigator in China has the feature of irregularity. This is mainly because of the recruiting system of related administration, such as Maritime Safety Administration. In recruiting, the specific position of work is not listed clearly; only education background, degree, certificate or major in university are needed. That will lead to a situation where there is no suitable personnel for each position. In China, a graduate of marine engineering will finally take charge of maritime casualty investigation, and things like this often happen. The personnel department only pays attention to the overall performance of applicants, not caring about the specific knowledge background. It is also caused by the education mode of China, especially the current university education mode. In addition, the position exchanging in Maritime Safety Administration is also frequent, especially the transverse position exchanging, which will make the expertise of the position become weaker. As well as recruiting new people, they should be familiar with the business of their new field, and obviously they hardly research deeply into this field. In most cases, they only imitate the previous people's work, which is also not deep, no human factor researching. This is a vicious circle.

3.4 Ways of improving the human factor aspects in maritime casualty investigation

3.4.1 The measures to be taken in general

Under this special national condition, perfecting human factors aspects in maritime casualty investigation of China is very difficult. Some scholars suggest setting up a integration organization for maritime casualty investigation in China, like other developed shipping countries; however, this change means the thorough transformation of current China's maritime organization, which involves many entities` interest, and it is obviously hard to realize. Some scholars suggest changing the current recruiting system of Maritime Safety Administration in order to recruit more specialized people. However, it is also hard to realize. This is because if the position requirements emphasize the specialized field, the number of recruits will decrease further. In addition, working in Maritime Safety Administration in China means being a civil servant. Currently, the treatment and payment of civil servants in China is not very optimistic compared to the past. Therefore, more and more navigational graduates think that entering Maritime Safety Administration is not a good option. They may hesitate to choose to be a civil servant when they receive another offer from enterprise. If the recruiting system becomes stricter, obviously fewer people will be recruited. Hence, changing the situation of imperfection of human factors aspect cannot directly overcome the shortcoming of China's maritime casualty investigation system. Taking into account the current national situation, there are two things that can be done in short time, without changing the fundamental situation of China, and may receive obvious fruition. One is to enhance the specialized training for maritime casualty investigators. The other is to introduce the existing model of accidents to facilitate the maritime casualty investigation in China. The latter one is more important.

3.4.2 Something related to training

As mentioned above, the quality of maritime casualty investigators in China is relatively low. From result of the questionnaire targeting more than 1,000 maritime casualty investigators in China, we can clearly witness this situation.

Table 3.1 The degree of education of China's maritime casualty investigators

Degree of education	Master	Bachelor	Junior College	Vocational School	Senior High	Junior High	Total
Numbers	7	144	350	275	147	81	1004
Percentage	0.7	14.3	34.9	27.4	14.6	8.1	100

Source: Maritime Education Research

Table 3.2 The technical tile situation of China's maritime casualty investigators

Technical title	Senior Professional	Medium Professional	Junior Professional	No technical title
Numbers	40	200	232	594
Percentage	3.8	18.8	21.8	55.7

Source: Maritime Education Research

Table 3.3 The English level of China's maritime casualty investigators

English Level	Outstanding	Good	Normal	No ability
Numbers	10	40	211	787
Percentage	1.0	3.8	20.1	75.1

Source: Maritime Education Research

Table 3.4 The Certificate holding situation of China's maritime casualty investigators

Certificate	Master/Chief Engineer	Chief Officer/Second Engineer	Second Officer/Third Engineer	Third Officer/Fourth Engineer	No
Numbers	21	24	67	55	877
Percentage	2.0	2.3	6.4	5.3	84.0

Source: Maritime Education Research

From the four tables above, we can clearly find that most of the maritime casualty investigators in China have low level of education, low technical title, poor English ability and no certificate of seafarers.

Honestly, to meet the special requirements of maritime casualty investigation, the investigators should not only handle the knowledge of navigation, collision avoidance, ship handling, engine management and other professional knowledge of maritime domain, but also need the knowledge of law, phycology, evidence and system analysis engineering. The latter one is especially important to research human factors (Huang, 2010).

As early as 1980s, IMO once set up maritime casualty investigation training program in Dalian Maritime University for the people engaging in maritime affairs in developing countries of Southeast Asia. However, 30 years have passed, and neither involvers nor requirements of IMO have changed a lot. Today, the requirements for investigators become much higher and more complicated.

Therefore, to enhance the human factors aspect in maritime casualty investigation, improving training programs for investigators is a good choice. But simply increasing the numbers cannot be effective; the programs or course should focus on human factors aspect. In order to realize this, the following suggestions can be considered. First, enhance the knowledge of researching in management aspect. In most

circumstances, the accident has direct or indirect relationships with management failure, which always involve human factors. Second, enhance the complexity of analysis method. Simplification is a good trend in current society, but in maritime casualty investigation, simplification is not good any more. The more complex and thorough, the more accurate for the investigation of accident causes. Investigating thoroughly is the basis of stipulating prevention measures. Therefore, multiple analysis methods should be used and combined to analyze an accident, which should be inculcated into trainees` mind in the program. Third, refer to the newest spirit of IMO model course for maritime casualty investigation as soon as possible. IMO aims to enhance the quality of global maritime casualty investigators and published the model course for them. The course in China can refer to the knowledge and method in IMO model course in order to meet the requirements of IMO in maritime casualty investigation. Fourth, introduce accident model to enhance the research of human factors aspect. In the training program, teacher can instill the mechanism and function of accident model. The accident model, which is emphasized by IMO and its model course with the intention of enhancing the human factors research, is a good and simple way for China's investigators to investigate human factor effectively in short time without huge specialize knowledge background. For example, the SHEL(Software-Hardware- Environment- Liveware) model and Hybrid model, namely the Swiss Cheese model, all set focus on human factors aspect in the accident. Even though the investigators have low ability and degree, after being instilled of the concept of accident model, they can analyze the accident especially in the human factors aspect much better than before, because the model has the characteristic of integration and has already been mature.

3.4.3 Something related to model

As mentioned above, introducing accident causation model is a direct way for China's maritime casualty investigator to enhance the depth and attentiveness of their analysis

in human factors aspect under the national condition and situation of China's maritime organization structure. Actually, accident causation model is popular in every developed shipping country. In 1990, James Reason brought out the idea of Hybrid Model, namely Swiss Cheese Model. This model assumes that the accident is caused by the failure of decision and management at first, then the unsafe act is formed and finally the defenses system breaks down. This model provides the accident analysis with an integrated analysis framework, which can be directly used by investigators (Wang, 2012). In addition, SHEL Model can also facilitate investigation to a large extent, which focuses more on the interaction between people and surroundings. The detailed introduction and application of these two accident causation models will be presented in next chapter. As far as I am concerned, given the current situation of China's maritime organization, the accident causation models can not only be taught by teachers in investigation training program, but also be directly put into use in investigation. The superior administration should encourage their investigators to use the methods of accident causation models to analyze the accident, at first as recommendation and then gradually become mandatory for investigations.

CHAPTER 4

The accident theories and models in maritime casualty investigation

4.1 The introduction of accident theories and models

As mentioned above, introducing the relative mature accident causation model is an easy way to enhance the human factors aspect in China's maritime casualty investigation. In this chapter, after the introduction of some accident causation models which are widely used in maritime accidents, the detailed application of two main models for current hot accident in China will be presented, as a reference or recommendation for the future development trend for China's maritime casualty investigation, which can be considered by the relevant authorities in China.

When we talk about accident models, we cannot leave accident causation theory alone. In fact, accident causation theory can be considered as accident mechanism and accident model, which are achieved and extracted from the analysis of plenty of typical accident causations. These mechanism and models reflect the regularity of accident happening and can do qualitative and quantitative analysis of accident causations. In addition, they can provide scientific and complete basis for the prevention of accidents and enhancement of safety management work. As a result of their features of scientific, advanced, simplicity, visual and methodological, accident causation theory and models are widely used in many fields, such as engineering, medical, aviation, education, navigation etc.

With the development of scientific technology and mode of production, the basic regularity of accident happening is continuously changing. Therefore, there are more than ten typical accident causation theories and models, which successively go into people's horizon.

4.2 Some basic accident theories and models

4.2.1 Accident causal chain theory and model

There are mainly four accident causal chain theories and models in the history. Heinrich is the first one to propose this theory. He uses this theory to illustrate the relationship between different factors that lead to casualty and the relationship between these factors and the harm caused by the accident. The core idea of this theory is that the casualty accident is not an isolated event; rather it is caused by a series of causations. That is to say, the harm and casualty have chain relation with the causations. The Heinrich's accident causal chain theory has five parts, which are ancestry and social environment, fault of person, mechanical or physical unsafe act, accident and injury respectively. This theory can be considered as domino as shown in the figure. If the first domino is pushed down, the other ones will go down subsequently. If one of the dominoes is removed, the chain is broken and the accident process will be ended. Heinrich thought that if the middle one is removed, namely the unsafe act and unsafe condition, the accident will be ended for the safety work in enterprise. However, this theory has obvious disadvantages, because Heinrich thought this theory too simple and absolute. In fact, the relationship between dominoes is complicated and random. That the previous domino goes down cannot ensure the next one will go down, too. The next one can either stand or go down. In other words, unsafe act and condition do not always lead to the accident and harm. However, Heinrich's theory is still important, which can provide guidance for the subsequent research for accident models and facilitate the development of accident causation theory.

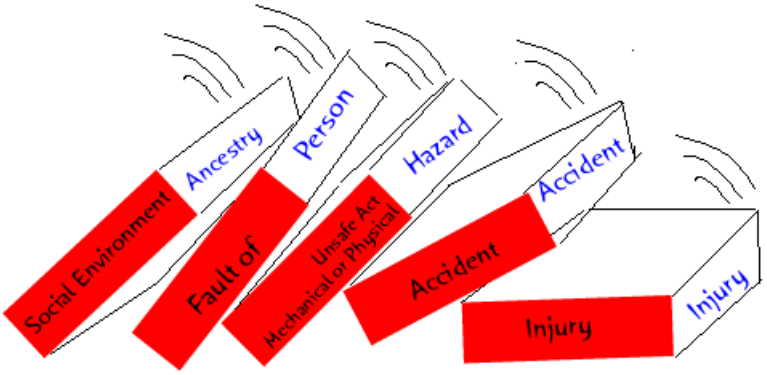

Figure 4.1: Heinrich`s accident causal chain theory

Source: personal.cityu.edu.hk

After Heinrich, Frank Bird raised a more advanced accident causal chain theory on the basis of Heinrich`s theory, which coincided the modern safety better. Bird`s theory. It has five parts, too. However, they are different from Heinrich`s theory. For Bird`s theory, five parts are respectively lack of management control, indirect causes, immediate causes, event and injury/damage.

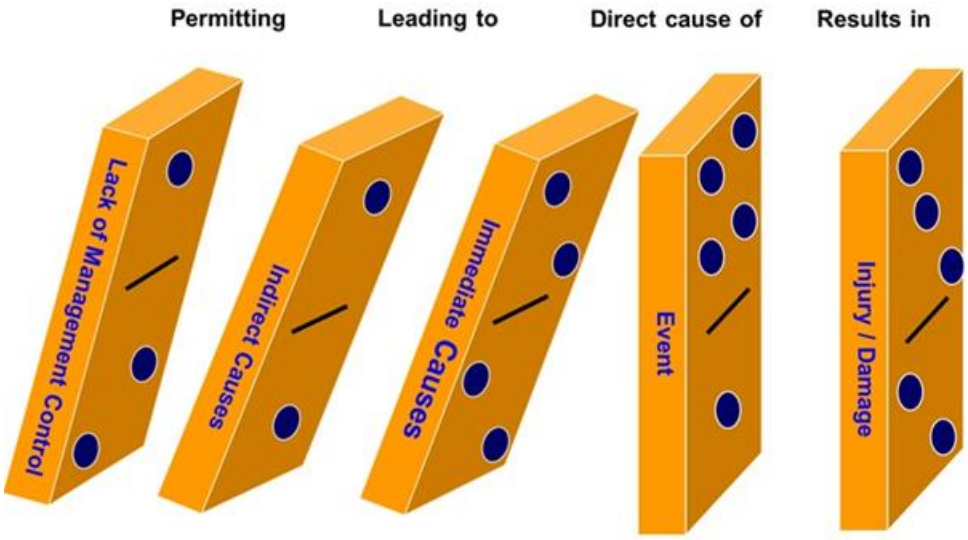

Figure 4.2: Frank Bird`s theory

Source: linkedin.com

Edward Adams is another scholar to amend the Heinrich`s theory. Adams`s theory and

model is shown in table 4.1.

Table 4.1 Edward Adams`s theory

Management system	Management failures		On-scene failures	Accident	Harm or loss
Objective Organization Function	Leaders have decision failures in the following aspects or no decision: Policy; Objective; Standard; Responsibility; Rank; Assessment; Authority granted.	Safety technology personnel have negligence and management failure in such aspects: Behavior; Responsibility; Scope of authority; Code; Guidance; Initiative; Enthusiasm; Business action.	Unsafe act; Unsafe conditions.	Casualty accident; Damage accident; Non-casualty accident.	For human; For matters.

In Adams`s theory and model, unsafe act and condition are called on-scene failures, in order to remind the characteristics of unsafe act and condition. The core of the theory is to research deeply for the latent reason of on-scene failures. On-scene failures are caused by management failures of leaders and safety technology personnel. The

failures of managing level have strong impact on the final accident. Management failures are caused by the problems in enterprise and company's management system, such as how to organize management work, how to identify management target, how to plan, how to implement etc. Management system reflects the central mind, goal and standard. In Adams's theory and model, the importance and impact of management system are emphasized, which will influence the subsequent advanced models to some extent.

Japanese scholar Tetsuzo Kitagawa also amended Heinrich`s accident causal chain theory and expanded it. The previous theories limit the scope into the internal part of enterprise. In fact, the reasons for the accident are usually multiple, such as politics, economics, cultures, education, technology level, social environment, which all have impact on the happening of the accident and its prevention. Based on this thought, Kitagawa raised his model as shown in table 4.2.

Table 4.2 Tetsuzo Kitagawa`s theory

Basic reason	Indirect reason	Direct reason		
School education reason; Society reason; History reason.	Technology reason; Education reason; Physical reason; Psychological reason; Management reason.	Unsafe act; Unsafe condition	Accident	Harm

In Kitagawa`s theory, each part has beyond the scope of enterprise safety work.

However, it is important to fully understand these basic factors to use the scientific technology, management method to improve finding out indirect reason in order to reach the goal of accident prevention.

4.2.2 Some accident models based on human factors

These accident theories have a common viewpoint that human errors can lead to accident, and human errors are caused by the reflection failure of people to external environment. In 1972, Wigglesworth first raised the model based on human factors. He believed that all kinds of information give stimulators to human's sense organ. If the operators reflect correctly, the danger will not happen. On the contrary, the danger will happen and may lead to casualty or loss.

Sully's model is another model based on human factors. It divided the accident happening process into two stages, namely are danger emerging stage and danger releasing stage. These two stages both have an information processing system like human's sensory process. In the emerging stage, if all steps are correct, the danger can be eliminated or controlled. If one step is wrong, the danger may happen. In releasing stage, if all steps are correct, although facing to the emerging danger, the danger can still be avoided. Otherwise, the danger will turn to harm or loss.

Lawrence's model is based on the model of Wiglesworth and Sully, it was first raised to research the accident in gold ore of South Africa in 1974, but it can be applied into some complex accidents in other enterprises, too. The core of this model is alert, such as preliminary alert, alert accepting, alert identifying, danger assessing, and action taking. It is suitable to the external environment disaster, which people have little ability to prevent. However, in order to avoid casualty accidents, people should realize and assess the danger as soon as possible and take actions.

4.2.3 Accident models widely used in maritime sector

Like other fields, accident models can be used to research the accidents in shipping industry. Although this field has some uniqueness, the accidents in this field still have many similarities with accidents in other fields like engineering or aviation. The most common two models in shipping industry are SHEL model and Hybrid model, which will be introduced in details in next part. Both two models are related to human factors researching. Hybrid model is based on Heinrich`s accident casual chain theory, which is also shown in the form of domino, and take the human factors into consideration. SHEL model is based on the human factors and help facilitate the information collecting in maritime casualty investigation.

Apart from this, in the history of accident theories and models, there are also some other ones, such as energy transferring theory, dynamic changing theory, track crossing theory, which all make contribution to the research and analysis of the accident.

4.3 How accident model helps improve the human factor aspects in investigation

4.3.1 The steps of human factors investigation

There are many accident models that can be applied when investigating human factors, such as SHEL model, Accident Causation Model, Generic Error Modelling systems and Taxonomy of Error. There are six steps for human factors investigating; 1) collecting accident information, 2) identifying the process of accident, 3) identifying the unsafe act or decision and conditions, 4) identifying the types of failure and violation, 5) identifying the latent factor of accident, and 6) identifying the latent safety problems and establish safety measures. Among these steps, step 1, namely collecting accident information is related to the SHEL model, and steps 3 to 5 are related to Hybrid model. They are useful in identifying the latent unsafe conditions

when carrying out maritime casualty investigations. After identifying the latent factor in previous steps, latent safety problems can be identified and measures will be taken in step 6. On the whole, the process of investigating human factors can be considered as the applications of two key models, namely, SHEL model and Hybrid model.

4.3.2 The SHEL model

Colleting the information of personnel, operation, facilities, environmental conditions which are related to the happening of accident is the first step of the whole investigation process. It is important to research this information systematically in order to analyze the human factors, which lead to accident, comprehensively. In addition, researching this information deeply can also facilitate the collection of relevant information and the formulation of accident database, which can satisfy the logical demand of investigation. In the actual investigating process, many factors are combined with each other and hard to identify, therefore, missing even a little information is very lethal for the investigation. With the intention of avoiding this situation and enhancing the reliability of information collecting process, many investigators apply the SHEL model as a tool of information collecting. Using this model can effectively avert a lot of problems subsequently. This is because the SHEL model considers all important factors for all important working systems and the SHEL model considers the interrelationships of all the factors in every working system. What's more, the SHEL model focuses on the impact from peripheral factors to central factor, which is related to the working efficiency.

The process of investigating human factors can be considered as the answer to some simple questions, like what, who and when, and some advanced questions, like how and why. In most situations, the result of the investigation is under the condition of actual act and environment. Some are useful and some are useless. SHEL model can help identify the importance and interrelationships between them.

As mentioned above, the SHEL model consists of four parts:

L-Liveware, internal and external

H-Hardware

S-Software

E-Environment

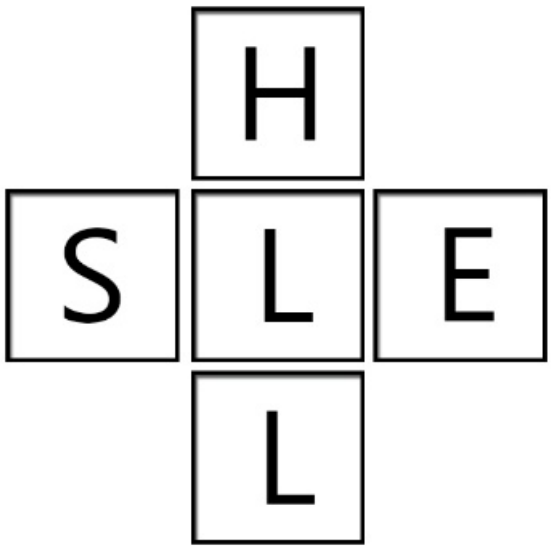

Figure 4.3: SHEL model

Source: nycaviation.com

As shown in the figure, SHEL model not only exhibits the four composing parts, but also show the relationships and connectors between liveware and other parts. The connectors in SHEL model are supposed to match each other. What's more, the SHEL model can exist in a complicated system, which consists of all the parts mentioned above.

The central liveware part is the most useful and flexible part in the system. This liveware part can be applied into every operators or assistants. It is not only considered as a composing part, but also has interaction with other surrounding parts. All people, connectors or links compose the latent area for human factor investigations. That is why SHEL model has strong connection with human factors

and improves the investigation into human factors. Apart from the central liveware part, there is also another liveware part in the surrounding of the central part. The external liveware part mainly plays the role of interacting with central liveware part, such as management, leadership, supervision, support, task-sharing, delegation, culture, communication and cooperation between crew members. The most frequent error caused by link between livewares is communication error, which is due to misleading, ambiguous, inappropriate or poorly constructed communication between individuals. In many cases, the collision accidents between ships are caused by communication error, either communication in each ship or communication between two bridges. Therefore, clearly researching the livewares link is rather important after an accident and SHEL model is a better weapon to research this link than other methods. In tradition investigation of China, there is hardly eyesight on the liveware part, let alone the link between livewares. The hardware part includes all the facilities and equipment on board. For example, the facilities in the bridge, the design of the working places, the screen, the control system, the seats, the alerting system, the live saving appliance and etc. The link and connector between liveware and hardware is mainly Man-Machine interface or ergonomic. The problems in this link are usually caused by inappropriate operation, such as the wrong operation of radar, ECDIS, fire-fighting equipment and etc. Apart from this, poorly designed equipment, missing operational material, badly located or coded instruments and control devices, warning systems that fail in alerting informational or guidance functions in abnormal situations can also lead to the problems of link between liveware and hardware. The software part in SHEL model refers to the non-material part in the system, such as regulations, working procedures, handbooks, checking lists, charts, recommendations, computer software, training, information etc. The mismatch in the link between liveware and software may be caused by insufficient or inappropriate procedures, misinterpretation of confusing or ambiguous checklists, confusing or misleading documents, charts, maps, irrational indexing of an operations manual etc.(Baumler, 2016). The last part is environment, which refers to the internal and external environment, such as climate, temperature, visibility, vibration, noise. Sometimes it is related to some impact results

from the environment, which may have influence on communication, decision, cooperation, perception, awareness etc. In detail, the error in this link may show in the form of disturbance of biological rhythms, such as jet lag, irregular work-sleep patterns, perceptual errors induced by environmental conditions, such as visual illusions, flawed operator performance and errors as a result of management failure. The investigators use this SHEL model to collect information widely and effectively, because each components of the SHEL model has connection with liveware part, namely human factor.

After identifying what, who and when, in other words, collecting enough information, investigators should enter next step, namely identifying how and why. At this time, the information collected in previous step is supposed to be used, which is found by SHEL model. The investigator should use the existing information to identify the accident process. In 1990, a professor of Manchester University created a model, which is like an assembly line framework, namely the Reason`s Hybrid model or Reason`s Swiss cheese model. As an accident causation model, it can help investigator know the happening process of accident. Hybrid model can also facilitate the information collecting in SHEL model and help identify how the information impacts on human behaviors. As mentioned above in previous part, like SHEL model, Hybrid model consists of five parts, but unlike SHEL model, it is shown in the linear form, separately fallible decisions, line management deficiencies, psychological precursor of unsafe acts, unsafe acts and inadequate defenses. It is in the timeline sequence and each of these parts have some relationships with each other. The linear form makes each part have the characteristic of briefness, which is an important characteristic of the accident. Because some causations of accident do not take long time, they can happen in just a second, and it is hard to position the specific location. Therefore, the accident causation model, Hybrid model, is created on the basis of accident sequence and the concept of ambiguous accident process. Although the final causation of the accident may be the inadequate defenses or unsafe acts as shown in the last in the linear form, for example, the disabling of alerting system and

inappropriate operation in MMI, the most important things in this model is not these two parts. The more serious causation may lie in the latent area, such as the individual and organization layers. In Hybrid model, the fallible decisions and line management deficiencies play rather crucial roles, and in SHEL model, the link between liveware and software is the same thing, which emphasizes the importance of individual and organizational layers, such as unsuitable regulations, inappropriate procedures, insufficient training, overwhelming workload and tight working period etc. In actual, the information collecting and identifying process of accident are not conflicted. Although there may be some overlapping area of these two models as mentioned above, the investigator will not take it into consideration. On the contrary, these two models will facilitate each other, the information achieved in SHEL model can help the analyzing of Hybrid model. The inspiration and interrelationship in Hybrid model can also facilitate the information collecting process. In the process of maritime casualty investigation, the collecting information can compose the SHEL model. On the other hand, the Hybrid model can show a framework of accident in sequence, in order to identify all the unsafe operation or decision conditions of accident. In short, neither of these two models is dispensable, and both of them help analyze in human factors aspect and contribute a lot to the investigation.

4.3.3 The Reason's Hybrid model

Reason's Hybrid model is one of the most typical accident causation models, which are widely used in maritime casualty investigation. Its framework is like a Swiss cheese as shown in the figure.

Figure 4.4: Swiss cheese model

Source: psnet.ahrq.gov

Hybrid model has five basic elements, respectively are fallible decisions, line management deficiencies, psychological precursor of unsafe acts, unsafe acts and inadequate defenses. Each of these elements is like a piece of cheese, which is covered with small holes. These holes can be seen as the deficiencies in each layer. Put these five elements in a linear form or overlap them, some holes in each of them may be overlapped, too. Penetrating the holes of all layers and finally going through the limited window of accident opportunity, the accident can happen. That is why Hybrid model focuses on the linear relationship of each element, but not one individual element when it is used to carry out maritime casualty investigation. The final limited window of accident opportunity is resulted from the combination effect of previous deficiencies in each layer in linear and logical form.

Among these five layers in Hybrid model, the uppermost level is the fallible decisions. It is related to decision-making aspects in manager or administration level, such as policy, regulations, provisions and personnel stipulated by the company and administration. In Hybrid model, fallible decision is a latent causation, because it cannot be identified clearly only by superficially investigation. The fallible decisions can be found by deeply researching the information collected in the previous step, such as applying SHEL model, or combining the superficially investigation results. In

other words, it can be found by analyzing information in SHEL model and it can also be found by deliberating from other sub layers and active causations in the Hybrid model. The second layer of Hybrid model is line management deficiencies. It is related to the linking between the administration and crew members. In other words, it refers to the second level manager of the system. In shipping system, the line management refers to the manager crew members, such as Master, Chief engineer, Chief Officer, who are responsible for the decision-making and command on board. Line management deficiencies layer is also a latent causation, somewhat like the uppermost layer-fallible decisions, because they are both related to the management aspects. However, compared with the fallible decisions layer, this layer also has some differences. Due to its position, of being in the middle of the upper administration and lower member, it can be deliberated from either upper or lower layer. For example, the decision of administration has direct impact on the manager crew members, and the act and psychological precursors are also influenced by the management of manager crew members. The third layer, psychological precursors of unsafe acts can be seen as a mental and physical precondition for crew members' unsafe acts. The mental aspects are related to the negative emotion of crew members, such as anxiety, anger, sadness, fear, loneness etc. The physical aspects may be fatigue, sick, wound etc. They may be influenced by the environment of the working place, the characteristics of crew members, even the decisions and management of administration or manager crew members. This layer is also a latent causation in the model, but it is closer to the direct causation than previous two layers. It directly leads to the unsafe acts, which is the fourth layer of the Hybrid model and is considered to be the direct causation of the accident. Influenced by the previous causation one by one, the crew member will do some unsafe acts that are harmful to the ship. Unlike previous three layers, unsafe acts layer is the active causation, which is usually identified in the investigation firstly. The last layer inadequate defenses refer to the missing of insufficient defending measures. After an accident, if the defending measures or facilities are perfect and advanced, the accident can be avoided or relieved in some extent. On the contrary, the defending measures or facilities are not

advanced, even missing, the accident will go on and finally the limited window of accident opportunity will be penetrated. This layer is both latent and active causation. As a final checkpoint of the model, it is directly related to the happening of accident. However, it cannot be identified by superficial investigation, it is related to the upper decision level to some extent, such as the regulation of administration or the command of Master, even the corruption of the company. As we see, the Hybrid model has strong linear characteristic, which organizes all the human factors information investigated or derived from SHEL model and bring the detailed process of accident to the investigators in order to help them identify all the causations, whether latent or active one.

After collecting information and identifying the accident process, the investigators should identify the unsafe operations, decisions and conditions. Unsafe operations refer to the inappropriate behaviors or latent unsafe environment which may lead to danger and unsafe decisions refer to the non-effect decision or minus-effect decision, which may lead to danger, too. Unsafe conditions refer to latent occasion and environment, which may lead to danger. After applying SHEL model and Hybrid model, the information will be used to identify these factors. However, there may be more than one factor mentioned above in the actual accident, the accident should be appraised many times to ensure the reliability by using the SHEL model and Hybrid model. Based on these steps, investigator can continue identify the type of failure and the all the latent factors of accident, and then stipulate the safety measures to prevent the accident happen again. Therefore, the SHEL model and Hybrid model play a rather important role in the human factors investigation. Apart from this, when identifying all latent factors of accident, the investigation should still be based on the information collected and organized in the first and second steps, namely using SHEL model and the Hybrid model, which emphasizes the importance of these two models.

CHAPTER 5

The practical application of SHEL model and Hybrid model on sinking accident of Orient Star

5.1 The general information of the accident

The sinking accident of Orient Star is the most serious maritime casualty accident in China even in the world in recent years. After analyzing how these two models facilitate the research on human factors in maritime casualty investigation, these two models will be applied to the actual accident case to find out the causation of the accident on human factors aspect.

On June 1st, 2015, 9:30pm, the cruise ship Orient Star of Chongqing Orient Vessel Company capsized and sank in the water area of middle reaches of Yangtze River. The ship was on her voyage from Nanjing to Chongqing and encountered tornado in Damazhou waterway of Hubei Jianli. Although the rescue team responded quickly, 442 people died in the accident and only 12 people survived, because the ship sank quickly, too.

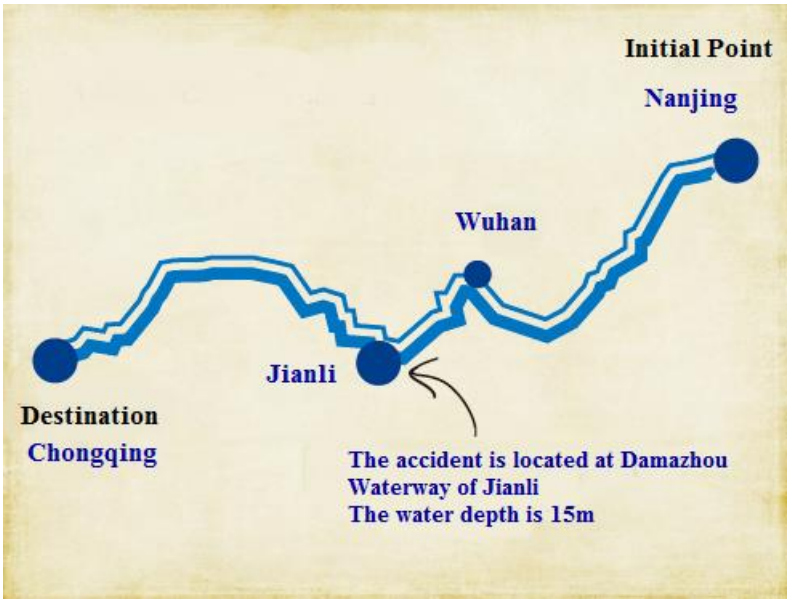

Figure 5.1: The voyage route diagram of Orient Star

Source: Xinmin Weekly

Soon after the accident, State Council authorized and established the investigation group, which invited the academician and expert in authority to participate, to investigate the accident around the factors of wind, ship and human. The investigation group insisted on the principle of scientific, rigorous, legal, honest and effective. They carried out plenty of experiments to identify the weather condition during the period of accident and comprehensive survey to find out the safety hidden danger. After collecting a large number of evidence documents and evidence from crew members, tourists and witness, convening a lot of conferences and deeply researching on the accident, the investigation group finally formed the investigation report.

The final investigation report identified that the sinking accident was caused by a rare and sudden weather condition, which had the downburst with the squall line. It was severe convection weather and brought about enormous wind force instantaneously, which nearly reach the 12 beaufort scale, and severe heavy rain at the same time. Although Master took some measures to make ship stable and to prevent the wind at that time, the strong wind and heavy rain still make the maximum wind heeling moment reach twice as much as the ship's maximum wind resistance ability. The ship continuously went backward and was out of control and finally capsized and sank. The investigation group considered that although the wind and capsize resistance ability of the ship met the requirements of standard, it cannot resist the extreme severe weather. In addition, Master and Chief Officer on watch had little recognition of severe weather condition and its risk, which resulted in the negative response in emergency situation.

5.2 The application of SHEL model and Hybrid model

However, the final analysis result raised by investigation report is related only to wind and ship factors, it didn't mention the human factors, which were also supposed to be

the key factors and causation of accident. Therefore, in this part, the SHEL model and Hybrid model will be applied to find out human factors of this accident and identify the causation related to human errors.

Table 5.1 SHEL model of Orient Star sinking accident

Liveware	Crew members, tourists
Hardware	Radar, AIS, GPS, ECDIS, NAVTEX, design of the superstructure, design of bridge, design of evacuation passage
Software	Safety training of ship company, safety assessment of ship company, safety management system of ship company, survey of port office, daily safety inspection of ship etc.
Environment	Severe weather condition, strong convection, 12 scale wind and heavy rain

The link between livewares can be crew member to crew member, crew member to tourist or tourist to tourist. On Orient Star, the communication between crew member is common, after 9 o`clock pm, realizing the severe weather, Master went to bridge to guide the helmsman and Chief Officer on watch, which had no obvious fault. The problem in this link is mainly crew member to tourist. The crew member had no instruction for tourists when they realized the severe weather, they only thought how to operate the ship under the strong wind and heavy rain, but not considered the evacuation preparation for the tourists, which is the reason why there were few tourists escaping from the ship. The link between hardware and liveware is always MMI, namely man machine interface, however, there was no fault in the MMI aspect, crew members had no inappropriate operation on related facilities when accident happened. However, the design of superstructure has some problems. There is no corridor on the side of the cruise ship, which made the escape of tourists more difficult. Under this condition, the crew member should instruct the tourists the other evacuation route, but this did not happen, too. The link between software and liveware

is the failure in regulations, mainly for the ship company. The Master and Chief Officer on watch had little recognition of severe weather condition, because the safety training of ship company and safety assessment of the ship company are missing and ignored. Apart from this, the failure in supervision of administration and safety management system are also crucial to this accident. Under this severe weather condition, Master still wanted to continue the voyage, which is not the consideration by Master alone, but influenced by the ship company. The ship company has many failures in its safety management system and is lack of awareness of risk assessment. Finally, the link between environment and liveware is absolutely the panic caused by adverse weather. In order to prevent the wind, the helmsman altered the course of the ship under the instruction of Master, which made the ship have bigger wind moment. Under this panic, crew members didn't care about the tourists, and that is why nearly all of the tourists were killed.

After using SHEL model to collect information of Orient Star sinking accident on human factors aspect, the Hybrid model can be used to identify the accident process and causation of each layer.

Table 5.2 Hybrid model of Orient Star sinking accident

Fallible decisions
1.Imperfection of safety training of Chongqing ship company
2.Imperfection of safety assessment of Chongqing ship company
3.Flaw of supervision of Chongqing port office
4.Imperfection of safety management system of Chongqing ship company

Line management deficiencies
1.Master continued the voyage under the severe weather condition
2.There was no evacuation instruction
3.Crew member cannot obey the Master`s thought under the authority gradient

Psychological precursors of unsafe acts
1.Panic of crew members caused by little recognition of severe weather
2.Panic of tourists that made them perplexed when ship sank

Unsafe acts
1.Crew member alter the course to counter the wind
2.Tourists didn`t escape immediately

Inadequate defenses
1.No evacuation plan
2.Rescue team reach the scene late

The above tables are the five parts of Hybrid model in this sinking accident. We can find that the management aspect is the most crucial, which lead to the subsequent failures of other layers. In fact, this accident was mainly caused by the severe natural disaster, which was hard to forecast. Therefore, the unsafe acts or the precursors would not be the main causations of this accident. However, the management deficiencies of the company and related administrations may have resulted in these failures. There is no doubt that the human factors causation is not the most important causation in this accident, but the failures on human factors aspect can also give investigator and safety management members a lot of edification, which guide them to improve the safety management system in order to prevent the similar accident in the future.

CHAPTER 6

Conclusion

Accidents accompany the development of shipping industry all the time. Maritime casualty investigation is the most useful weapon to the goal of preventing accidents happening again by finding causations from all dimensions and drawing lessons and proposing prevention measures. In China, maritime casualty investigation has some deficiencies. Investigators in China don't pay attention to the human factors aspect because of the limit of administration and some other reasons. This is mainly because the special national condition of China. No human factors analysis and research make the investigation in China very limited and immature. However, China is a big shipping country, accidents happen frequently, so the enhancement of China's maritime casualty investigation is imperative. Under this condition, China should use the advanced methods in developed shipping countries for reference. Using the accident causation theory and accident models are good ways for China to improve its level of investigation and not obeying the big environment of national condition. There are many accident theories and models, such as accident causal chain theory, models based on human factors etc. The two advanced models, SHEL model and Hybrid model can help facilitate the development of China's investigation and improve the depth and significance of investigation. What's more, these two models both focus on human factors aspect, which is lacked by China's maritime casualty investigation. The SHEL model can help facilitate the information collecting process of investigation and Hybrid model can help investigators identify the accident causations and process clearly. In this thesis, the SHEL model and Hybrid model are used on Orient Star sinking accident to help find out some human factors and causations as an example for China's investigation to apply advanced models into use. By continuously referring to the advanced experience of developed shipping countries, China is supposed to find its own style of maritime casualty investigation, which accords to the national condition and also take human factors aspect into account.

Sincerely, to be a true big shipping country, China still has a lot of works to do.

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