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## A study of the human factors in maritime safety

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**World Maritime University**

Dalian, China

**A Study of the Human Factors in Maritime Safety**

By

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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**

**(Maritime Safety and Environmental Management)**

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## **Acknowledgements**

First of all, with total sincerity, I feel grateful to Professor Liu Zhengjiang for his help. The thesis has been finished. In consideration of the very basic principles of academic morals and ethic, the declaration hereby goes to the fact that the thesis presented right here is out of my original research effort that I have made on the advice of my supervisor. With all might and main, no portion of this thesis has been cited without being appropriately referenced. I take responsibility for any breach of copyright law that might arise.

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## **Abstract**

The current study on human factor enhances the awareness of human elements in maritime safety, and encourages further application of curbing human elements in the supervision agenda, thus ensuring the safety status of the ships at sea. The topic on human factors has grown to be more complex for people to measure along with the changing of times brought about by advanced technology like unmanned shipping and artificial intelligence, which asks higher but more complex demands for seafarers.

Plenty of studies have been focusing on human factors in the maritime safety, giving birth to a great deal of feasible and abundant findings concerning management, relevant conventions, culture and effective solutions. Based on plenty of previous studies on human factors in maritime safety, the methods for analyzing human factors are diverse which makes the analysis on human factors Persuasive and accurate. Besides, the current study uses an experiment in the form of questionnaire to help analyze the causes of human factors, to measure the potential effects brought by human factors and then come up with appropriate solutions to eliminate and even prevent the incidence of human errors.

**Key words:** Human factors, Human errors, Maritime safety, Questionnaire

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## **Chapter One Introduction**

### 1.1 Historical process and definition of human factors

The shipping industry has always been a field of high risk for people engaged in it. Due to the complexity of marine environment and constantly changing weather conditions, the ships, at any time, are very likely to meet their own doom, the undefendable natural disasters like rainstorm, thunder and lightning, tsunami, ice pack, violent storm and roaring waves. However, in recent several decades, the ships have been gradually turning themselves into the trend of upsizing, specialization and high-speed coupled with the faster pace of the whole shipping industry. Inevitably, the latent risks at sea never fail to come up with the pace of development, which, in other words, reveals that the maritime safety will remain to be a perpetual and significant matter. In 1994, the International Maritime Organization noted that the maritime casualties caused by human factors occupy about 80 percent of total maritime accidents, or even more.

In the mid-18<sup>th</sup> century, relevant statistics and analysis concerning maritime casualties began to exist. Although studies during that period of time mainly focus on the causes for maritime casualties from the perspective of technology, equipment, actually, plenty of requirements asked for human behaviors have emerged.

In 1930s, at the very beginning, Heinrich first put forward that the major cause for accidents originate from human factors. Since then, many experts and scholars began to pay attention to the human factors in maritime affairs, which mainly centered around quantitative statistics and analysis. Then, useful information closely related to human factors could be extracted from these statistics and the elements of affecting the occurrence of human errors can be identified further.

During that period of time, it has been universally known to the whole maritime industry that the human factors account for a major part of maritime casualties. Nevertheless, the publicized information simply attributed the maritime casualties to

human errors rather than dig out the fundamental reason for human errors through systematic analysis. In accordance with international and domestic statistics of maritime casualties at that time, various definitions about human factors, especially the range of human errors, vary from institution to institution like insurance companies, courts, shipping enterprises and classification society, which led to the disparity of statistical results, and the final results were usually prone to define the infringement liability. Therefore, experts pointed out that it is necessary to standardize the items and definition of human errors so as to make the casualty results objective and persuasive. Therefore, via long-term analytical research of maritime casualties by the Maritime Safety Committee and Maritime Environment Protection Committee of the International Maritime Organization, the uniform terms for human factors were announced, including 6 sections, they are, human error, diminished human performance, marine environment, safety administration, management and mental action. As is obvious from these terms, they highlight the drawbacks of human physiology, mentality, behavior and competence as well as the external marine environment. Such change signifies the research emphasis on human factors rather than simply on technology matters. In other words, in marine field, the human factors have captured wide attention both at home and abroad, and the maritime safety management has opened up a new era since then.

There still exists disparity between Western and Eastern cultures. Specifically, as for the definition of human factors, domestically, the actual meaning of human factors accounts for the part of human errors, which emphasizes more the negative effects or consequences brought out by human behaviors. Objectively speaking, one coin has two sides, so as human factors.

As is evident from current studies, plenty of feasible information collected and experience accumulated all prove that the human factors play a significant and vital role in maritime affairs, especially on issues concerning maritime safety. With regard

to maritime safety management, it is inevitable that maritime casualties will come into discussion. Such discussion proceeds mainly from two angles, they are, centering around human factors when estimating risks at sea and setting the occurrence of casualties as prerequisite when reflecting on human factors. These two analytical angles are combined together so as to comprehensively present relevant effects brought by human factors, functioning as a positive reference for ensuring safe shipping at sea.

## 1.2 Objective of the study

There is one fact that people could not deny, that is, the risks climb up with the development of technology, in which respect human beings have always been performing themselves as the core during various kinds of industrial revolution, be they unmanned shipping, artificial intelligence or even the subversion of the shipping industry. In other words, human beings remain a perpetual discourse power as well as revolution power, which, at the same time, giving birth to the human elements as core. As a matter of course, the effects produced by human elements are ubiquitous, be they angels or devils. Therefore, this study comes into sight with the vision of further delving into the real essence of the human factors, the possible effects coupled with as well as the potential risks that could be avoided in advance.

Specifically, the objective of the current study is obvious, that is, to ensure the maritime safety for seafarers as individuals, the shipping enterprises and all parties engaged in it. In addition, the purpose of the current study is to identify and classify human errors, to analyze multifarious effects caused by human elements, and then find out the essential cause for human errors. Finally, based on previous findings, the incidence of maritime casualties is in a position to get eliminated so as to uplift the maritime security management.

### 1.3 Significance of the study

The significance of the study on human factors in maritime safety is self-evident. To attain faster economic growth, the comprehensive transportation comes first. The water transportation keeps itself an indispensable and vital position among all transportation systems. In early 2002, the International Maritime University said that the shipping industry may have become an industry of the greatest international characteristics, while, of the highest risk. The exploration of the essential cause of maritime casualties has currently become an academic focus. In this respect, the human factors affect the maritime safety affairs a great deal, the significance of which is reflected on the following aspects.

First, the study on human factors works as a reference for providing China Maritime Safety Administration with the system and mode of curbing human elements. The current focus on supervision mainly lies in checking equipment in the ship, while the supervision on human elements merely emphasizes on the limitation of certificates. Therefore, the current study raises and even enhances the awareness of human elements, and encourages further application of curbing human elements in the supervision agenda, thus ensuring the safety status of the ships at sea.

Second, the current study makes survey of ships more targeted and exact. The International Association of Classification Societies divides the human elements into five aspects, they are, technology, manning, training, management and environment. Among these five aspects, only technology and environment are concerned with supervision while putting aside any ingredients related to humans. For instance, whether or not the design of the equipment takes the ergonomic factors into account, whether or not the structure of the equipment is applicable for maintenance and repair by human forces. The study on human factors inspires relevant parties more on the previous matters.

Third, the effective measures being taken help improve the maritime safety management via probing into the human factors. It is hard to define the exact meaning of definition. For instance, no maritime casualty does not absolutely mean the real safe condition of the whole operation system or any potential risks. The purpose of checking ships is to find out potential risks and eliminate the incidence rate. Once again, the awareness of emphasizing more on human elements deserves to get enhanced thus changing the previous focus on merely checking equipment on ships.

Forth, with much more knowledge about human elements, inevitably, it must have generated effects on the education and selection of talented people in the shipping industry. During the voyage, the manning of talented people in the shipping industry matters in terms of reducing the occurrence of maritime casualties. Specifically, the highly talented means those people of vitality and good health, sophisticated technology skills need in work, communication skills, legal awareness and so on. China Maritime Safety Administration has published plenty of regulations with regard to the strict, systematic, formal management of seafarers' training, certificates and watchkeeping. In addition, a number of domestic shipping education institutions have been dedicating themselves into perfecting the teaching syllabus in this field, gradually establishing their own educational system with much severer standards. This improvement will function positively on training seafarers, also as a basic prerequisite for reducing maritime casualties caused by humans.

## **Chapter Two Literature Review**

### **2.1 Specific studies on human factors**

Based on the historical process and definition of human factors presented in the previous chapter, gradually, the awareness of studying, highlighting and curbing human factors has been enhanced in recent decades, which can be seen from the existing studies on this matter.

As for the significance of curbing human factors, Wu (2015) and Li (2005) all emphasized the common two points. First, the further study on human factors helps China Maritime Safety Administration with establishing the system and mode of eliminating human errors thus ensuring maritime security. Second, it is beneficial for maritime educational institutions to innovate their own teaching syllabus, counting more human elements like mentality and health conditions in.

There always remains a dispute about the horrible consequences caused by human factors. In 1994, the International Maritime Organization noted that the maritime casualties caused by human factors occupy about 80 percent of total maritime accidents. Nevertheless, some other scholars think that 100 percent of maritime accidents are caused by human factors. Inevitably, another one dispute comes upon, that is, is there only the human factor working? With regard to this question, Zhang (2000) noted that the maritime casualties were affected by the combination of three elements, they are, human, ship and environment, among which the human factor is arranged as the core. Therefore, the study on human factors indeed keeps an eye on eliminating the incidence of maritime casualties.

To raise and even enhance the awareness of human factors is indispensable. As is evident from the study written by Li (2005), it says that the uniform terms for human factors were announced by the Maritime Safety Committee and Maritime Environment Protection Committee of the International Maritime Organization, including 6 sections, they are, human error, diminished human performance, marine environment, safety

administration, management and mental action. This seems to hint that they highlight the drawbacks of human physiology, mentality, behavior and competence as well as the external marine environment, functioning as a milestone for the turning point of human factors. In other words, the human factors have captured wide attention both at home and abroad, and formally stepped onto the stage of a new era.

After noticing the importance of human factors, He (2009) mentioned that the International Maritime Organization has also paid greater attention to human elements than ever before. Besides that, to perfect the seafarers' basic quality means not merely a device to establish the safety systems in the shipping enterprises but also the one to ensure maritime safety via curbing human elements. In short, he held the view that the human factors take into account the constitutions of the seafarers, the mental and physical conditions, and political and cultural background. All these findings on human factors are awaited to put into effect with appropriate improving methods rather than "safety management on paper".

#### 2.1.1 Seafarers' fatigue of human factors

When it comes to human factors in maritime safety management, the study may fail to go on devoid of discussing about seafarers' fatigue, which is getting worse with much stronger working intensity for seafarers.

Seafarer fatigue happens primarily due to lack of sleep, heavy workload, physical environment and stress. Specifically, time allocation is related to the time of day of the transport operation hours, a long duration of wakefulness, inadequate sleep, pathological sleepiness and pronged working hours. Besides, the physical environment is counted as one of the main influencing factors conducting to faults and health problems, considering the noise, temperature, illumination, radiation, humidity and comfort. Sometimes, the ship tossing about on the stormy sea will make sleep quality

low, the very limited manning on ships intangibly intensify seafarers' workload, and the jetlag is to blame for low-quality sleep arousing fatigue.

As for the severity of seafarer fatigue, the risk facing a person of 17 hours' continuous sleeplessness is equivalent to that of the person whose blood alcohol concentration is up to 0.05%, according to the report released by the Adelaide Centre for Sleep Research. That sets us wondering what fatigue reflected in the overtime work really implies if it is equivalent to drunk driving, while the living proof reveals that fatigue will lead to disastrous consequences. Besides that, another research released by the Institute of Medicine Committee Sleep Medicine and Research shows that an increasing amount of proof has identified the negative impacts brought by the lack of sleep on neurobehavior with respect to cognitive behavior and quick-minded decision-making. Specifically, the faults in judgement and decision-making caused by lack of sleep has come to the top list of the causes accounting for the accidents at sea. Moreover, this sort of overload work is even wrongly considered as an act of hardworking and the devotion to work. What is commonly seen is that the majority take the overload work for granted, and some even work for extra 4 or 5 hours per day just for more remuneration while putting aside personal health and the potential safety hazard on the ship, but remuneration should not encourage unsafe work practices and is not an incentive to violate regulations.

For some shipping enterprises, they may maximize their profits to a large extent while neglecting the impacts and even loss generated by seafarer fatigue. The cost of fatigue, of course, is too high to afford, concerning the insurance costs of the sinking and grounding, the cost of lost seafarers and ruined reputation and that of pollution and salvage operations. Fatigue is a sort of torture, which is unacceptable in a normal commercial enterprise. For most part, the birth of fatigue could be attributed to lack of sleep, stress, and heavy workload, and consequences may happen, be they predictable



or unpredictable. A safety management system, of no doubt, should take the crew's health and welfare into account.

What consequences will happen if seafarers' fatigue cannot be gradually relieved? For seafarers, shipowners and even the whole shipping industry, fatigue could be fatal. For seafarers, the long-term fatigue, be it acute or chronic, will do more harm than good to longevity. In addition, the extreme fatigue will lead to disastrous consequences. For instance, the seafarer of extreme fatigue may fail to get notice of the emergent situation even when sea water pouring into the engine room fails to wake them up eventually leading to ship's sinking. Besides that, the fretful feelings may get generated due to fatigue and then conflicts happen among seafarers. And low response times, irritability and physical effects from standing for long periods may also be cited here in light of extreme fatigue.

As is evident from the report released by the International Maritime Organization, several elements accounting for fatigue come into sight, they are, external weather conditions, basic conditions of ships, management concerning with contract, time allocated for on-duty and off-duty hours, manning levels, watchkeeping, assignment allocation and so on. Seafarer fatigue happens primarily due to lack of sleep, heavy workload, physical environment and stress. Specifically, time allocation is related to the time of day of the transport operation hours, a long duration of wakefulness, inadequate sleep, pathological sleepiness and prolonged working hours.

#### 2.1.2 Maritime casualties caused by human factors

Wu (2015) mentioned that three types of casualties could be caused by human factors, they are, collision, stranded and fire. As is what is usually said, 80 percent of the maritime casualties are caused by human factors, while the incidence rate of collision, caused by human factors, accounts for 85 percent of maritime casualties. The collision among ships may cause damage to not only ships but also cargos. Even worse,

such collision may threaten life on ships, marine environment and ecosystem. So how could this collision happen? And how can we reduce the incidence rate? After the elicited study on this issue, human factors emerge fatal effects during operation. In other words, human errors lead to collisions. There are five aspects explaining the collisions caused by human factors, they are, fatigue driving and sleepiness causing many driving accidents, the breakdown of machine, shortage in professional knowledge, the self-egoism ignoring potential risks, unavoidable collision after normal give-way. It is hard to exactly count such collisions due to humans is unlikely to completely get devoid of external and internal elements, and that's where the uncertainty lies in.

In 1990, the Changjiang 0802 fleet collided with the Chongqing fleet, capsizing the ship Changlin 1 and causing the pouring of concentrated sulfuric acid into the Yangtze River. Unfortunately, such collision has brought about disastrous consequences to environment as well as negative effects on quality of life. The severity of such pollution is beyond the compensation measured by money.

In 2018, the maritime casualty of the oil tanker Sanchi caused significant impacts on environment. The tanker was carrying about 1 million barrels of condensate and then the fuel has spread into the East China Sea after the collision. It could be counted as a sort of catastrophe for marine environment. Actually, the profound reason for this collision is multiple, such as the information-transmission capability, law-based and human-based management. In a word, none of these aspects are completely free from human elements.

Wu (2015) has also pointed out that the maritime casualties could be caused by multiple elements, be they human elements or environment. Besides that, she also mentioned the negative sides of automatic driving. For instance, the long-term utilization of automatic equipment would paralyze the driver, which then makes drivers in the condition of fake security and low alert. Worse still, the drivers will feel at a loss when any emergent situation happens. In this respect, the awareness of

preventing risks means a lot as for the ongoing unmanned driving with the eliminating incidence rate.

The occurrence of the ships' getting stranded is second only to that of collision in the maritime casualties. While the human elements account for major parts of ships' getting stranded, as is noted by the International Maritime Organization. The reasons for ships' getting stranded have been analyzed, as is noted by Wu (2015).

First, the violation of basic conditions when deciding an appropriate and secure shipping route.

Second, the drivers rely more on the modern technology like navigation to measure the ship's actual position while putting aside self-positioning.

Third, the inaccuracy in measurement caused by negligence and mistakes also appear on the list.

Forth, the uncertainty from meteorological changes like smog makes it more difficult to position exactly.

Fifth, the lagging-behind information fails to offer any updated information about the instant changes.

In a nutshell, as is evident from Wu's study, the human elements should account for the majority of the maritime casualties thus generating effective solutions to specific problems concerned. Besides, the solutions involved in must include moral ethics since the human elements has been closely related to the security of life and property at sea. Otherwise, the International Maritime Organization has now been implementing SOLAS Convention and STCW Convention, and ensuring the implementation of ISM Rules. At the same time, the shipping enterprises is supposed to shoulder the responsibility of ensuring the seafarers' physical and psychological quality as well comprehensive abilities.

## 2.2 Methods for analyzing human factors

After the previous section discussing about the human elements concerning maritime casualties, it is indispensable to analyze human factors in a more scientific and cautious way so as to make the results more accurate and persuasive.

Zhang and Xu (2000) highlighted the importance of the analysis on human elements, and relevant methods are of great needs. The reasons for analyzing human elements and figuring out effective methods have their own merits. First, the risks caused by human elements could be quantitatively assessed and predicted. Second, the reason for human errors could be reasonably analyzed and assessed. Third, it would become more targeted and convenient to identify any latent problems on ships. Then, at that period of time, the three methods mentioned by Zhang are problem-oriented method, the method of security system engineering and setting up database.

The first method, the problem-oriented method, is merely based on the current accident which has happened regardless of a comprehensive analysis on the whole security system as well as further analysis and prediction on latent failures.

The second method, security system engineering, means to curb or even eliminate unsafe elements and latent failures via practicing systematic theories. In this way could the incidence rate be controlled to the minimum so as to reach a safe circumstance. Specifically, the security system engineering includes security analysis, security assessment and security measures with the security assessment as the core. By the way, the method of security system engineering compensates for the drawbacks of the first method as for predicting and preventing latent failures caused by human elements.

The third method, setting up database, functions through data communication, data management and data counting. Since the updated information of data is of great importance to send alarm instantly during transmission supported by advanced equipment while serving the ships at sea.

At the early stage, the above methods work to a very limited degree. Nevertheless, later on, other effective and creative methods and application emerge in an endless stream.

Five years later, Li (2005) put forward Human Reliability Analysis Theory, which is based on security system engineering, considered to be a newly emerging subject focusing on human reliability at that time. After the step of risk identification, risk assessment and decision-making in the security system engineering, the Human Reliability Analysis Theory systematically analyzes the human elements, including the identification of human errors in maritime casualties, the quantitative assessment on seafarers' reliability and the causes of human errors in maritime safety management. In addition, the International Maritime Organization divided the human elements into six sections, they are, human errors, diminished human performance, marine environment, safety administration, management and mental action. All these seem to hint at the significance of delving into human elements in maritime casualties, signifying the emphasis on humans rather than simply on technology and equipment. In other words, in marine field, the human factors have captured wide attention both at home and abroad and given birth to the aftercoming improved methods for assessing and analyzing human elements so as to make the use of methods more persuasive and authoritative.

Besides that, Li also utilized the failure tree analysis and the table of human errors to count the casualties caused by human errors and vividly present the causes.

Specifically, among all human elements, fatigue is a major cause of accidents in transport operations. Therefore, it is of great need to focus on maritime casualties caused by fatigue, especially the practical methods for identifying fatigue. Liu (2013) mentioned Analytical Hierarchy Process in his study, a kind of analysis combining both qualitative analysis and quantitative analysis. Its mindset is to establish a describable but independent structure in accordance with all-level purpose and each

level will respectively compare with the nearby one as for its own significance, thus generating an evaluation matrix. After counting up the weights of each level, the weights of each level to the total sum of all level will figure out. The Analytical Hierarchy Process will go through four steps, namely, to establish a structure of levels, to make an evaluation matrix, to count up weights of each level and to sort in sequence. Besides that, Li (2013) also come up with another method, the Fuzzy Comprehensive Evaluation, the key point of which lies in the application of scientific principle, systematic principle, objective principle and practical principle to form a systematic comprehensive assessment of seafarers' fatigue. By the way, seafarers' fatigue will remain a perpetual hot spot in discussion. Pan (2009) also emphasized that over-fatigue, doing harm to mental and physical health, should account for a main part of maritime casualties.

As is what has been defined by the International Maritime Organization, the human elements include six terms, human error, diminished human performance, marine environment, safety administration, management and mental action, among which the human error affects a great deal as for the incidence rate of maritime casualties. in this respect, Li (2005) has mentioned several methods identifying human errors, they are, Human Hazard Operation, Skills-Rules-Knowledge Model, SHERPA(System of Human Errors Reduction and Prediction), GEMS, HRMS(Human Errors Management System), but none of them is capable of defining the errors in cognition, violation of rules, organization and management potentially caused by humans. However, another two methods appear to be more effective in human errors identification, Failure Tree Analysis and Table of Human Error Analysis. Table 1 is written to show an example of the analysis on human errors.

Table 1 – Human errors of lifeboat evacuation

Steps	Errors	Consequences	Correction	Elimination of errors
Check the wind speed, direction and sea condition	No acquisition of relevant information.	If condition underestimated, lifeboats and seafarers will be at risk.  The lifeboats will crash into the platform without the full use of wind speed.		The assessment on lifeboat security should be ensured by at least two persons and then they take action.
Check the compass on the mast.	Acquisition of false information.	The helmsman will drive the ship towards the platform.	No effective methods can be taken without smoke and fire.	Change the position of the compass with reading confirmed by at least two persons.

It is a simple and practical method and widely used by the maritime industry with the merits of vivid demonstration and convenience. Nevertheless, one of the demerits of this method lies in neglecting the potential psychological mechanism.

As for Failure Tree Analysis, it means to describe human errors and effects on system, a kind of logical structure, defining the unexpected events such as human errors, breakdown of hardware or software and environmental accidents. Failure Tree Analysis consists of two types of gates, Coincidence gate and Or gate(或门), the use of which can propel the event at low level into a higher level. In addition, Failure Tree Analysis is also used as a device for qualitative analysis and quantitative analysis.

For qualitative analysis, the purpose of qualitative analysis is to find out the minimal cut set or minimal radius set in the failure tree, a set of basic events, and then establish the structural function. If the events of the minimal cut set all happen, the top event will definitely happen. What's more, if none of events in the relative congregation of the minimal cut set and minimal radius set happen, the top event is will not take place.

For quantitative analysis, it aims to use the failure tree as a model to estimate the incidence rate of the top event and assess the reliability and security of the system via figuring out the significance of each bottom event as for leading to the incidence of top events so as to take effective measures to problems concerned.



## **Chapter Three Influencing Ingredients of Human Factors**

### 3.1 Health conditions

During the operation at sea, humans, of no doubts, perform a vital role in daily production, which is considered to be an internal element. When compared with equipment and meteorological changes at sea, humans maintain their own individualities and uncertainties, which foreshadows the threats caused by human errors. Since each person has his own individuality, their errors could be this or that. While in turn universality and unity also persist in human elements, mainly reflected in the errors often mentioned like collision, getting stranded and fire accidents.

The relation between human elements and maritime safety should put humans as the main body. By the way, as for the study on humans, their ability directly or indirectly affects the actual production, divided into two types, innate factor and acquired disposition. As is evident from the statistics and analysis collected, the effects caused by human elements on maritime safety can be expounded from three aspects, they are, physical health, mental health and personal ability.

#### 3.1.1 Physical elements

A major part included within the human elements is fatigue, and the International Maritime Organization has analyzed the reasons for seafarers' fatigue, mainly reflected in management, ships, seafarers themselves and other relevant external ingredients.

As for management, seafarers' fatigue is closely related to their working hours, some seafarers even work extra hours merely for more remuneration while at the cost of their health. By the way, such working extra hours with more remuneration must have something to do with the corporate culture. For me, personally, I think such overtime work at sea is a sort of torture sacrificing personal health, and the loss outweighs the gain, letting alone seafarers' operation at sea has already been of high

risk. Besides, the arrangement in the contract, manning level, on-duty management, task assignment, and so on.

As for ships, the following aspects will affect seafarers' fatigue, they are, automation level, equipment reliability, vibration level, the quality of working and living environment and design of the ship.

As for seafarers themselves, their experience matters, consisting of time, training and practical operation, team cohesion and individual abilities.

As for the external elements, it will definitely come to weather conditions, port state, ice regime and traffic concentration at sea.

In short, more detailed information about the elements leading to seafarers' fatigue which accounts for a major part of human errors needs to be further discussed. Nevertheless, there is one fact that we could not deny, that is, so many elements altogether are very likely to affect seafarers' physical conditions. In other words, sometimes, humans' body is too weak to bear this or that burden from all directions. No matter what the time is, seafarers' physical condition always deserves great attention. There is a saying that the body is the capital of the revolution.

As for the consequences brought out by fatigue, several elements need to raise concerns. First, the fatigue driving could be fatal. Human body maintains its own physiological rhythm during one day of 24 hours. In addition, the physical strength changes with the degree of fatigue. When voyaging at sea, a suitable arrangement should take into account the humans' physical conditions. The disparity between humans and equipment lies in the adjustment needed when in constant operation. If people are in long-time non-sleeping state, the energy, endurance and strength consumed is tremendous, a danger signal when voyaging at sea. Second, seafarers are unlikely to adapt to the diet on ships. The shipping industry asks higher demand for seafarers' physical strength and other comprehensive qualities needed in daily work. While it is unlikely to ensure that fresh fruits and vegetables can be provided in time,

causing the loss of nutrition, and such lack of nutrition could be a haphazard ingredient to seafarers' health. Furthermore, the differences between the south and the north also lead to the disparity in diet, letting alone personal fancy in food. Therefore, to improve seafarers' adaptability to diet is also counted as a solution to problems concerned.

Third, seafarers themselves get seasickness. Compared to the inadaptability to diet, the seasickness that seafarers are confronted with is a common scene. The seasickness means, with ships mooring at the seashore, people feel abnormal stimulus in vestibulum auris internae when suffering from chaotic shaking and vibration forced by stiff winds and waves.

### 3.1.2 Mental elements

The most extrusive feature of mental elements is reflected in emotional response, which is closely related to seafarers' daily work and life. Among all effects caused by human elements in maritime safety management, the psychological factor has captured wide attention, while also ignored by plenty of studies to a large degree. As a matter of fact, the psychological factor has produced great burden to seafarers. As is evident from relevant materials, the general psychology states that emotion is a kind of reflection of the need between the objective and the subjective, accompanied by the attitude towards the external world generated by cognition and awareness. While in turn, the fluctuation in emotions would generating sorrow, fear, panic and insecurity, directly or indirectly affecting people's normal life and behaviors. Thereof, such extreme behaviors or even mistakes could be a signal leading to risks. The reflection of human elements lies in the negative sides of psychology. The most common psychological problems are presented below.

First, seafarers inevitably emerge negative emotions when confronted with severe environment at sea, and the majority feel exhausted about the repeated process going on every day. Therefore, under such circumstance, seafarers are unlikely to always

maintain a positive attitude towards work. Furthermore, since everyone on ships is in their own position with clear position, it is inevitable that the communication between the superordinate and the subordinate may come across plenty of problems, especially concerning the cultural conflicts among seafarers from multifarious nations.

Second, seafarers may also suffer from mental disease, it is possible that negative emotions would be developed into mental disease coupled with further deterioration, doing harm to human bodies and closely affecting maritime safety. Due to the special nature of marine industry, seafarers have to sail far away from home leading a wandering life at sea, suffering from the torture of nostalgia. Especially, the older seafarers have spent the majority of their lifetime at sea, leading a life bearing heavy burdens. Nevertheless, such circumstance may have become their normal part in life. Furthermore, after the long-term loss of touch with the external world, it is difficult for seafarers to escape from their inadaptability to society or even their original family. Things and their surrounding people changed all of a sudden, it is reasonable that seafarers may have unconsciously become accustomed to their work and rest, be it beneficial or harmful, and interpersonal relationships at sea. Naturally, contradictions among seafarers' families erupts, sometimes, even for trivialities. By the way, for freshmen at sea, during their early course of adaptation with hardships, with the frequent changes in their physiological rhythm, the sense of anxiety, exhaust, insecurity is likely to get generated. In addition, loneliness and solitude is also an obstacle for seafarers to overcome. In short, for seafarers, the early course of adaptation at sea, the hardships will obstruct their advance proceeding ahead in marine industry.

### 3.2 Personal competence for handling emergent situations

The definition of competence has the meaning of the quality reflected by the reach of an object or the accomplishment of a task. Actually, one was born without being

equipped with genius competence for dealing with various kinds of situations but with gradual fostering year by year. There is one fact that we could not deny, that is, the incidence of a maritime casualty happens due to some weakness in competence which generates errors. Therefore, for seafarers' competence, the shipping industry and relevant administration should pay more attention and devote more effort into education and training. Hereby, seafarers' competence includes mainly three types, they are, learning ability, behavior competence and management competence, all of which function together performing a critical role in human elements.

### 3.2.1 Learning ability

For seafarers, the learning ability consists of two parts, the matter of theoretical knowledge and actual practice. By the way, there is a very interesting point concerning the meaning of learning, also related to the cultural differences between the West and the East in structuring characters. In Chinese, the meaning of learning is called as *xue xi*, 学习. The Chinese character “学” means imitation, and “习” means practice, during the period of which the imitation includes the matter of theoretical knowledge and then the action of imitate, and then the real practice emerge genuine knowledge, and then repeatedly practice and imitate.

Although the subject of navigation requires a lot in terms of practice, the limitation in educational institution fails to put practice but theory on the top priority, emphasizing more on exams on paper. Meanwhile, the real operation is based on the good matter of theoretical knowledge. Therefore, we could not deny the value and significance of theoretical knowledge. Due to the short period for students to stay on ships, the cultivation of the ability in operation relies more on the later-on experience accumulation. In other words, their learning ability, to some extent, is usually reflected by the later-on operation on ships. Inevitably, under domestic educational background,

seafarers without certificates is in no position to work on board. In addition, the assessment on the professional ability needs not merely the basis of professional knowledge but also the real operation and working experience. That is to say, their practice ability could be counted as one of the standing points in sailing career, also the basis for ensuring the maritime safety. Seafarers need to develop professional ability in daily work, especially concerning the utilization of advanced equipment, the reconnaissance of breakdown, so as to ensure safety at sea. Nevertheless, it becomes increasingly uneasy for seafarers to keep highly efficient during on-duty hours coupled with seemingly endless emergence of new and advanced equipment which requires higher demand for seafarers than ever before. Currently, plenty of accidents occurred due to inappropriate use of equipment, so seafarers need to keep themselves prepared for maritime safety.

As for the ability in operation, due to the features in domestic education institution, the exam to test has always been seen as the sole purpose of learning. The way and the content prepared for students to learn is largely based on theories, like indulging in empty talk, or even worse, kill to death students' initiative for learning, that is, cramming teaching method. For teachers, they teach what will be tested on paper. For students, they learn what will be tested on paper, completely devoid of independent thinking, being a machine specially coping with piles of exams. Even though everything goes on smoothly that students have acquired the qualification of working on board, they lose their own initiative for learning. The numerous problems like the emergence of new knowledge and the utilization of new equipment come on heels of the loss in learning ability. Besides that, the learning ability is also closely related to experience. The length of time is not necessarily equivalent to experience, but no record of working on board is also in no position to relate to experience. For instance, such experience may refer to a calm attitude towards urgent situations and immediate action to avoid accidents. The actual use of knowledge sooner or later will turn into

experience, and then experience will give birth to new knowledge. In addition, to conclude plays a vital role in eliminating the incidence rate after casualties, and it is a responsible act for seafarers to reflect on the casualties to eliminate the incidence rate and improve themselves. In short, experience is the basis for preventing casualties and ensuring safety at sea, and sophisticated technology and abundant experience perform together as multi-insurance at sea.

The learning ability also concerns the matter of communication. As for communication, language comes to the top priority. The talented seafarers should be adept at English, which functions as not merely a critical device for achieving successful career but also an element of qualifying the job on board. Teamwork turns out to be inevitable and important especially when seafarers from different countries gather on board. Suppose if there is any obstacle or misunderstanding in daily communication, negative effects will come upon thus indirectly generating maritime casualties. The deficiency in English has gradually becomes an obstacle for seafarers to finish their work smoothly when cooperating with foreign seafarers.

### 3.2.2 Self-management

This section mainly discusses the self-management and personal behavior. The behavioral competence mainly refers to the competence for exercising rights in accordance with law and bearing relevant responsibility. The one owning behavioral competence must be equipped with basic rights. The self-management is reflected by several aspects, they are, the sense of obedience, the sense of responsibility, and team spirit.

First, the sense of obedience is a reflection of behavioral competence. It matters whether the subordinate seafarers will do as what he has been told by the superordinate level, where lies a common problem domestically. When working on board, the team spirit asks for higher demands for obedience when cooperation needed among seafarers, which also ensures organization and orderliness. While in turn, the lack of

obedience will fail to fulfill the cooperation among each other, and sooner or later, things will get worse. Furthermore, the sense of obedience lay the basis for normal use of technology and theoretical knowledge.

Second, the sense of responsibility involves a great deal. The sense of responsibility itself appears to be a covert element, actually, the effects brought out by it is overt. For seafarers, it is a career closely related to risks, the importance of the sense of responsibility turns out to be self-evident. Nevertheless, the lack in responsibility indeed will result in risks at sea, at very large proportion. For quite long time, the shipping industry has been proceeding maneuver and revolution centering around responsibility.

Third, the team spirit works as a critical device for cooperation on board. There is a fact that we could not deny, that is, with the development of social productivity, the normal operation in society requires higher demands for team cooperation. Suppose a team without a leader, due to the lack of team spirit, everything seems to like a heap of loose sand. Especially for the shipping industry, the daily work on board is an existing form of cooperation among seafarers, for which the importance of team spirit is self-evident. Someone also pointed out that seafarers' quality consists of professional quality and ideological quality, the lack of which could be incomplete, both of them binding on each other and relying on each other. Nevertheless, there also exists a mistake that the shipping industry will need humans less than before with the constantly developing automation and modernization in the shipping industry. Just because of this, accompanied by the advanced technology in the shipping industry, such changes or even revolution have posed severe challenges concerning personal qualities both mentally and physically for seafarers on board.



### 3.3 Working environment

The physical environment is counted as one of the main influencing factors conducing to faults and health problems, taking into account the noise, temperature, illumination, radiation, humidity and comfort. Sometimes, the ship tossing about on the stormy sea will make sleep quality low, the very limited manning on ships intangibly intensify seafarers' workload, and the jetlag is to blame for low-quality sleep arousing fatigue. During the long-time severe working environment and voyage at sea, seemingly endless emergence contingency, heavy workload and mental stress all together generate in seafarers psychological and psychosocial problems of different levels, which deserves greater attention. In other words, the working environment on board should partly account for human errors.

First, negative induced emotion coupled with panic feelings arouses inside of seafarers. While drifting along abroad and afar for a period of long time, seafarers would become homesick, under which circumstance, isolated by the sea, is hard to get relieved or even eradicated. What's worse, the monotonous and stifling lifestyle on board will feed them up with the sense of dreariness, surrounding noise and vibration making them inclined to be vexed. All these working together contribute to the seafarers' sense of fear when confronted with any possible accidents and emergence contingency.

Second, under-performance condition leads to lower working competence. The highly evaluated anxiety in seafarers will affect their biological intelligence thus lowering their working efficiency and effectiveness. With such loose attitude towards work on board, in the course of time, the impacts on working performance and competence will further deteriorate emotional aspects, and then seafarers trapped into a vicious circulation in the matter of psychology.

Third, commonly seen problems concerning personality and conduct exist. It is difficult to escape from one-way negative feelings. Affected by high pressure on board,

they, to a certain degree, lack rationality in their conduct, which, furthermore, will give birth to the inclination of irritation and meanness. Besides, excessive drinking will morally degenerate their sense of responsibility towards both themselves and their family.

Forth, the tristimania and other neurosis emerge and bring about unaccountable side effects on seafarers. Such symptoms are primarily manifested by dreariness, depression, bluntness in mind, blockage in thought and so on. What's the worst, suicide happens, as is evident from the report released by the UK P&I Club in 2017, suicide comes as the primary cause for the seafarers' death, the amount of which occupies 15-percent of the total death number of seafarers.

## **Chapter Four Experimental Investigation**

### **4.1 Research questions**

Since the current study is to focus on human elements in maritime safety, all matters within human factors fail to be discussed any further without centering around human errors. The current experiment is to delve into three main questions, they are, the causes for human errors, the effects brought by human elements and the way to eliminate human errors. Before analyzing these three matters in detail, it is indeed of great necessity to proceed an experimental investigation on human errors. As the very prerequisite of fairness, such investigation will proceed in a form of questionnaire, and people picked out randomly working for the shipping industry will be invited to finish the questionnaire, due to the fact that their answers are concluded from their actual experience. As a result, the analysis based on this experiment could be more persuasive and authoritative.

### **4.2 Different methods and modes for analyzing human factors**

Before carrying on the experiment, several methods and modes for analyzing human factors are presented in this section for reference and comparison and to extract the conclusions from different methods and then pick out key points, be they common or unique.

At the very beginning, three methods are the problem-oriented method, the method of security system engineering and setting up database.

The first method, the problem-oriented method, is merely based on the current accident which has happened regardless of a comprehensive analysis on the whole security system as well as further analysis and prediction on latent failures.

The second method, security system engineering, means to curb or even eliminate unsafe elements and latent failures via practicing systematic theories. In this way could the incidence rate be controlled to the minimum so as to reach a safe circumstance.

Specifically, the security system engineering includes security analysis, security assessment and security measures with the security assessment as the core. By the way, the method of security system engineering compensates for the drawbacks of the first method as for predicting and preventing latent failures caused by human elements.

The third method, setting up database, functions through data communication, data management and data counting. Since the updated information of data is of great importance to send alarm instantly during transmission supported by advanced equipment while serving the ships at sea.

At the early stage, the above methods work to a very limited degree. Nevertheless, later on, other effective and creative methods and application emerge in an endless stream.

Five years later, Human Reliability Analysis Theory was born, based on security system engineering, considered to be a newly emerging subject focusing on human reliability at that time. After the step of risk identification, risk assessment and decision-making in the security system engineering, the Human Reliability Analysis Theory systematically analyzes the human elements, including the identification of human errors in maritime casualties, the quantitative assessment on seafarers' reliability and the causes of human errors in maritime safety management. In addition, the International Maritime Organization divided the human elements into six sections, they are, human errors, diminished human performance, marine environment, safety administration, management and mental action. All these seem to hint at the significance of delving into human elements in maritime casualties, signifying the emphasis on humans rather than simply on technology and equipment. In other words, in marine field, the human factors have captured wide attention both at home and abroad and given birth to the aftercoming improved methods for assessing and analyzing human elements so as to make the use of methods more persuasive and authoritative.

Besides that, Li also utilized the failure tree analysis and the table of human errors to count the casualties caused by human errors and vividly present the causes.

Specifically, among all human elements, fatigue is a major cause of accidents in transport operations. Therefore, it is of great need to focus on maritime casualties caused by fatigue, especially the practical methods for identifying fatigue, that is, Analytical Hierarchy Process, a kind of analysis combining both qualitative analysis and quantitative analysis. Its mindset is to establish a describable but independent structure in accordance with all-level purpose and each level will respectively compare with the nearby one as for its own significance, thus generating an evaluation matrix. After counting up the weights of each level, the weights of each level to the total sum of all level will figure out. The Analytical Hierarchy Process will go through four steps, namely, to establish a structure of levels, to make an evaluation matrix, to count up weights of each level and to sort in sequence. Besides that, another method, the Fuzzy Comprehensive Evaluation, the key point of which lies in the application of scientific principle, systematic principle, objective principle and practical principle to form a systematic comprehensive assessment of seafarers' fatigue. By the way, seafarers' fatigue will remain a perpetual hot spot in discussion.

As is what has been defined by the International Maritime Organization, the human elements include six terms, human error, diminished human performance, marine environment, safety administration, management and mental action, among which the human error affects a great deal as for the incidence rate of maritime casualties. In this respect, Li (2005) has mentioned several methods identifying human errors, they are, Human Hazard Operation, Skills-Rules-Knowledge Model, SHERPA(System of Human Errors Reduction and Prediction), GEMS, HRMS(Human Errors Management System), but none of them is capable of defining the errors in cognition, violation of rules, organization and management potentially caused by

humans. However, another two methods appear to be more effective in human errors identification, Failure Tree Analysis and Table of Human Error Analysis.

It is a simple and practical method and widely used by the maritime industry with the merits of vivid demonstration and convenience. Nevertheless, one of the demerits of this method lies in neglecting the potential psychological mechanism.

As for Failure Tree Analysis, it means to describe human errors and effects on system, a kind of logical structure, defining the unexpected events such as human errors, breakdown of hardware or software and environmental accidents. Failure Tree Analysis consists of two types of gates, Coincidence gate and Or gate(或门), the use of which can propel the event at low level into a higher level. In addition, Failure Tree Analysis is also used as a device for qualitative analysis and quantitative analysis.

For qualitative analysis, its purpose is to find out the minimal cut set or minimal radius set in the failure tree, a set of basic events, and then establish the structural function. If the events of the minimal cut set all happen, the top event will definitely happen. What's more, if none of events in the relative congregation of the minimal cut set and minimal radius set happen, the top event is will not take place.

For quantitative analysis, it aims to use the failure tree as a model to estimate the incidence rate of the top event and assess the reliability and security of the system via figuring out the significance of each bottom event as for leading to the incidence of top events so as to take effective measures to problems concerned.

### 4.3 Experiment

This section is to introduce the current experiment which contains the subject, procedure, method, design and results of the experiment. The experiment proceeds in the form of questionnaire, and the participants who engage in the shipping industry invited to finish the questionnaire are picked out randomly so as to present the real

scene of the shipping industry. However, this questionnaire has its own limitations, the range of the participants is limited in number, and the results of the questionnaire mainly focus on the participants randomly sorted out. By the way, it is the randomness of the participants that makes the questionnaire persuasive, reliable and valid to a certain degree.

#### 4.3.1 Subject and procedures

The subject of the questionnaire is to figure out the elements affecting the cause of human errors, to analyze the importance of each element working on human errors, so as to accurately find out effective ways to solve problems in the matter of human errors. The subject is always centering around the three directions, they are, to find out human errors, to analyze human errors and to eliminate human errors.

The procedure of the questionnaire is simple and explicit, consisting of the enumeration of various elements from 1 to 28 and the importance at different levels. The participants are invited to finish the questionnaire by deciding the degree of importance of each element. Finally, after the collection and analysis of all data, the most vital element affecting the occurrence of human errors will come into sight.

#### 4.3.2 Method and design

The questionnaire consists of 28 elements and three choices for each element. Specifically, these 28 elements are designed in accordance with the six section, human error, diminished human performance, marine environment, safety administration, management and mental action. The experiment within a certain range means to better figure out the cause of human errors, the effects brought out by human errors and ways to eliminate human errors. As for three choices for each element, the choices are designed according to the importance of each element. The design of the questionnaire

helps present a clear and vivid judgement on the important or trivial elements of human errors. The questionnaire is presented in the Table 1.

Table 1 - Questionnaire

		very important	less important	not important
1	working environment			
2	weather conditions			
3	long-term isolation from updated information			
4	irregular on-duty and off-duty hours			
5	regulations made by the shipping enterprises			
6	the implementation of relevant conventions concerning human errors			
7	management system by the superordinate level			
8	regular physical examination for seafarers			
9	the emphasis on human errors			
10	training and certificate			
11	human relations			
12	response to emergency contingency			



13	mental health			
14	physical health			
15	personal quality			
16	the rely on advanced technology like AI			
17	personal feelings like loneliness and nostalgia			
18	age			
19	experience			
20	seafarers' reflection on their own daily work and errors			
21	effective communication among seafarers			
22	team spirit and cooperation			
23	political and cultural background			
24	more remuneration			
25	working attitude			
26	professional knowledge			
27	the utilization of equipment on board			
28	lagging-behind backup			

There are in total 16 participants invited to finish the questionnaire, the majority of them taking positions in Maritime Safety Administration, some other having the experience of working on board. The final results and analysis based on this

questionnaire would be very close to the real situation happening in the shipping industry, keeping pace with the times, to come up with actually effective measures to solve the problems concerned.

#### 4.3.3 Results

As is evident from the results in the questionnaire, two elements have won the most votes, they are, irregular on-duty and off-duty hours and working attitude. 15 of 16 participants all choose these two elements as the important elements affecting the incidence of human errors. Besides, the working environment and mental health, voted by 13 participants, have also been considered as two vital roles in the influencing human errors. In addition, the following elements have acquired more than half of the votes, they are, training and certificate, physical health, personal quality, seafarers' reflection on their daily work and errors, effective communication among seafarers, team spirit and cooperation as well as professional knowledge.

As for the less important ingredients affecting the human errors, the following elements should not be ignored, they are, the emphasis on human errors as well as more remuneration. Although they are not the critical role in curbing the occurrence of human errors, they indeed deserve certain and indispensable attention.

Among all the elements listed in the questionnaire, age and political and cultural background have been ranked as the least important elements that would affect the occurrence of human errors. That is to say, human errors may have rare relations with seafarers' age and nationality.

Each element has three choices, they are, very important, less important and not important. Compared with the former two choices, few participants choose "not important", and they are prone to confirm the effects of each element on human errors. The questionnaire designed here means to present any possible elements affecting

human errors and find out the key ingredients via the collection of data. Therefore, the solutions to problems concerned could be more targeted and effective.

#### 4.3.4 Discussion

The results of the questionnaire have come to see the light of day, then there comes upon a question, that is, is there any traces for the birth of these results? Therefore, this section will analyze these results in detail thus generating effective solutions to problems concerned.

First, in accordance with the results in the questionnaire, when it comes to the elements affecting human errors, irregular on-duty and off-duty hours as well as working attitude come to the top priority. Separately speaking, these two elements belong to different sections in the definition of human factors respectively. Among six sections in human factors, human error, diminished human performance, marine environment, safety administration, management and mental action, working hours belongs to management and working attitude belongs to mental action. Due to the specialty in the shipping industry, it is hard to adjust the on-duty and off-duty hours in accordance with the normal biological clock. That is to say, such on-duty and off-duty hours is inevitable. Inevitably, the long-term abnormal work and rest hours on board has become normal scene, which leads to endocrine dyscrasia both mentally and physically. The only thing that helps to relieve such circumstance is to reduce the on-duty hours for once per person and add more shifts. Then the working attitude varies from person to person, but it indeed performs a critical role in daily performance, which may be counted as a kind of initiative.

Second, as for the second important ingredient affecting the human errors, the choice of more remuneration has won most votes in this part. To some extent, seafarers may not make errors directly for more remuneration, but they may earn more remuneration while making errors unconsciously. Suppose to earn more remuneration

as a purpose, seafarers would work extra hours for more remuneration regardless of their mental or physical conditions, a sort of overload work. Nevertheless, this sort of overload work is even wrongly considered as an act of hardworking and the devotion to work. What is commonly seen is that the majority take the overload work for granted, while putting aside personal health and the potential safety hazard on the ship, but remuneration should not encourage unsafe work practices and is not an incentive to violate regulations. For the shipping enterprises, such matter deserves severe attention, since extra profits should not be made at the cost of life and safety. As a result, fatigue will emerge under such circumstance. Consequently, plenty of faults in judgement and decision-making caused by fatigue has come to the top list of the causes accounting for the accidents at sea. Therefore, in this respect, from my perspective, the matter of more remuneration has this or that relations with human errors, even any trivial traces of haphazard underlying beneath.

Third, as for the unimportant elements affecting human errors, age and political and cultural background have been considered as the least important ingredients in compliance with the results in the questionnaire. That is to say, age is not necessarily linked to human errors, but other elements brought about by the changes in age may influence the incidence of human errors, for instance, experience, mental and physical conditions. Among all the elements listed in the questionnaire, political and cultural background has been considered as the least important one. Maybe political and cultural background itself appears to be not so critical with respect to the direct cause of human errors. Nevertheless, it is inevitable for seafarers from different countries to communicate and cooperate with each other, and then the cultural conflicts may exist in language, behavior and understanding. Since seafarers' daily work need cooperation, team spirit has occupied a significant position on board. Besides, the shipping industry could be counted as an international industry, setting English as commonly an using language. The use of English is a problem needs to get improved when seafarers from

various countries work on board, even though misunderstandings among them may emerge due to the disparity in behavior, habits, regulations and cultural conflicts. By the way, the disparity in political and cultural background can rarely be eliminated by human force, since it is a kind of element born to be, too deep to be removed.

## Chapter Five Findings of the Present Study

### 5.1 Production

In the current study, a general but concrete phenomenon of human errors is prepared to be introduced from different dimensions, they are, features, status, elimination of human errors and effective solutions. In addition, the figures produced by the questionnaire will be presented in a straightforward way.

#### 5.1.1 Onset of productivity

In the current study, the onset productivity is defined as the session which contains the results of external or internal elements affecting the incidence of human errors. Figure 1, Figure 2 and Figure 3 will present a directviewing understanding of the present study.

Figure-1

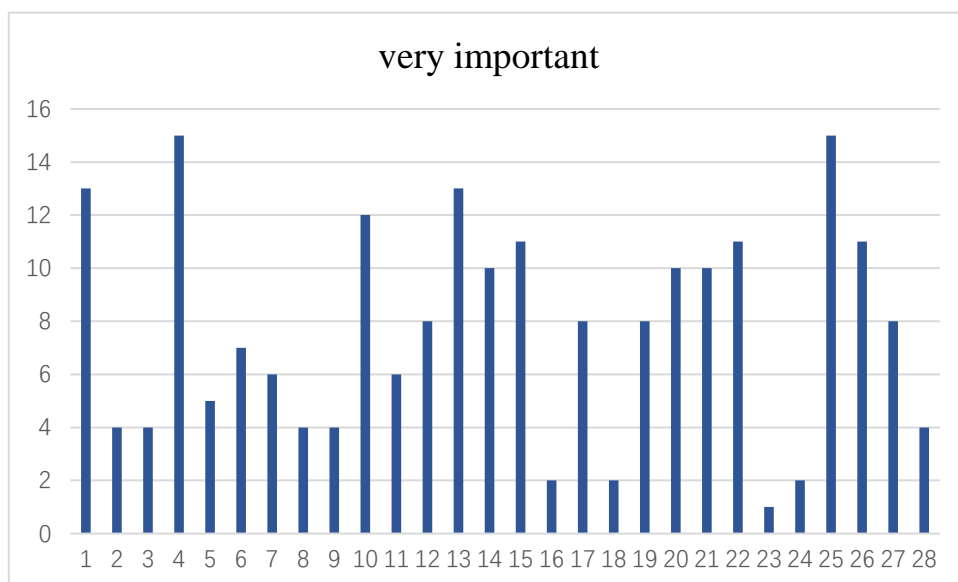


Figure-2

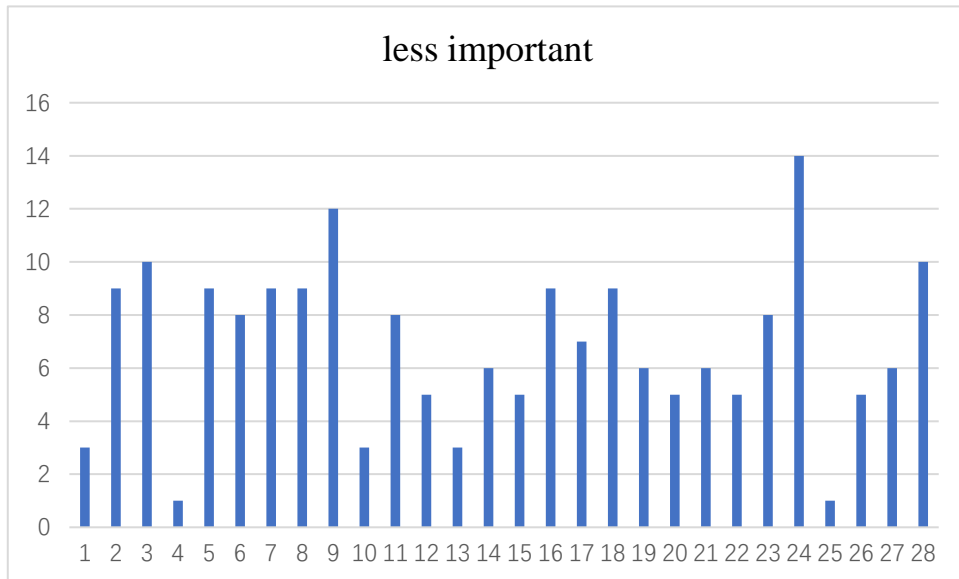
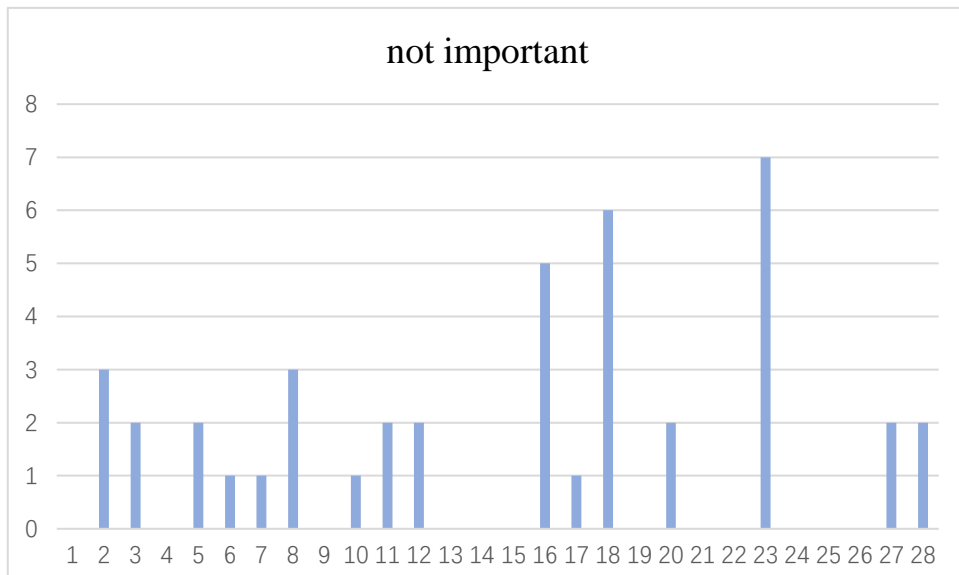


Figure-3



Based on the productivity of the questionnaire, these three tables show the number of the votes for each element of different-level importance. The participants

invited to finish the questionnaire are now working for the shipping industry, the data is persuasive in quality rather than in quantity.

As is evident from the Figure 1, the element 4 of irregular on-duty and off-duty hours and the element 25 of working attitude have obtained most votes. In addition, the element 1 of working environment and the element 13 of mental health have also captured wide attention.

In compliance with the information revealed by Figure 2, most participants all think that more remuneration is a less important element affecting the incidence of human errors. To some degree, it does not worth to earn more remuneration at risk of making errors. Nevertheless, sometimes, seafarers' sense of risks is weak and obscure, in other words, they rarely realize the risk brought by working extra hours just for more remuneration. There must be a relation linked with each other, that is, if seafarers work extra hours, it is inevitable for them to fall into fatigue, and then fatigue in mentality and physiology will weaken seafarers' alert on potential risks or make them less capable of coping with emergency contingency at sea, and, at last, a tragedy happens. From another perspective, perhaps participants hold the view that seafarers are unlikely to work extra hours for more remuneration.

In Figure 3, age and political and cultural background have been considered as the least important ingredients in compliance with the results in the questionnaire. For one thing, age is not necessarily linked to the incidence of human errors. For another, political and cultural background has been considered as the least important one. Perhaps political and cultural background itself appears to be not so critical with respect to the direct cause of human errors. It is inevitable for seafarers from different countries to communicate and cooperate with each other, and then the cultural conflicts may exist in language, behavior and understanding.

### 5.1.2 Features of human factors



In accordance with the results and analysis of the experiment, it seems that each element is independent, but the fact shows that each element inevitably has this or that links with each other. Besides, all these elements are always centering around six terms, human error, diminished human performance, marine environment, safety administration, management and mental action. Therefore, the external and internal elements affecting the incidence of human errors could be concluded as humans, regulations, marine environment. The internal element refers to personal differences in individuality, mental and physical health, talents, ability, and so on. The external element means marine environment, including weather conditions and working environment.

Human factor is affected by mental and physical elements, response speed, biological rhythm and external environment, in which humans' weaknesses are lying. Several features reflected by human errors are listed.

First, human errors have repetitiveness, the cause of which could be various and constant, and no one could ensure that the same faults could never happen more than once. For instance,

Second, human errors have maintainability. Since human errors may lead system into an error state, more often than not, under such error state, manual operation will join in thus effectively eliminating and overcoming possible consequences to return the system into normal state.

Third, humans have learning capacity. People can reduce the incidence of human errors via learning so as to uplift performance, adapt to environment and meet the requirements in daily work. After a certain period, the incidence rate of human errors will distinctly descend. The learning capacity has links with the internal element of personal quality with talents, advantages and disadvantages included in.

Forth, humans have the potentiality of causing the incidence of events. Such potentiality may lie in human frailty.

The above features of human factors help analyze the fundamental reason for human errors from different perspectives in order to produce effective solutions to eliminate the incidence of human errors.

### 5.1.3 Prevention of human errors

As is distinct from the results of the questionnaire, most participants choose irregular on-duty and off-duty hours and working attitude as the very important elements. For seafarers, the on-duty and off-duty hours on board is an inescapable ingredient, and the key solutions to solve the problem lies in the safety management.

First, to enhance safety management is indispensable and urgent especially when working on board. As for this matter, several elements should be taken into account.

1. The regulations of safety management may include solutions of making effective and practical rules, setting emergency response system, establishing the system of analyzing the fundamental reasons for human errors, building exchange cooperation platforms within and outside, establishing systematic regulations for recruitment, training and certificate.
2. To enhance the awareness of safety via setting up security culture system.
3. Create a working environment of proper pressure so as to prevent the incidence of human errors, including effective time management, task assignment taking into consideration individual features, personality and personal willing.
4. Make sure that mutual communication is instant and accurate with effective measures of solving the problems of communication system, making full use of informal communication system, cultivating the skills of information collection and analysis, confirming and overcoming obstacles of communication,

5. To establish the team accounting for crisis management so as to prevent and manage the incidence of human errors.

Second, implement effective seafarers' selection system. With the unceasing development in automation, some vital positions like captains and drivers appear to be especially important in the matter of maritime safety, which asks higher demand in knowledge, skills, psychology, mentality and personality. The scientific device of examine individual qualification for mental quality, team spirit, behavioral traits and communication competence has captured wide attention and recognition in the respect of the prevention of accidents at sea.

Third, enhance the theoretical analysis on the events of human factors in maritime safety. the effective and persuasive analysis on human factors help release the fundamental reasons for human errors and weak points, which produces instant analysis and put them into effects via feedback system so as to prevent the incidence of human errors.

Forth, improve the system of human, machine and environment which could be counted as a whole. From a systematic perspective, the balance between human and machine could be obtained through adding new safety devices, uplifting the automation level and perfecting the ventilation, illumination, temperature and humidity level on board to ensure reliable and safe operation on board so as to eliminate the possibility of human errors caused by obstacles in machine and environment.

Fifth, to foster seafarers' psychological quality should come to the top priority. As is obvious from the results of the questionnaire, most participants all choose the element of working attitude as the important factors accounting for human errors. By the way, the working attitude sometimes depends on personal initiative. In other words, mental condition or psychological quality may curb seafarers' working attitude imperceptibly. Individual psychological quality is very likely to affect the potential

ability and the role of man to play. For instance, human errors are very likely to happen due to negative mental conditions. Someone once pointed out that, among three elements of theoretical knowledge, practical skills and psychological quality, of no doubts, psychological quality holds a leading position. For example, when confronted with danger and hazard on board, people of weak psychological quality will fall into panic while putting life and property aside.

Sixth, to establish multiple system of prevention is necessary and urgent due to unavoidable elements in the nature of work on board and predictable and unpredictable risks at sea, be they human errors or other parts. Due to the complexity of human errors at sea, relevant prevention measures must be abundant in technology, organization, management and culture. Otherwise, unitary measure or solution will fail to tackle with unexpected conditions. With the combination of technology, management and culture, to establish multiple system means to set up a vertical prevention system from the perspective of decision-making, organization, technology, events analysis and feedback, of an initiative to explore and recognize potential human errors. At length, all these solutions work together to eliminate and prevent the incidence of human errors so as to ensure and uplift maritime safety.

## **Chapter Six Conclusion**

### **6.1 Findings of the study**

Plenty of studies have been focusing on human factors in the maritime safety, giving birth to a great deal of feasible and abundant findings concerning management, relevant conventions, culture and effective solutions. Besides those findings of previous studies, the current study has also produced several findings based on the results and analysis of the questionnaire.

First, the topic on human factors never exists as a single influencing element affecting the incidence rate of human errors. In other words, human factors have relation with machine, environment. In order to eliminate human errors, the attention should be paid to a much broader aspects like the role of system, environment and culture.

Second, the topic on human factors has grown to be more complex for people to measure along with the changing of times brought about by advanced technology like unmanned shipping and artificial intelligence, which asks higher but more complex demands for seafarers on the other hand.

Third, all elements affecting human factors are centering around six terms, human error, diminished human performance, marine environment, safety administration, management and mental action. Therefore, the external and internal elements affecting the incidence of human errors could be concluded as humans, regulations, marine environment.

### **6.2 Limitations of the study**

Due to the limitations in the collection of data, the experiment in the study has its own weak side, that is, the range of the participants is limited in number, and the results of the questionnaire mainly focus on the participants randomly sorted out. Besides,

other miscellaneous methods like Failure Tree Analysis and Table of Human Error Analysis could be in use so as to plump the results of the experiment.

## References

- Bao, J. Z., & Liu, Z. J., Z., & Li, J. M. (2010). Quantitative analysis model of human factors in marine accident. *Journal of Dalian Maritime University*, 36(2), 51-54.
- Chen, Q. (2013). *Research on effects of human factors in shipping navigation safety*. Wuhan University of Technology, Wuhan, China.
- Energy Institute (2008). *Guidance on Investigating and Analyzing Human and Organizational Factor Aspects of Incidents and Accidents*. London: Energy Institute.
- Gu, H. (2002). *A study on the characteristics of sailors' attribution and handling*. Suzhou University, Suzhou, China.
- He, Y. X. (2009). *Studies and countermeasures on influences to SMS due to China seafarer behavior*. Wuhan University of Technology, Wuhan, China.
- Hou, X. H. (2013). *Research on Maritime Safety Information Broadcast Benefit Assessment Methods*. Wuhan University of Technology, Wuhan, China.
- Huang, J. B. (2014). *The Prevention of the Seafarers' Fatigue on-duty*. Guangzhou Maritime Center, Guangzhou, China.
- Li, C. (2005). *The analysis of human elements in maritime safety*. Shanghai Maritime University, Shanghai, China.
- Li, J. F. (2018). *Analysis and Assessment of Risk Factors for Mild Cognitive Impairment Based on the NIRS Brain Functional Network*. Shandong University, Shandong, China.
- Li, J. F. (2019). *Study on legal issues of maritime facilitation and port state supervision*. East China University of Political Science and Law, Shanghai, China.
- Lin, W. W. (2014). *Analysis of the effect of organizational factors on seafarers' fatigue based on Bayesian network*. Shanghai Jiao Tong University, Shanghai, China.
- Li, T. Q. (2006). The human elements and prevention of maritime casualties. In *Wave Tsunami and Navigation Technology, Seminar on Maritime Safety by Chinese Institute of Navigation*. Guangzhou: Chinese Institute of Navigation.
- Pan, X. F. (2009). Fatigue: greatest root cause of maritime accidents. *Shipping Management*, 31(1), 36-39.
- Su, H. Y. (2017). *Research on legal issues of maritime occupational safety and health management in China*. Dalian Maritime University, Dalian, China.
- Sun, J. (2017). The human element and maritime safety. *Journal of Regional Governance*, 8, 135-136.
- Sun, H. T., & Wu, Z. L. (2007). The implementation of International Guidelines for Safety Management. *The Journal of Dalian Maritime University*, 33(02), 63-69.
- Wang, D. M. (2009). Human factors and maritime transport safety. *China Maritime Safety*, 2, 48-51.
- Wang, H. X., & Wang, X. J. (2017). Research of seafarers' fatigue based on literature

- review. *World Shipping*, 40(11), 13-19.
- Wu, Y. N. (2015). *The research for human element in maritime safety*. Dalian Maritime University, Dalian, China.
- Xue, G. F. (2019). The construction of marine environmental protection mechanism in South China Sea within the sight of the Belt and the Road. *Journal of Political Science and Law*, 6, 75-78.
- Xu, L. P., & Zhang, C. L., & Liu, F. S. (2000). A research on human elements in safety at sea. *Journal of Dalian Maritime University*, 26(1), 57-61.
- Xu, L. P., & Zhang, C. L., & Cui, L. S. (2000). Methods for the study on human elements in maritime safety. *Journal of Dalian Maritime University*, 26(3), 76-79.
- Xu, Y. G. (2009). The human factors in maritime casualties. *China Water Transport*, 9(2), 50-51.
- Xiao, W. H. (2012). *The Research for the Role of the Third Sector in Maritime Accidents Investigation*. Dalian Maritime University, Dalian, China.
- Yang, J. B. (2013). *Maritime engineering college students' values education research*. Dalian Maritime University, Dalian, China.
- Yang, Y. M., & Han, X. G., & Guo, H. (2009). A brief study on human elements in maritime casualties. In Chinese Institute of Navigation, *Academic Seminar by Professional Committee of Marine Shipping*. Dalian: Chinese Institute of Navigation.
- Zheng, B., & Jin, Y. X. (2010). Analysis on factors leading to human fault in marine accidents based on attribute reduction. *Journal of Shanghai Maritime University*, 31(1), 91-94.