8-27-2017

Analysis the human factors of maritime accidents based on HFACS—MTA–CM

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Analysis the human factors of maritime accidents based on HFACS—MTA–CM

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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

(INTERNATIONAL TRANSPORT AND LOGISTICS)

2017

DECLARATION

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

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

(Signature): ………………………….

(Date):…………………………..

Supervised by
Prof. Shi Xin
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ACKNOWLEDGEMENT

First of all, I am sincerely thanks to WMU and SMU professors related to ITL2017 program. They shared their huge knowledge and experience, which make me able to fulfill my dream.

I would like to express my deepest gratitude to my supervisor, Prof. Shi Xin, for his guidance and advice on my research. Without his help, I couldn’t finish this work.

I am deeply thankful all classmates of ITL2017. They make the classroom more dynamic and make learning more interesting

I also wish to express my thanks to my best friend: Xie and Gao. they always listen my worries during the period of research and try to give me a positive and cheerful energy.

Finally, I would like to express my gratefulness to my beloved family, my mother and my father, always supported me financially.

Abstract

Title of Research paper: Analysis the human factors of maritime accidents based on HFACS—MTA–CM

Degree: **MSc**

More than 80% of the world's accidents from human factors, such as maritime traffic accidents, which has become the consensus of the industry. This paper from the perspective of the influence of human factors on maritime accidents, with the base of the "Swiss cheese" model, proposed the human factors analysis and classification system for marine traffic accident(HFACS—MTA). Then combined with cognitive map (CM) technique. The HFACS—MTA–CM is a hybrid accident analysis method, it can analysis the causes of the accident and the analysis of the reasons for the relationship between the horizontal logic. Then a case application will use this model to analysis. The proposed method is used for many marine accident cases to analysis the influence of human factors in the course of events. Consequently, the study can contribute to find and prevent from human factors in marine accidents.

Key words: Human Factors Analysis and Classification System (HFACS), cognitive map, human factors, maritime accident

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LIST OF ABBREVIATIONS

ANP	Analytic Network Process
CM	Cognitive Map
FFTA	Fuzzy Fault Tree analysis
FTA	Fault Tree Analysis
FAA	Federal Aviation Administration
GRA	Grey Relational Analysis
GCV	Global Central Value
HFACS	Human Factors Analysis and Classification System
HOFS	Human and Organizational Factors
IMO	International Maritime Organization
IUMI	international Marine Insurance Federation
JCG	Japan's Coast Guard
MTA	Marine Traffic Accident
MAIB	Marine Accident Investigation Branch
NBS	National Bureau of Statistics
NCV	Normalised Central Value
RCA	Root Cause Analysis
R-GCV	Central Values of the Rank-global
R-NCV	Central Values of Rank-normalization
SEM	Structural Equation Modeling

Chapter 1 Introduction

1.1 Background

The global trade between region and region, country and the country is constantly being broken by the increasingly prosperous sea transport, which has greatly promoted the connectivity of the world economy. According to the 2016 of The United Nations in the world economic situation and outlook, the year of 2016 global economic recovery, the world economy is growing at 3.2 percent, At the same time, China is the most powerful force driving world economic development, The economy maintained strong growth, contribution to the world economy to increase by more than 30%, the gross domestic product in 2016 reached 74.4 trillion yuan, year-on-year growth of 6.7%, In the external economy, total imports and exports is 24.33 trillion yuan, year-on-year growth of 0.9%. Among them, exports 13.84 trillion yuan, decreased 2 percent; Imports were 10.49 trillion yuan, increased 0.6 percent. The shortfall in imports and exports was 3.35 trillion yuan (exports minus imports), decreased 9.1 percent from the previous year(NBS 2016).

The realization of the foreign trade depend on the strong guarantee of transportation, as of the end of 2016, China's marine transport has about 160100 ships, reduce by 3.5% over the previous year, the net year load is 266.2271 million tons, decreased 2.3%, carrying 1.0021 million seat, reduce 1.5%, Container 1910,400 TEU, the total power of the ship reached 595 billion. These ships dotted distribution inland waterway network and coastal waters in our country, and it reached out to all over the world, a total of 4.26 billion tons of cargo transportation task, including coastal transport freight volume of 1.522 billion tons, ocean freight volume of 625 million tons.

It still need to see, although the ship with the high-speed economic development, there are many kinds of maritime traffic accidents, maritime traffic safety situation is still grim, and the development of high speed and the trend of mass of the ship, once cause a maritime safety accidents may cause serious casualties, property losses and the environmental pollution.

As the main means of transportation of maritime transportation, the ship's safety and security also receive more and more attention. From June to the end of September 2013, China's maritime transportation system carried out a nationwide inspection of safety transportation. There are 158 cases of maritime traffic accidents, 148 people missing, 87 ships shipwrecks, and 2.5 billion yuan in direct economic losses(Wang xuejun, Lou&Yuan, 2014). The transportation safety work is still a long way off.

It is the common concern of the ship transportation, driving technology and management, to avoid maritime accidents and ensure the safety of navigation.

Maritime traffic is becoming more and more busy, the navigation density is increasing, the waterway transform to crowded , and the harbor has become less empty, causing collision and stranding.

Undoubtedly, the maritime accident problem research is absolutely necessary, which is good for the safety of marine life, prevent marine environment from pollution, and for marine busy area’s good running.

China is a maritime power, especially after the founding of new China, the Chinese ocean-going fleet has gradually expanded and established a good reputation in the fierce competition. However, due to economic conditions and other factors, the Chinese fleet tends to old, and the incidence of all kinds of maritime accidents is also much. To this, many experienced navigator and scholars of various cases of ship navigation colleges maritime accident did a lot of research, makes a lot of issues for the analysis, and put forward some useful suggestions(Li bangchuan 2010).

There are a lot of factors can be roughly divided into two categories: human factors and natural factors to influence the maritime accidents. According to the statistics, human factors accounted for more than 80% in the cause of the accident at sea, a lot of maritime accidents are caused by natural factors and human factors indirectly related. Therefore, it is necessary to study the methods of Marine investigation based on human factors to find out the reasons behind the accident and formulate corresponding countermeasures to prevent and reduce the occurrence of maritime accidents.

1.2 Purpose of research

In the face of large personnel, property and environment loss caused by maritime accidents, it is necessary for us to make deep and comprehensive analysis on it, explore the inner law between the relevant influencing factors and serious accidents. The purpose of this paper is to analyze the human factors that affect the final result of maritime accidents, and build the relation model between the accident consequence and the human factors that are affected. The significance of the study lies in:

1. Avoid maritime accidents or reduce the occurrence of serious maritime accidents

Through in-depth analysis of key human factors of maritime accidents, explore in what condition more serious accident occurred, the police officers are to improve ship maneuverability, reduce accidents, avoid accidents become more serious.

2.Reference for the determination of the accident result of a maritime survey institution

China's maritime organization has collected data, the reasons, ascertain the accident liability’s obligations, therefore, the factors influencing the accident are discussed, and for reference by maritime related agencies, summarize the experience and lessons, to make the grade and more reasonable accident of effective measures to avoid or reduce the maritime accident.

1.3 Outline of the paper

Chapter 1, literature review, overview related researches, studies and reports and discusses the background of the maritime accident. Chapter 2 talk about the maritime accidents and various factors of maritime accidents. Chapter 3 talk about the methodology I used, and the new model I created. In Chapter 4, a case application with the new model.

1.4 Previous research

Arben Mullai (2011) examined a conceptual model for ship collision accident. This model is based on a large number of empirical data, such as the Swedish maritime management database for in-depth study. The database variables are organized and connected according to their attributes and are divided into eleven main categories or structures. In order to demonstrate this concept model, he choose one non-metric and five metric variables, called the fatality rate, ship attributes (i.e. age, total tonnage, length), the man in the ship, and the accident at sea. Structural equation modeling (SEM) method was used to analyze. The combination of the two independent variables, the ship's attributes and the ship's people, predicts a variance of fatality about 65%.

Shih-Tzung(2013) Chen based on the analysis and classification system of marine accident human factors (hfacs-ma), and this paper puts forward a special human and organizational factors (HOFS) framework for maritime accident investigation and analysis. There are five levels in the framework which is in line with the core concepts of HFACS, The prototype is a Swiss cheese model and the Hawkins SHEL model. The framework also conforms to the guidelines of the International Maritime Organization (IMO). A case study on the disaster of a free enterprise pioneer is presented to demonstrate the proposed methodology and demonstrate a comprehensive insight into the accident by analyzing the results of the complementary integration of the results of the analysis HFACS. Several advantages of the accident analysis framework are described.

Ingrid Årstad and Terje Aven(2016) focus on the understanding of the complacency of major accidents related to safety issues. Through the insights gained from accident reporting and theoretical analysis, we try to understand why current practices often lead to misleading overconfidence in risk management. Then, through the seven conditions of prudent practice to define what is the complexity of recognition. These prudent practices can improve the management of risks associated with major accidents and ensure careful avoidance of major accidents.

WANG Haiyan, JIANG Hui and YIN Liang(2013) think In recent years, human factors have become the main cause of maritime accidents. In order to prevent accidents, it is necessary to understand the mechanism of human error and the weak link of human error system. On the basis of a large number of studies on human error of ship accidents, the brittleness model of complex system based on cellular automata is established by using the brittleness theory of complex system. Through the study of the influence of human error factors on the whole system, the corresponding accident control strategy is put forward. This paper provides a new method to study the mechanism of human error accident.

Emre Akyuz(2016) describes a new hybrid approach to assess the potential of business emergencies in a real ship accident, since maritime safety is of great importance to the maritime transport industry. Hybrid accident analysis model integrates network analysis (ANP) and human factor analysis and classification system (HFACS) method. The HFACS model provides a conceptual framework for the investigation and analysis of the role of human error in maritime accidents and the ANP method provides an assessment of the correlation between factors. The novelty of this paper is to propose a different perspective in the analysis of marine accidents, the priority weights of the accident cause and the human error of the ANP model. A hybrid accident analysis model was established to improve the safety of the marine transportation industry and to prevent casualties. The proposed hybrid method is illustrated for a real ship accident case: a serious liquefied petroleum gas leak from a gas carrier.

Serdar Kuma and Bekir Sahin(2015) explore the causes of marine accidents / incidents that are caused by the marine accident investigation department records (MAIB) occurring in the North of 66 °33′ in the years from 1993 to 2011 with a root cause analysis. Root cause analysis (RCA) presents a clear cause and prevention of future events. Fuzzy Fault Tree analysis (FFTA) is proposed to reduce the probability of occurrence of this problem. The risk level of each factor is determined by expert consultation. In this study, accidents are considered to be the most observed events. The root cause of injury accidents is the negligence of the accident. In order to combat this phenomenon, the scientific results of this research can open a dialogue between law makers and shipping companies, aiming to reduce events. In addition, it is believed to contribute to the development of crew training manuals and capacity requirements, as well as the opening of the Arctic sailing training center.

ZHANG Xinxin, XUAN Shaoyong, XI Yongtao and HU Shenping(2013) in order to research the causation factors of human errors in marine traffic accidents quantitatively, the influencing degree of the causation factors which lead to human errors is analyzed, so as to control accidents caused by human errors． On the base of introducing the classification framework of human‘ unsafe behavior and the“man—machine-environment”system ． the Human Factors Analysis and Classification System(HFACS)is used and the Human Error Analysis and Classification System for Marine Traffic Accident(HEACS—MTA)is proposed to classify human errors in marine traffic accidents． The Grey Relational Analysis(GRA)is used to analyze the accident causes quantitatively, and the conclusion is made that the management factor is the root cause of the accidents．The order of the main human error factors which lead to accident is precondition for unsafe acts, unsafe supervision, unsafe acts and organizational influences．

Wang jun and Yang bing(2012) combined with The human factors analysis and classification system (HFACS) and fault tree analysis method (FTA), proposed maritime investigation analysis model, determined using the steps of the model, and analyzes the reason of the actual case analysis results show that using the model: using the model to guide the maritime investigation personnel to identify the direct cause of the accident analysis, accident behind reason, logic relationship and clarify the reason, the reason for classification is stored in the database can also provide useful data for risk assessment and early warning

ZHANG Lili, LYU Jing and AI Yunfei(2016) in order to better understand the mechanism of maritime accidents induced by human errors, the inducement combination modes are analyzed and predicted based on the history data. An inducement classification system of maritime accidents induced by human errors is developed based on the core concept of the Swiss Cheese Model and Human Factors Analysis and Classification System(HFACS)． The inducement factors are quantified in form of matrix By matrix transform and clustering analysis, the main inducement combination modes are obtained. Then, the modes are predicted by Bootstrap method The results may help decision-makers to implement targeted and maneuverable preventive measures, and improve the maritime transportation safety.

Yang think It is considered that crew factors are often the leading factors of accidents. He used 3 specific accident case and analyzes the cause of the accident to explain the lack of work sense of personal safety, can not completely clear risk of the potential of the work, and to take the necessary preventive measures, do not pay enough attention to the safety of ship charge, inadequate training, failed to complete in accordance with the company's ISM management system requirements. When the ship safety accident occurs, the supervisor fails to learn the lessons in time, without timely summing up experience, which leads to the occurrence of safety accidents.

Yang jin huan think with the rapid development of shipping volume in Yunnan Province, the annual occurrence of ship accidents is also increasing. This paper makes a statistical analysis of the ship accident data of Yunnan Province in recent 10 years, and from the aspects of ship accident type, accident type, fault location of the accident are analyzed. Finally the influencing factors of the cause of the accident from the angle of system safety engineering were analyzed, and puts forward the corresponding countermeasures.

Deng xiu lan(2007) think The main factors that lead to ship accidents are human factors, natural environment factors, machinery and equipment factors. Through a large number of marine accidents analysis, the main factors are human factors. Emphasizes the importance of human factors, and puts forward some measures to improve the control of human factors: Improve the quality of the crew, and keep the ability of several members and social responsibility education, the establishment of a more I biochemical rest and entertainment system.

Marine accident analysis is one of the most significant milestones in enhancement of maritime safety and environmental awareness. On the base of introducing the classification framework of human’s unsafe behavior and the“ human—machine-environment” system, This paper use the Human Factors Analysis and Classification System(HFACS)is used and the Human Error Analysis and Classification System for Marine Traffic Accident(HEACS—MTA)is proposed to classify human errors in marine traffic accidents. Then combined with cognitive map (CM) in marine accident analysis. The HFACS—MTA–CM model is recognized as hybrid accident analysis approach provides distribution of human error by taking the operational evidence into account. The proposed investigation model is applied to various marine accident cases in order to analyse the role of human factors in the course of events. Consequently, the study can contribute to identify and reduce human errors in marine accidents.

Chapter 2 the factors of maritime accidents

2.1 maritime accidents

As the main body of the water transportation industry, the operation environment of the ship is different from that of land transportation, which has formed the special background of the ship accident. The characteristics of the operating environment are mainly reflected in the dynamic factors such as the change of the crew's fluidity and shipping routes. The fluidity of the crew affects the normal maintenance and safe running of the ship; The constant change of shipping routes has caused the ship to face different Marine environment, which greatly affects the safe operation of the ship. Moreover, the working environment inside the ship is also very bad, which has important influence on the normal operation of the ship machinery and the safe navigation of the ship. The ship is in the environment of large temperature change, large humidity change, salt fog, oil mist and other corrosive gases, which accelerate the corrosion of ship machinery. The mechanical equipment of the ship is in a working condition of high temperature, high pressure and vibration during normal operation. It is easy to produce the inevitable friction and wear to reduce the performance until the failure.

The types of ship accidents can be divided into: collision, stranding, contact loss, fire, storm, shipwreck and other accidents. By collecting and organizing the representative ship accidents in some countries and regions, the classification statistics of ship accidents are classified according to their types, as shown in figure 1 （Zhan Jun Long, Seung Keon Lee1．2010）:

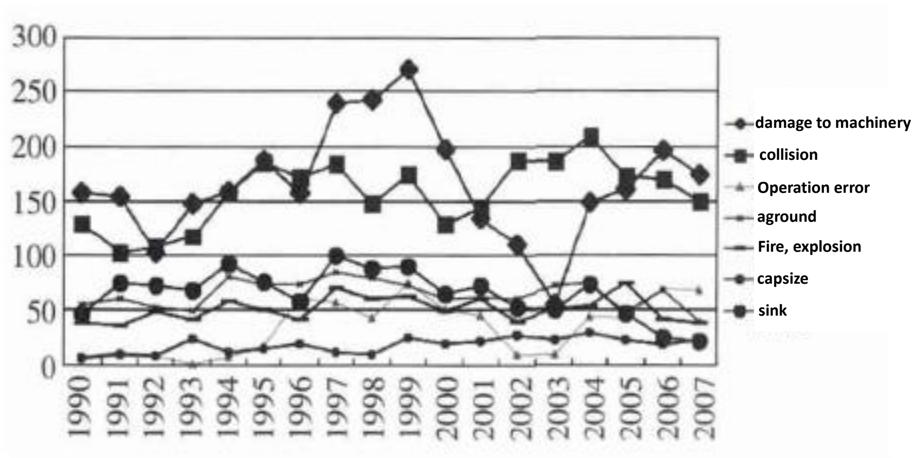

fig 1: Classification of major Marine accidents in Korean from 1990 to 2007

As you can see in figure 1, the damage to machinery is the main part of the ship accident, followed by is the collision accident. In the other five types of ship accidents, the proportion of incidents occurred from high to low is operating errors, aground, fire and explosion, capsizing and sinking. As we found through the analysis of the accident types, the number of damage to machinery casualty accidents is large, and by a line trend can be seen in figure 1, the change of the number of damage to machinery accident is large too, study the accident of damage to machinery to reduce the number of ship accidents is very important. According to statistics, from January 2008 to June 2010, a total of 95 damage to machinery accidents occurred within Ningbo's respective jurisdictions, among them, 19 happened in 2008, 45 happened in 2009, 31 happened in the first half of 2010, the frequency of accidents present growth trend, it serves to show damage to machinery has become one of the biggest threats of maritime traffic safety hidden trouble.

Japan's coast guard (JCG) shipwreck accident statistics show(2012:7-9), in 2011, there were 2187 maritime accidents in Japan and the surrounding seas, including 647 collision accident, accounting for 30% of the total accidents, 2007-2011 five years accumulative total of ship collision accident is 3966, accounted for 32% of total accident of accidents, the proportion of the original is bigger than the statistics of the other 7 kind of accident. Quoted the European Union Maritime Safety Agency (EMSA) annual report on accident statistics for 2010(2011), in this year, the collision and touch within its jurisdiction has a total of 288 cases, accounted for 44.7% of all accidents, in Hong Kong, in 2011, a total of 351 cases of accidents, the collision accident ratio as high as 57.8%, about 203 incidents. In 2011, the accident happened in Weihai maritime bureau has jurisdiction over the waters, seven of the nine accidents are the collision accidents(Weihai maritime bureau,2012), the tianjin maritime safety administration statistics of 2001 ~ 2009 year within its jurisdiction water traffic accident, collision accident is still the main type of the accident, about 40%(Shi xiuwu & Zhujian,2010).

Collision accident not only happens at a high frequency but also causes great loss to cargo, ship, property and environment.

The international Marine insurance federation (IUMI) survey said the collision of ships was one of the most important factors causing serious damage to the ship and total loss to the ship, as measured(IUMI, 2012) in table 1:

Tab.1:>=500GT loss statistics of ship collision

	1997-2001	2002-2006	2006-2011
ratio of serious damage to the ship	18%	22%	23%
rate of total loss to the ship	14%	15%	9%

The relevant maritime authorities in Japan have calculated the number of different types of accidents that caused the deaths and disappearances of the people, and the results show that the collision accident was the highest in the statistics in a continuous year.

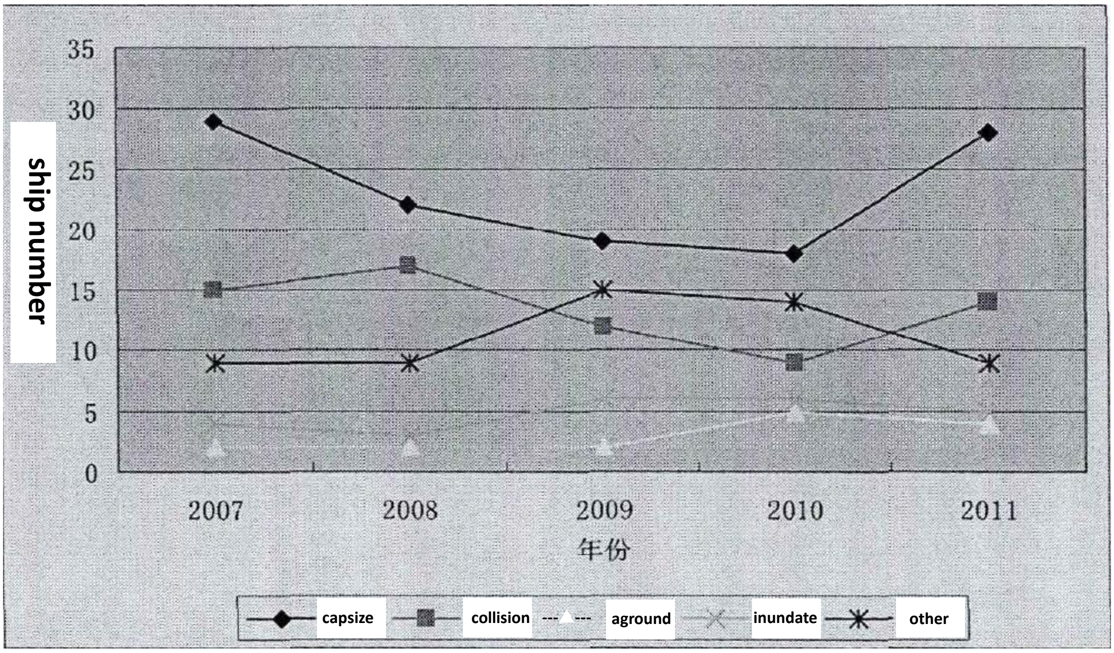

Fig.2 The number of ships leading people dying or missing in different kind of accident

In addition, the ship collision accident may also bring pressure to the environment. Take oil spill as an example, oil and its refined products not only have flammable and explosive, and the chemical composition of the complex will cause water pollution, endangered aquatic creatures and human health(Pan haitao, 2008). The international association of oil and gas producers released a study that showed(2010), the average of each collision of oil tankers in the world would result in 2,922 tons of oil spills.

Although countries of the world have their own standards for maritime accident types, but it can be see visually, the rate of ship collision accident in maritime traffic accident is quite high, and is likely to be associated with the accident caused a large number of the ship badly damaged, casualties, ecological pollution and high property losses. Therefore, the study of collision accident is still the research focus in maritime management.

Fire and explosion loss of ship account also for a large proportion of total cases. The "solidarity" wheel burned down the whole ship in April 1978 because of throwing cigarette butts. Many oil tankers in our country have been blown off by irregularities of electric welding. In 1917, the French arms ship "MengBo" collided with the Norwegian freighter in the port of Halifax, Canada, It triggered the worst big bang before the atomic bomb was invented.

In contrast, the world fleet has been developing towards a large scale, with a high number of total losses. We can see, tonnage of fleet in the world increase year by year, the ships become diversification, high speed, large and old age. Marine development occupies the traditional route, make the ship's navigable waters narrow and the ship's navigational conditions deteriorate. However, the development of science and technology, the improvement of safety management level can effectively offset the deterioration of navigation conditions, and restrain the upward trend of the maritime accident.

The result of the international maritime community concluded that the high maritime situation is that the past success is to attach importance to the people, machine, environment of technical conditions, the past mistake lies in the neglect of the maritime causes 80% of human factors, this led to the development of the ISM code and the advent of PSC. Strengthen safety management and control of human factors, according from "man - machine - environment - management" maritime security system of the elements of comprehensive security to safeguard the maritime safety, this formed the consensus of the international maritime world to control modern maritime affairs.

The cause of ship accident has different characteristics because of the type of ship and the type of accident.

Because of the different types of vessels are different in terms of transport goods, so the cause of the accident is different: (1) the container ship. Because of the special property of explosion, flammability, poison and corrosion of dangerous goods, there may be explosions, fire, casualties and Marine pollution. (2) oil tanker. Because all sorts of tanker carrying oil is low ignition point, explosibility very easily, so the tanker oil supply, transportation and cleaning process, if not strictly abide by the operation procedures, strengthen the supervision and inspection, will cause potential safety hazard. (3)Dry bulk carriers. Mechanical failure and damage of structure in the proportion of dry bulk ships sea accidents is very high, and tend to occur in the old age of the ship, it shows that insufficient mechanical aging, mechanical power and mechanical maintenance, structure aging, the shortage of structural strength is the main reason for the accident(Yujian, Zhangmen & Bao fawei, 2008). (4) the LNG carrier. When the LNG leak occurs, the concentration of methane in the mixture that is formed with the air will explode, triggering a fire. And because of the low temperature and rapid degeneration of the LNG, the low temperature brittle fracture of the hull materials can destroy the integrity of the hull structure. The leak also causes the concentration of methane in the air to rise sharply, killing people(Sun guoqing, 2013).

Different types of accidents are also caused by different factors. The frequency of machine damage accident occurred at higher frequency, and according to the relevant data, the cause of failure of the machine was caused by poor maintenance, abnormal loss of parts and error of operation. Collision and grounding accident is largely caused by human error, including the crew strain ability is poor, gross negligence, the navigator's mistake and don't obey the rules of the relevant forecast and avoid rules, and so on. In addition, the failure of propulsion systems, steering machines or other mechanical equipment can cause collisions. In addition, error of operation is also an important factor to accidents, including decision-making errors and improper operation. In all kinds of common accidents, fire and explosion are the main forms of oil tanker accidents.

Bulk ships and bulk carriers account for a large proportion of merchant shipping lost tonnage. As of December 31, 2008, oil tanker and bulk carrier loss amount respectively accounted for 42% and 37% of the total loss amount merchant fleet in the world, and in the two types of ships, especially some old ship has caused maritime accidents rate of high risk.

Through the above analysis of ship types, type of accidents and the characteristics of accidents, it can be concluded that human factors and mechanical equipment factors are the main causes of accidents. According to the theory of system safety engineering, the influence factors of ship accident from on macroscopic can be divided into human(crew, ship companies and managers), ship (ship itself mechanical equipment and oil) and environmental factors.

2.2 The human factors of maritime accidents

The statistical analysis of related ship accidents shows that the proportion of ship accidents caused by human factors is 80% or more. For the crew, mainly in the job responsibility is not strong, maintenance is not in place, low level of business and operational errors. For the shipping company managers, the lack of daily supervision and management of the ship, resulting in security risks. Human is the key factor in the operation of a ship, and the condition of a ship is directly related to human. If you can master the technical knowledge fully, through the good ship maintenance, Choose a seaworthy environment, the crew work carefully, make human, ship and environment in good condition, it can effectively avoid accidents. Human factors have become the main cause of ship accidents, because human have instability, including knowledge, skills, responsibilities, experience, physiology, psychology, health, behavior characteristics and many other aspects(Yang yufeng, 2009). Control human factors it is difficult to completely prevent and control of ship accidents, but mismanagement, poor maintenance and maintenance of the ship accident error, unreasonable design, processing wrong, installation is not correct, poor material properties such as human factors can be controlled by has a large proportion, therefore, if these factors by regulating human's behavior to prevent and eliminate, can greatly reduce the occurrence of ship accident.

2.3 The other factors of maritime accidents

The engine damage accident is an important component of the ship accident, which is caused by the breakdown of the ship's machinery and equipment. The failure of Marine machinery and equipment is mainly caused by the following aspects: (1) materials, The quality of materials of various parts is defective or all kinds of oil contain impurities, which will cause the failure of related parts directly or indirectly when using. Therefore, it is essential to ensure the quality of various components, materials and oil products at the source, which is the basis for preventing accidents. （2）Equipment work exception. Including poor combustion, poor lubrication, leakage, excessive temperature, overload and long running time. It is generally due to material defects or irregular behavior of ship crew and other factors that lead to abnormal equipment work and cause malfunction. （3）Operation management. Including poor processing, poor installation, poor sealing, poor fuel purification, poor oil purification, improper operation and improper management. This kind of behavior error can lead to the failure indirectly, but it is often an important factor that leads to the mechanical failure. Many factors are apparent in mechanical equipment, but are associated with human factors. Therefore, to strengthen the safety operation of ship crew is a basic guarantee for the good operation of marine machinery and equipment(Zang yanyou,2008).

Environmental factors are directly related to the safety of the ship's operation, so make sure the vessel is in good working conditions and navigation conditions. The natural environment includes hydrology, meteorology and topography, and the impact of ship accidents is reflected in：（1）The decrease of the horizon. Due to the influence of meteorological conditions, such as fog, rain and snow, and the reduction of the visual distance caused by night, the operation of the ship become difficult, resulting in the increase of the probability of ship accidents. (2)The weather is bad. The wind and waves caused an irresistible natural disaster to the voyage. (3)The Marine reef, shoal and water barrier have obvious influence on the ship. The navigation environment includes two aspects: transportation conditions and navigation facilities. Traffic condition refers to the density of ship traffic and the volume of traffic. Navigation is more difficult to navigate in narrow channels and in dense water. The harbor, sea area, sea-route and channel, coastal and traffic dense waters are the marine accident prone area. Therefore, we should strengthen the regulation of these areas, create a good navigation environment and guarantee the safe operation of ships. The navigation facilities resulted in the failure of the marine accident is the fault of the navigation mark, lighthouse and the failure of sea voyage data. However, according to a large number of accidents, the proportion of accidents caused by environmental factors is very small because of adverse environmental factors can be circumvented by artificial analysis and operation.

Chapter 3 Methodology for accident analysis

3.1. Human factors analysis and classification system for Marine Traffic Accident (HFACS—MTA)

In 1990, James Reason, a professor studies at Manchester, England, proposed the famous "Swiss Cheese" model. The model shows that the accident followed “the wrong decision, Mismanagement, The direct prerequisite for the formation of unsafe behavior, the unsafe behavior, defense system failure ". Provides a unified analysis framework for the cause of the accident investigation, and promote the development of accident investigation methods(James R, 2003). But the model is only a descriptive description, not defined in detail, and cannot be applied directly to practice.

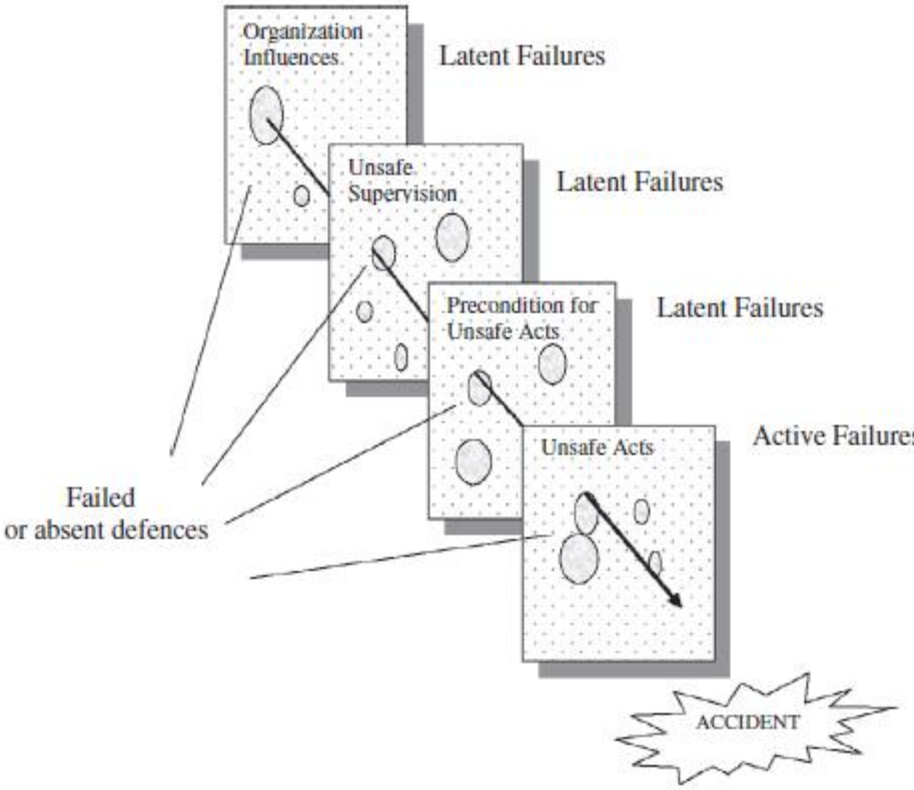

Fig.3: Swiss cheese model for human error causation

The beginning of the 21 century, Wiegmann and Shallpell(2001) in USA based on "Swiss Cheese" model, put forward the human factors can be applied to flight accident investigation in the analysis and classification system (Human Factors Analysis and Classification System. HFACS). The system transplanted into the Federal Aviation Administration in 2001 (FAA) to analysis of civil aviation pilot error, It has been beginning widely used in aviation. The theoretical basis of HFACS is the "light penetration cheese" model, which is proposed and established to make the pioneering REASON model applied in practice.

Because of its application in accident analysis, a variety of HFACS applications have been used in the past few years. The HFACS framework appears to have been improved and improved in various applications. However, update is secondary but it didn’t transform the initial kernel framework inside the model. Wiegmann and Shappell (2001) extended this theory by providing a all-sided, friendly structure to help user check and analyze man-made errors in the aviation field. In fact, specialized models are need according to the requirements of the application domain, becaus the model was created for the aviation field at beginning.

For finding the organizational reasons among the marine accident inquiry, the modified model of HFACS (schroder - hinrichs et al., 2010), which is related to the mechanical space, was adapted. In addition, the system and multifactor analysis of the sea, in order to identify different types of accidents, was recently considered a new model, called hfacs-coll (Chauvin et al., 2013).

HFACS is the base of investigation and analysis of the theory about human error accident. Usually the accident is not isolated, from the beginning of the organization and management, through a series of mistakes, eventually caused by people's unsafe behavior. The accident chain is that organizational influence - unsafe supervision - Unsafe Precondition - Unsafe behavior s - accident. To break through the 4 levels of defense accident may occur. If the accident is to be resisted by any one of them, the accident will be eliminated in the hidden danger. In this paper, the 4 layer of defense is mean the human factors. HFACS can be used to analyze the causes of the accident, get a chain of basic ideas at the logical level, analysis the cause of the accident has a strong reference. At the same time, HFACS fully gives management factors on the impact of the accident: accident---directly cause---indirectly cause--- root cause.

On the surface, Marine traffic accidents by human are caused by unsafe behaviors by the crew, caused by the crew's negligence, errors, mistakes and violations. In fact, the unsafe behavior is a surface phenomenon of human error, is to find the root cause of the first step. HFACS-MTA from top to bottom can be divided into 4 levels, they are:

organizational influence, unsafe supervision, unsafe precondition and unsafe behavior s. Among them, the first 3 human error factors have potential impact on maritime traffic accidents, resulting in unsafe behavior happpened, and ultimately lead to accidents. In order to find the root causes of human error, evaluation of maritime traffic accidents' human error causes better, the four levels of primary factor index are divided into 12 secondary factors, see Figure 4:

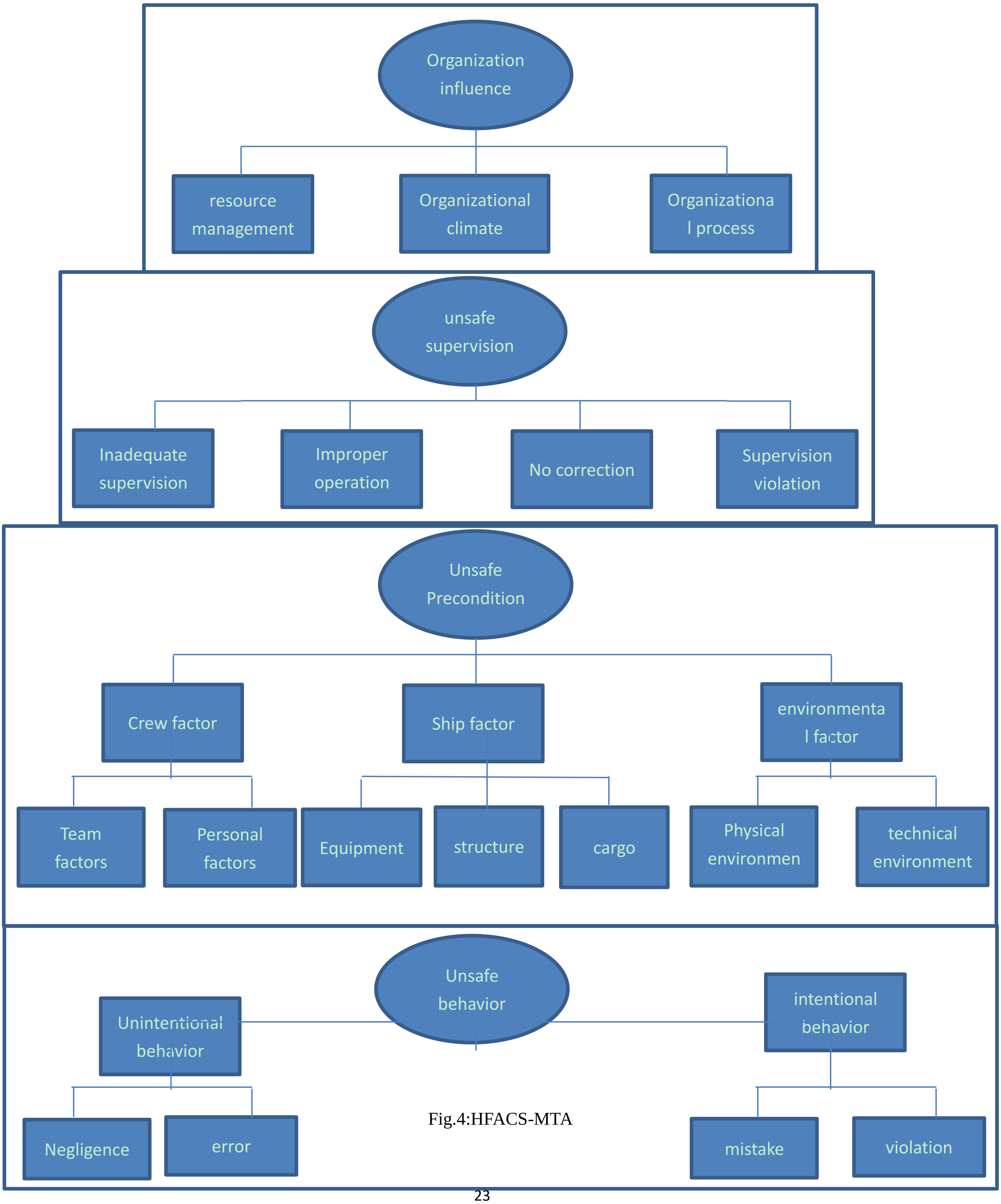

Fig.4:HFACS-MTA

HEACS-MTA is built on the basis of HFACS, and there are two parts of the HFACS transformation, which are part of the unsafe behavior and unsafe precondition.

The part of the unsafe behavior structured by the classification framework of human unsafe behavior presented by REASON(James R, 2003). This framework discuss the unsafe behavior of the people from the people's mental state, and divided into intentional behavior of non-intentional behavior; the former includes negligence and error, the latter is divided into mistakes and violations.

The part of unsafe precondition learn from the theory of "human one-machine environment" theory, from the impact of maritime safety: crew factors (people), the ship factors (machine) and environmental factors (environment) 3 angles to classified and discussed: the crew factors are divided into teams and individual factors; the ship is divided into equipment, structure factors and the goods of factors; environmental factors are divided into physical and technological environment.

3.2. Cognitive mapping (CM) technique

Cognitive map is a kind of based on the concept of describing one main point of the tool. Tolman (1948) introduced the basic principle and contour of CM technology for the first time. Its purpose is to be a method of psychology. The method is then transformed and used to solve policy question. The study used cognitive mapping to study the psychological patterns of policy makers, which have been used for years in policy analysis and complex problem management (Axelrod, 1976). The main idea of a cognitive map is to make sure people make decisions about any environment or problem.

This method effectively solves the related factors and requires the decision makers to analyze the causal relationship between these factors. In other words, people may describe their understanding of the relationship between the key factors they define, thus establishing a cognitive mapping. The CM model is often considered to be the best method to evaluate different issues of expert opinion. Figure 5 is a simple of a cognitive map model with variables (A, B, C,...). Is introduced as a node.

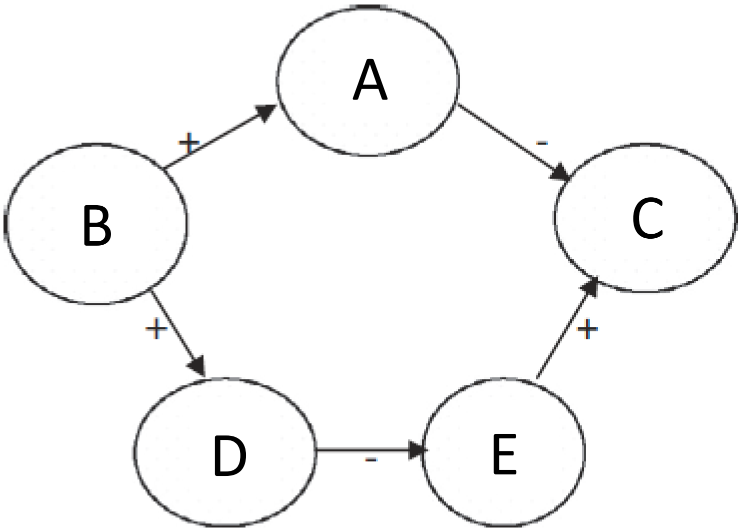

Fig5: A simple example of CM

The arrows represent a causal relationship between nodes. The line among two elements is the sequence of each of the nodes that link them. The expression in front of the arrow can be considered as the reason for the arrow. The positive and negative signs on the arrows give a cause-and-effect relationship between the nodes. If the sign on the arrow is positively, it means that the effect of one node on the other is positive. When the relationship among nodes is negative, a negative sign is attached to the arrow. If it is no sign, it indicates that no relationship exists among the nodes. When deciding the cause-and-effect relationship between nodes, the relationship of the square matrix could be used for study.

The cognitive map was introduced into a network of nodes linked by arrows, which revealed a person's view of the question (Eden, 2004). Some researchers have conformed and used cognitive map technology to mimic human reasoning and thinking. In addition, the study of CM technology in the network system (zhang, 1994), a decision-making analysis (Axelrod, 1976) and BPR (Kwahk and Kim, 1999) is highly used at different application fields. Beyond that, according to the pearl causality network form, Kim and pearl (1987) introduced the inference engine of causality and diagnostic reasoning. The technology was also used in engineering science, introducing the theory of graphite in the research circuit (Styblinski and Meyer, 1998) and description plant control (Gotoh et al., 1989).

Although its practical applications are wide, the application of CM technology in the ocean is limited. the CM method was used to simulate the maritime operational feedback. In addition, the general model of the black sea environmental management (Kontogianni et al., 2012) was successfully established through CM technology. The paper proposed method, which combined HFACS-MTA and cognitive map technology, it can be think as the newest research at maritime accident analysis.

3.3. HFACS—MTA–CM model

Now, a new analysis of maritime accidents will be introduced. This model simply combines HFACS-MTA with CM technology to simulate man-made factor in maritime accident analysis. This method, called HFACS-MTA-CM, is a mixed accident analysis model, which offers the distribution of man-made factor by taking into account the evidence. firstly, the important cause of maritime accidents is certain. then, these factors are classified according to the HFACS-MTA structure, where the cognitive map technique determines the relationship between the causes identified in a Marine accident. After that, lists the reasons for prioritization. FIG.6 shows the flow chart and model of Marine accident analysis.

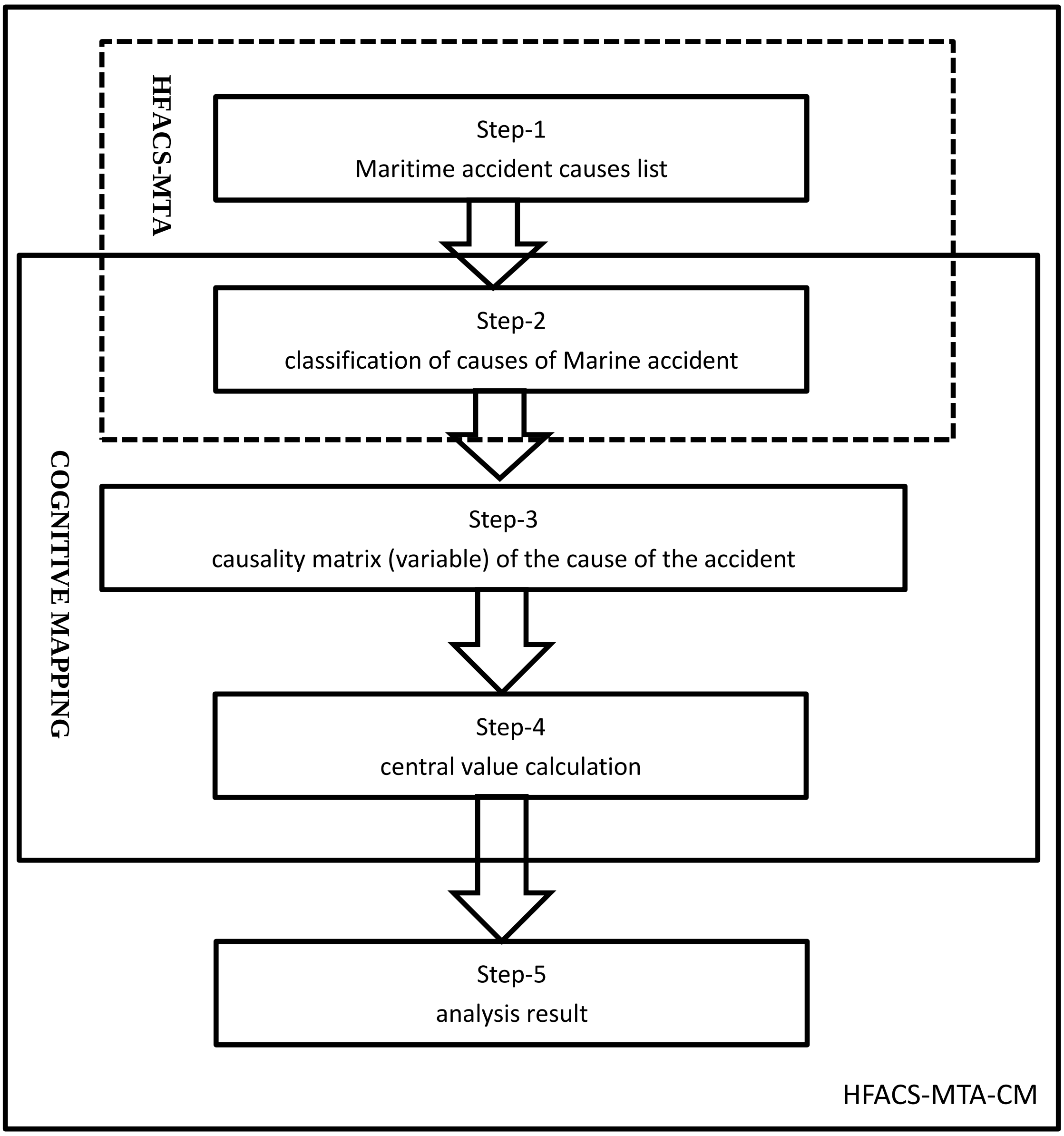

Fig.6: HFACS-MTA-CM

The model contains five steps, each of which is explained is showed:

(1) : Marine accident causes list: the purpose of this part is to decide the cause of the accident. Human error can lead to accidents, and the best method to avoid the accidents is to determine the main man-made factor. And, the cause and effect of Marine accidents are analyzed. The cause of the accident will be listed on the list.

(2) : classification of causes of Marine accident: this part uses the HFACS-MTA to determine the cause of various accidents. After each incident code and table, according to the HFACS-MTA framework, the framework has four layers. Therefore, each factor is distributed under the HFACS-MTA model. Make an example, " commercial pressure " is an cause of accident and should be classified under " Organization influence ".

(3) : causality matrix (variable) of the cause of the accident: the purpose is to introduce HFACS-MTA into cognitive map technology through using the relational square matrix. It can help determine if the cause of an accident affects other reasons. namely, CM gives the correlation between variables. In order to determine the cause of the accident, the CM technology should be built in the HFACS-MTA application. According to the reason of the accident of HFACS-MTA application classification and the evidence. Causality can be divide into positive, negative or neutral. The cognitive map method can converts the cause of accident reasons into available information.

(4) : central value calculation: the center mainly considers a reference point indicating the importance of a factor on the map (iden et al., 1992). For quantitatively supporting the model, the central value of each causal relationship should be fully utilized. The causal relationship assessment for each incident was further analyzed and the impact of each accident was sequenced. After obtaining the central value, these factors are followed by cross-columns and rows. The value of the central can be showed in two ways: global central value (GCV) and normalised central value (NCV). GCV offers priority, and NCV expresses the distribution of the cluster, which is checked by HFACS-MTA layers. If the number of GCV of the factor is big, then these factors directly impact the occurrence of the accident, and it may also occur in other cases. Namely, the organization should pay more attention to these factors to

prevent from the accident.

(5) : analysis result: in the final stage; The cause of the accident is the biggest GCV, which is showed the important factor influence the accident. To prevent it, the main causes of accidents should be eliminated.

Chapter 4 Case application

4.1. case introduce

In this part of the marine case study, the HFACS-MTA-CM model is demonstrated. For using the method to a real case, a meaningful maritime accident is discussed, that is, neglect of maintenance results in a fire in the engine room. The features of the cabin require advanced safety level and operation plan. Taking into account the fire problems in the cabin (key aspects of maintenance and evacuation) was found as a new situation. The case has been investigated by the marine accident investigation department. The purpose of this application is to avoid any parallel incidents on the ship. Let's briefly review the accident process

Case(Zheng zhenxiong & Lizheng,2013): August 10, 2012 about 8:53, loading 1296 TEU Container ship, the maximum draft is 11 meters of B ship is anchoring at the anchorage of Xiamen port, ready to recruit Hong Kong District berth, due to the high temperature and high pressure lubricating oil and gas of engine room's no.2 auxiliary lubricating oil temperature sensor extruded to exposed high temperature smoke exhaust device, let the engine room fire. The accident caused the cable, control box, instrument and distribution board of the Marine engine to burn down. And caused a electrical engineer to be injured and no water pollution were caused.

What happened: On August 10 before the morning meeting, the chief engineer found in the control room No. 2 auxiliary oil temperature display is not stable, fluctuating between 82 and 91 degree centigrade, normally it is 84 degree centigrade, so in the early meeting requirements check No. 2 auxiliary motor's abnormal situation. About 8:51, after anchoring, electrical engineer examine the No. 2 auxiliary, found the oil temperature sensor loose wiring but not broken, in order to check out the sensor circuit, on the removal of the lock nut of the sensor, and use a screwdriver pry sensor. As a result, high temperature and high pressure oil and gas ejection, part of the spray to the high temperature smoke exhaust pipe exposed, leading to smoke pipe fire, electrical engineer get injured, the fire soon spread to the main engine pressurization. The chief engineer did not report the captain at first, tried to extinguish the fire as soon as possible, but he failed. Around 8:59, the engine room is in full fire alarm, and the chief engineer requests the captain to agree to evacuate all the people of the cabin and release the large carbon dioxide fire extinguishing system. The captain called for the shipping company urgently, but it was delayed because of the poor contact. The consent by the shipping company, the cabin staff to evacuate and confirm the pumps, blower, air duct, host engine room skylight, fire door and oil tank quick closing valve and power cut off, the captain ordered about 9:29 cast large carbon dioxide fire extinguishing system. About 10:15, the Xiamen maritime search and rescue center duty room received the accident report, immediately launched the emergency plan, deployed four rescue boats to the scene of the accident. At the top of the chimney, the smoke was still heavy, and at about 10:51, the captain ordered second large carbon dioxide fire extinguishing systems. About 12:12 to 13:10, four rescue boats have arrived at the scene of the accident, cooling the accident ship. About 15:30, when the second large carbon dioxide fire extinguishing systems were all manually released, the smoke detail at the top of the chimney decreased. About 17:55, fire work ended, no signs of resurgence.

Through the analysis of the cause of the accident, there are two reasons: the direct cause of the electrical engineer in violation of the rules, not the source of pressure valve is closed and the pressure relief, then remove pipe with pressure, resulting in oil gas spraying high temperature and high pressure, high temperature exhaust contact exposed parts, resulting in a fire and continued burning; and the cabin is flammable, combustible more body surface paint, to support combustion. The indirect reason: the engine room maintenance is not enough. Before the incident, when the cabin crew try to repair the NO.2 auxiliary machine, The heat insulation material of the NO.2 auxiliary machine has been found to be powder. Part of the insulation material falls off, causing the smoke tube to become exposed, but no effective measures have been taken, then the exposed pipe was exposed to the slippery oil and caused fire.

After the event, the suggestion of the accident report focuses on the individual's human error, operation and management errors, comply with the ISM rules. They also made suggestion s to the shipping company that action should be taken to strengthen the safety management of ships and the training procedures for seafarers.

The following sections of the study illustrate that these recommendations can be incorporated into the HFACS-MTA-CM model and that similar accidents can be prevented in the future.

4.2. Marine accident analysis

4.2.1. Causation with HFACS-MTA

This section details the causes of marine accidents and classifies human errors in accordance with the HFACS-MTA framework. As refered earlier, the original purpose of using HFACS-MTA is to determine the factor of the system mapping at the next stage of the model. From the evidence and facts of the accident report based on the HFACS-MTA level, the cause of the maritime accident is shown in figure7 .

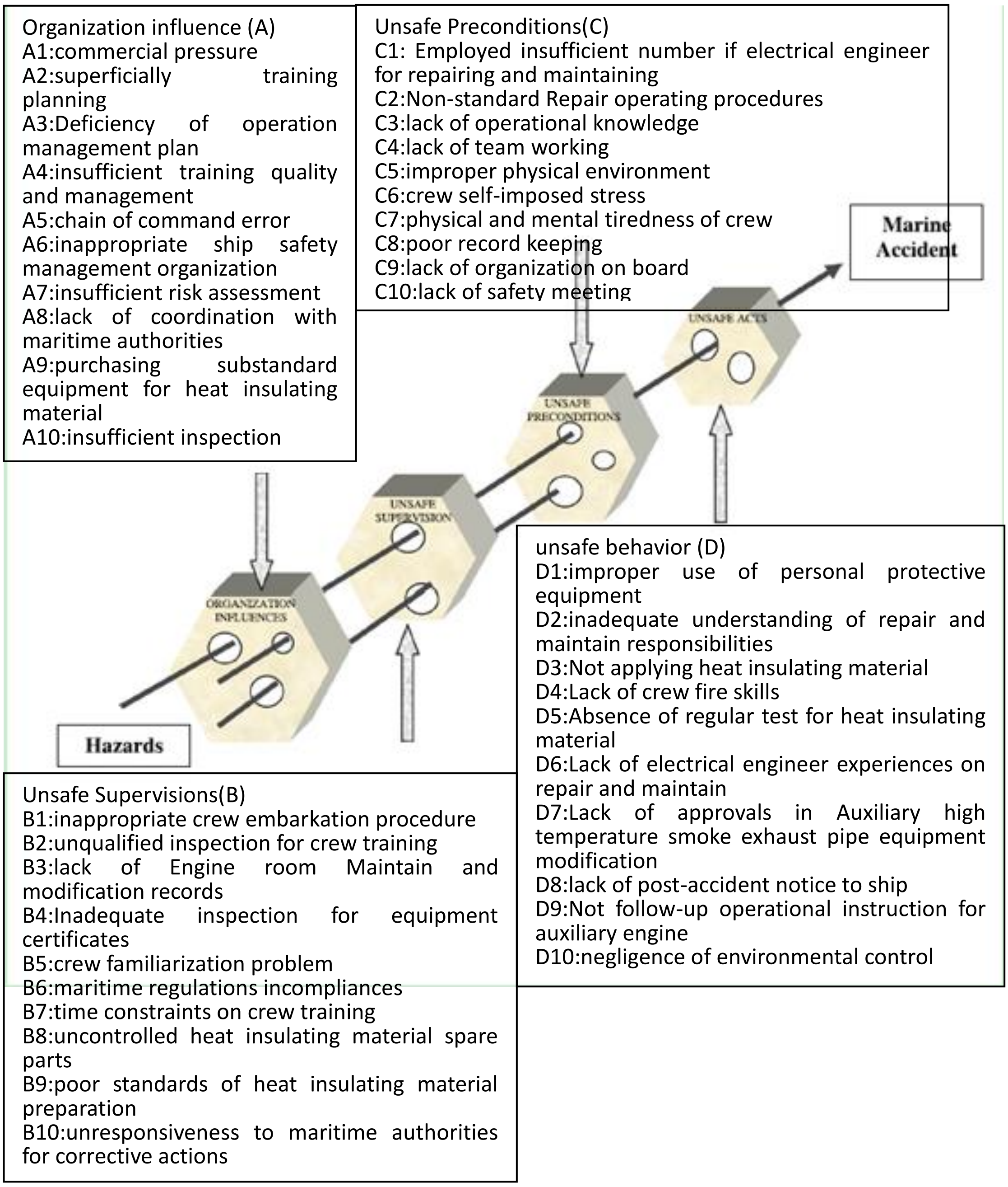

Fig.7: Marine accident causation based on HFACS-MTA levels

In Figure 7, every marine accident reason is distribute to the HFACS-MTA hierarchy level with a number and a letter. A causal matrix will established between evry factor to facilitate the coding of each cause of maritime accident. Such as, “A4 – (insufficient training quality and management)” is the forth element of organizational influence. Moreover, under the influence organization, it has “insufficient training quality and management”(a4), because the training quality and management by the company has a positive impact on the ship’s management team. For another example, “Lack of crew fire skills” (D4) belong to unsafe behavior, because the crew did not have enough study to defend fire. Therefore, the rest of the accident caused by the accident, from the marine accident investigation report, is listed under the analysis of HFACS-MTA mechanism.

Make a long story short, human errors in marine accidents are classified as four important level, every of which serves as a parclose to keep future marine accidents away.

Now, let’s discuss the human impact factors that affect the ship’s accident case based on the four levels of HFACS-MTA:

The first one is organizational influence, I list 10 human factors that cause of the organization influence.1 commercial pressure, business pressures can cost more time to the captain, ship company, or other management team in order to take advantage of the problem, thereby wasting time and preventing the accident from being redeemed. 2 superficially training planning, the fire treatment is not accurate and timely, usually lack of fire drills. 3 Deficiency of operation management plan, the shipping company lacks the management experience of the fire safety of the crew. 4 insufficient training quality and management, the ship company are not strict enough to train and manage the crew of the ship. 5 chain of command error, The shipping company and the captain’s command were not precise and decisive. 6 inappropriate ship safety management organization, shipping companies lack safety education and safety supervision. 7 insufficient risk assessment, the shipping company lacks the risk control and risk assessment of the safety incidents. 8 lack of coordination with maritime authorities, shipping companies usually lack communication with the maritime department, resulting in the rescue of the accident is not smooth enough, in a timely manner. 9 purchasing substandard equipment for heat insulating material, bought unqualified material ,The loss of heat insulating material results in fire. 10 insufficient inspection, shipping companies lack inspection, supervision, at the organizational level.

Tab.2: the factors of Organization influence

Organization influence (A)	
A1	commercial pressure
A2	superficially training planning
A3	Deficiency of operation management plan
A4	insufficient training quality and management
A5	chain of command error
A6	inappropriate ship safety management organization
A7	insufficient risk assessment
A8	lack of coordination with maritime authorities
A9	purchasing substandard equipment for heat insulating material
A10	insufficient inspection

The second level is unsafe supervisions. Here are 10 human factors which are about the unsafe supervisions.1 inappropriate crew embarkation procedure, the unqualified skills of electricians and other related crew members are not in place, indicating that there are some problems in the recruitment process of the crew members. 2 unqualified inspection for crew training, the result of the training of seafarers is not strict supervision, resulting in regulatory loopholes. 3 lack of Engine room Maintain and modification records, There is no routine maintenance for the engine room of the accident, and there is no reasonable maintenance record. 4 Inadequate inspection for equipment certificates, the electrician did not check the equipment certificate carefully. 5 crew familiarization problem, the cohesion between the crew is not enough, things encountered insufficient unity, problem-solving is not timely enough. 6 maritime regulations incompliances, failure to comply with the relevant marine safety regulations. 7 time constraints on crew training, lack of training time for crew members resulted in unskilled crew skills and panic in the event of an accident. 8 uncontrolled heat insulating material spare parts, There is not enough spare part heat insulation material, resulting in no timely maintenance of high temperature smoke exhaust pipe, leading to fire.9 poor standards of heat insulating material preparation , the quality of the prepared heat insulation material is not good, but also one of the causes of the fire. 10 unresponsiveness to maritime authorities for corrective actions, the relevant departments of the inspection feedback, rectification requirements are not dealt with in time.

Tab.3: the factors of Unsafe Supervisions

Unsafe Supervisions(B)	
B1	inappropriate crew embarkation procedure
B2	unqualified inspection for crew training
B3	lack of Engine room Maintain and modification records
B4	Inadequate inspection for equipment certificates
B5	crew familiarization problem
B6	maritime regulations incompliances
B7	time constraints on crew training
B8	uncontrolled heat insulating material spare parts
B9	poor standards of heat insulating material preparation
B10	unresponsiveness to maritime authorities for corrective actions

The third level is unsafe preconditions. We have 10 human factors which are about the unsafe preconditions. 1 Employed insufficient number if electrical engineer for repairing and maintaining, electrical engineer maintenance skills are not skilled, no daily practice. 2 Non-standard Repair operating procedures, the electrical engineer violates the operating rules and does not close the pressure source valve, and then releases the pressure piping system, resulting in high temperature and high pressure oil and gas splashing and touching the exposed parts of the high temperature exhaust device. 3 lack of operational knowledge, the electrical engineer lacks the operation knowledge of maintenance and repair and produces hidden dangers. 4 lack of team working, Lack of team consciousness, failed to control the fire in the first place and reduce the loss. 5 improper physical environment 6 crew self-imposed stress Lack of crew experience, unexpected events, can not save the situation in a timely manner. 7 physical and mental tiredness of crew, The physical and psychological exhaustion of the crew leads to a decrease in work efficiency and responsiveness. 8 poor record keeping. 9 lack of organization on board, lack of organizational management and undisciplined discipline on board. 10 lack of safety meeting, lack of safety meeting, lack of awareness of safety education, lower awareness of crew safety.

Tab.4: the factors of Unsafe Preconditions

Unsafe Preconditions(C)	
C1	Employed insufficient number if electrical engineer for repairing and maintaining
C2	Non-standard Repair operating procedures
C3	lack of operational knowledge
C4	lack of team working
C5	improper physical environment
C6	crew self-imposed stress
C7	physical and mental tiredness of crew
C8	poor record keeping
C9	lack of organization on board
C10	lack of safety meeting

The last level is unsafe behaviors. It also have 10 human factors resulted in this ship accident. 1 improper use of personal protective equipment, the electrical engineer did not wear protective equipment, which led to injuries. 2 inadequate understanding of repair and maintain responsibilities, electrical engineer 's maintenance and maintenance knowledge is insufficient, no sense of responsibility. 3 Not applying heat insulating material, Led to the fire. 4 Lack of crew fire skills, The crew's ability to fire is low and loses the chance to extinguish the fire in the first place. 5 Absence of regular test for heat insulating material, should be replaced in time with better insulation materials to eliminate fire hazards. 6 Lack of electrical engineer experiences on repair and maintain, electrical engineer 's maintenance skills are poor. 7 Lack of approvals in Auxiliary high temperature smoke exhaust pipe equipment modification, there is a serious fire safety hazard. 8 lack of post-accident notice to ship, after the engine cabin fire, did not inform the captain promptly, has wasted certain rescue time. 9 Not follow-up operational instruction for auxiliary engine, not immediately shut down the associated machine. 10 negligence of environmental control.

Tab.5: the factors of Unsafe Behavior

Unsafe Behavior (D)	
D1	improper use of personal protective equipment
D2	inadequate understanding of repair and maintain responsibilities
D3	Not applying heat insulating material
D4	Lack of crew fire skills
D5	Absence of regular test for heat insulating material
D6	Lack of electrical engineer experiences on repair and maintain
D7	Lack of approvals in Auxiliary high temperature smoke exhaust pipe equipment modification
D8	lack of post-accident notice to ship
D9	Not follow-up operational instruction for auxiliary engine
D10	negligence of environmental control

4.2.2. Establishing relation matrix

To analyze the causality of Marine accidents, the relational matrix is built in table 6. All causes associated with Marine accidents are given in the causal matrix.

The every causal relationship of Marine accident is evaluated as positive, negative or neutral to measure the priority of all factors. Insert a plus sign if a positive relationship is available. If there is a negative relationship between causes, a negative sign is inserted into the relational matrix. For instance, in safety, under the unsafe preconditions of “lack of operational knowledge (C3)” and “ Lack of electrical engineer experiences on repair and maintain (D6)”, in the case of unsafe behavior, with a positive signal for evaluation. The electrical engineer did not have enough operational knowledge, leading the lack of electrical engineer experiences on repair and maintain and resulted in Marine accidents. Therefore, the intensity of the causal relationship between the two factors (C3 and D6) is considered positive. On the contrary, there is no causal relationship between the physical and mental tiredness of crew (C7) and Not applying heat insulating material (D3) because the crew’s physical and mental tiredness is not related to the lack of heat insulating material. There is no dependency between the two factors (C7 and D3), the relevant definitions are zero (chaib – draa and Deshornais, 1998). There is no negative sign in the relational matrix.

	Organization influence (A)										Unsafe Supervisions(B)										Unsafe Preconditions(C)										Unsafe behaviors(D)									
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
A1		0	0	0	0	0	0	0	+	+	+	0	0	+	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0
A2	0		0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	0	0	0	0	0	0	0	+	+	+	0	0	0	0	+	0
A3	0	0		+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
A4	0	0	0		0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	+	+	0	0	0	0	0	0	0	0	+	0	+	+	+	0	0	0	0
A5	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0
A6	0	+	0	+	0		0	0	0	0	0	+	0	0	+	+	+	0	0	0	0	+	+	0	0	0	0	0	+	+	+	+	0	0	0	+	+	0	+	0
A7	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
A8	0	0	0	0	0	0	0		+	+	0	0	+	+	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	+	0	0	0
A9	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0
A10	0	+	+	0	0	+	+	+	+		0	0	+	0	0	+	0	+	+	0	+	0	0	0	0	0	0	+	+	0	+	0	+	+	+	0	+	0	0	0
B1	0	0	0	0	0	0	0	0	+	+		+	0	+	+	+	0	+	0	0	+	0	0	+	0	0	0	0	0	0	+	+	+	+	+	+	0	0	0	0
B2	0	+	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0	0	0	0	+	0	+	0	0	0	0	0	0
B3	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
B4	0	0	0	0	0	+	0	+	0	+	0	0	+		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
B5	0	0	0	0	0	+	+	0	0	0	0	0	0	0		0	0	0	+	0	0	+	+	0	0	0	0	0	0	0	0	+	0	0	0	+	0	0	+	0
B6	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0
B7	0	+	0	+	0	0	0	0	0	0	0	0	0	0	+	0		+	+	0	0	+	+	+	0	0	0	0	+	0	0	+	0	0	0	+	0	0	0	0
B8	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0
B9	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	+	0		0	0	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0
B10	0	0	0	0	0	+	+	+	0	0	0	0	+	+	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	+	+	+	0	0	0	0	0
C1	0	+	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	+	0		+	+	+	0	+	+	+	0	0	0	+	0	0	0	+	0	0	0	+
C2	0	+	0	+	0	0	+	0	0	0	0	0	0	0	+	0	0	0	+	0	0		+	0	0	0	0	0	+	0	0	+	0	0	0	+	0	0	+	0
C3	0	0	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+		0	0	0	0	0	+	0	0	+	0	0	0	+	0	0	+	+
C4	0	+	0	+	0	+	0	0	0	0	0	0	0	0	0	0	0	+	+	0	+	+	+		0	0	0	+	+	0	0	+	0	0	0	+	0	+	0	+
C5	0	0	0	+	0	+	+	0	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	+		+	+	+	+	0	0	0	0	0	0	0	0	0	0	0
C6	0	0	0	+	+	+	+	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	0	+	0		+	+	0	0	+	+	0	0	0	0	0	0	+	0
C7	0	+	0	0	+	+	+	0	+	+	0	+	0	+	0	+	0	+	+	0	0	0	0	0	0	+		+	+	0	+	0	+	+	+	0	0	0	0	+
C8	0	0	0	+	0	0	+	0	0	+		+	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	+	0	0
C9	0	+	+	+	0	+	+	+	0	+	0	+	+	+	0	0	0	+	0	0	0	0	0	+	0	0	0	+		+	0	0	0	0	0	0	+	+	0	0
C10	0	+	+	0	0	+	+	0	0	0	0	0	+	0	0	+	0	0	+	0	+	0	0	0	0	0	0	+	+		+	0	0	0	0	0	0	+	0	0
D1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0
D2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	+	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
D3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	0	+	0	0	0	0	0	0	0		0	0	0	0	0	0	+
D4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
D5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0

D6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	+	0	0	0		0	0	+	+
D7	0	0	0	+	0	0	0	0	0	0	0	0	+	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0	0		0	0	0
D8	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0
D9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
D10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Tab.6: Causal relation matrix of marine accident.

4.2.3. Centrality values

This part is the most important phase of the case study, which turns the findings become useful information. Both GCV and NCV of each factor are in table 7, indicating the central value of causal factor in Marine accident analysis. In addition, the results include central values of the rank-global (R-GCV) and the central values of rank-normalization (R-NCV). The last column shows the percentage of each factor of NCV.

The GCV of each factor can be found by calculating positive and negative signs in the relational matrix. In addition, the neutral signs in the relational matrix are ignored and will not be calculated when finding the central value. For example, according to the relational matrix, " lack of team working (C4)" is at the level of unsafe preconditions, with a total of twenty-four positive values. Therefore, the GCV of this concept is considered to be 23. At the same time, NCV can be found by standards-based column standardization. For instance, the NCV found for C4, is 0.13, and its percentage in the cluster is about 13%.

4.3. Findings

Tab.7: Centrality values of causal factors in marine accident analysis.

	GCV	R-GCV	NCV	R-NCV	%
A1	7	34	0.05	7	5
A2	18	10	0.13	4	13
A3	5	38	0.04	9	4
A4	21	6	0.15	3	15
A5	4	40	0.03	10	4
A6	27	2	0.20	1	20
A7	13	19	0.09	5	9
A8	10	27	0.07	6	7
A9	6	37	0.04	8	4
A10	26	3	0.19	2	19
B1	16	12	0.13	2	13
B2	11	21	0.09	5	9
B3	8	33	0.06	10	6
B4	11	21	0.09	5	9
B5	15	14	0.12	3	12
B6	10	27	0.08	8	8
B7	14	16	0.11	4	11
B8	11	21	0.09	5	9
B9	21	6	0.17	1	17
B10	9	30	0.07	9	7
C1	18	10	0.10	6	10
C2	20	9	0.11	5	11
C3	21	6	0.11	4	11
C4	23	4	0.13	2	13
C5	11	21	0.06	10	6
C6	15	14	0.08	7	8
C7	22	5	0.12	3	12
C8	14	16	0.08	8	8
C9	28	1	0.15	1	15
C10	13	19	0.07	9	7
D1	9	30	0.09	6	3
D2	16	12	0.16	1	18
D3	11	21	0.11	3	12

D4	11	21	0.11	3	12
D5	9	30	0.09	6	10
D6	14	16	0.14	2	15
D7	10	27	0.10	5	11
D8	5	38	0.05	10	5
D9	7	34	0.07	8	7
D10	7	34	0.07	8	7

The one who have the biggest total GCV is the most important factor in the map. GCV distribution is shown in figure 5. " lack of organization on board (C9 / GCV: 28) seems to be the most important factor," the survey found. Instead, the " chain of command error” (A5 / GCV: 4) is the least important factor. This result can be verified by a common assumption that the traditional shipboard hierarchy is not usually allowed to have problems in the command chain. This fact actually supports the reliability of the results of the model.

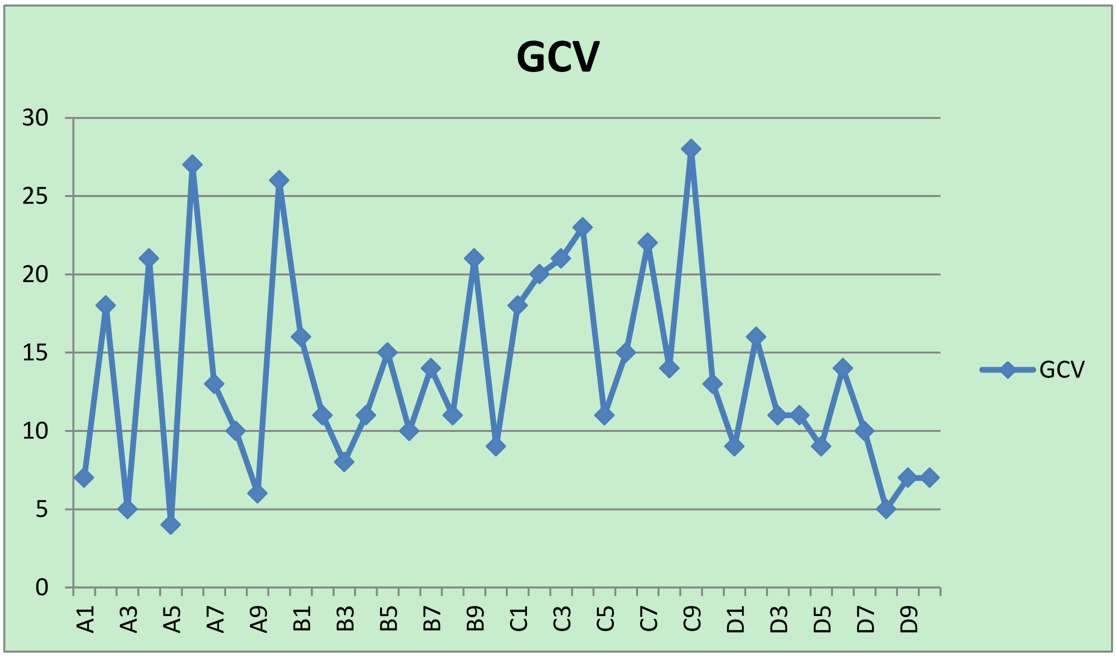

Fig.8:Global centrality values (GCV) distribution

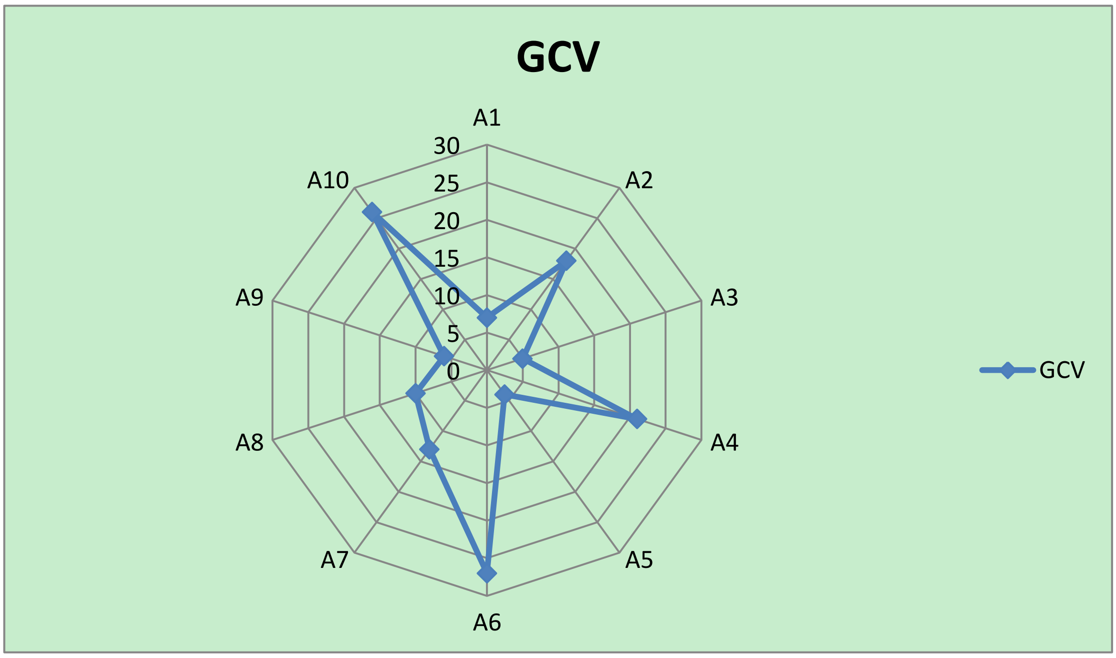

Fig.9: Centrality values of causes under organisation influences

For understanding the causes of Marine accidents, it is better to evaluate the results according to the level of HFACS-MTA. FIG. 9 illustrates the influencing factors under the organization influence by the resulting GVC value. In this figure, the position of the "A6 (inappropriate ship safety management organization) “clearly indicates that it has the biggest GCV under the influence of the organization. The cause of Marine traffic accident A10(insufficient inspection) is the second important factor in Marine traffic accidents. In addition, the A4 (insufficient training quality and management) is the third biggest factor. A5 (chain of command error) is very close to centre of the graph , it means A5(chain of command error) have no impact on marine accidents.

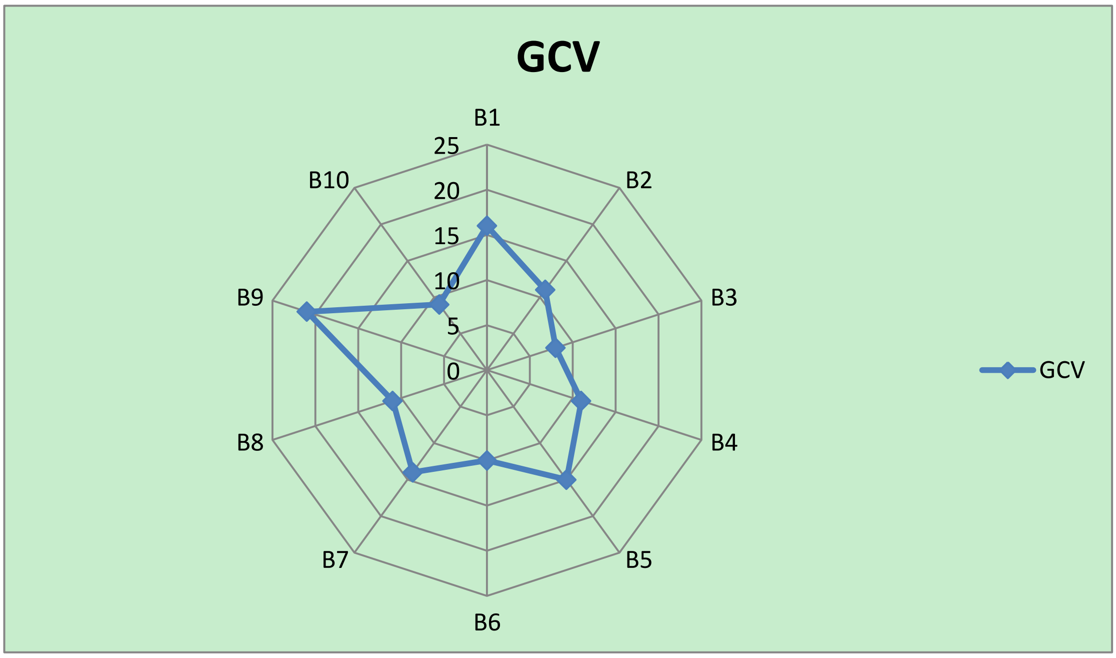

Fig.10: Centrality values of causes under unsafe supervisions

In addition, figure 10 depicts the GCV for all causes of unsafe supervisions levels. Clearly, the B9 (poor standards of heat insulating material preparation) is the most important factor in levels of unsafe supervision. Then, B1 (unqualified inspection for crew training) is the second important factor. The B5(crew familiarization problem) was found to be the third cause of Marine accidents. As the B3 (lack of Engine room Maintain and modification records) have the lowest central value, it is considered irrelevant in Marine accidents.

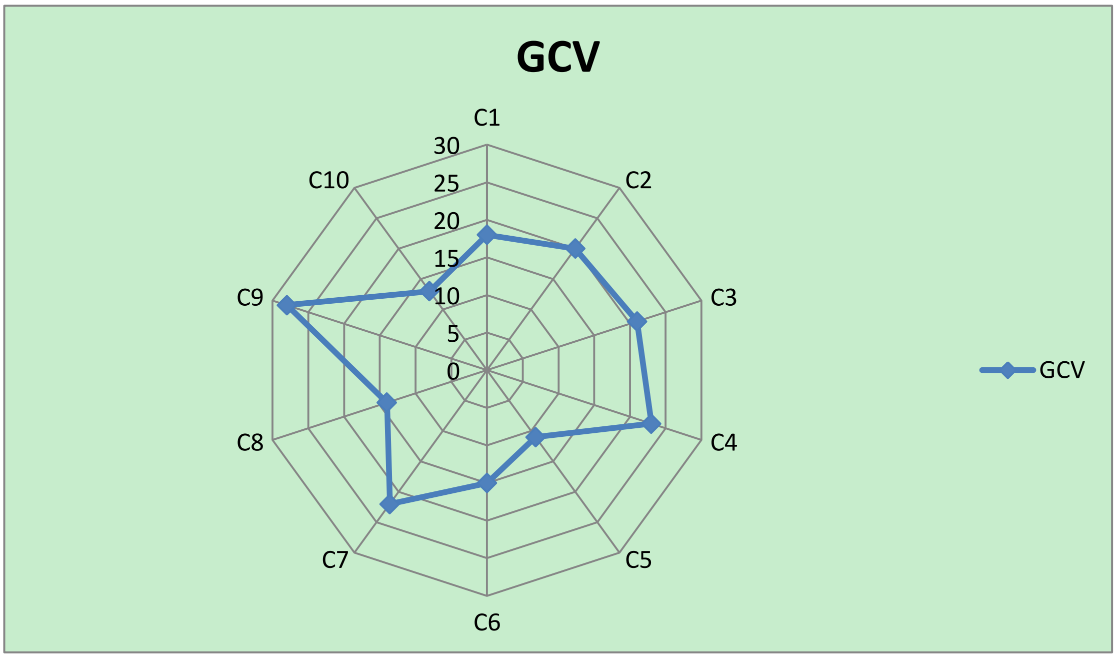

Fig.11: Centrality values of causes under unsafe preconditions

Figure 11 provides the central value of the cause of the unsafe preconditions level. C9 (lack of organization on board) is the most important factor in unsafe preconditions level. In addition, C4 (lack of team working) is found the second high GCV factor of marine accidents. Then, C7 (physical and mental tiredness of crew) is found as the third major causes of marine accident. In contrast, C5 (improper physical environment) has the smallest GCV and has minimal impact on maritime traffic accident causation.

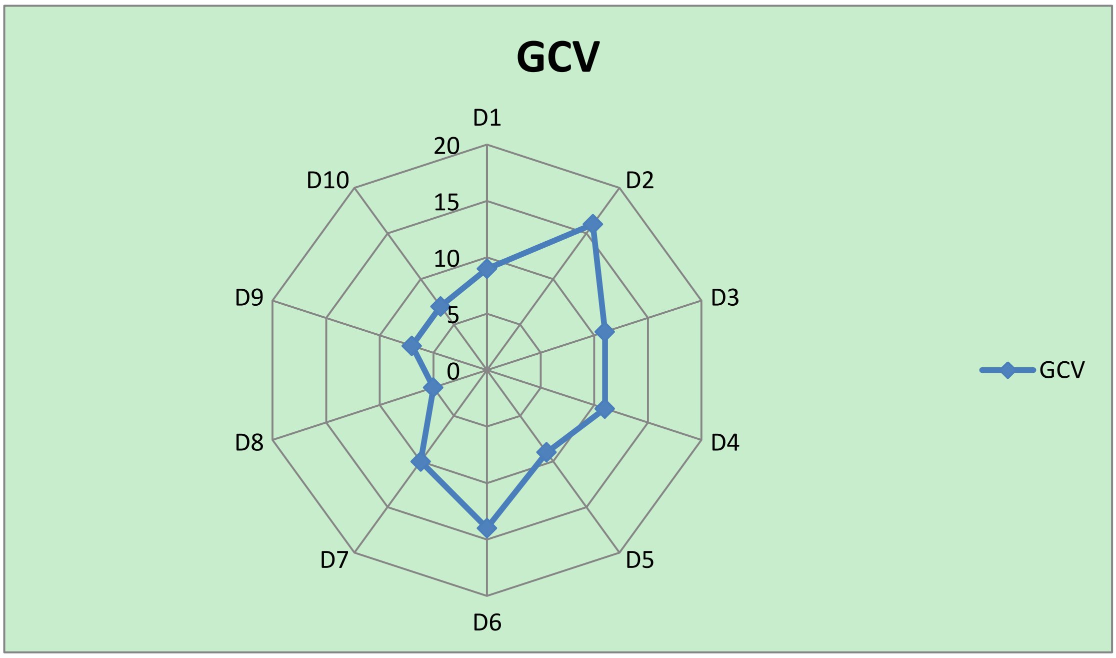

Fig.12: Centrality values of causes under unsafe behavior

Figure 12 describes the central value of the cause of unsafe behavior level. The distribution of value emphasizes that D2 (inadequate understanding of repair and maintain responsibilities) is the main contributing factor. The second major factor impact on the Marine accidents is D6 (Lack of electrical engineer experiences on repair and maintain). D3(Not applying heat insulating material) and D4(Lack of crew fire skills) are the third major factor in Marine accidents occurring at unsafe behaviour levels. On the other hand, the D8 (lack of post-accident notice to ship) appears to be a minor factor in maritime accidents that occur at unsafe behaviour levels.

Tab.8: Total distribution of centrality values

	Total GCV	%
organization influence	138	25.2
unsafe supervision	126	23.0
unsafe preconditions	185	33.8
unsafe behavior	99	18.1

Finally, figure 13 illustrates the total distribution of the central values of every level in the HFACS-MTA framework. The results are as follows: (1) unsafe preconditions (total GCV: 185,33.8%), (2) organization influence (total GCV: 138,25.2%), (3) unsafe supervision (total GCV: 126,23.0%), (4) unsafe behavior (total GCV: 99,18.1%). The results make it clear that unsafe preconditions are the most critical level of the organization's key case analysis.

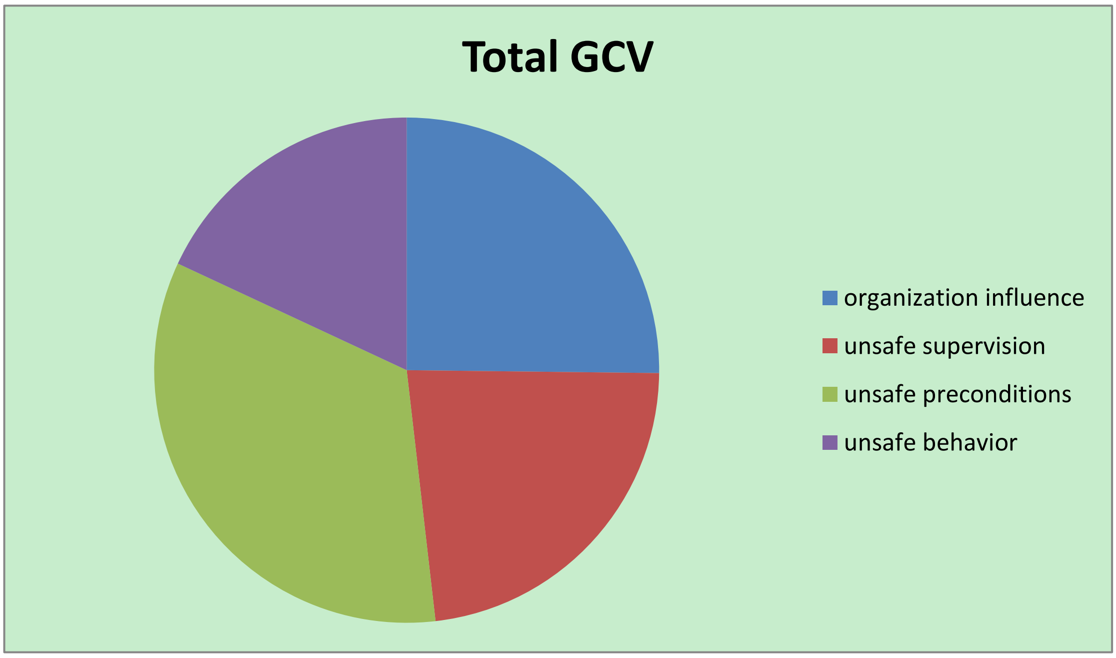

Fig.13: Total distribution of centrality values

Chapter 5 Conclusion

The study presents a model of Marine accident analysis, which was called HFACS-MTA-CM. It combines HFACS-MTA with CM technology to analyze the influence of human factors in sea accident. It offers an efficient method for people to get the important factors that cause Marine accidents. Therefore, it can identify and prioritize the cause of the accident or potential cause.

This paper applies this method with a accident. In the application, the method confirms that the important contribution of accident with the biggest central values should be rule out. This method puts forward the maritime accident protect measures to remove the important influencing reason. Because the method is convertible, it could be changed and applied in other organizations, such as docks, and ship recycling industries. It is said that the method is not only adapt to ship accidents, but to any other industries with human factors. Furthermore, the method can apply to strengthening maritime security.

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