Personal Identification (PIN) Safe Model to Analyze Unsafe Actions that Characterize Maritime Accidents

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Personal Identification (PIN) Safe Model to Analyze Unsafe Actions that Characterize Maritime Accidents

（事故原因の解析に基づく海難分析に関する研究）

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SUMMARY

This research focuses attention on safety challenges in maritime accidents, as the basis of conditions of unsafe actions of the human factor. Analyzing data is based on reports from JTSB (Japan Transport Safety Board) during 1991-2008.

All equipment and systems has sensitive operations in working environment. While interacting of human in working performance have limitations in human element. In the strategy of Personal Identification (PIN) Safe model within working environment considering two condition about substandard practices of operators and substandard working conditions of operators. Substandard conditions are broken down from attribution of causes interacting with adverse mental states, adverse physiological states, and physical/mental limitations. Types of substandard practices include crew resource mismanagement and personal readiness. Each of these subcategories is discussed in the model of the characteristic of the human element in analyzing data. In the theory of causation in the maritime field is mentioned that one of the root cause analysis problems considered using 4 M (Man, Machine, Media, Management) Factors. Every factor while interacting where the center is a human who has the limitation in decision-making/taking actions will result in unsafe conditions or unsafe actions. While generating have a significant error from standard performance, can be said to be human error. Any unsafe actions or conditions lead to incident or accident has risks.

Reliability of safety critical system is implemented in risks for human beings in its environment, such as unsafe actions in maritime accident. Critical systems engineering is to avoid disasters. A critical system is any system whose 'failure' could threaten human life, the system's environment of the organization which operates the systems. These people may interact with system or not. In safety critical system, people need to be aware of these risks and know what to do in the case of problems. Any reasonable conclusion possible as Personal Identification (PIN) Safe model is done in logic of pattern in working environment.

In this research (as shown in fig.1.3) Logic of patterns (AND/OR), as developed by the author, is used to illustrate how a combination of both can occur. In the logic of the patterns, the author has conducted research how to implement logic such as AND / OR to determine the exposure of sensitive situation using taxonomy error codes which is implemented in a union set. It is integrated into a model called a

Personal Identification (PIN) Safe model. Based on this reasoning, Personal Identification (PIN) Safe model is done in logic of patterns of human beings.

The result of this research is:

a. Identifying human elements in risk.

Identifying human elements is based on unsafe actions and their root cause to determine any kind of risk in maritime accidents. Any unsafe actions have different characteristics that lead to kinds of maritime accidents. The assessment step is applied in probability weight as a measure to determine the level of risk associated with a specific hazard. The result indicates the level of consequences from a risk. Minimizing the decrease of quality human performance as impacted in unsafe actions is implemented with 3A (awareness, action and attitude) behavior in part of PIN Safe model.

b. Improving quality of decisions in response to unsafe actions

Quality of decisions is increasing quality sense of decisions by input, process and output to get situational awareness and situational familiarity in working environment to minimize any significant deviations, particularly in the maritime transport system. These elements are embedded in very complex, interdependent, and dynamic relationships. The maritime transport system is a very complex and large-scale socio-technical environment system consisting of human actions that interact with each other and operate in a physical environment in the term man-machine-media and management. Knowledge of working environment is one part of decreasing the risk value of an individual ship. Every risk will reach to accident. Considering further that it has the probability accident which is determined by the ship's time and location. Effective analysis and practice is the counter measure for reducing the human elements' involvement by studying the patterns that have the same value as of probability weight in taxonomy error. These have been developed in order to get the performance shaping factors by PIN Safe model as anticipation of engineering controls.

c. Controlling the patterns of unsafe action in risk

Risk is the probability and severity of loss from exposure to the hazard. The accident probability for an individual ship is determined using so called "exposures" and a casualty rate. The exposures are the number of potential casualty sensitive situations in which the ship can be involved that could lead to an accident. This process definition will be easier to recognize by the taxonomy error in the performance of the seafarer.

The probability weight and severity of accident that could result produce a pattern from the hazard, based upon the exposures of personal unsafe actions within the hazard. From such pattern there can be shown how navigation problems contribute as the highest input to the collision accident. It is expected that the exposures are a key to developing human performance. During operations of workers, it can be seen how they will be affected by a given event or, over time, by repeated events.

d. Monitoring the patterns of unsafe action

Repeated events as unsafe actions need evaluation. Regarding these situations, the author has been researching methods in the control of taxonomy error of unsafe actions till within 4M factors as a comprehensive monitoring information process in PIN Safe model. These are needed for the role of management to evaluate. Strong management to analyze events' characteristics of unsafe actions is important in establishing the evaluation strategies. Monitoring all factors should be done to avoid critical situations and to minimize human casualty. In chapter 5, there is a result that highest cases of human casualty come from unsafe actions such as improper management for ship operation, management of electrical equipment, improper handling and other tasks, improper fishing work, poor management of passengers and cargo loading; and others. There is the need for keeping continuous and specific training in a limited time. Knowing the kind of monitoring in unsafe actions can help to map features of human limitations to get a unique approach to improving human performance.

The summary dissertation has structures consisting of:

In chapter 1, the background comprising the reasons for the research issues is explained.

In chapter 2, the terms of safety in maritime systems are explained, such as the safety responsibilities within the industry at the international, regional, flag state regulations, and port state control levels. The emphasis is placed on the International Safety Management (ISM) Code, which provides the minimum standards and guidelines for operational safety management in the maritime system. The maritime system is interconnected by 4M (Man, Machine, Media and Management) factors which cover the four pillars of basic safety in critical situations. Clearly, the human elements are identified in the maritime system as people abilities and limitations, and the influences of man, machine media, and management by IMO and Anita Rothblum. Taking into account the characteristic of maritime accidents, the human elements are explored in this dissertation with the main focus being on the unsafe actions of seafarers, and their underlying contributors such as the operators' personality that have a deep influence on the operator's performance. The external elements that are included are the environment, the society and ship itself, as these have a direct influence on operators and are deemed to be aspects of the human element.

In chapter 3, the theories of accident causation being prevented by identifying the root causes of maritime accidents are described. These stem from known accident investigation techniques and the methods are based on the management model (Henrich's Model) and on behavior models (human error, human factors, human elements).Collaboration activities are directed to control the unsafe personal performance of certain knowledge, attitudes and abilities. The chapter describes the accident causation theories. The importance of understanding the accident causation theories is recognized by how unsafe actions in the construction workplaces cause losses through safety response – the similarity is used as a model for the maritime system.

In chapter 4, the creation of the integration of an unsafe action in the design of safety critical systems, by the new method called Personal Identification (PIN) Safe model, is used. Strong management to identify every characteristic of unsafe actions is reached to establish the evaluation strategies. PIN Safe model is a counter measure to devise a systematic identification of substandard, unsafe actions and critical events associated with characteristic accidents on a ship. PIN Safe model is shown in anticipation of engineering controls. Its model includes anticipation of all human factors. Initiating events as unsafe actions will lead to process deviations. Measurement parameters in all operations by approaching logic of patterns can help to suggest for improved motivation of the self; and censoring of equipment by ergonomic design is useful to help to reach good performance in the working environment.

In chapter 5, the identification of unsafe actions in risk recognizes unsafe action as being one of the features of the human element. There are many unsafe actions that lead to failures, such as improper look-out, fatigue, no indication of navigation lights and shapes, signaling failures, improper ship's speed, ignoring the COLREGS, main engine failure, etc. The initial investigation is begun to study unsafe actions (as seen in fig 1.1 and 1.2) to know the risk of every unsafe action. Any unsafe actions have different characteristics which can lead to maritime accidents and their consequences.

In chapter 6, the human performance behavior of the seafarer's decision-making is analyzed. Using logic of patterns in probability weight value, interactions of unsafe actions by taxonomy of error modes are analyzed. Such actions include, but are not limited to, control failure, omission or repetition, reversal, too fast, too slow, too early, too little, too much, wrong input and miss-calibration associated with various scenarios within the precepts of 4M (Man, Machine, Media and Management) factors.

The author shows that human elements have caused the probability of accident, and shown are the patterns of unsafe actions in maritime accidents.

In chapter 7, the consideration and conclusion are implemented to show the results of research in all previous chapters. The results conclude that the human elements that contribute to unsafe actions when interacting with equipment and other systems, illustrate the fact that anyone has limitations, anyone has different characteristics of unsafe actions. And that strong management is needed, as is monitoring and controlling of operations in a breakdown. Safety culture in all parties. The evaluation assessment will be reached to improve safety culture at sea.

Further research is also shown.

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CHAPTER 1
INTRODUCTION

1.1 Background

"Almost 90 percent of world trade is transported by sea, in ships. On ships are carried food, fuel, raw materials, commodities and goods on which we all depend. Seaborne trade facilitates the global economy and it is no exaggeration to say that almost everything we touch has, at some point in its existence, been transported by sea or derived from something that was transported by sea. Today we acknowledge the seafarers who operate the ships, bringing cargo safely to its destination, keeping to the schedules, day in and day out, regardless of the conditions they may have to face. Without seafarers, our lives cannot be sustained. Yet, to most of us, seafarers are virtually invisible". When opening the Year of the Seafarer in 2012, the above declared by Koji Sekimizu, Secretary-General of the International Maritime Organization (IMO) [1].

The number of seafarers around the world serving in international trade is estimated to be approximately 1.5 million people. The community of the seafarer is able to raise world awareness of the vital role that seafarers play in the global economy and bring to the fore their role in safety and efficiency; both with minimal impact on the environment.

Improving the performance of seafarers is to be one of the most important tasks of safety at sea. Maritime accidents have increased with the number of ships. They are known to be caused by human, environmental, and technical factors. Human errors are inseparable from the human element that influences the mariner's decisions and actions. The number of qualified sailors has not kept pace with the increasing number of ships. A look at maritime casualties reveals that 96% of all accidents can be attributed to the human element [2],[3],[4] wherein a study concluded that 60% of all accidents are directly caused by human errors, whereas a further 30% of accidents are indirectly caused by human error. Thus, the human elements has a strong impact on maritime accidents. Therefore, improving the living conditions on ship and ensuring the competence in qualifications of the crew are important factors for seagoing individuals.

1.2 General Goal

This research is conducted in light of the safety challenges to merchant shipping. The fact that the human element is involved in maritime casualties, including collisions, has attracted concern from all parties in the maritime industry. The researchers from various countries especially from Europe and the USA have done a great deal of work.

In order to see the extent of the problem, various human element classifications used in different accident reports and databases will be reviewed. The Japan Marine Accident Inquiry Agency (JMAIA) merged with the ARAIC (Air and Rail) from October 2008 and together are now known as the Japan Transport Safety Board (JTSB). Thus the JTSB is the Japanese government agency that investigates accidents on ships and marine equipment. The JTSB (Japan Transport Safety Board) and its data reports [5] are classified under two main headings: kinds of accident and causes of accidents at sea.

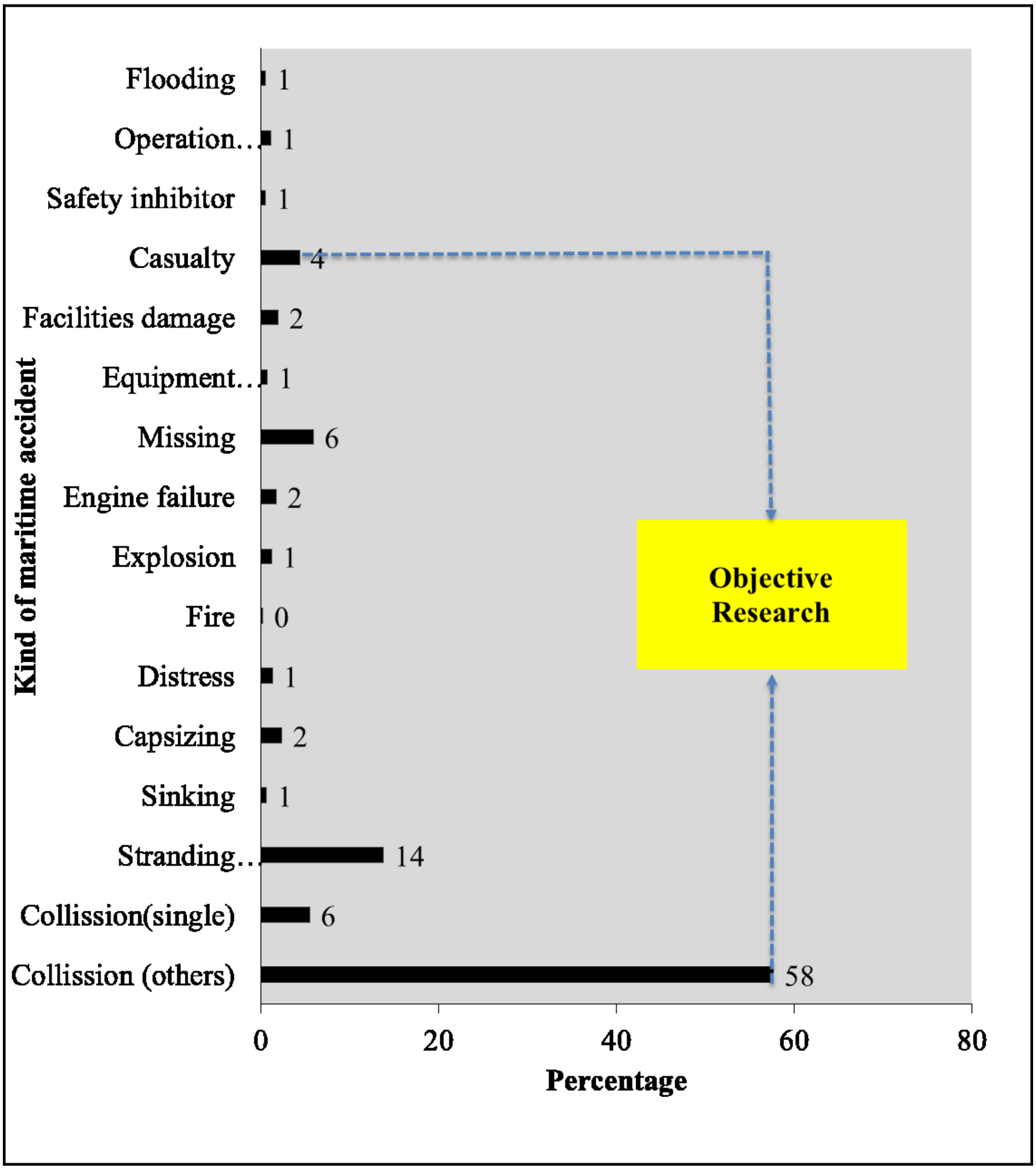

Fig.1.1 Report of maritime accident in 1998-2008, Japan

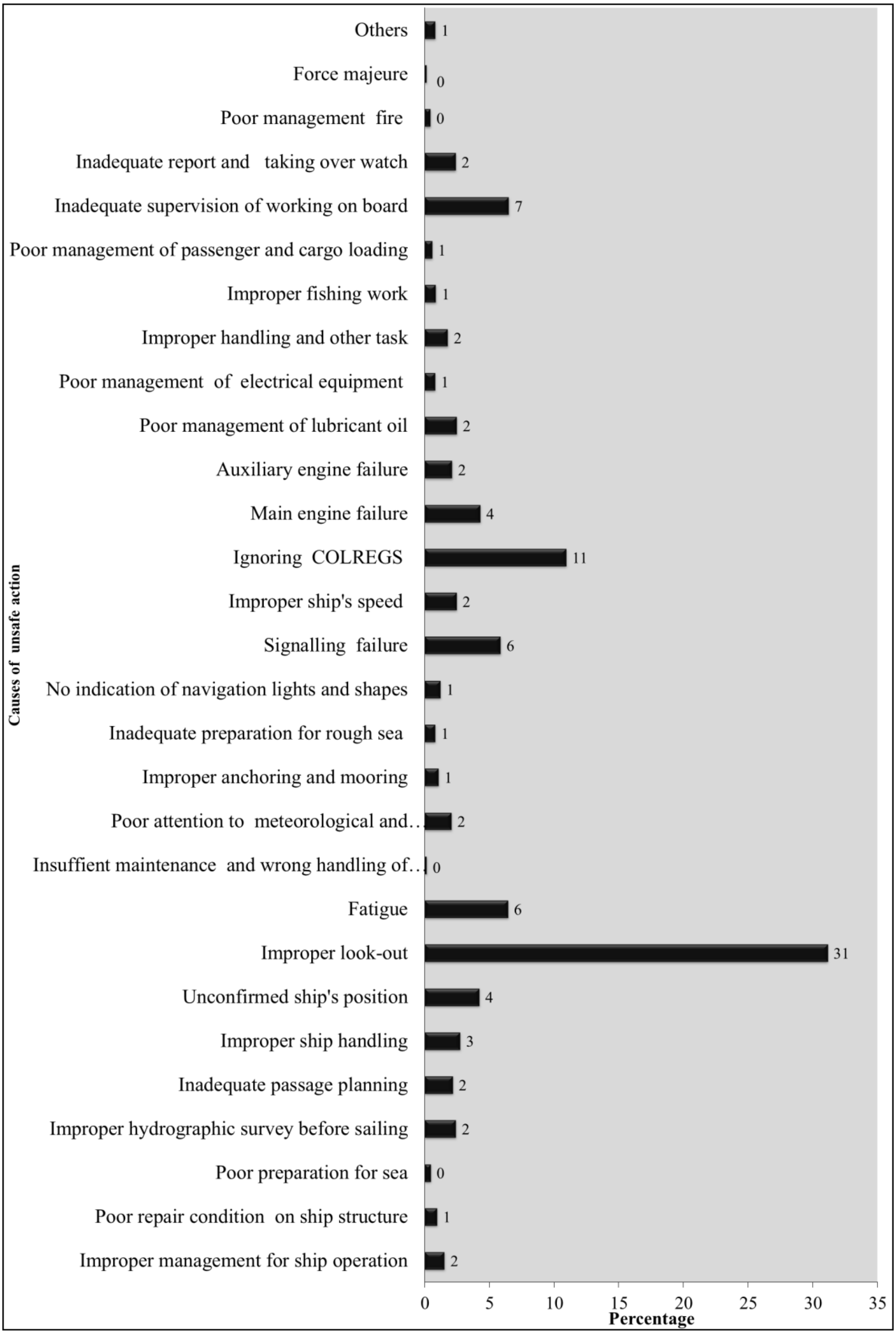

Fig. 1.2 Report of unsafe action in maritime accident, in 1998-2008,Japan

Fig.1.1 describes the types of accidents that happen every day, such as collision, stranding/ grounding, sinking, capsizing, distress, fire, explosion, engine failure, missing, equipment damage, facilities damage, casualty, safety inhibitor, operation inhibitor, flooding. From the data found that 3 (three) categories were involved in the majority of maritime accidents: collision was involved in 64.10 %, stranding is 13.93 % and engine failure is 2.0 %. Fig.1.2 indicates causes of maritime accidents. Causes of maritime accident are events brought about by unsafe actions of the human element, such as improper management for ship operation, poor repair condition on ship structure, poor preparation for sea, improper hydrographic survey, poor course selection, improper ship handling, unconfirmed ship's position, etc. More detailed explanations will be explained in chapter 5.

The current research is conducted in light of the safety challenges in merchant shipping. During the previous 18-years period 1991-2008, it was estimated that more 23,515 cases of marine accidents occured (Appendix-A).

One way to minimize accidents at sea is to better developed human elements' performance within the very complex and large-scale in Socio-Technical Environment (STE) of maritime systems. The system comprises human and man-made entities that interactwith each other and which operate in a physical environment. The main elements of the system are objects of transport, infrastructures and facilities, which are linked by 4 M (man, machine, media, and management) factors in their activities.

1.3 Methodology

The method used in this dissertation consists of the following steps:

1. Constructing a classification for collecting and storing the data of human elements involved in human casualty and collision accidents.
2. Gathering data of human elements involved from various sources especially from current written accident reports.
3. Collecting experiences with and guidance for retrospective unsafe actions cases and making model standards for safety.
4. Describing of the industrial use for improved human performance by using taxonomy errors in unsafe actions in maritime accidents.

1.4 Dissertation Structure

In chapter 1, the background comprising the reasons for the research issues is explained.

In chapter 2, the terms of safety in maritime systems are explained, such as the safety responsibilities within the industry at the international, regional, flag state regulations, and port state control levels. The emphasis is placed on the International Safety Management (ISM) Code, which provides the minimum standards and guidelines for operational safety management in the maritime system. The maritime system is interconnected by 4M (Man, Machine, Media and Management) factors which cover the four pillars of basic safety in critical situations. Clearly, the human elements are identified in the maritime system as people abilities and limitations, and the influences of man, machine media, and management by IMO and Anita Rothblum. Taking into account the characteristic of maritime accidents, the human elements are explored in this dissertation with the main focus being on the unsafe actions of seafarers, and their underlying contributors such as the operators' personality that have a deep influence on the operator's performance. The external elements that are included are the environment, the society and ship itself, as these have a direct influence on operators and are deemed to be aspects of the human element.

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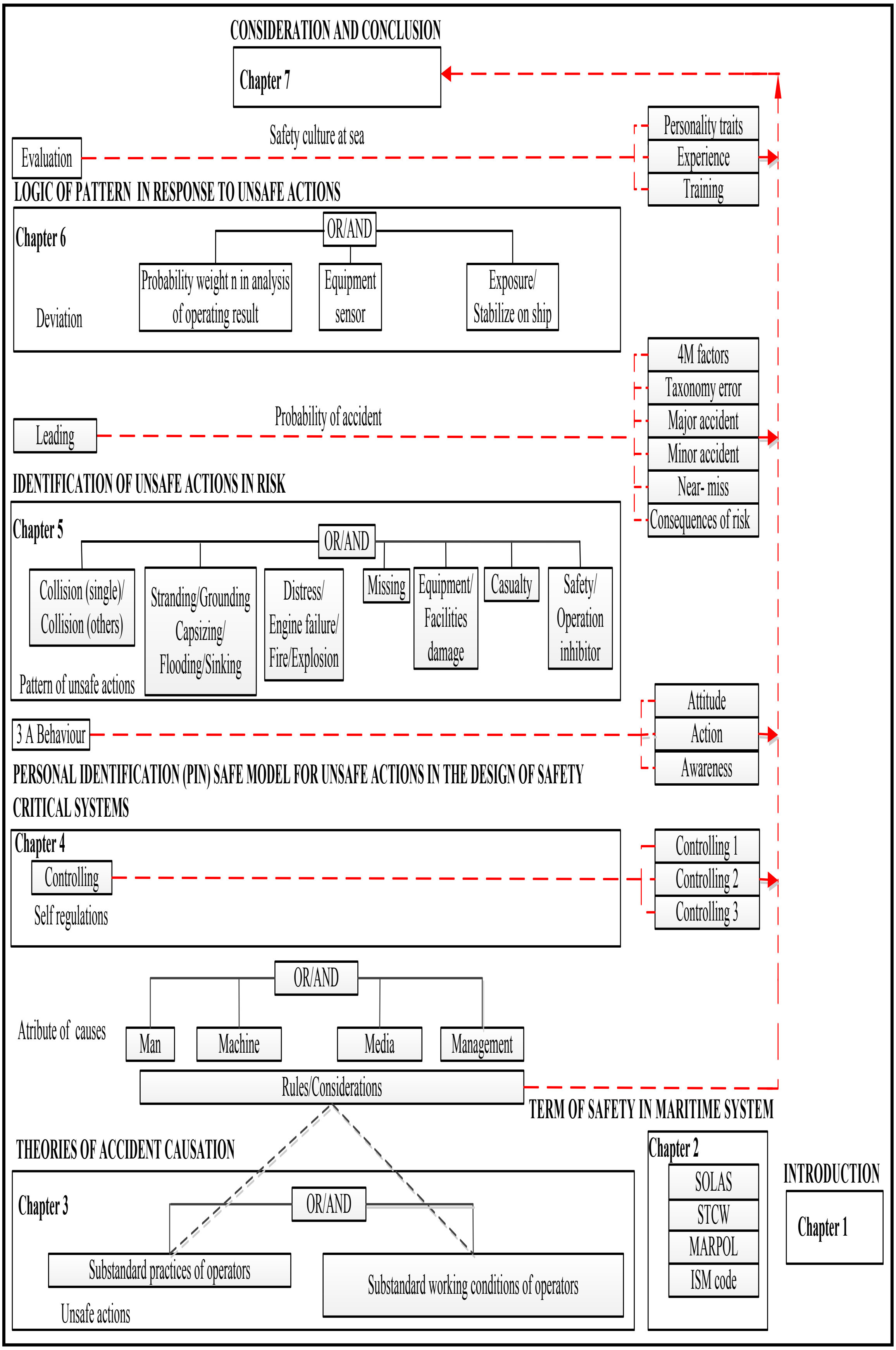


Fig 1. 3 Summary of dissertation flowchart

CHAPTER 2
TERM OF SAFETY IN MARITIME SYSTEM

Unless safety is the dominated characteristic of an organization's culture, there will be no collecting of documentation of unsafe actions from an event caused by human factors. The statement of safe actions of the term is the "developed stage of a technical capability at a given time as regards products, processes and services, based on relevant consolidated findings of science, technology and experience" by the International Organization for Standardization is ISO (International Standard Organization) and the International Electro technical Commission (IEC) in reference number ISO/IEC 90003:2004.

This chapter is describing an overview of the statement of safety through regulations. Types of safety regulations are included in any overview of relationships in a maritime system. An overview within the responsibilities of 4M factors in safety culture. Reducing violations of rules is needed as a requirement of a ship to support a good safety culture. Safety culture will be developed if maximum safe actions are implemented to reduce failures in the organizational maritime system.

2.1 The Concept of Safety

In the literature reviews Adreas [6] has mentioned about:
The term safety is derived from the Latin 'salvus, meaning 'safe'. In existing literature, there are several definitions of safety. Leveson [7] argued that if we deal with security and reliability in absolute terms and that could envision safety as a continuum, where one end is freedom from loss and with the continuum stretching towards increasing loss. "Safety is freedom from accidents or losses". Redmill et al. [8] refers to safety as a state, and that a safe state is a state where the perceived risk is acceptably low (and may include unperceived risk). They also argue that "perfect safety is impossible to achieve and, even if it were achieved, it would be impossible to prove that it had been achieved". Even though there are many definitions of safety, they all have in common the aspects of being free from something undesired, unwanted or unacceptable.

A standard definition of safety is defined by ISO and IEC is "freedom from unacceptable risk" in ISO/IEC Guide 51, 1999 [9].

2.2 Perspective of Safety in the Maritime System

The culture of safety and casualty in maritime system is defined as concern about unsafe actions given which lead to incident or accident causation by human elements.

Why is “human elements” chosen?

Because humans are not simply an element like others such as machine, media, and management. They are the center of the shipping company. They are the secret of its successes and the victims of its failures. It is human nature that drives what happens every day at work from the routine tasks of a ship’s rating, right through to the policy decisions of the IMO [10].

IMO (1997a) interpreted the meaning of the term “human elements” as “a complex multidimensional issue that affects maritime safety and marine environmental protection”; it involves the entire spectrum of human activities performed by ship’s crew, shore-based management, regulatory bodies, recognized organizations, shipyards, legislators, and other relevant parties [11].

In the context of safety, the term of human factor has been defined by the UK Health and Safety Executive as follows [12]:

The perceptual, mental, physical capabilities of people and interaction of individual with job and working environments, the influence of equipment and system design on human performance and above all, the organizational characteristics which influence safety related behavior at work.

Kuo [13], however mentioned in the context of safety that is not always possible because safety is not absolute, but it is governed by personal perception. As technology advances and new ship concepts are developed, the limitation of the approach to regulatory perspective becomes noticeable.

2.3 Safety Regulations in Maritime Field

Safety Regulations are rules issued by the government to manage the risk of harm that could occur and to minimize the effects of hazards to the public. Transport, which can be considered as a "mobile" danger, has been at the fore front of regulatory control.

In shipping, the (UK) government implemented early intervention for certification of masters and deck officers and later, when steam was introduced such intervention was applied to marine engineer officers. The foundering of so many ships at sea and resultant loss of life and cargo in the nineteenth century led to the introduction of the Load Line to ensure adequate buoyancy and freeboard. The loss of Titanic led to The International Convention on the Safety of Life at Sea (SOLAS) which required all passengers’ and crew on a ship to have to adequate lifesaving equipment. In order to gain proper understanding of safety management within shipping, knowledge of the most important laws and the international regulative framework is necessary.

As pointed out from literature reviews Kuo [13] fig. 2.1.gives the overview of the International Regulatory System, Maritime Administration, and conventions related to safety management, and they are shown as support to safety culture.

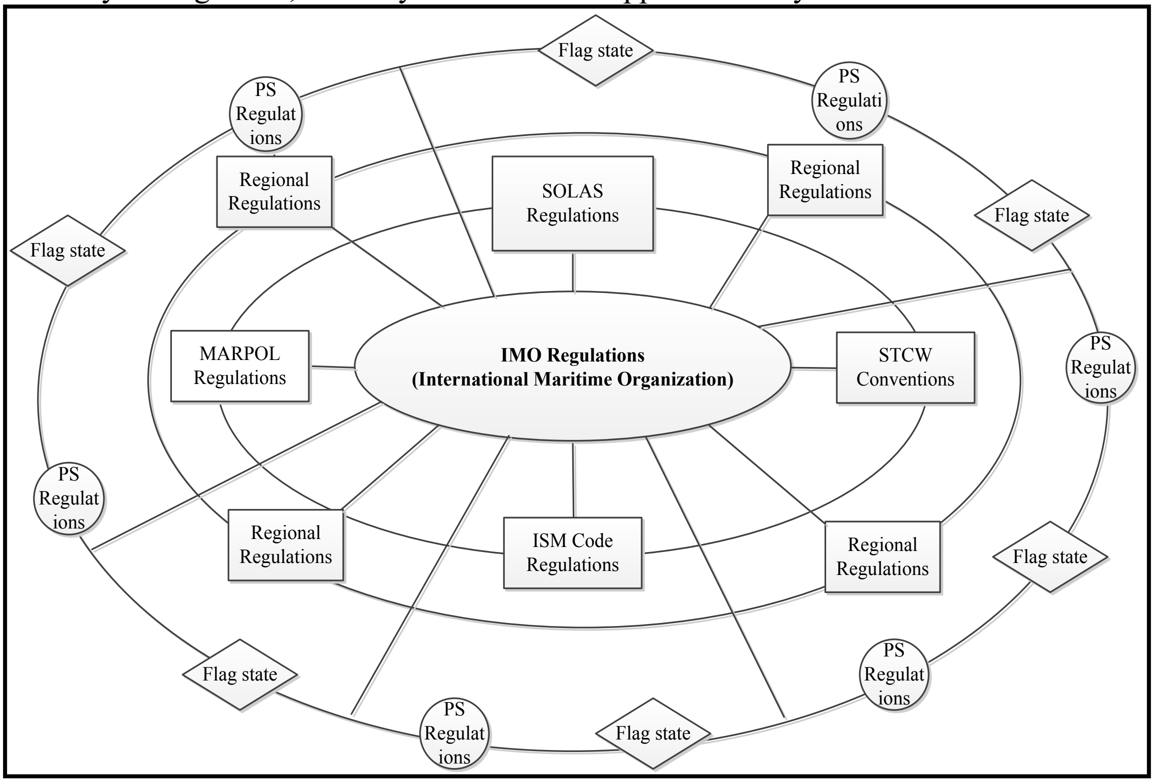


Fig.2.1 Types of safety regulations

There are many safety rules with varying levels of interest and application. Thus it helps to group or classify them in some way, so as to assist in gaining an understanding of their roles and applications such as IMO (International Maritime Organizations) Regulations, local rules, Flag state and Port State (PS) regulations. This classification involves the details in section below:

2.3.1 International Regulations

Regulations in this group have international implications that they affect ships which operate in international waters. They come from the International Maritime Organization (IMO) through conventions, protocols and resolutions which are then processed through various committees. First, in 1948 an international conference held in Geneva, Switzerland adopted a convention to formally establish the Inter-Governmental Maritime Consultative Organization (IMCO), but it did not come into force until 1958. IMCO was changed to the International Maritime Organization (IMO) in 1982. It now has its permanent building in London and had a membership of 170 member states s and three Associate Members are entitled to attend, as are the intergovernmental organizations with which agreements of cooperation have been concluded, and non-governmental organizations in consultative status with IMO [14]. There are many international regulations relating to maritime safety, as highlighted the below:

2.3.1.1 Safety of Life at Sea (SOLAS) Convention

Safety of life at sea has always been most important issue ever since ships were used to carry passengers and cargoes, but it was only after the sinking of the passenger ship Titanic that formalization began. The Titanic sank on 12 April 1912 with the loss of 817 passengers and 673 crews on her maiden voyage from Southampton to New York. This led to calls for unifying separate safety agreement to ship safety e.g. mutual recognition of certificates and survey and more coordinated approach to the safety life at sea. Fig. 2.2. details the conference of SOLAS.

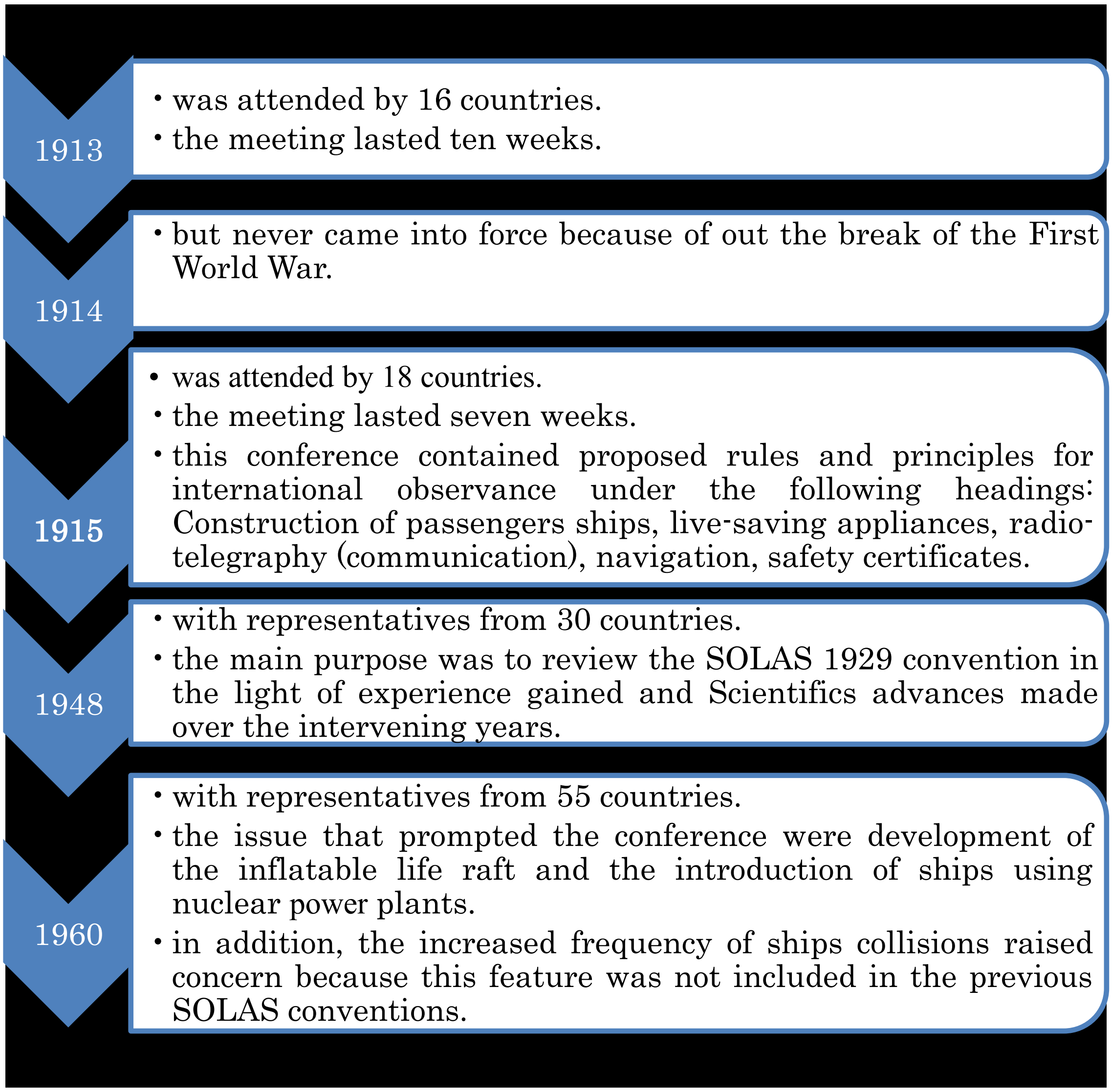


Fig.2.2 History of SOLAS

This led to the revised SOLAS 1960 and further conferences took place in 1974, 1990 and 1995 with significant amendments made regularly. The latest version of

SOLAS regulations are given in IMO [15].

2.3.1.2 Prevention and Control of Pollution from Ships (MARPOL) Convention

Growth in demand for oil as the primary energy source is the second half of the 20th century led to the development of increasing size and cargo capacity. These VLCC's (Very Large Crude Carrier) transported oil to and from both on-shore and off-shore refineries. This increase in maritime traffic introduced a new problem, which of Marine Pollution from oil. There are effects of activities of shipping that influence marine pollution it can occur in several ways with the most significant being runoffs from land into rivers and adjacent seas; collisions between ships, grounding, discharging of oil, and disposal of engine room wastes into the sea.

The regulations are made to cover accidental and operational oil pollution of the sea caused by chemicals, goods in package form, sewage, and garbage. There are also the problems of air pollution and that is dealt with under new regulations. IMO was given the task to design and build a system to provide compensation to those who had suffered financially as a result of pollution. For details see the IMO regulations [16].

2.3.1.3 STCW Conventions

Kuo [17]. The International Convention on Standards of Training, Certification and Watch keeping for Seafarers (STCW) was first held in 1978 and was the first to set minimum standards for training and certification of ship officers.

In 1995 amendments were done to the convention in 1978 and two-part STCW code was produced.

Part A of the code is mandatory. The minimum standards of competence required for seagoing personnel are given in detail in a series of tables. Chapter II of the code, for example deals with standards regarding the master and deck department.

Part B of the Code contains recommended guidance which is intended to help parties implement the convention.

There are two aspects of STCW 95 that are worth a brief comment. Firstly chapter I dealt with a number of common issues that have significant implications. For example, the concept of Port State Control, where the port could hold the vessel for deficiencies in meeting code regulations such as certificates, not in the order. Others include the use of simulators for crew training, fatigue and prevention personnel as a precaution. Secondly, not all countries were willing to be party to the convention, and a special feature required the contents of the convention to be obeyed by ships of non-parties countries while visiting ports of countries who are parties. A major change was the authority given to verify the training providers in all countries where such facilities exist. The STCW Convention is currently being revised again at the time of writing.

2.3.1.4 The International Safety Management (ISM) Code

Oltedal [18]. The ISM Code became mandatory for all merchant vessels above 500 gross tons in two waves, depending upon type of vessel, namely, July 1, 1998, and July 1, 2002. Until the adoption of the ISM Code, IMO had attempted to improve shipping safety largely by improving the hardware of shipping (e.g., the construction of ships and their equipment). By comparison, the ISM Code focuses on the way shipping companies are managed. The ISM Code is the first to provide regulations and guidelines to promote the development of sound management and operating practices in order to ensure crew safety and avoid damage to the environment. The shipping industry is known to have a reactive approach toward safety as the process of regulating the activity has evolved primarily as a response to maritime disasters. Development of the ISM Code was also based upon a growing recognition that loss of life at sea and environmental pollution are influenced by the way in which companies manage their fleets.

The ISM Code requires shipping companies to develop, implement, and maintain a safety management system, which includes the following functional requirements: (1) a safety policy; (2) instructions and procedures to ensure safe operations of ships in compliance with relevant international and flag state legislation; (3) defined levels of authority and lines of communication between and amongst shore and shipboard personnel; (4) procedures for reporting accidents and non-conformities with the provision of the ISM Code; (5) procedures to prepare for and respond to emergency situations; and (6) procedures for internal audits and management reviews. In the code's guidelines, emphasis is placed on near-miss reporting and how to create an organizational atmosphere in which people are willing to report accidents and non-conformities by developing a just culture.

The concept of culture is known to be a fundamental element in James Reason's [19] theory of safety culture and safety management also. Moreover, in order to achieve the development of an organizational safety culture, IMO identifies three key elements: (1) recognizing that accidents are preventable by following correct procedures and establishing best practices; (2) constantly thinking about safety; and (3) seeking continuous improvement. IMO's approach and perspective to safety culture is apparently instrumental, where safety culture is seen as something that may be engineered by an organization's structures and control systems in order to produce desired behavioral norms and accompanying safety outcomes.

Molland [20].The main topics in the ISM Code are the emergency preparedness by establishing procedures and programs for drill and exercises (section 8), to ensure that the master is properly qualified for command, and is given the necessary support to perform his duties safely (section 6). Responsibilities and authority aboard the ship must be defined, and a person ashore having direct access to the highest level company management must be designated to provide a link between the company and those and board, to ensure the safe operation of the ship (section 4). The master's responsibility and authority is particularly defined (section 5), in particular implementing the policy, motivating the crew, issuing instructions, verifying that requirements are observed and reviewing the safety management system (SMS) for the ship.

2.3.2 Regional Regulations

Kuo [21]. These regulations have been devised by one or more countries and the requirements have to be satisfied by ships entering the regional waters and generally, there is a correlation with international regulations. International regulations can be regarded as directives given by IMO to member states. They could then "fine tune" them in order to meet flag state's specific requirements. Sometimes of group of countries have similar problems and more coordinated approach would be more beneficial than each flag state action on its own. This is true while there are already formal arrangements for the group of nations to function in cooperative manner.

For example, the European Union (EU) has, in 2006, 25 members and it has regulations for maritime activities would tend interface well with international regulations. From time to time, one or two major maritime accidents occur and maritime safety raises its profile under media and public pressure. This type of situations often leads to calls for regional regulations to safeguard the maritime interest of the community.

2.3.3 Flag State Regulations

Oltedal [22]. Under international law, it is the flag state which regulates all the ships registered in the country of the flag. Some of the regulations can be similar to international and regional ones but others are specified within the flag state. Each flag state may have a national register, second register, and/or open register. A national register is reserved to vessels with national ownership. Second registers, which are additional to national registers, are mostly open registers. In an open register, ships owned by foreign entities may register. The creation of second registers is a response to intensified competition in the market for ship registration. In the early 1980s, the shipping market experienced a severe depression. Since the late 1980s, a number of states have created second registers in addition to their first national register in order to provide some or all of the advantages of an open register as a result of the economic crisis.

2.3.4 PSC (Port State Control)

According to the IMO (International Maritime Organization)
Port State Control (PSC) is the inspection of foreign ships in national ports to verify that the condition of the ship and its equipment comply with the requirements of international regulations and that the ship is manned and operated in compliance with these rules.

Many of IMO's most important technical conventions are provisions for ships to be inspected while they are visiting foreign ports to ensure that they meet IMO requirements. These inspections were originally intended to be a backup to flag State implementation, but experience has shown that they can be extremely effective, especially if organized on a regional basis.

This ensures that as many ships as possible are inspected but at the same time prevents ships being delayed by unnecessary inspections. The primary responsibility for ships' standards rests with the flag state but port state control provides a "safety net" to catch substandard ships.

Oltedal [23] IMO has encouraged the establishment of regional port State control organizations and agreements on port State control - Memoranda of Understanding or MoU's - have been signed covering all of the world's oceans: Europe and the north Atlantic (Paris MoU); Asia and the Pacific (Tokyo MoU); Latin America (Acuerdo de Viña del Mar); Caribbean (Caribbean MoU); West and Central Africa (Abuja MoU); the Black Sea region (Black Sea MoU); the Mediterranean (Mediterranean MoU); the Indian Ocean (Indian Ocean MoU); and the Riyadh MoU.

2.4 Responsibilities Human Elements in Safety Culture

The development of safety culture in international trade and shipping in today's globalized market has to a large degree determined the regulative structure of the seaborne industry. The international regulative system is of high priority for the safety of ships and crew sailing on the seas, as every shipping company is required to relate to this during daily operations. In order to gain proper understanding of safety management within shipping, knowledge of the most important laws and the international regulative framework is necessary.

Having an effective safety culture is more and more considered as one way to achieve the desired safety standards as it pays good attention to human behavior. The goal is to find ways to develop a positive attitude towards safety and encourage safe behavior to minimize human errors and violations.

In analyzing accidents, marine and non- marine, it has been noted that humans play a key role. Sometimes they are responsible for causing the accident and their actions sometimes have increased to prevent catastrophic incidents. While technology interactions with humans are how people behave during work and their attitudes while a part in contribute to the accident. It is important features are known in others factors such as media and management.

In Kuo [24] pointed out that:

The main features of safety culture can be considered under the following headings:

<u>Safety thinking</u> is safety culture related to how people think about safety in the context of what they are doing in a variety of activities and the decisions are made.

<u>Human behavior</u> is about how humans will behave in various situations.

<u>Attitudes</u> is influenced by the attitude held can vary from a very responsible and positive attitude to irresponsible and negative attitudes.

2.5 Implementation Safety of "Human Elements" in 4M (Man, Machine, Media, Management) Factors

In the maritime system established by Rothblum [25], people-related human elements include knowledge, skill, abilities, memory, motivation and alertness. Kuo [26] incorporated the following human elements into safety systems: personal capabilities including both intellectual capabilities and physical capabilities; the influence of personal characteristics (such as personality, response to stress, attitude and leadership and teamwork qualities) on performance; the influence of hardware, software, and the working environment on human beings' performance; and the impact of the safety culture on human beings' behavior.

Clearly, the human elements commonly identified in maritime system are people abilities and limitations, the influences of man, machine media, and management. Taking into account the characteristic of maritime accidents within the human elements to be explored in this dissertation mainly focuses on the unsafe actions of seafarers, and the underlying contributors such as the operators' personality that have a deep influence on the operator's performance. The external elements including the environment, the society and ship itself that have a direct contact with operators will be deemed as one aspects of the human elements. The detail of these human elements, found by approaching one aspect such as unsafe actions in the taxonomy (classification) error will be discussed in chapter 6.

CHAPTER 3
THEORIES OF ACCIDENT CAUSATION

It is important to recognize that a product or system is designed then given input by humans. Humans are using product, making decisions, taking action, modifying, and ignoring instructions. It is really important to know how to create so that humans can produce a good performance from their own perspective.

This chapter describes an overview of humans in accident causation viewed from several factors that are the element of human factors such as physical, physiological factors, psychological factors and psychosocial; and their limitations. Additionally is the need to recognize accident causation not only from unsafe actions because in other studies there are theories unsafe conditions.

3.1 Human Factors

Investigations about accident have identified many causes contributing to their occurrence. The fact that human error contributed to the accidents is generally accepted but there is no consequence of the importance of this factor. Regarding the proportion of marine accidents caused by human errors varies from 50 percent to 90 percent of the total. P & I Club reports covering the years 1987 to 1991 support these statistics and point to claims, especially in terms of cargoes, pollution, collisions, property damages and injuries to both crew and non-crew. Firstly, in 60 percent of the total number of claims recorded, human error was a direct cause, and over 30 percent human error was an indirect contributions Kuo [27].

The Marine Accident Investigation Branch (MAIB) [28] of the United Kingdom Department of the Environment publishes an annual report of maritime accidents. For the year 1999, the MAIB noted the relative causal factors of maritime accidents involving death. Summarizes their findings about 37 % of accidents leading to death are attributable to human factors. Looking deeper, 25% is attributable to “working methods” and an additional 17 % to “movement about ship”. In the United States, the human factors and ergonomics community considered working methods and movement about the ship to be within the scope of human factors/ergonomic concerns (e.g., task and vessel design and procedural practices).

Feyer, et al. [29]. In the context of the safety of maritime systems, “human factors” covers “a wide range of elements involved in the interaction between individuals and their working environment.

UK Health and Safety Executive [30] the phrase “human factors” means:
The perceptual, mental and physical capabilities of people and the interaction of

individuals within job and working environments, the influence of equipment and system design on human performance, and, above all, the organizational characteristics, which influence safety-related behavior at work.

Both the above quoted in Petersen, D [31], L. Zhejiang [32] definitions cover the human beings' capabilities, jobs and working environment, the effects of system designs on human performance and organizational characteristics. These are really important observations with a number of human element related initiatives charged with developing and providing effective means to design equipment for human use, and to address man, machine, media, management that are proven to minimize the human error.

3.2 Scoping Human Elements Involved

Here, some important information is conveyed. First, human beings are treated as a component of a system. In this system, there are still some other components. So the term "human elements" may be used to refer to human beings' functions and performances in the system.

As mentioned in [33], human element is a component of a system. For the task of exploring the impacts of human elements involving casualties in incidents or accidents, it is necessary to identify all human elements involved in safety in maritime transport system.

3.2.1 Relation in Personality

In the personality of a human being there are several things that must be considered then and then developed by the individual. Here are some important things to consider about factors in human within personality (see in table 3.1) IMO [34]

Table 3.1 Human personality

Within a personality		Limitations
Factors in humans	Element in humans	
1. Physical factors Description : physical capability of the individual to perform required actions and movements	Age; sex; strength; weight, sitting; height; reach, etc.	1.Memory 2. Workload 3. Attitude 4. Personality traits 5. Experience 6. Knowledge 7. Training
2. Physiological factors. Description: Physiological condition of individual including stable and transitory states which could affect the individual's	Nutritional factors; health, stress; fatigue; communication skills; mood; reaction time error rates; sensory limitations; Illusions; alcohol; drugs,	

situational awareness and behavior.	partial incapacitation.	
3. Psychological factors. Description: Maintaining situational awareness is paramount to ensuring safe voyage.	Information processing, with consider about sensing, perception, decision making, action and feedback.	
4. Psychosocial. Description: Individual's approach to situation, include any event or condition in the individual's social environment.	Personal loss, interpersonal conflicts, financial problems, significant life style changes, family pressure, culture differences.	

Source: IMO, 2000

3.2.2 Relations in a Maritime System

The culture of an organization can be defined as the way to do things around environment working such as culture provides a context for action which binds together the different factors. They are influenced by the factors 4 M (Man, Machine, Media and Management) in the maritime system. Maritime system covers conditions of activities in shipping which have beneficial values and social effects to every country. Pointed out from Rothblum [35] as mentioned earlier, the maritime system is a people system (fig.3.1). People interact with technology, environment, and organizational factors. Sometimes the weak link is with the people themselves; but more often the weak link is the way that technological, environmental, or organizational factors influence the way people perform. Let's look at each of these factors.

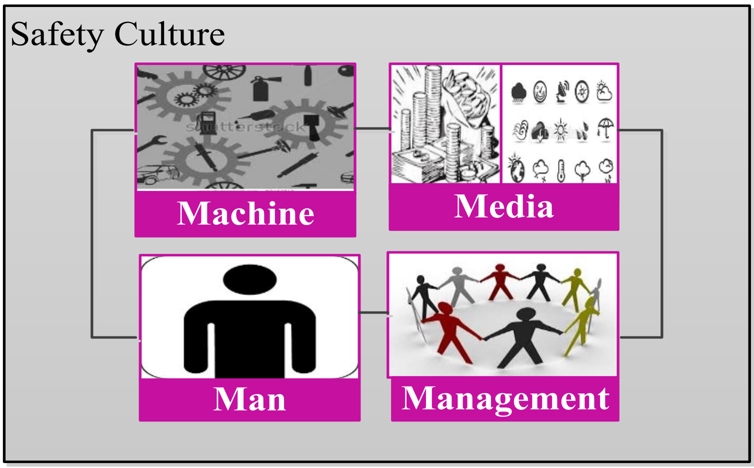


Fig.3.1. Maritime system in 4M (Man, Machine, Media and Management) factors

Regarding in fig. 3.1, can be described as follows:

The man of the maritime system is includes the ship's crew, pilots, dock workers, Vessel Traffic Service (VTS) operators, and others. The performance of these people will be dependent on many characteristic of both innate and learned behavior. As human beings, all have certain abilities and limitations. For example, there isn't a machine in the world that can interpret a radar screen as well as a trained human being can. On the other hand, we are fairly limited in our memory capacity and in our ability to calculate numbers quickly and accurately. Machines can do a much better job. In addition to these inborn characteristics, human performance is influenced by knowledge and skills also. It has acquired, as well as by internal regulators such as motivation and alertness.

The design of machine or technology is influenced by how people perform. People come in certain sizes and have limited strength. For example, a manned machine that is designed to be used outdoors only has a key-board entry password that cannot be entered by gloved hands/fingers; or a cut-off valve that is positioned out of easy reach. Both will have a detrimental effect on performance.

Automation is often designed without much thought to the information that the user needs to access. Critical information is sometimes either not displayed at all or else displayed in a manner which is not easy to interpret. Poor design can lead to inadequate comprehension of the state of the system and to poor decision making.

The condition of the environment or media can also affect of human performance. By environment are included not only weather and other aspects of the physical work environment (such as lighting, noise, and temperature), but also the regulatory and economic climates. The physical work environment directly affects one's ability to perform. For example, the human body performs best within a fairly restricted temperature range. Performance will be degraded at temperatures outside that range, and fail altogether in extreme temperatures. High sea states and ship vibrations can affect locomotion and manual dexterity, as well as cause stress and fatigue. Tight economic conditions can increase the probability of risk-taking (e.g., keeping schedule at all costs).

The condition of management includes crew organization and company policies and these also affect human performance. Limitations of crew size and training decisions directly affect crew workload and their capabilities to perform safely and effectively. A strict hierarchical command structure can inhibit effective teamwork, whereas free, interactive communications can enhance it. Work schedules which do not provide the individual with regular and sufficient sleep time produce fatigue. Company policies with respect to meeting schedules and working safely will directly influence the degree of risk-taking behavior and operational safety. In establishing the structure of a maritime system, the components such as operator, ship environment and society are considered. Accident occurrence has also been included into the system structure.

3.3 Human Error

The majority of accidents occur due to human actions in making decisions or taking action. But in addition to unsafe actions are also considered unsafe conditions. Because of numerous condition hazards in the workplace it is not always possible to identify and eliminate all but an effective accident investigation program is very important to know critical data of behavior in taxonomy error. Accident prevention can be assisted by identifying the root cause of the accident, and this is made possible by techniques such as accident investigation theory and the theory of human error causing accidents.

3.3.1 Heinrich Domino theory

Hosseinian et al. [36] describes about Heinrich was the pioneer in the accident causation theories. He proposed that the accidents causation theory between man and machine has a relationship in the term of frequency and severity of action. Abdelhamid, T, et al. [37] The unsafe actions are considered wherefore the management role is needed approach to accident prevention, costs of accidents and the impact of safety on efficiency. According to statistics on accident reports Heinrich deduced that 88 percent of accidents are due to unsafe actions of workers, 10 percent due to unsafe conditions and 2 percent of all accidents are associated with act of God such as natural disasters or force majeure. Fred A.Manuele [38] describes that according to Heinrich, man failure is the problem and psychology is an important element in correcting it. Selection of remedies is based- on practical cause-analysis that stop at the selection of first proximate and most easily prevented causes in the selection of remedies (See fig. 3. 2).

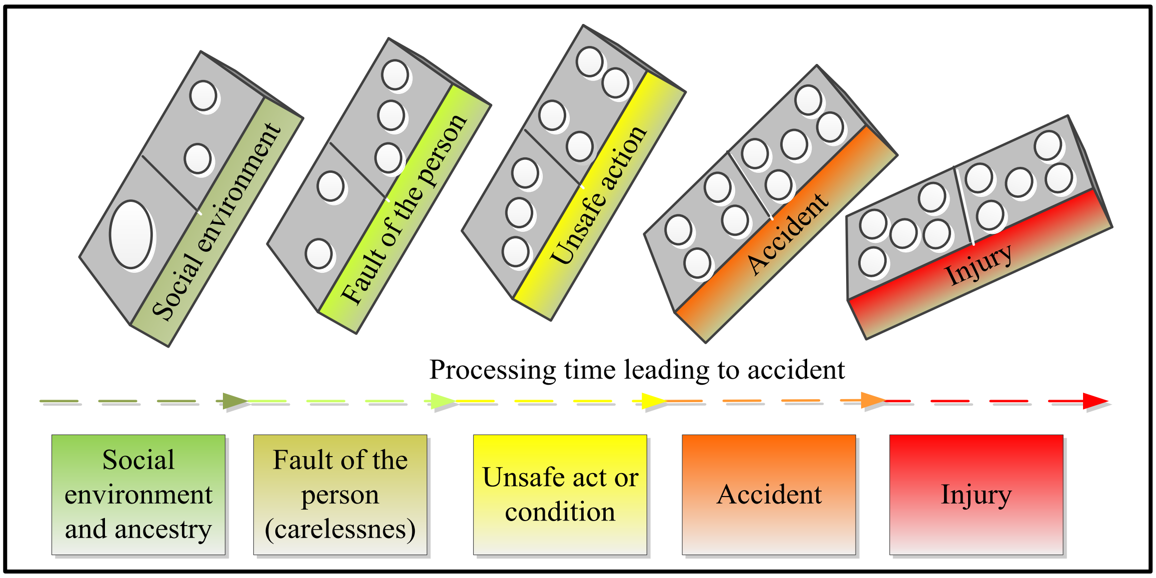


Fig.3.2 Domino theory of accident causation

Heinrich established the 'Domino theory' which is based on five sequential factors as following, Taylor, G,et al. [39]:

a. Ancestry and social environment. Ancestry and social environment are the process of acquiring knowledge of customs and skills in the workplace. Lack of skills and knowledge of performing tasks, inappropriate social and environmental conditions will lead to faults of person.

b. Faults of person (carelessness). Faults of person or carelessness are negative features of a person's personality although these unwanted characteristics might be acquired. The result of carelessness is unsafe act/conditions.

c. Unsafe actions and/or mechanical or physical condition. Unsafe actions/conditions include the errors and technical failures which cause the accident.

d. Accident. Accidents are caused by unsafe acts/conditions and subsequently lead to injuries

e. Injury. Injuries are the consequences of the accidents.

The Heinrich's domino theory is comprised of five standing dominos which will fall one after the other if the first domino (Ancestry and social environment) falls. The accident can be prevented only if the chain of sequence is disturbed, e.g. the unsafe actions/conditions can be eliminated in order to prevent the accidents and associated injuries. Heinrich's domino theory was credited for the process of simplifying the human behavior control in accidents. Heinrich domino theory became the basis for many other studies on accident causation models with the emphasis on management's role in accident prevention; these studies are called Management Model or Domino's Updated Model. Management models believe that the management system is responsible for occurrence of accidents.

3.3.2 The 'Swiss Cheese' Model

Ridley, J. et al. [40]. The 'Swiss Cheese' accident causation model was first developed by James Reason (1970-1977) as a linear accident causation model. The theory is currently widely used since it simply suggests that the organizations tries to prevent accidents by defenses in order not to allow the risks and hazards become loss (see fig.3.3). These organizational defenses are divided into two groups:

1. Hard defenses are automatic alarming systems, physical obstacles, engineered safety appliances and weak points included into the main system for protection such as fuses.
2. Soft defenses are dependent upon the personnel and procedures, regulations of required performance, investigation, checking, regular procedures of performance, education and training, supervision and working permission. Soft defenses also involve supervisors and operators as the pioneers. Losses to people, equipment, assets are the

potential consequences of hazards in an organization.

Reason claims that a trade-off exists between the level of protection provided for the product and the production. The risks included in any product should be defended by the organization for the well-being of customers but the level of safety and protection should be equivalent to the risks associated with the work overview in Seyyed S. H, et al. [41]. If the level of protection is higher than required then the company will not be commercially profitable and if the protection level is less than the associated risks the occurrence of accident is susceptible and the organization will lose the business opportunities. The equilibrium between the protection and the production is essential for the durable commercial survival of the business; since the production process is visible the product can be managed and inspected for the desired output but the level of protection can be measured only after the inadequacy is determined. See in fig.3.3.

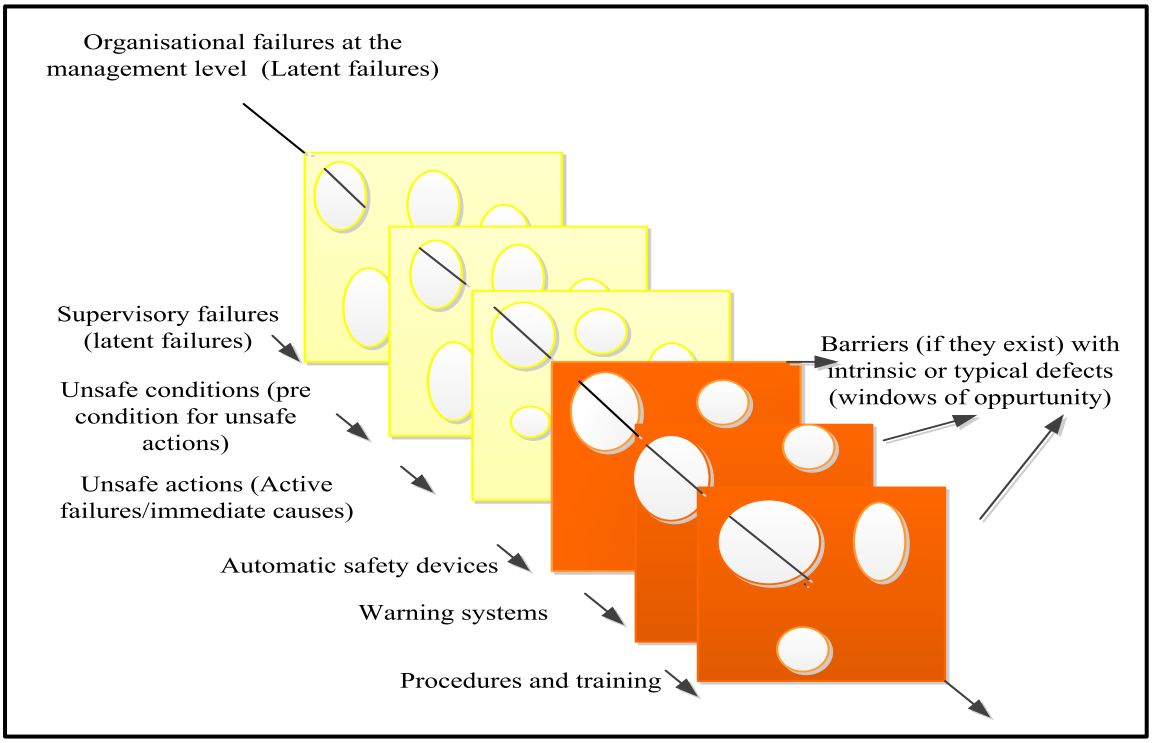


Fig.3.3 Swiss cheese Accident Causation Model (James Reason, 1970-77)

Although organizational accident defenses are seen as obstacles which prevent the hazards from converting into losses, the obstacles and barriers have holes in them like slices of Swiss cheese. Reason called his model Swiss cheese because of theses defects in the organizational defenses. The foremen of an organization are in charge of the sharp-end procedures which represent the “unsafe actions” slices of cheese in the model. The holes in the unsafe actions slices are the human errors or unsafe actions. Reason believed that accidents are caused by active failures and immediate causes which are the results of mistakes, slips and violations of standards. Accidents can be either caused by singular human error or a combination of them as immediate causes of accidents; the combination of violation and mistake is a very usual cause of accidents. There have been a lot of improvements in technology and engineering and that means that technical failures should be eliminated. Therefore most of the time human error is blamed to be the major cause of accidents. In fact, the more improvements have been achieved in technology and engineering, the more the number of accidents caused by human error are reported. Unsafe conditions are represented by holes in the next slice of Reason. Swiss cheese model: the unsafe conditions and the psychological risk factors are the contributory factors to unsafe actions of workers. Unlike active failures and immediate causes in previous slice, the holes in this slice are the hidden contributory factors of accident. The relationship between unsafe conditions and unsafe actions are a one to many interactions. Unsafe conditions can lead to many hazards and unsafe actions in pointed out Stranks J. W. [42].

3.3.3 Accident Root Causes Tracing Model (ARCTM)

Fang, D.et al. [43]. This model is Accident Root Causes Tracing Model (ARCTM) it shows further advances from many of the previous accident models. Many important rules of the model have been derived from the effort of Heinrich (1959), Petersen (1971), Bird (1974), Ferrell ((as referenced in Heinrich et al. (1980)), and Petersen (1982). The main concept proposed in ARCTM is that an occupational accident will occur due to one or more of the following three root causes.

a. Not identifying unsafe conditions that existed before an activity was started or that develop after an activity was started.

b. Not deciding whether the next action is right, even after the worker identifies the existence of unsafe condition (ignoring unsafe condition).

c. Deciding to take unsafe actions regardless of initial conditions of the work environment.

Clearly, these root causes develop because of different reasons, and also point to different issues that should be considered for corrective actions. ARCTM was designed to guide the investigator through a series of questions and possible answers to identify a root cause for why the accident occurred and to investigate how the root cause developed and how it could be eliminated.

3.4 Safety Response Model (SRM) - Summary

Investigation of the accident should be based on the root cause of the problem. Generally the root cause of the problem comes from unsafe conditions and unsafe actions or otherwise when unsafe actions were caused by unsafe conditions. Events have occurred that will accumulate regardless of whether human behavior is evidenced by human error, human factors or human elements. Every event has the probability of a risk, but in following the developments and lessons learnt from prior accidents previously studied, newer methods can minimize levels of accidents.

When looking further about the accidents that occurred in the maritime management system, there is no single causation factor; the work environment is a reciprocal relationship between man, machine and media in maritime management system. Accident investigation is generally a way of result finding: an investigation's analysis of the factors contributing to the accident and recommendations, the investigation's suggestions as to how similar accidents could be prevented. Results of findings need to be used to apply to standard safety rules to help rearrange events to be safe. When it is implemented, the priority of safety will be known.

Relationships of factors that are intended to produce a strong safety culture in workplace, and which is supported by the right decision (fig. 3.4). The root causes analysis will be explained in Chapter 5 to show the relationship in maritime accidents.

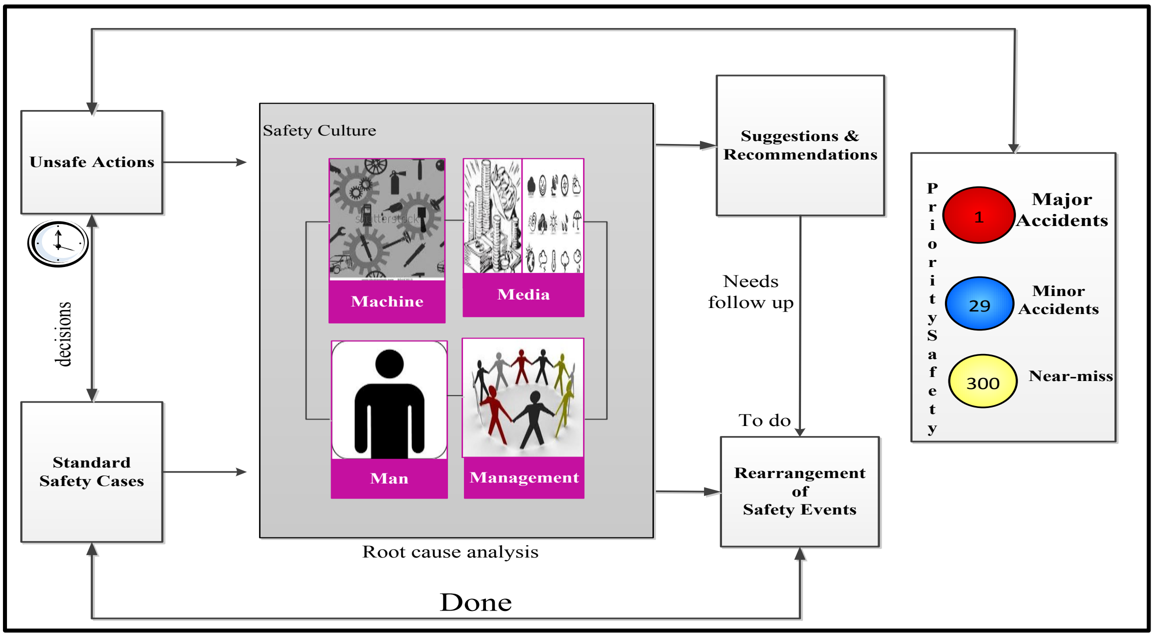


Fig.3.4 Steps response of safety

CHAPTER 4
PERSONAL IDENTIFICATION (PIN) SAFE MODEL FOR UNSAFE ACTIONS IN THE DESIGN OF SAFETY CRITICAL SYSTEMS

Human factors within human elements are contributing to risk in safety critical systems. However, current approaches to integrating human element issues in the development of safety critical systems appear not fully sufficient.

Human error is a part that cannot be separated from the human element because it influences the actualization of a person's action or performance.

Personal Identification (PIN) Safe is modeled to devise a systematic identification of substandard, unsafe actions and critical events associated with characteristic maritime accidents.

This section's results are researched of the human elements that produce unsafe actions when interacting with equipment and other systems. Procedures develop deviations which become human error instigated unsafe actions. This is particularly true of collision accidents and human casualties. Depending on the social atmosphere of the working environment, limitations of self can be attributed as cause for accidents. This model will be an opportunity to improve safety culture at sea.

4.1 Overview Countermeasures in Unsafe Actions

Ian Sommerville [44]**.** A critical system is any system whose 'failure' could threaten human life, the system's environment or the existence of the organization which operates the system. Failure in this context does not mean failure to conform to a specification but means any potentially threatening system behavior, so it can also be said that the failure is "unsafe actions".

Socio-technical critical systems have failures that often occur, including the following:

Hardware failure

Hardware fails because of design and manufacturing errors or because components have reached the end of their natural life.

Software failure

Software fails due to errors in its specification, design or implementation.

Operational failure

Human operators make mistakes. Now perhaps the largest single cause of system failures. People and operational processes are very important elements of critical systems. Systems have properties which are emergent.

Risk reduction is a key factor in the design of safety in critical systems. Human error is an essential part during the risk reduction process. When a system is operational a human may create failure and the system itself is design so that it can be provide the help needed to overcome it. The integration of human factors analysis into systems design is traditionally a difficult problem. Author and designers need to be able to explore and evaluate solutions.

In this chapter an approach is presented that allows the design of risk reduction and safety barriers and that supports barrier implementation.

4.2 Integrated PIN Safe Design in Unsafe Actions

Leading operational system with latent safety may create adverse effects, e.g. hazards, to system itself, or to its environment. A design team will use tools to identify such potential hazards. If humans participate in a system, designers may resort to well established human factors methods such as human reliability analysis (HRA), THERP4, or HEART5, or to human factor experts.

Reliability of a safety critical system is vital when there are risks for human beings in its environment, such as unsafe actions in a maritime accident. These people may interact with the system or not. In safety critical systems, people need to be aware of these risks and know what to do in the case of problems. Based on these reasons, Personal Identification (PIN) Safe method is done in logic of pattern as value within human beings. In the structure within management information (see fig.4.1) is an important issue. It takes the form of experience feedback of every seafarer, and incorporates traceability and various types of information system to know path and processes interact in the working environment.

Other ways in this chapter have been attempted to give the structure of Personal Identification (PIN) Safe model as a systematic identification of unsafe actions with the processing of characteristic accidents on a ship. A comprehensive PIN Safe should be done to eliminate or to control during the operational in lifetime of a ship particularly unsafe actions. Both the engineering and the management of measuring instruments, especially databases that are in place to control process parameters, should be addressed. How these controls are degraded by technical failures, human failures or external failures, to lead to undesired events, constitutes an elaborate part of PIN Safe.

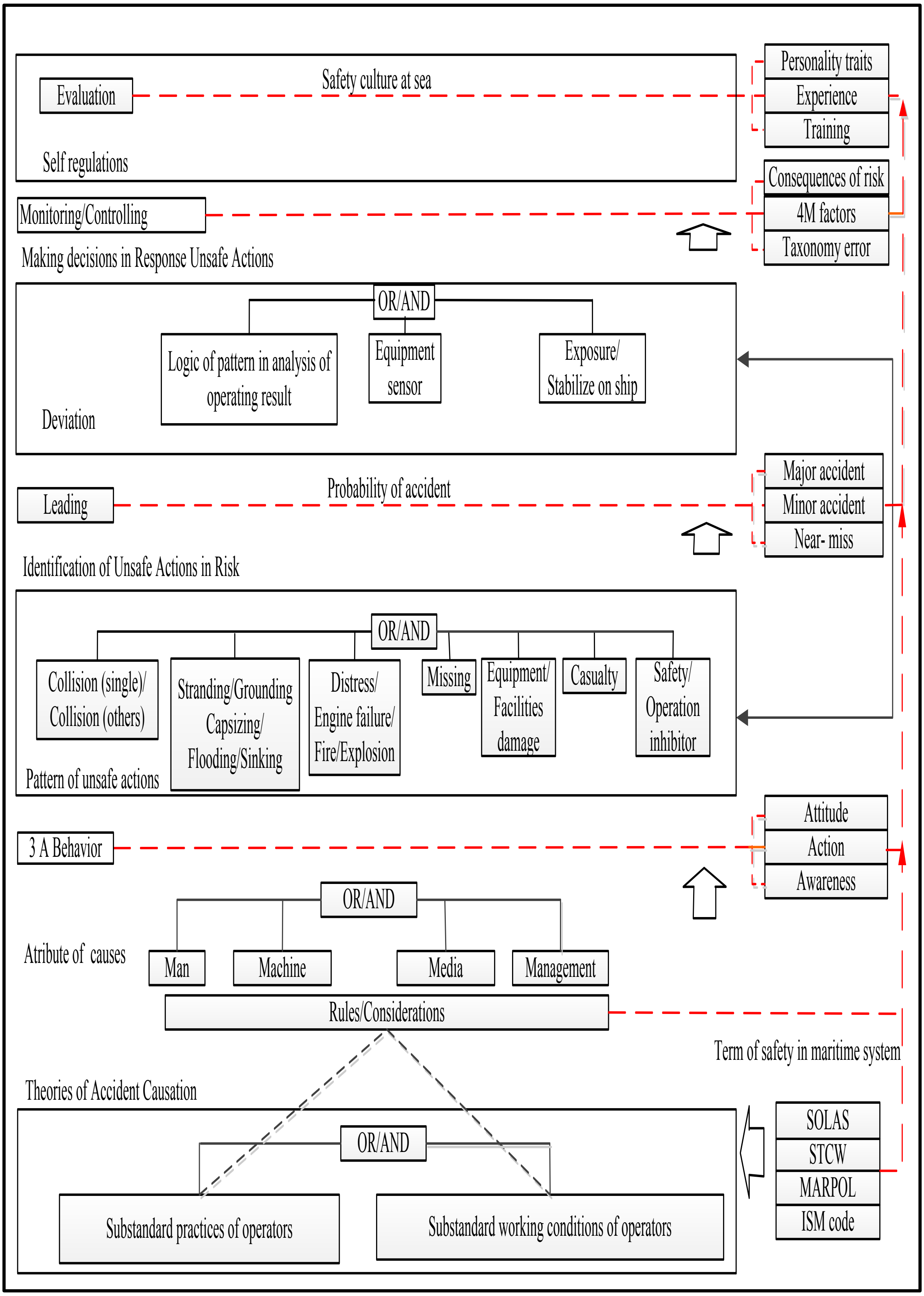


Fig.4.1 Strategy of Personal Identification (PIN) Safe model at maritime accidents

4.2.1 PIN Safe in Identification of Unsafe Actions

In an incident investigation, the investigator starts with the immediate actions and events surrounding the incident and then works backwards to uncover contributing causes. In terms of human error, those immediately linked to the incident are typically “unsafe actions”. Thus, investigators must dig deeper into why the unsafe actions took place. As pointed out Anita Rothblum [45], as a first step, it is useful to consider any preconditions for unsafe actions. There are two major subdivisions of unsafe conditions (preconditions): substandard conditions of the operators and the substandard practices as they are committed. Substandard conditions are broken down from attribution of causes interacting with adverse mental states, adverse physiological states, and physical/mental limitations. Types of substandard practices include crew resource mismanagement and personal readiness. Each of these subcategories is discussed in the model of the characteristic of the human element in analyzing data.

4.2.2 PIN Safe in Management Strategy

Fig. 4.1, shows the accident/incident causation model. This is a key to understanding the kind of barriers that are needed to contain the propagation of an unwanted event. The model shows that the basic initiating events of any undesired event are technical failure, human failure or external failures or a combination thereof. Human beings are the weakest link in any engineering system S.G. Kariuki, et al. [46]. This is due to the fact that all engineering systems rely on human intervention in some respect. However, many methods do not give human failure the weight it deserves as a major contributor to unwanted events. Human failure is more complex than just a single operator action. To comprehensively address human failure, a broader perspective of the process of the voyage on board should be envisaged.

Strong management is needed to have the right time information at the real time and under the right format. Controlling a situation is not only a matter of availability of information or data. It is also a matter of knowledge and how to control process information (fig.4.2) Rivai,H.,et al. [47].

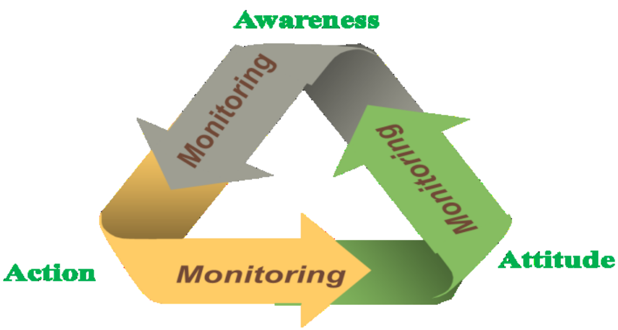


Fig.4.2 3A(Awareness,Action,Attitude) in control behavior

Table 4.1 3A in control behavior

Awareness	Awareness is the expression or ability to perceive, to feel, or to be conscious of events, objects, or sensory patterns. In this level of consciousness, sense data can be confirmed by an observer without necessarily implying understanding. Awareness of expression of decision-making is appropriated for retaining an item/part/equipment, restoring its given condition. Incorrect, incomplete or unclear planning of maintenance or operability verification actions such as maintenance, servicing, installation, alignment, corrective, inspection or functional testing phases of work. Deficiencies in definition of decision of work scope, work order, operation order or procedure.	Monitoring	Monitoring is generally means to be aware of the state of a system or condition of equipment and reflects on the effects of maintenance actions because of errors or deficiencies in the design or modification of documentation, equipment, systems, installations or computer programs.
Action	Action is process of doing something, to achieve an aim. Action of decision-making is taken in response to sudden and unexpected incidents. Because of the lack of knowledge or poor information on the violation, so specific training on human behavior in emergencies is given so that deviation violations can be minimized.		
Attitude	Attitude is steady way of thinking or feeling about something. Attitude of decision-making is considered as the ability to coordinate to control operations of equipment or systems. Methodological is the ability to explain the actions taken and methods used. Learning is the ability to analyze about incidents, accidents and operational experience. Mindfulness is needed everyday activities because lack of training, of specialist or cross functional knowledge for the tasks or their planning.		

4.2.3 PIN Safe in Anticipation of Engineering Controls

This includes anticipation of all human factors. Initiating events as unsafe actions will lead to process deviations. Measurement parameters in all operations by approaching by logic of patterns (Appendix-B) can help to suggest for improve motivation of self. Censoring of equipment by ergonomics design, it is useful to help to reach good performance in the working environment.

Knowledge of working environment is one part of the risk value of an individual ship and can indicate the probability of an accident for that ship for a given time and location. Fig. 4.3 Rivai.et al. [48] shows the probability of failures that exist in a navigation system that itself is influenced by several factors. The ship navigation system comprises ship, navigation environment, and navigation technology, all of which consist of different parts.

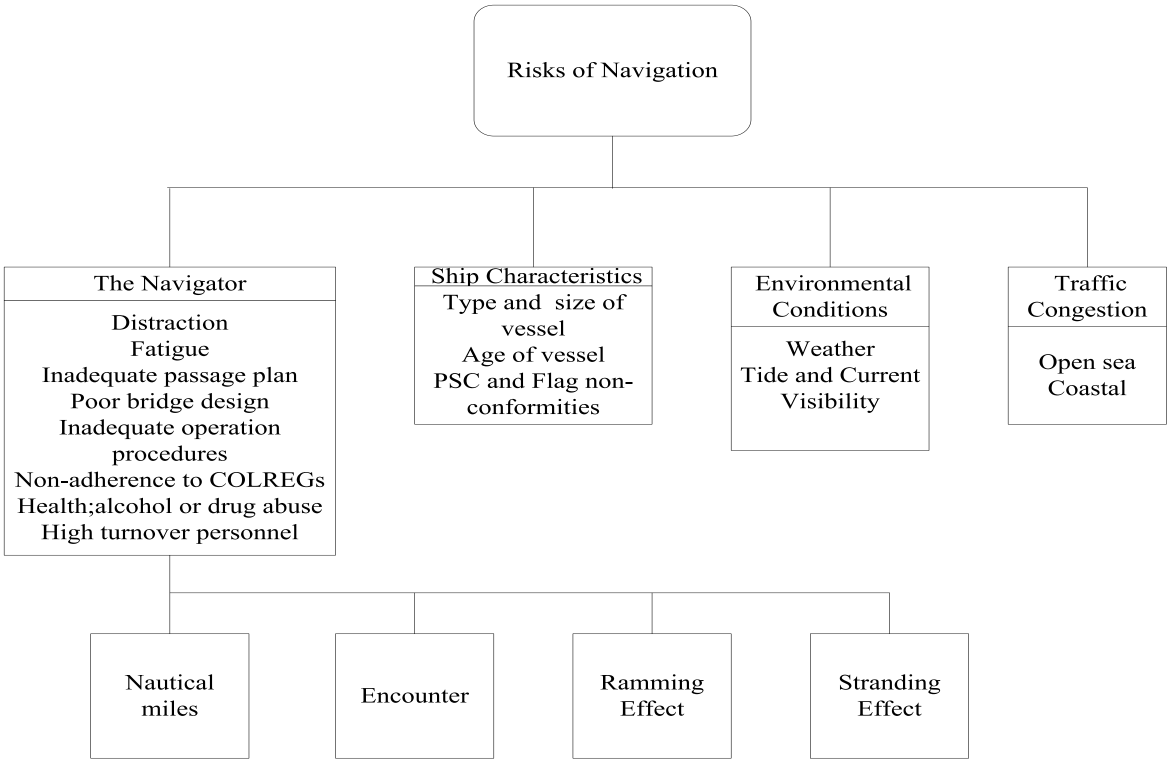


Fig.4.3 Condition of failure in navigation system

The accident probability for an individual ship is determined using so called "exposures" and a casualty rate. The exposures are the number of potential casualty sensitive situations in which the ship can be involved that could lead to an accident. For example, the exposure of collisions is an encounter between two ships. By relating these exposures with the actual casualties from the accident database, the casualty rates for the different accident types are derived Koldenhof,Y. et al.[49].When observing boating accidents, the failure probabilities are distinguished from the corresponding exposures, i.e.

Nautical miles. The nautical mile exposures are simply the time multiplied with the speed of the ship. The nautical miles are the basis for the calculation of the probability that a ship will be in an accident of the type such as founder, hull failure, engine failure or fire/explosion.

Encounter. The exposure measure for a collision is an encounter between two or more ships. There are two modes of the model. The first mode of the model, the collision risk, is calculated based on the average number of encounters for a ship per hour in the area. This model can be used to determine the average levels of risk in order to implement mitigating measures. In the second mode, the collision risk is calculated by the actual position, speed and course of all other ships in the area.

Stranding effect. The drifting contact occurs when a ship near the stranding line or fixed object experiences a failure in the propulsion engine or in the steering equipment. Since the ship slowly becomes uncontrollable as it loses speed, the combined effect of wind, waves and current may carry it towards the stranding line (or object). If dropping to anchor does not help or is impossible and the time for repairing exceeds the available time, the ship may cross the stranding line, which means that the ship grounds. This generally happens at a low speed.

Ramming effect. The ramming contact occurs when a ship is on a contact course with the stranding line, which means that a navigational error occurs. This error is undetected until the point of no return, and then the ship has contact with the stranding line (i.e. the ship grounds). The collision may be at the high or low speed depending on the time lapse between the point of no return and/or the implementation of corrective action after the detection of the error.

Flohberger, M, L. [50]. If a deviation proceeds uncorrected it may lead to an accident event. Engineering and management controls are protective measures which should be evaluated to establish how well the system could resist degradation due to a critical event. Condition on the dynamic behavior of the ship responsible for replicating the behavior of actual vessels in response to the actuators and the environment. The underlying dynamic model of the vessel must model both the rudder and the engine as they are the main actuators used during maneuvering as pointed out Karl Gunnar, et al. [51]. Taxonomy error as substandard unsafe actions of seafarer are an important part of the environment during navigation and maneuvering, and an experimental frame which is expected to accommodate in PIN Safe model of this process must include both the effects of the environment on the dynamics and the connection between the navigator and the environment. These controls include alarms, procedures, operator intervention, emergency relief and evacuation among others and are used when calculating the probability of risk value estimation. Maintaining to reduce unsafe actions is still important, though, in critical situations.

4.2.4 The Patterns of Unsafe Action in Risk Monitoring

Kirwan, et al. [52].Critical events have consequences, which have potential impact to accidents. Every accident that occurs when there has been interaction within unsafe actions of the seafarer in the working environment. Such interactions will have own characteristics or patterns.

Risk is the probability and severity of loss from exposure to the hazard. The assessment step is application of quantitative, qualitative or combined measures to determine the level of risk associated with a specific hazard. This process defines that will be easier to recognize taxonomy error in performance of seafarer. The probability weight (Appendix-C) within taxonomy error and severity of accident that could result from a hazard are based upon the exposures of unsafe personal actions. Personal exposures act as a key to developing human performance.

During operations workers will be affected by a given event or over time by repetitious event. Regarding these situations, the author has researched methods in controlling of taxonomy error of unsafe actions until within 4M factors as comprehensive monitoring information processing database. Those are needed for the role of management to evaluate. Strong management to identify every characteristic of unsafe actions is important in establishing the evaluation strategies. Evaluation of taxonomy error of unsafe actions till within 4M factors are one way to find a strategy to develop performance shaping factors for the seafarer to reach protective capacities.

The third type of exposure is as table 4.2:

Controlling 1:Hazard exposures monitoring.

Mapping in probability weight as information processing can help determine the level of exposures to the hazard and can recorded through database information of seafarers as protective capacity. This can be expressed in the terms of time, proximity, volume or repetition. Repeated exposure to hazard increases the probability of an accident occurring. Understanding that the exposure level can aid in determining the severity or probability of the risk in maritime accidents. Additional it measures a guide for devising control measure to limit exposures.

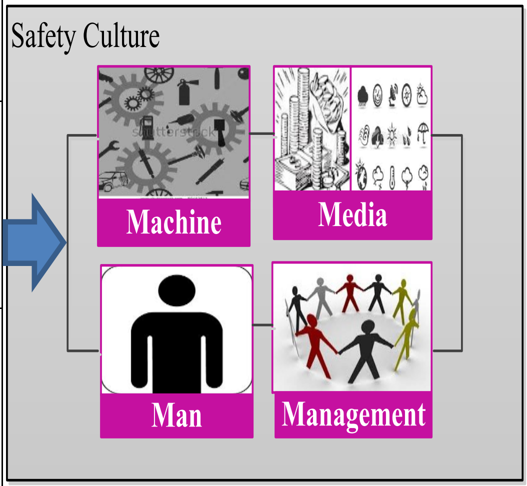
Controlling 2: Hazard severity monitoring.

Determining the severity of the hazard in terms of potential impact on the people, equipment or mission. Severity monitoring in database information processing should be based upon the worst possible outcome that can be reasonably expected. Severity categories are defined to provide in probability weight measure, one way to help prevent the worst credible accident resulting from limitations of human interrelations between environmental conditions, design inadequacies, procedural deficiencies, or system, sub system or component failure or malfunction within 4M factors.

Controlling 3: Probability monitoring.

Determining the probability that the hazard will be caused by risk in the term of severity as monitored in condition controlling I have mentioned above. Probability weight is considered in proportion to the cumulative probability of the identified unsafe action for risk (chapter 5). Assigning a measure accident to new strategy or system may be possible to implement in the planning process. An intelligent decision system will be created in the future research.

Table 4.2 3 keys in control of exposures

Controlling	Features	Expressed	Comprehensive aspect
Controlling 1	Hazard exposures monitoring	proximity; volume, repetition	
Controlling 2	Severity monitoring	potential impact on the people; equipment; mission;	
Controlling 3	Probability monitoring	determined through unsafe actions in actual numbers;	

Combinations of these in analysis can help result to minimize exposures on accident, to improve protective capacities in psychological factors based on IMO investigation of human factors. The further aspects can help and encourage self-regulations where possible as part effort to help develop a safety culture in the industry.

CHAPTER 5
IDENTIFICATION OF UNSAFE ACTIONS IN RISK

5.1 Introduction

Analyzing the human elements in accident of maritime system based on the statutory obligation to investigate marine casualties is in all main IMO/ILO Conventions. IMO Code A.849 (20) as amended by A.884 (21) for the investigation of marine casualties and incidents is widely applied although it is only a recommendation until now.

5.2 Source Data

The source data report that kinds of maritime accidents in the period 1998-2008 by Marine Accident Inquiring Agency (MAIA), Japan. The Japan Marine Accident Inquiry Agency (JMAIA), since October 2008 merged with the ARAIC (Air and Rail) and now known as the Japan Transport Safety Board (JTSB) is the Japanese government agency that investigated causes of accidents on ships. MAIA (Marine Accident Inquiry Agency) data search. The report of MAIA written that maritime accidents are selected as the main source for collecting the human element data involved in accident at sea.

Unfortunately, the author did not have about the report of investigation of maritime accident from JTSB (Japan Transport Safety Board). Author tries to explain scenarios relating to the causes of accidents associated by the frequency kind of maritime accidents has been happened by starting to analyze the human element as a factor that contributed the accident, the initially investigation began to study unsafe actions (as seen in fig. 1.1 and fig.1.2) and the others data report have written about percentage unsafe actions of maritime accidents in 1998-2008 as shows in table 5.1, and others value such as 0 means not found data about accident.

Table 5.1.Percentage unsafe actions of maritime accidents in 1998-2008

Unsafe actions causes of marine accidents	Variable	Year											Total	%
		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008		
Improper management for ship operation	X1	0.7	1.4	0.7	0.6	1.3	1.2	1.3	2.4	1.4	3	2.9	16.9	**1.5**
Poor repair condition on ship structure	X2	0.6	0.9	0.8	0.2	0.6	0.6	2.1	1.4	0.8	1.2	1.3	10.5	**0.9**
Poor preparation for sea	X3	0.5	0.1	0.1	0.5	0.5	0.3	0.9	0.4	0.1	0.6	1.2	5.1	**0.5**
Improper hydrographic survey before sailing	X4	2.3	2.2	2.4	2.3	3.3	2.3	2.1	1.8	3.3	2.4	2.2	26.6	**2.4**
Inadequate passage pallning	X5	2.1	1.9	1.3	2.3	2.3	2.5	2.4	1.7	2.5	2.4	2.7	24.1	**2.2**
Improper ship handling	X6	2.6	2.9	3.1	2.2	3	2.4	2.6	2.2	3.3	3.5	2.3	30.1	**2.8**
Unconfirmed ship's position	X7	4.1	4	4.2	4.7	3	4.3	3.9	3.5	5.6	4.9	4.1	46.3	**4.2**
Improper look-out	X8	30.4	27.9	30.6	32.6	35.1	33.9	33.2	29.6	29.7	29.2	30.1	342.3	**31.1**
Fatigue	X9	6.2	5.5	5.6	6.1	7.3	6.3	6.2	5.8	7.4	6.9	7.6	70.9	**6.4**
Insuffient maintenance and wrong handling of steering systems and nautical instruments	X10	0.1	0.1	0.4	0	0	0.2	0	0.2	0.1	0	0.5	1.6	**0.2**
Poor attention to meteorological and oceanographical information	X11	1.7	1.9	1.6	1.7	2.8	2.1	1.4	3	2.1	2.3	2	22.6	**2.1**
Improper anchoring and mooring	X12	0.6	0.9	1.1	1.5	1.1	1.2	1.2	0.9	0.9	1.6	0.8	11.8	**1.1**
Inadequate preparation for rough sea	X13	0.2	0.7	0.7	0.6	0.8	0.3	0.5	0.6	1.3	1.7	1.3	8.7	**0.8**
No indication of navigation lights and shapes	X14	1.4	2	1.1	2.2	1.4	1.3	1.8	0.9	0.6	0.5	0.8	14	**1.2**
Signalling failure	X15	6.2	5.9	6.8	5.2	5.8	5.9	6.2	7.1	5.2	5.4	4.7	64.4	**5.8**
Improper ship's speed	X16	4.4	3.3	4.1	4.3	0.7	1.5	2.4	3.2	1.9	0.9	0.4	27.1	**2.5**
Ignoring COLREGS	X17	12.2	12.9	12.1	10.5	11.3	11.9	11.1	10.8	9.7	9.1	8.7	120.3	**11**
Main engine failure	X18	4.4	4.8	4.6	3.4	2.1	4.9	5.3	4.7	4.2	4.9	4.1	47.4	**4.3**
Auxiliary engine failure	X19	1.5	2.6	3.1	3.3	2.2	1.5	1.5	2.9	1.8	1.2	1.7	23.3	**2.1**
Poor management of lubricant oil	X20	2.8	2.5	1.8	3.7	3.3	2.6	1.9	1.7	1.6	2.5	2.9	27.3	**2.5**
Poor management of electrical equipment	X21	0.5	1	0.9	1.3	0.7	0.9	0.7	0.8	0.9	0.5	0.5	8.7	**0.8**
Improper handling and other task	X22	0.9	1.3	1.4	1.3	1.3	1.7	1.4	3.1	2.2	2.8	2.4	19.8	**1.8**
Improper fishing work	X23	0.5	0.8	0.5	1.1	0.8	0.5	0.9	0.5	1	1.3	1.5	9.4	**0.9**
Poor management of passenger and cargo loading	X24	0.9	0.8	0.6	0.1	0.3	0.3	0.8	0.5	0.4	0.6	1.2	6.5	**0.6**
Inadequate supervision of working on board	X25	8.1	7.6	6.7	4.4	6.3	6.1	5.3	6.3	7.4	5.5	7.8	71.5	**6.5**
Inadequate report and taking over watch	X26	3.3	3.3	2.4	3.2	1.9	1.7	2.1	2.5	1.8	1.9	2	26.1	**2.4**
Poor management fire	X27	0.3	0.1	0.7	0.4	0.3	0.5	0.5	0.9	0.5	0.9	0.5	5.6	**0.5**
Force majeure	X28	0.3	0.1	0.3	0	0.1	0.1	0.2	0	0.2	0.1	0.2	1.5	**0.1**
Others	X29	0.3	0.1	0.3	0.3	0.5	0.8	0.4	0.9	1.7	1.9	1.8	9.1	**0.8**
Total		100	100	100	100	100	100	100	100	100	100	100	1100	**100**

The database which have these scenarios are given as an alternative ways to see the effect of unsafe actions that led to impact to losses at workspace, particularly in maritime field.

5.3 Data Analysis

Data analysis is obtained the whole of report to work on this research, establish a series of caused of parameters. These cause parameters as unsafe actions will be explained that the several ways how to studied factor appears. The root cause of the accident should be reviewed from several factors, such as previous explanation in chapter 2 and 3 is that the factors to be considered in the maritime system is man, machine, media and management. These were one way to minimize the effects of losses that will be occurred (fig. 5.1).

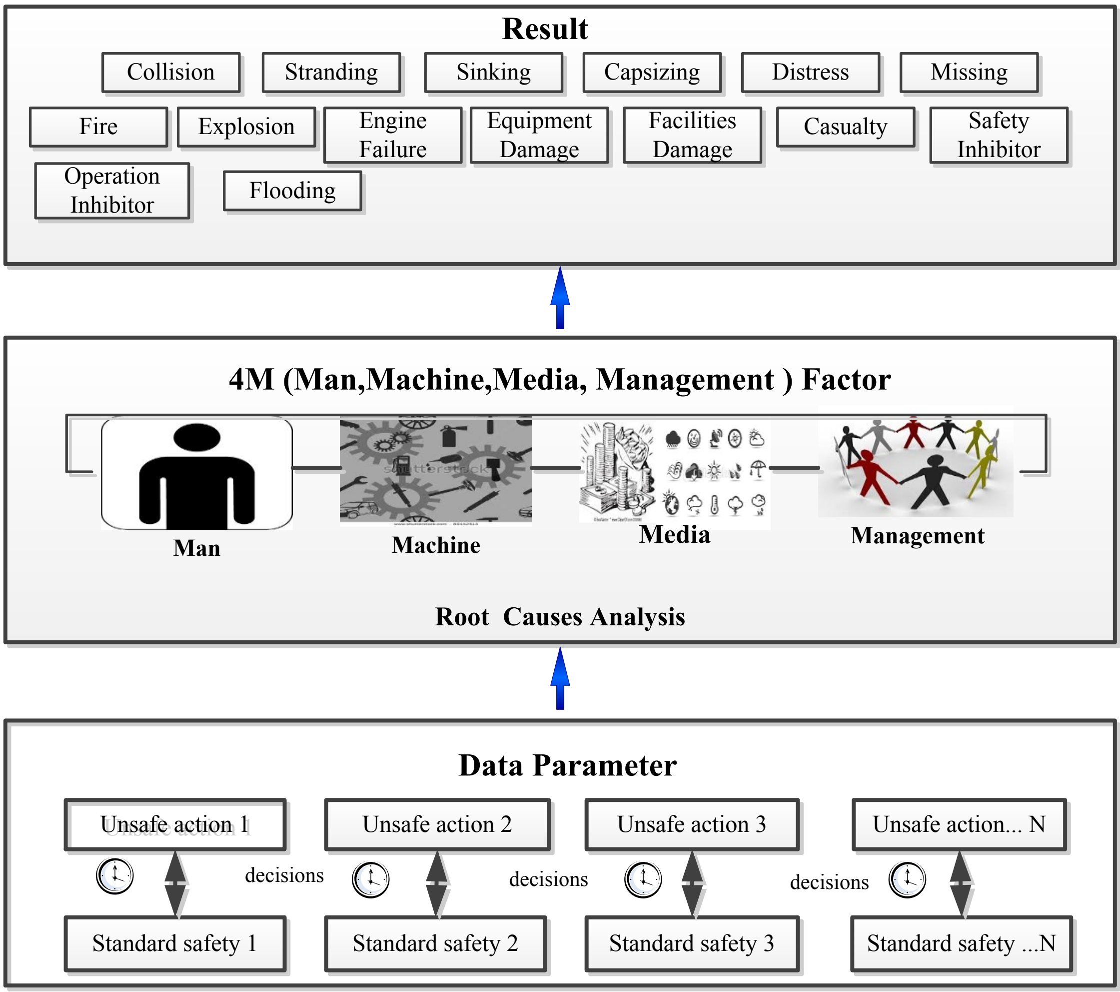


Fig. 5.1 Casualty of parameter

One by one will be described from sources in printed theories and from opinion of experts, from real accident report as well as result of exposure in unsafe actions.

1. Improper management for ship operation

Fig.5.2 shows number of cases probability that unsafe actions such as improper management for ship operation will lead to casualty, engine failure and collision are cases reach highest number of maritime accidents.

One of root cause is failed communication. Communication is more important during operation working, one of example communication breakdown approach formation maneuver, the maneuver should be aborted if appropriate and safe to do so and the subsequent actions taken by each ship should be indicated by the appropriate sound signals as prescribed in the International Regulations for Preventing Collisions at Sea (COLREGS) [53].

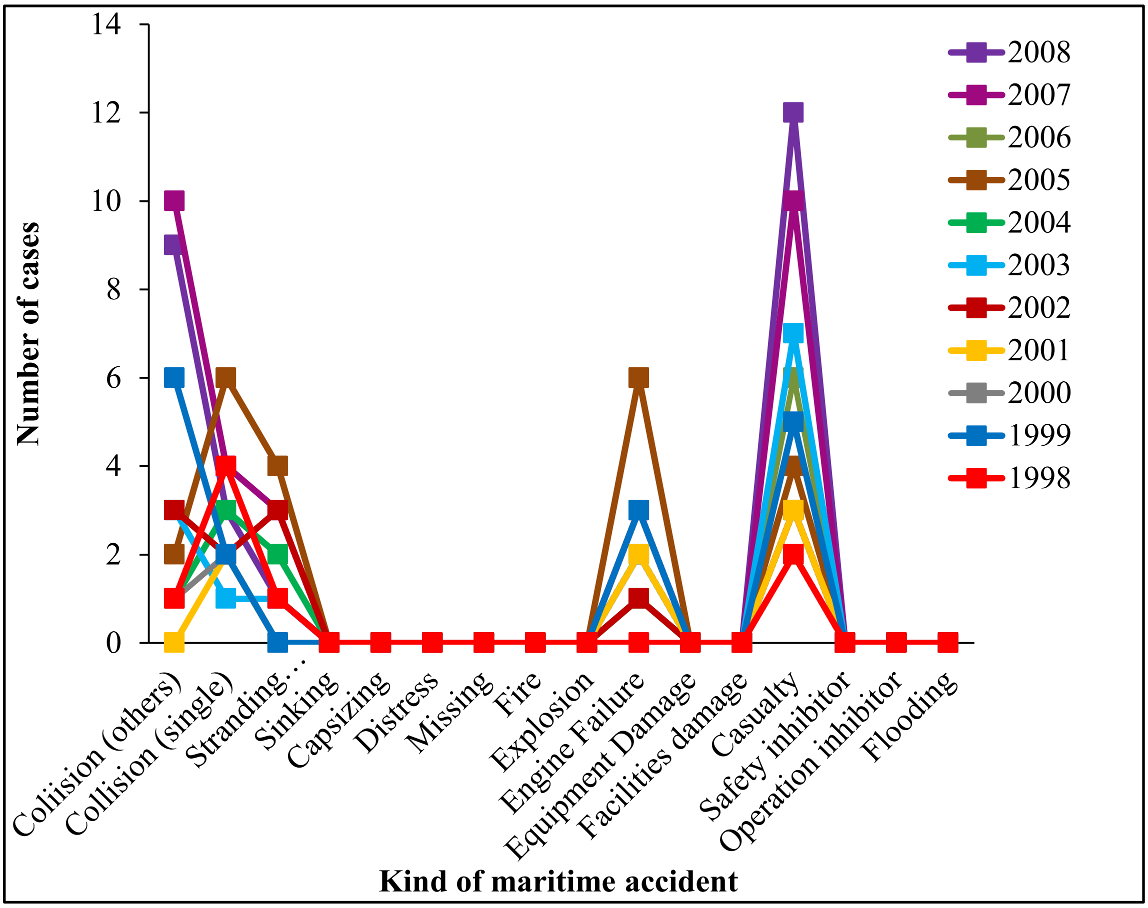


Fig.5.2 Improper management for ship operation, 1998-2008

2. Poor repair condition on ship structure

Fig. 5.3 shows number of cases probability that unsafe actions such as poor repairs condition on ship structure lead to engine failure, casualty and collision are cases reach highest number of maritime accidents. One of root cause is decreased of quality that less detailed checks, witnessing tests, measurements and trials where applicable of selected parts on the ship to identify corrosion, structural defects or damage to hull, machinery and /or piece of equipment which, based on the Society's Rules and the opinion of the surveyor remedial measures and/or appropriated recommendation condition of ship [54].

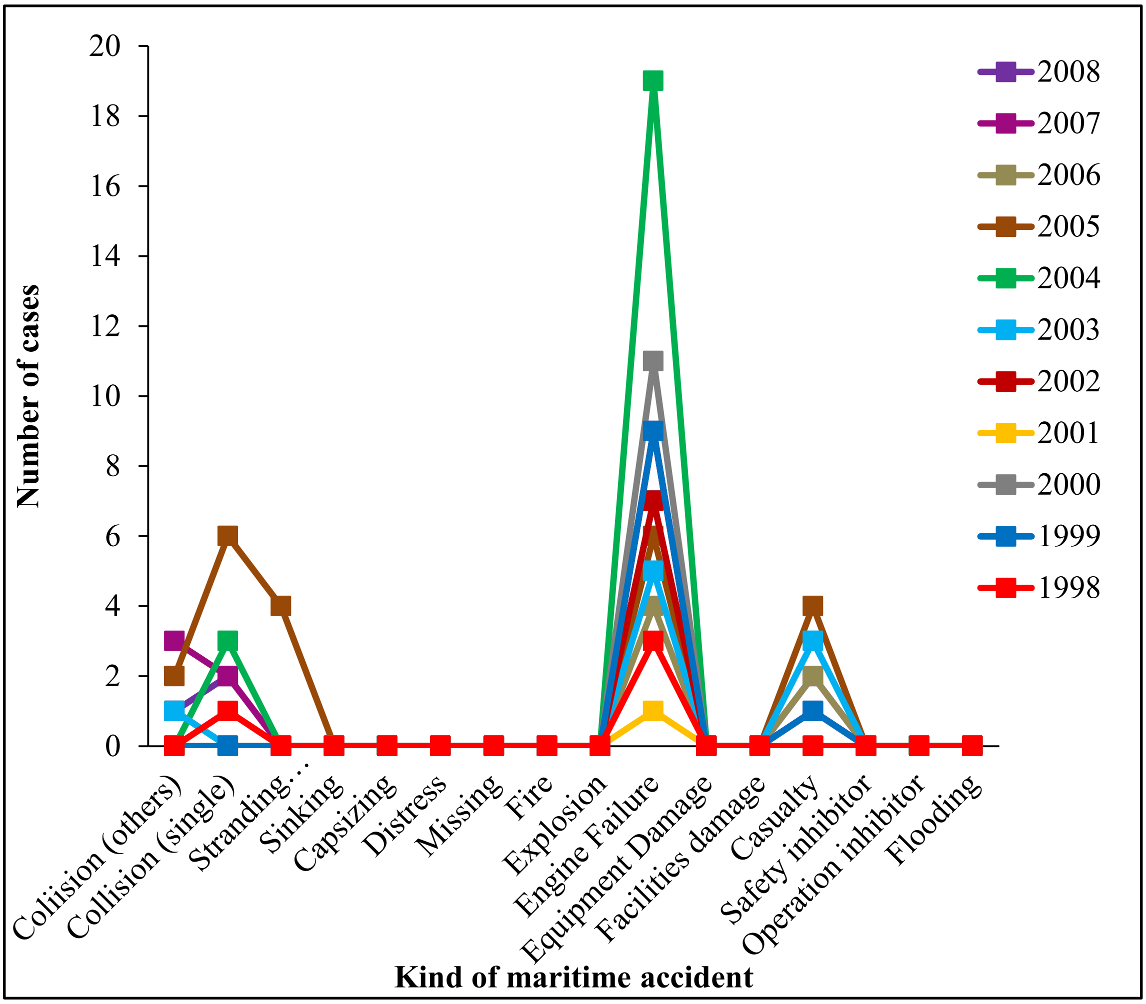


Fig.5.3 Poor repair condition on ship structure in 1998-2008

3. Poor preparation for sea

Fig. 5.4 shows number of cases probability that unsafe actions such as poor preparation for sea lead to operation inhibitor, stranding/grounding, collision and casualty are cases reach highest number of maritime accidents. One of root cause is decreased of knowing that the times of the tide and obtained up to date weather forecast (expected wind conditions) and checked the ship particularly steering and throttle controls, watertight hatches and drains. The vessel must be seaworthy, suitable for the conditions and able to take some impact from waves [55].

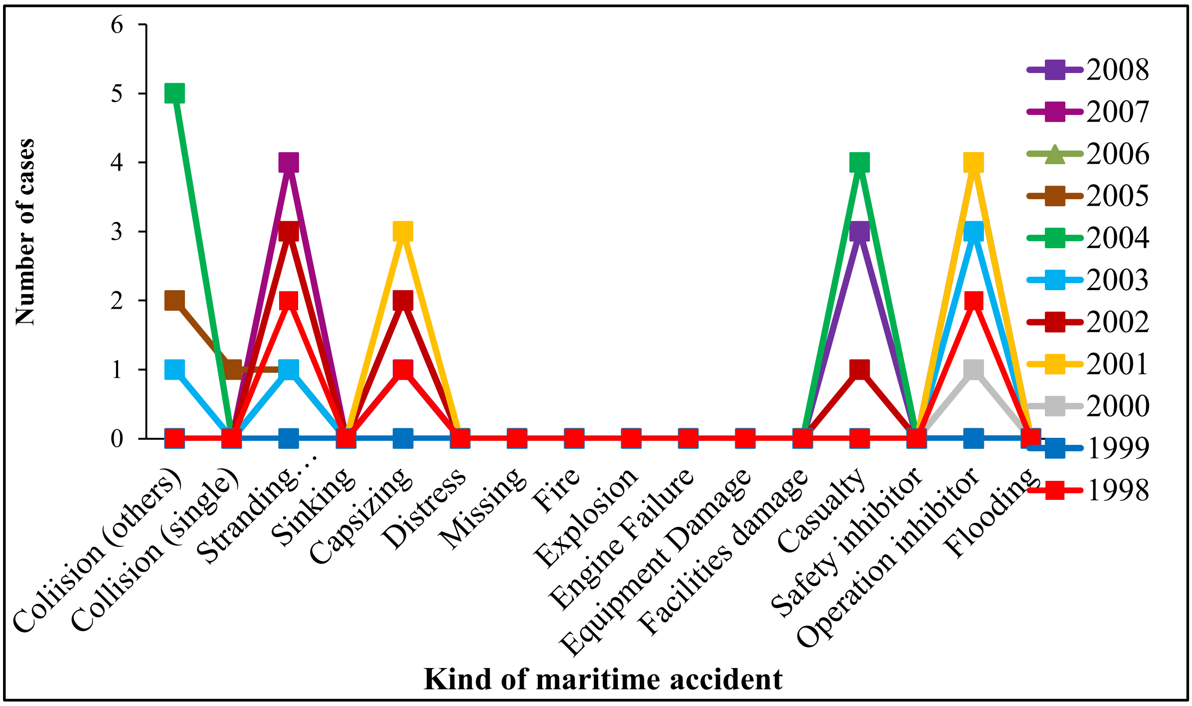


Fig.5.4 Poor preparation for sea in 1998-2008

4. Improper hydrographic survey before sailing

Fig. 5.5 shows number of cases probability that unsafe actions such as improper hydrographic survey before sailing poor preparation for sea lead to stranding/grounding, facilities damage and collision are cases reach highest number of maritime accidents. One of root cause is decreased of quality that improving hydrographic surveys and monitoring made them more effective, and rationalize marine charts and sailing directions through measures such as producing them in electronic form. The work of a hydrographic survey technician can be broken down into four main job functions: conducting pre-cruise logistics and survey planning, conducting field operations, managing data, and maintaining equipment. Within each of these categories there are a series of varied tasks that must be performed. Particularly coastal sea areas where a high proportion of marine accidents occur and also both commercial vessels and pleasure boats frequently operate. Responding to the movement of making the installation of the electronic chart display unit mandatory, will work to publish electronic navigation charts for more areas [56].

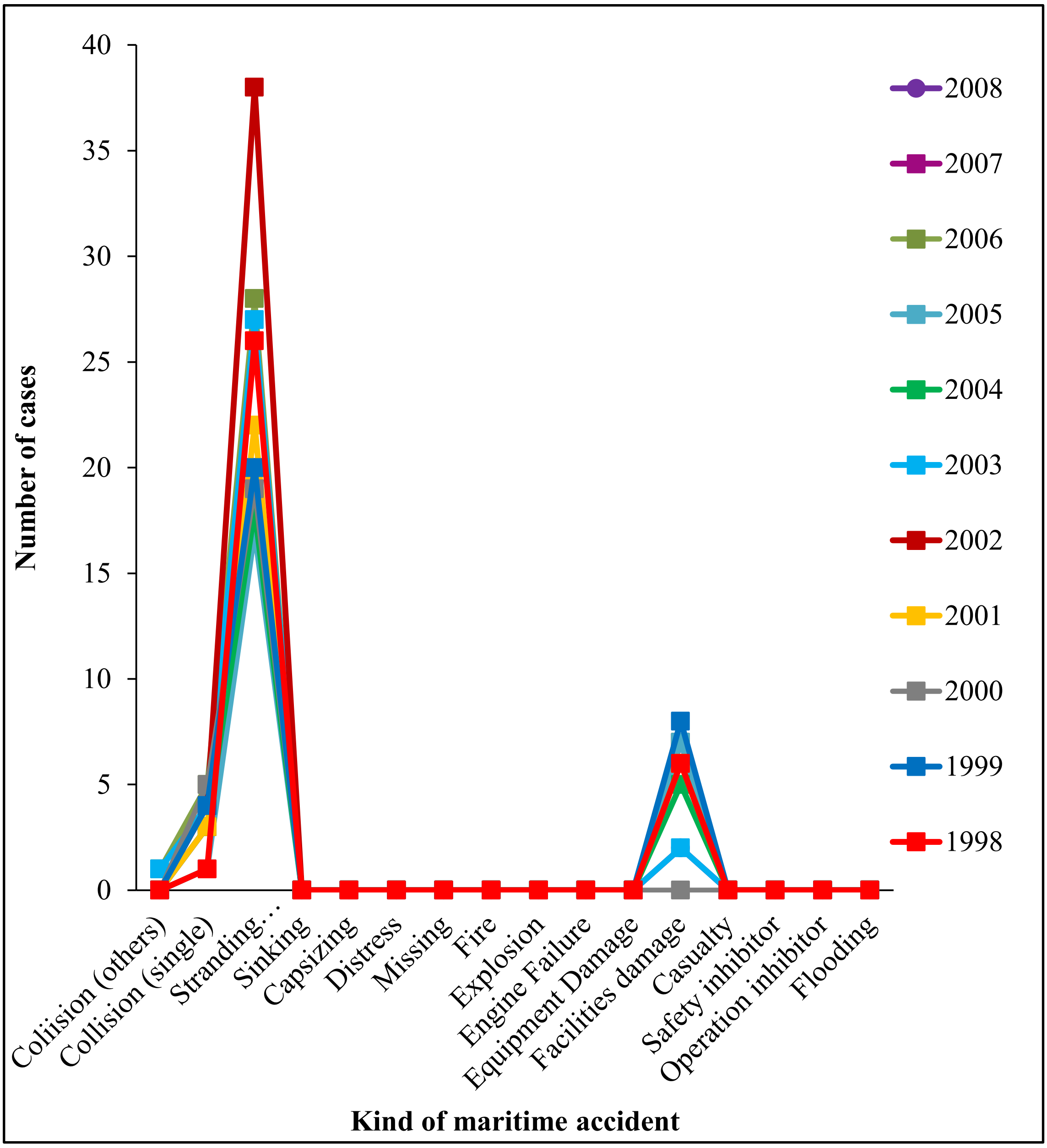


Fig.5.5 Hydrographic survey before sailing in 1998-2008

5. Inadequate passage planning

Fig. 5.6 shows number of cases probability that unsafe actions such as inadequate passage planning for ship`s lead to stranding/grounding, collision (single), facilities damage and casualty are cases reach highest number of maritime accidents. One of root caused is decrease of quality that knowledge and skills will affect to performance of the seaman. A seaman while selection and keeping ship's course that must be considered the time, discipline, money, appropriate technical knowledge and skills, support of equipment. Courses have not been selected to take advantage of weather and currents and most efficient routes.

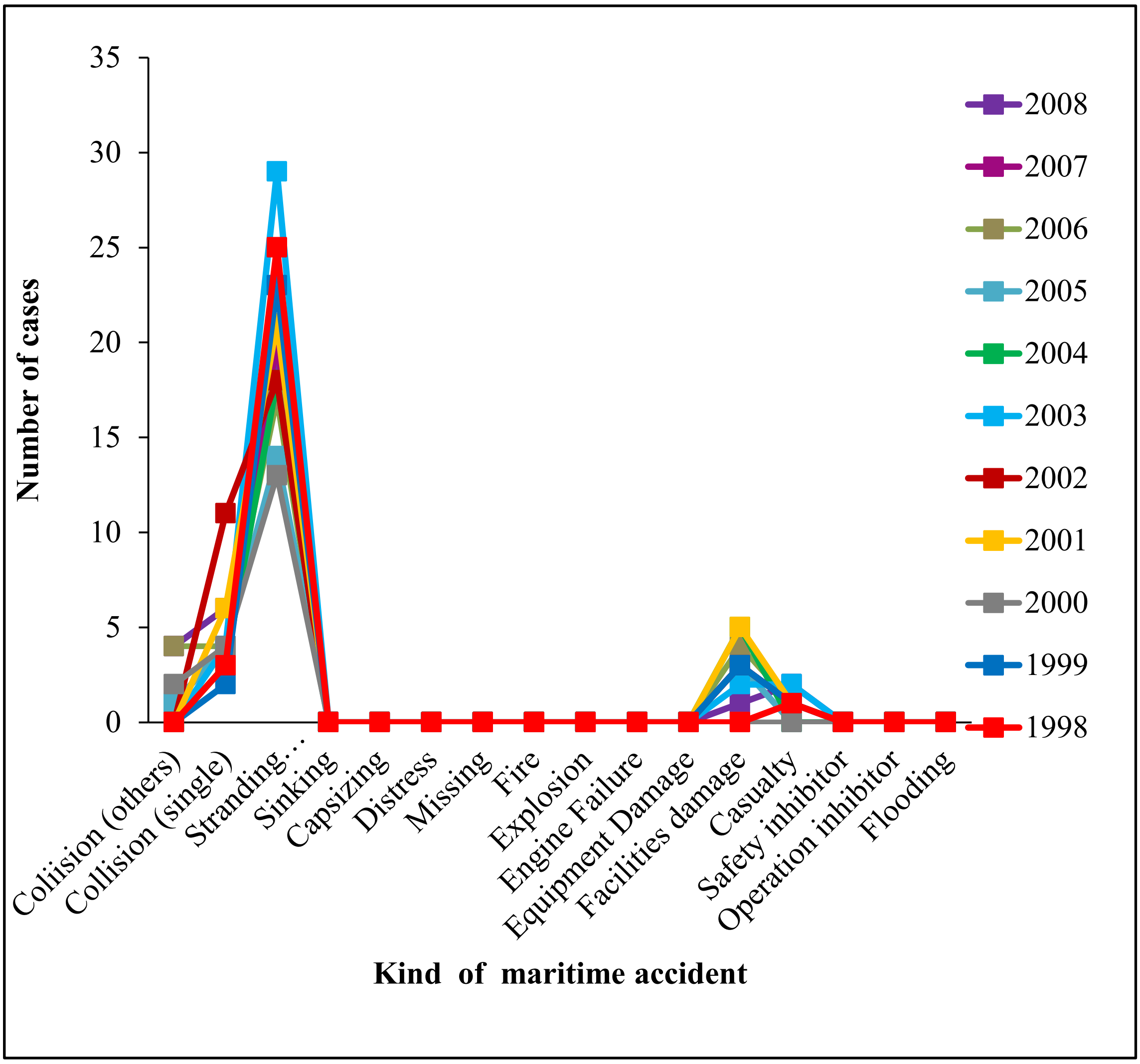


Fig.5.6 Inadequate passage planning in 1998-2008

6. Improper ship handling

Fig. 5.7 shows number of cases probability that unsafe actions such as improperly ship handling lead to collision (single), collision (others), stranding/grounding, casualty are cases reach highest number of maritime accidents. One of root cause is decreased quality of knowledge that fundamental skill of professional seamanship is being able to maneuver a vessel with accuracy and precision. Unlike vehicles on land, a ship afloat is subject to the movements of the air around it and the water in which it floats. Another complicating factor is the mass of a ship that has to be accounted for when stopping and starting.

Ship handling in confined waters, particularly in narrow waterways, has been receiving a great deal of attention. In regard to maneuvering performance, shallow waters may be defined as those in which the ratio of water depth to ship draft is three or less. At greater ratios, shallow-water effects on maneuvering performance became rapidly less significant as water deepens. Restricted water maybe defined as narrow channels or canals, waterways with vertical or overhanging banks or areas that include piers and breakwaters which introduce a substantial change in maneuvering characteristic or requirements. Obviously, more restricted waters include shallow water, and many include significant currents and tides. In restricted waters, areas available for navigation is limited [57]. Lack of adequate training and experience by officers.

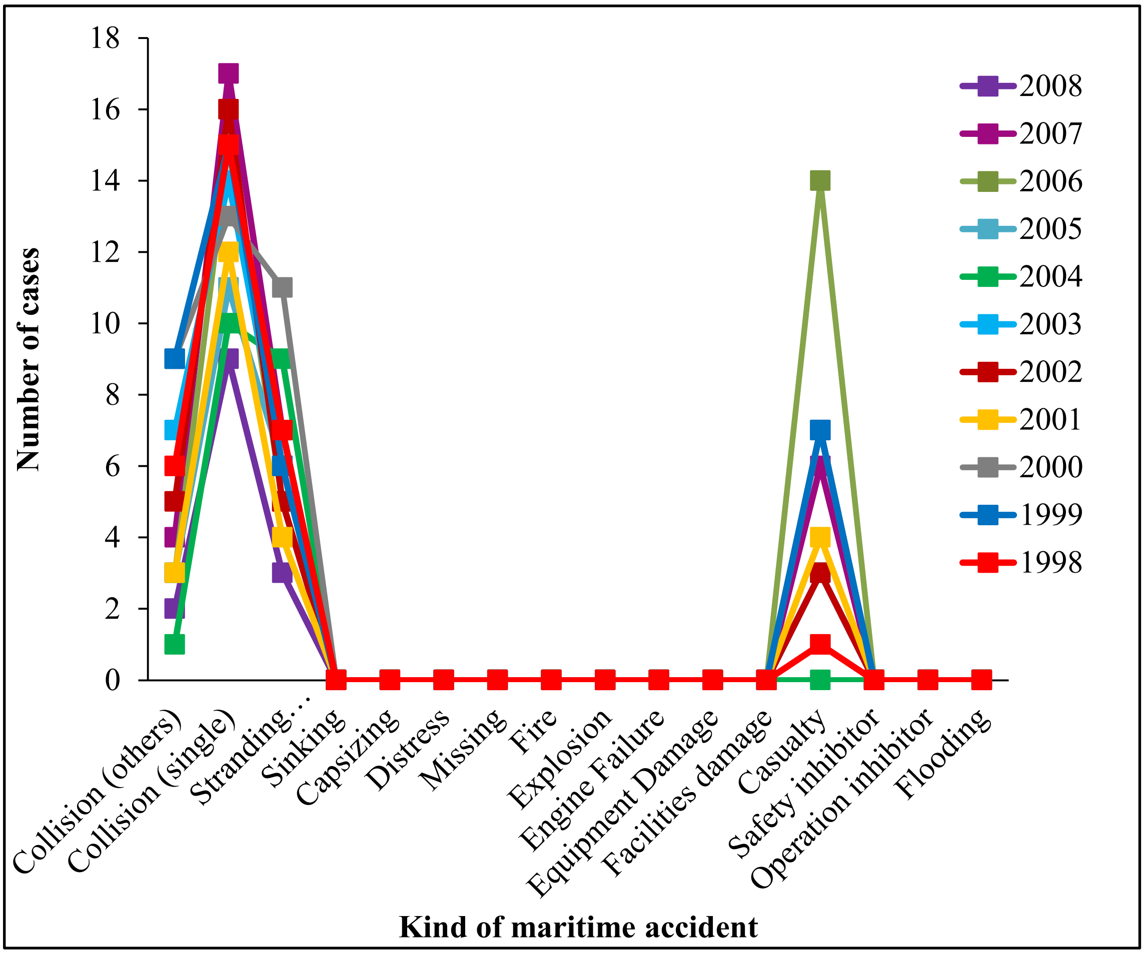


Fig.5.7 Improper ship handling in 1998-2008

7. Unconfirmed ship`s position

Fig.5.8 shows number of cases probability that unsafe actions such as unconfirmed ship`s position lead to collision, stranding/grounding and facilities damage are cases reach highest number of maritime accidents. One of root cause is decreased quality to identify ship or other ships because less to knowledge and skills that incorrect vessel heading, Estimated Time of Arrival (ETA) and destination information, unfamiliar with Automatic Identification System (AIS) or other navigation equipment to other vessels equipment that provides information for the unit to transmit. In consequence that the double bottom area of the vessel will probably suffer considerable damage, particularly if the ground is rocky. Keeping in mind the conditions of the neighboring sea area, the exact position of your ship shall be constantly checked and updated [58].

The outline of navigation, as commonly practiced in every sailing is sufficient to enable a person to conduct a ship from one port to another, or at least to show in plain simple terms the principle upon which it is done.

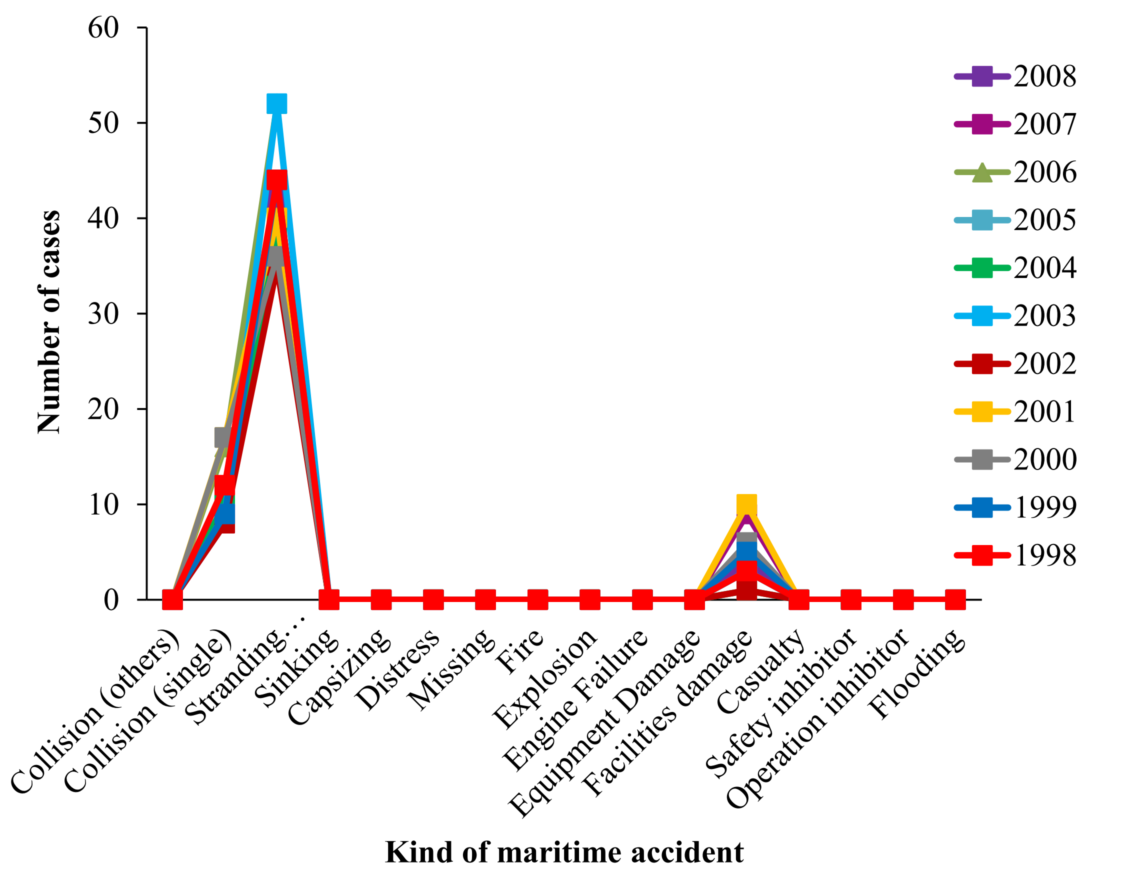


Fig.5.8 Unconfirmed ship's position in 1998-2008

8. Improper look-out

Fig.5.9 shows number of cases probability that unsafe actions such as improper look-out lead to collision (single), collision (others), stranding/grounding are cases reach highest number of maritime accidents. One of root cause is indicated that improper look-out to effect collision due to rules. The international COLREGs define, under Rule 5, the criteria for keeping a proper look-out. Look-out is an important element of safe watch keeping, especially when the visibility is restricted and includes look-out by hearing, radar, VHF, AIS as well as by sight. There is no excuse for an improper look-out but there are frequently reasons: lack of support, low discipline, disinterest, carelessness, laziness to name but a few. These unsafe actions occurred in these collision accidents are considered as poor lookout: no look-out man is arranged at proper position, particularly in restricted visibility conditions; the number of look-out men is not enough in prevailing circumstances; the duty of look-out is not properly conducted; all available means appropriate including the effect use of available instruments and equipment are not properly used; the situation is not fully appraised; anchor watch is not properly kept, Cockcroft ,A.,N et al. [59].

Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision. Maintaining is a proper look- out to avoid accidents.

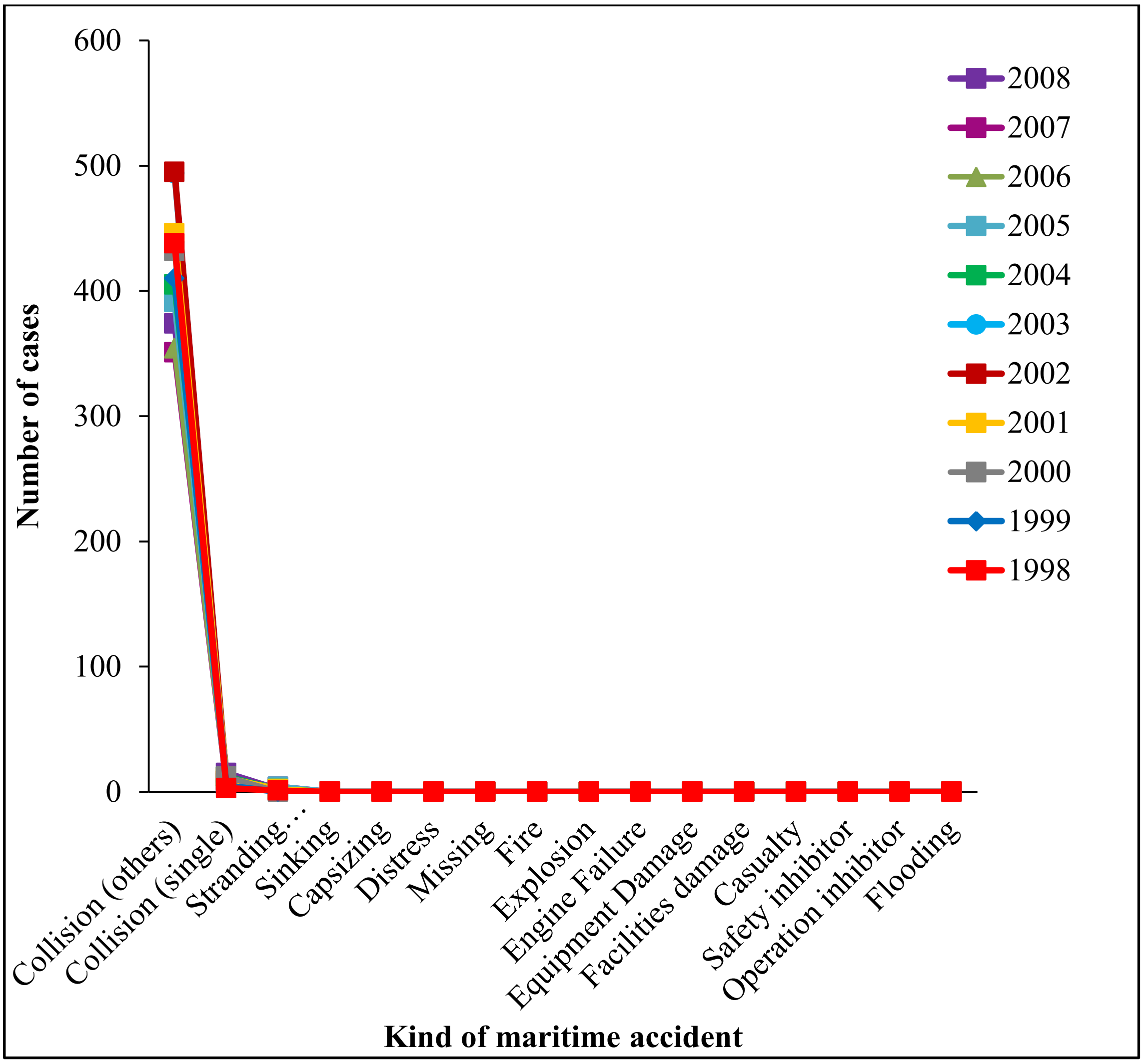


Fig.5.9 Improper Look-out in 1998-2008

9. Fatigue

Fig.5.10 shows number of cases probability that unsafe conditions such as fatigue lead to stranding as the most influenced between collision(single), sinking, casualty and equipment damage are cases reach highest number of maritime accidents.

One of root cause is controlled fatigue or snooze due to how the motion of the ocean can affect one's balance, coordination, response time, eyesight, hearing, reflexes, judgment and the ability to enjoy daily work. The combination of wind and waves can cause sea sickness, which will affect motor skills and one's ability to think clearly. However, the main reasons are overwork, under-manning and non-adherence to the STCW Hours of Rest requirements. Operating a ship while fatigued is always a bad idea MAIB [60]. Good coordination to avoid maritime accidents.

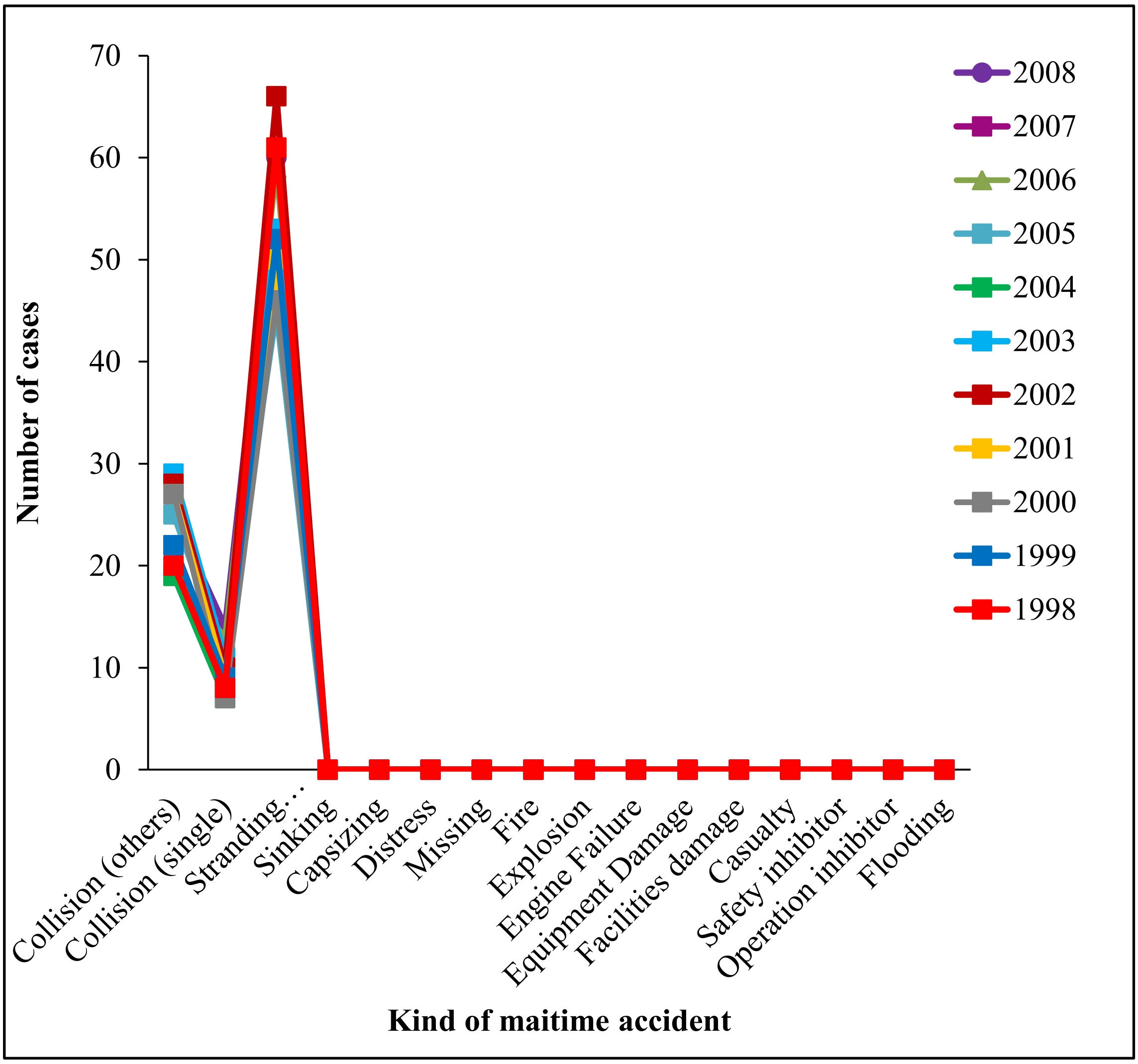


Fig.5.10 Fatigue

10. Insufficient maintenance and wrong handling of steering systems and nautical instruments

Fig.5.11 shows number of cases probability that unsafe actions such as insufficient maintenance and wrong handling of steering systems and nautical instruments lead to collision (single),collision(others) and stranding/grounding are the most influenced to maritime accidents. One of root caused is decreased quality attention to their vessel's steering system, as long as it does the job without excess friction or play, but vessels have age the systems need replacement. When installing is needed new steering, its good practice to replace a steering system with one of the same type as was originally installed on ship. This ensures that the ship will continue to handle as it was designed, and simplifies the installation process.

Repair parts for nautical instruments. These components must be replaced as units for safety and convenience since engine interfacing is standardized. Be sure to water-test in new system carefully as you become familiar with the changes in on ship's maneuvering.

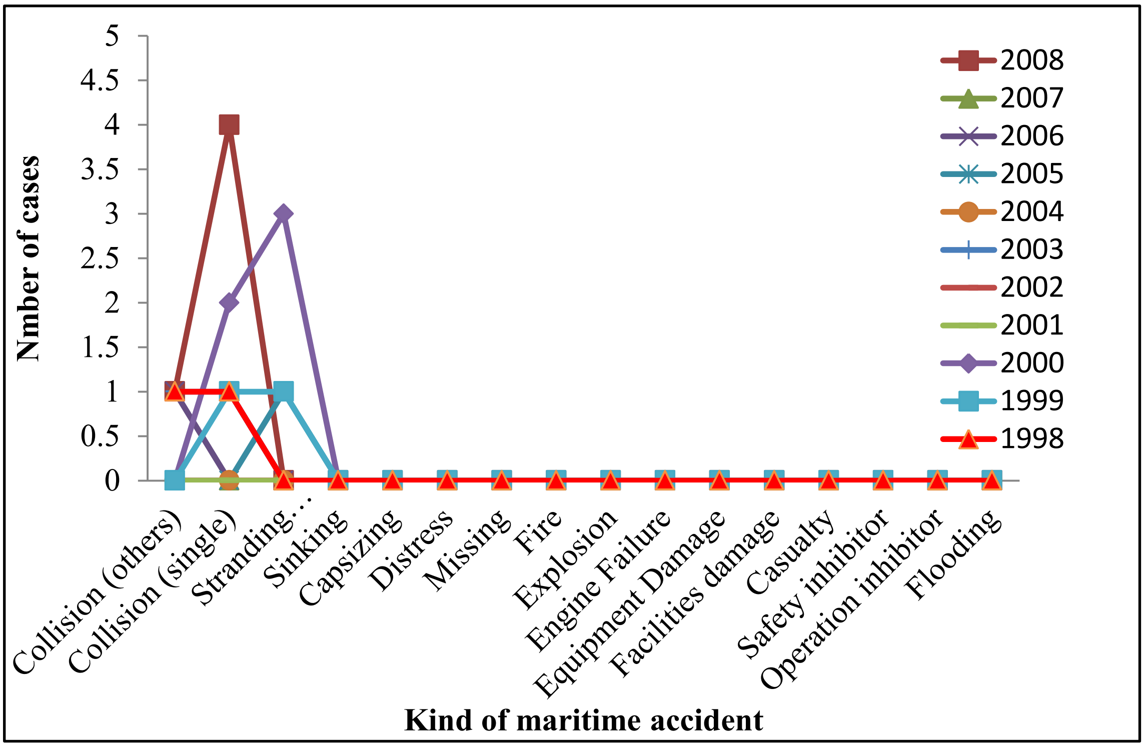


Fig.5.11Maintenance and wrong handling of steering systems and nautical instruments in 1998-2008

11. Poor attention to meteorological and oceanographically information

Fig.5.12 shows number of cases probability that unsafe actions such as poor attention to meteorological and oceanographically information lead to collision (single),collision(others) and stranding/grounding are the most influenced to maritime accidents. One of root cause is decreased of quality attention to meteorological forecast and warning services in support of the safety of life and property at sea. For those who work at sea or live near the coast, forecasts of maritime weather and ocean conditions have as important as forecasts of weather in general. Rough seas, freak waves, storm surges and strong currents can make many marine activities difficult and dangerous. High waves and storm surges can lead to coastal flooding. Tropical cyclones and associated phenomena can be the most dangerous conditions encountered by seamen.

Changes in ocean temperature can affect the marine ecosystem, from plankton to fisheries and influence weather and climate. Understanding that monitoring, mapping and predicting maritime weather and ocean conditions for adequate planning of coastal zone and marine activities and to provide a structure for early detection and warning marine related hazards [61].

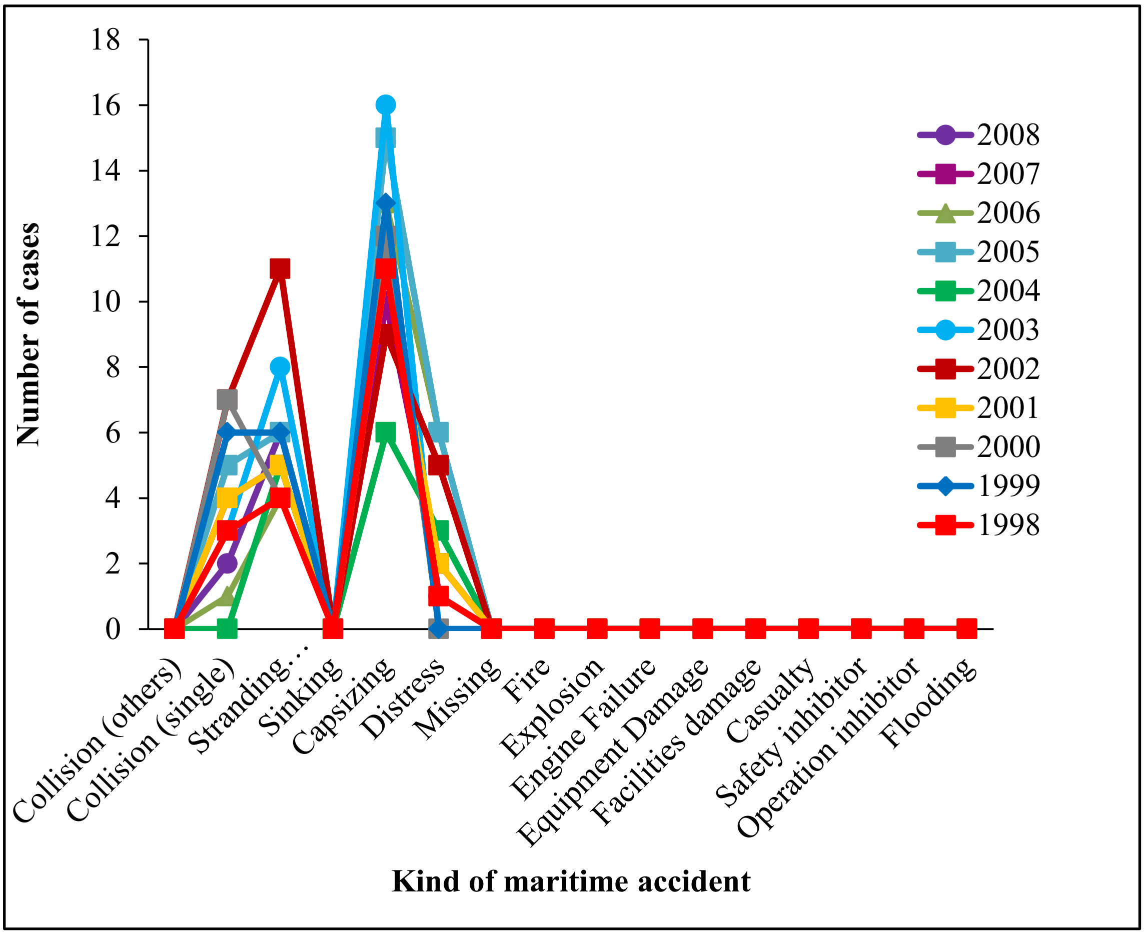


Fig.5.12 Poor attention to meteorological and oceanographical in 1998-2008

12. Improper anchoring and mooring

Fig.5.13 shows number of cases probability that unsafe actions such as improper anchoring and mooring lead to collision (others), stranding/grounding, distress are the most influenced to maritime accidents. One of root cause is decreased of quality that how to selected good anchorage and do not drag anchor [62], such as

(1) The anchorage where the anchor holds well shall be selected by large-scale charts, and the dragging of anchor shall be prevented by two anchor mooring if necessary.

(2) To discover dragging anchor early, the exact position of your ship shall be confirmed during anchorage, relevant.

The position un-correct anchoring in tidal waters is vital to minimize than anchoring improperly accident on a ship.

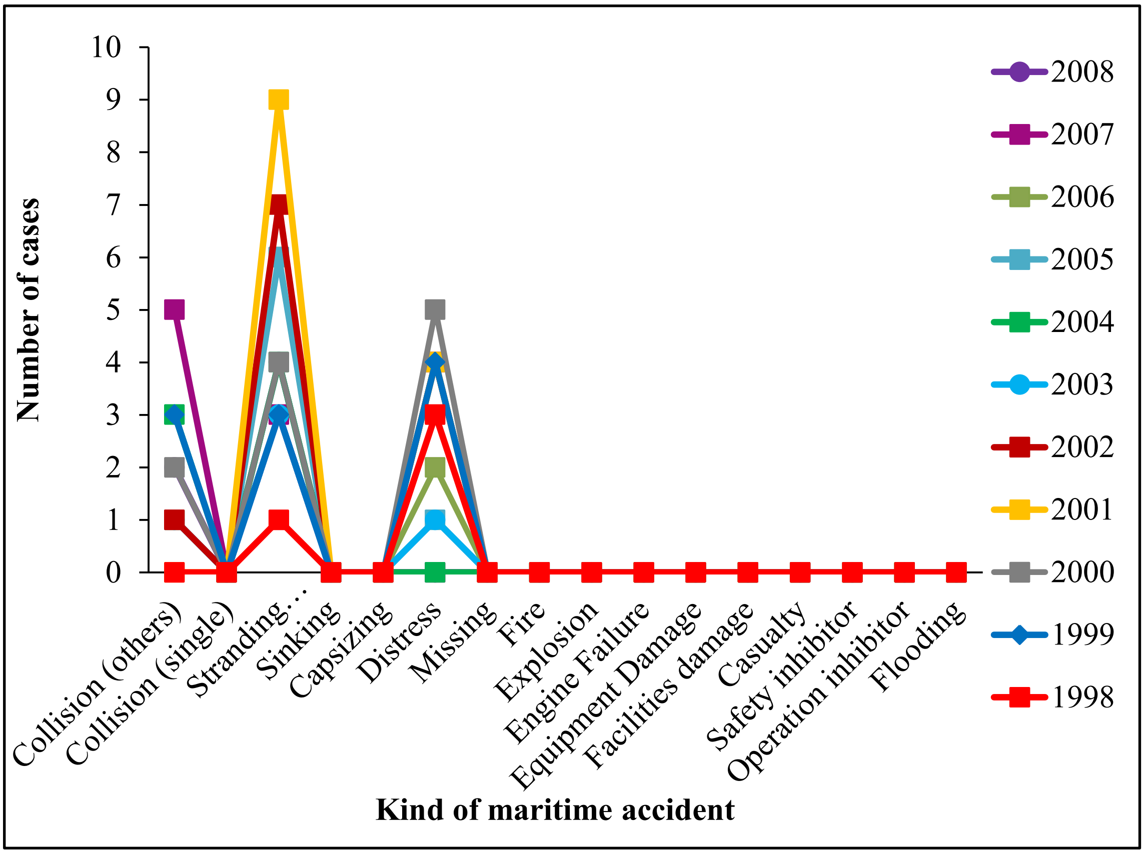


Fig.5.13 Improper anchoring and mooring in 1998-2008

13. Inadequate preparation for rough sea

Fig.5.14 shows number of cases probability that unsafe actions such as inadequate preparation for rough sea lead to capsizing, distress and stranding /grounding are the most influenced to maritime accidents. One of root cause is decreased of quality that time is a critical factor for reacting in a situation like rough weather. Weather forecasts are common at sea these days and if not, then the experienced seafarer can read the natural signs of wind, swell, pressure and temperature to learn if bad weather and rough seas are coming. Thus, seafarers are usually well prepared in advance of bad weather. However, sudden deteriorations, or enormous waves (such as tsunami) can catch us all unawares and that is where good training comes into play.

It is very important for a seafarer to know what to do in rough weather situations so that mistakes can be avoided and within minimal time on the ship can be prepared for rough sea such as steering control, machinery control, and other common precautions. Handling of the ship depends on the training, knowledge, skills and teamwork of the ship's staff. Continuous training to be able to prevent incidents for rough at sea will prevent the accidents.

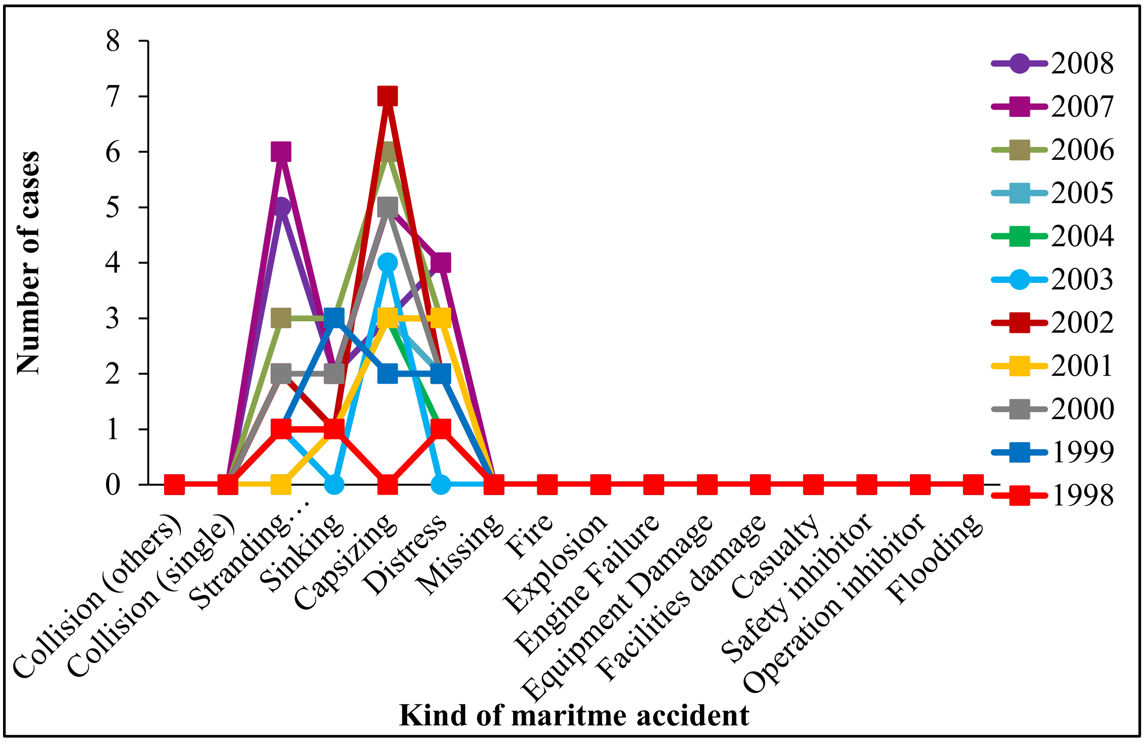


Fig.5.14 Inadequate preparation for rough sea in 1998-2008

14. No indication of navigation lights and shapes

Fig.5.15 shows number of cases probability that unsafe conditions such as No indication of navigation lights and shapes lead to collision (others) is the most influenced to maritime accidents.

Many root cause are referred that no light and shapes in rules follow

1. All weather conditions, if any light are lost or extinguished they must be replaced or repaired as soon as possible. A delay in attending to light or shapes in severe weather conditions because of danger to personnel should be recorded in the official log book.

2. No other light

A vessel 100 meters or more in length is required to use the available working or equivalent light to illuminate her decks when at anchor by rule 30(c), and smaller vessel at anchor may sue such light.

3. Restricted visibility

The prescribed light, if carried must also be exhibited in restricted visibility from sunrise to sunset. The words if carried are included are not fitted with navigation lights as their operations are restricted to daylight hours.

4. By day

Shapes must be exhibited by day, not merely from sunrise to sunset.

A vessel required to show a day signal should exhibit both light(s) and shapes(s) during the period of twilight [63].

No indication of navigation lights and shapes because of a ship cannot suspend piloting operations are condition of darkness falls and daytime navigational aids no longer can be seen. The purposes of identification, lights have individual characteristics regarding color, intensity, and system of operation. For this reason, aids to navigation are lighted whenever it is necessary its application involve the exercise of special skills and fine techniques, which can be perfected only by experience and careful practice. Continuous training to be able to prevent frequently no indications of light and shapes will prevent the accidents.

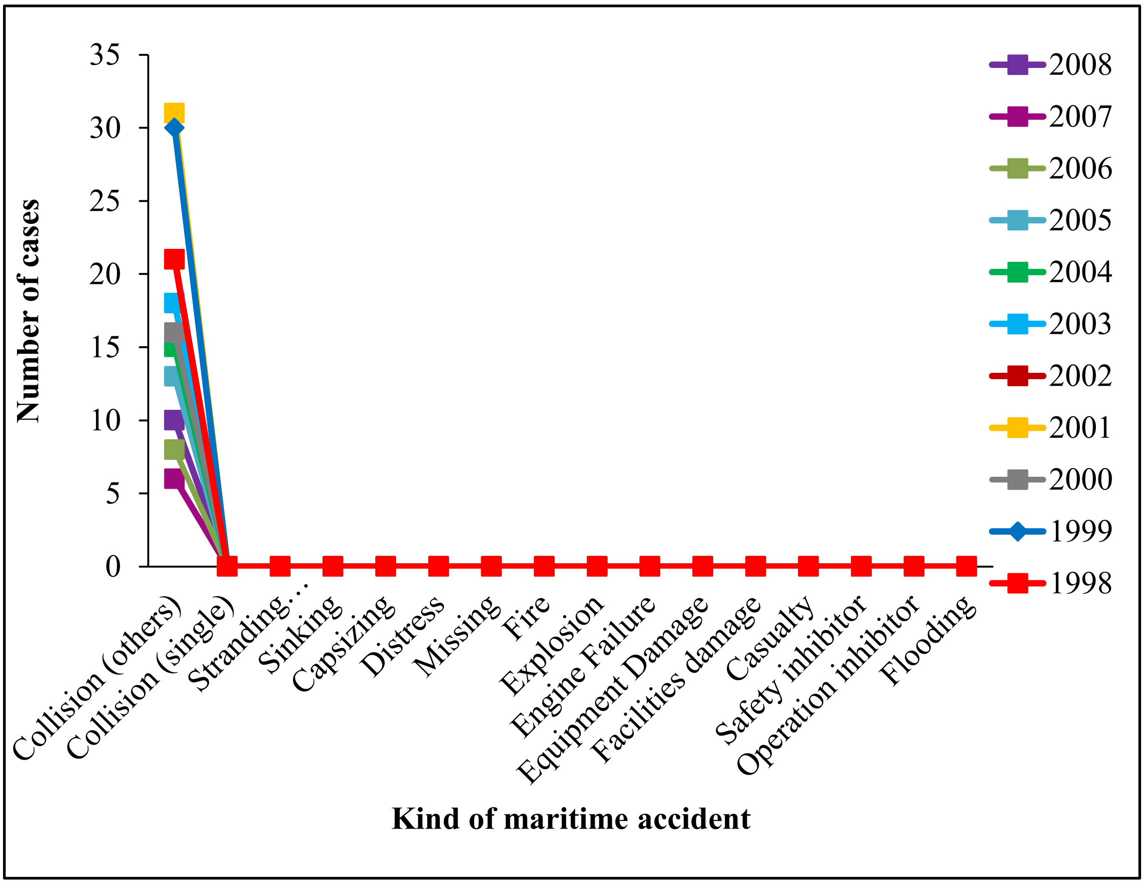


Fig.5.15 No indication of navigation lights and shapes in 1998-2008

15. Signaling failure

Fig.5.16 shows number of cases probability that unsafe actions such as signaling failure lead to collision (others), collision (single) and casualty are the most influenced to maritime accidents. One of root cause is referred that to lack of proper interpretation about maneuver by the relevant signals on the ship's whistle. In or near an area of restricted visibility, signals shall be used by vessels in accordance with the following specifications such as a sailing vessel, a vessel engaged in fishing, a vessel not under command, a vessel restricted in her ability to maneuver, a vessel constrained by her draft (except a vessel being towed by another power-driven vessel) and a power-driven vessel engaged in towing or pushing another vessel shall, when underway, sound at intervals of not more than 2 minutes one prolonged blast followed by two short blasts.

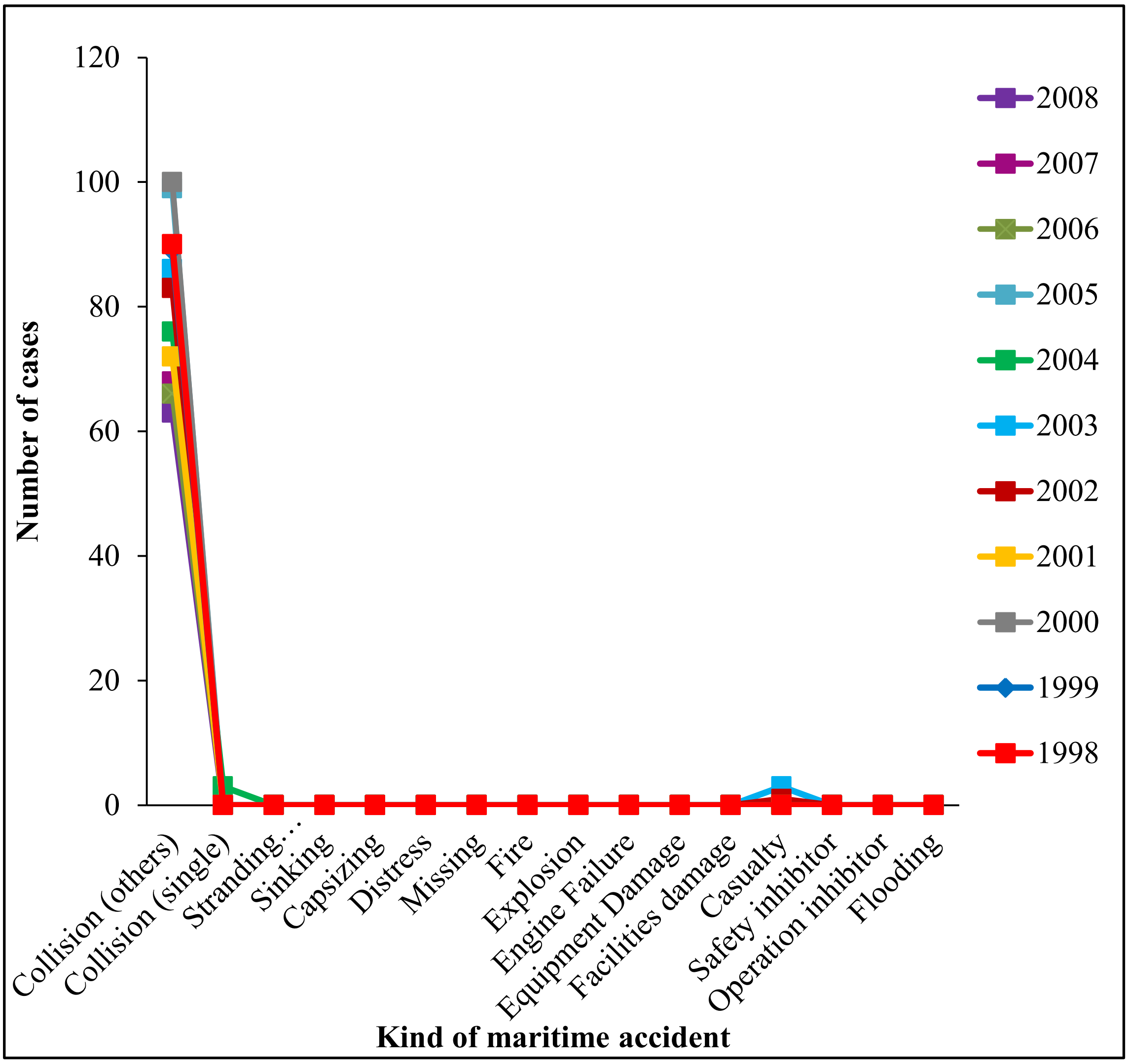


Fig.5.16 Signaling failure in 1998-2008

16. Improper ship's speed

Fig.5.17 shows number of cases probability that unsafe actions such as improper ship's speed lead to collision (others), collision (single), stranding/grounding and casualty are the most influenced to maritime accidents. One of root cause is referred that every vessel shall at all times proceed at a safe speed so that she can take proper and effective action to avoid collision and be stopped within a distance appropriate to the prevailing circumstances and conditions. In determining a safe speed the following factors shall be among those taken into account such as the state of visibility; in the traffic density including concentrations of fishing vessels or any other vessels; the maneuverability of the vessel with special reference to stopping distance and turning ability in the prevailing conditions. Check speed on a ship taking into account the situation in and the situation moving towards. Excessive speed contributes to many collisions, P& I Club [64].

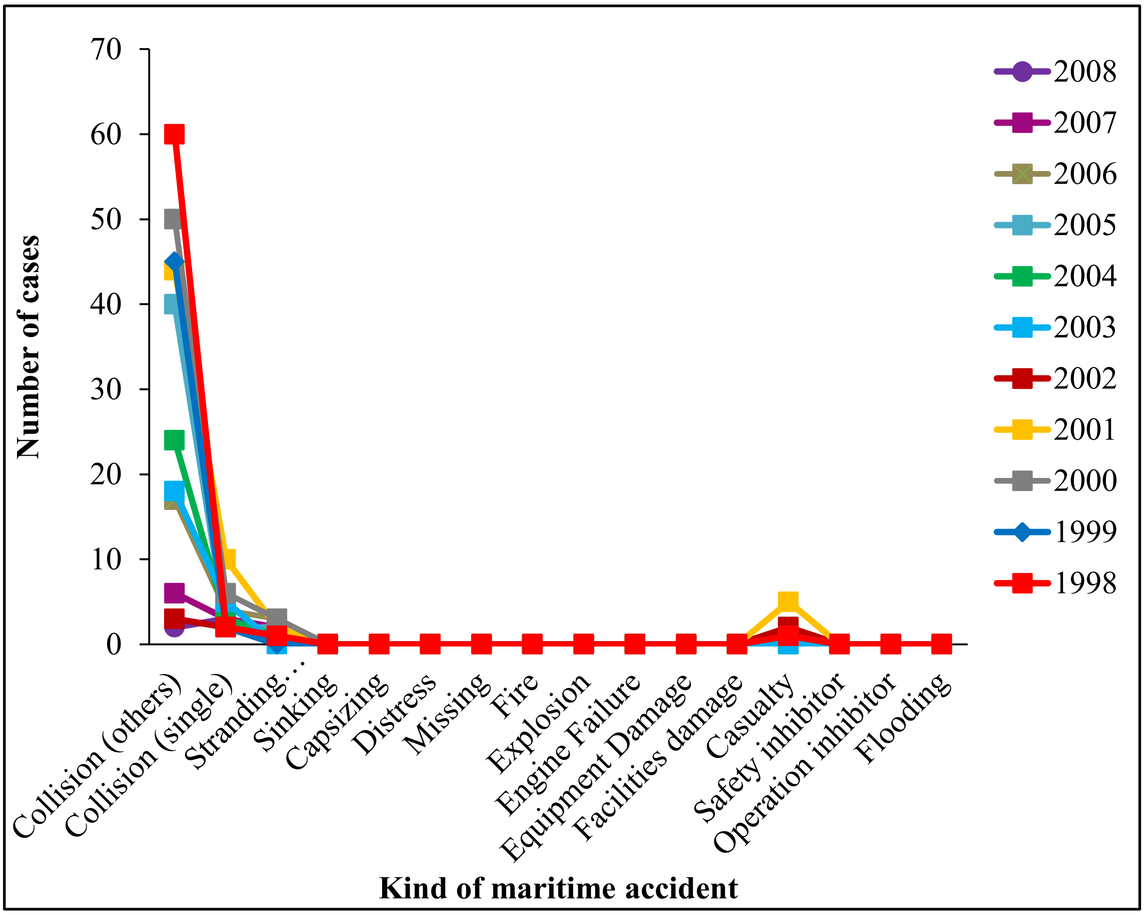


Fig.5.17 Improper ship's speed in 1998-2008

17. Ignoring of International Regulations for Preventing Collisions at Sea 1972 (COLREGS)

Fig.5.18 shows number of cases probability that unsafe actions such as not obeying of International Regulations for Preventing Collisions at Sea 1972 (COLREGs) lead to collision (others), collision (single), stranding/grounding are the most influenced to maritime accidents. One of root cause is referred that not obeying COLREGs can be put down to misinterpretation, even though the rules are quite clear. Keeping to reminds mariners of the basics of the COLREGs and that they must be kept well in mind and obeyed notwithstanding the profusion of equipment on the modern bridge. That equipment does not avoid collision. It is merely an aid to collision avoidance. What avoids collisions is compliance with the COLREGs.

Ignorance on how to apply them in sea conditions, and plain, deliberate non-adherence when the situation may not be obviously understood, ensures that accidents, close-quarters situations then collisions will occur (see in fig. 5.18).

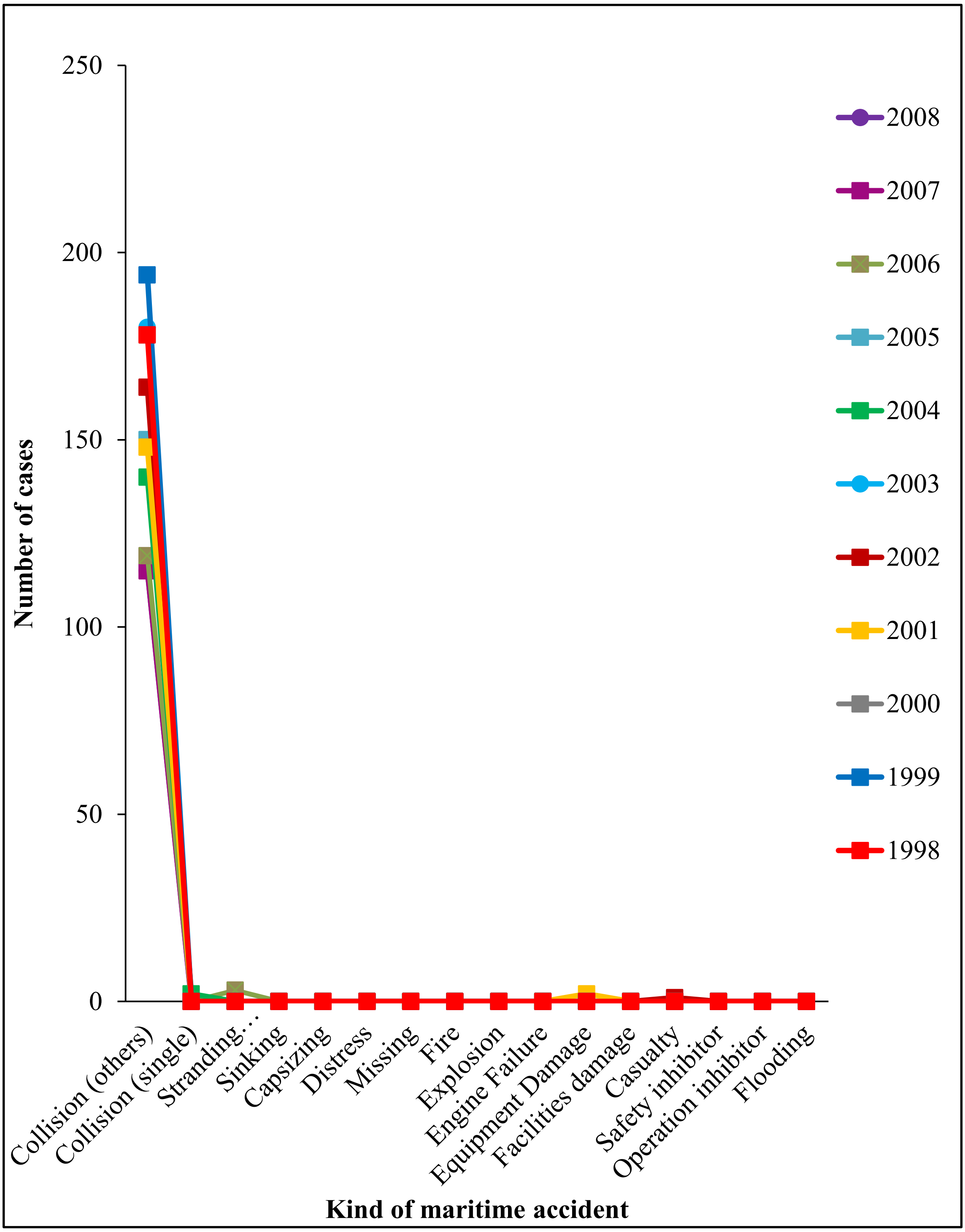


Fig.5.18 Ignoring of COLREG in 1998-2008

18. Main engine failure

Fig.5.19 shows number of cases probability that unsafe actions such as main engine failure lead to engine failure, flooding, operation inhibitor and fire are cases reach highest number of maritime accidents. One of the root cause are referred that lack of overhauling a cylinder, means lack of a routine periodical maintenance task on a marine diesel engine to ensure that the components of that cylinder have not worn excessively and are fit to continue service. Management of preventative maintenance and inspection work is required to ensure that equipment is capable of operating as designed and to reduce the likelihood of failures in service. Equipment manufacturers recommend service intervals and procedures for their equipment. If these are not observed, equipment can fail without warning [65].

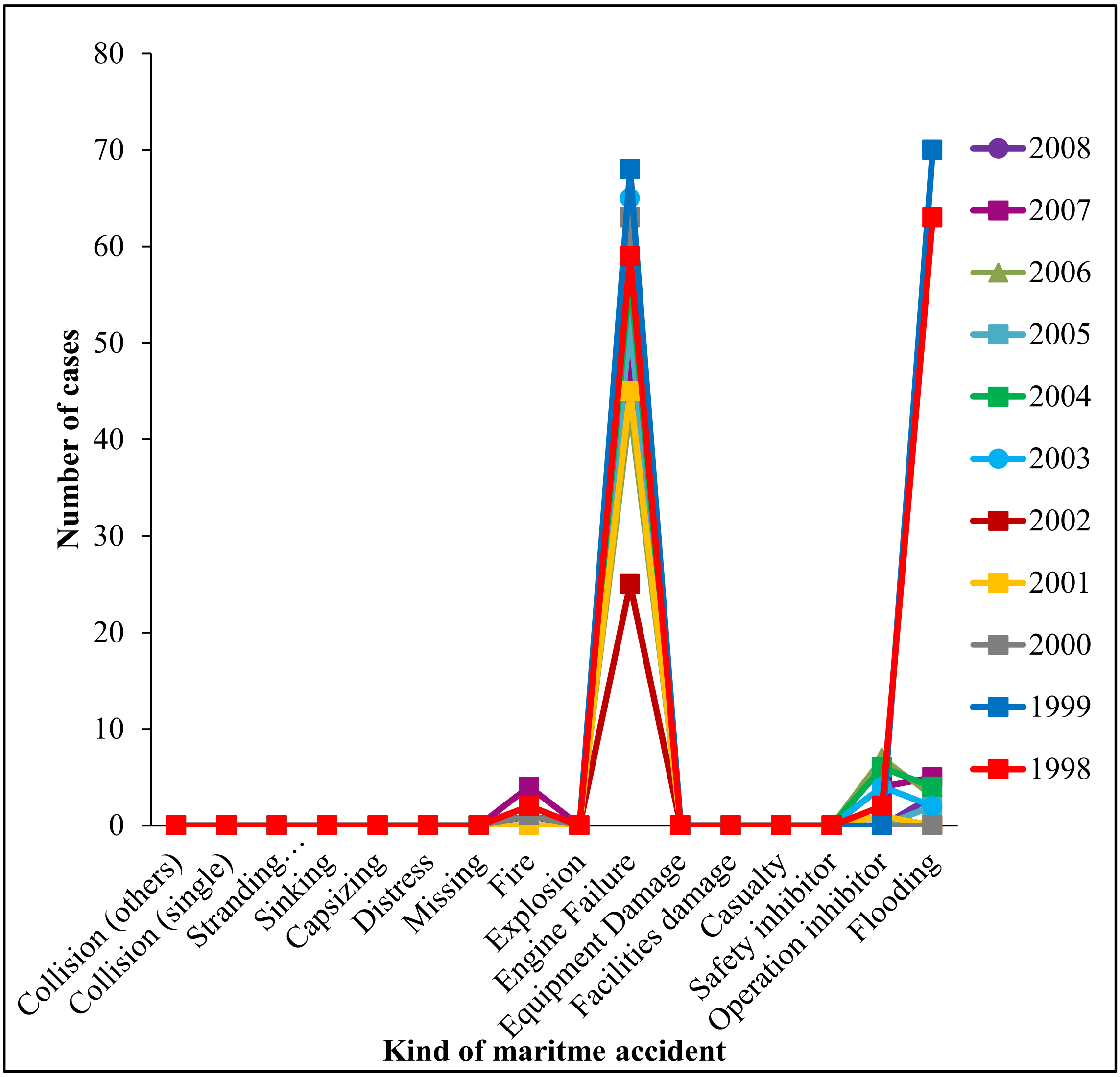


Fig.5.19 Main engine failures in 1998-2008

19. Auxiliary engine failure

Fig. 5.20 shows number of cases probability that unsafe actions such as auxiliary engine failure lead to operation inhibitor, fire and flooding are cases reach highest number of maritime accidents. One of root cause is decreased of quality that the first engine failure was troubleshooting marine auxiliary diesel engines (starting problems), the engine turns on air but does not run on fuel, choked fuel filters, during starting the safety valve blows, inadequate jacket water cooling, which led to the cylinders overheating and seizure of the pistons. An incorrect setting of the jacket water temperature controller was identified. This was exacerbated by blockages in the jacket water coolers. Good maintenance and cleanliness procedures should be followed. Prevention can often avoid expensive breakdowns and dangerous situations arising [62].

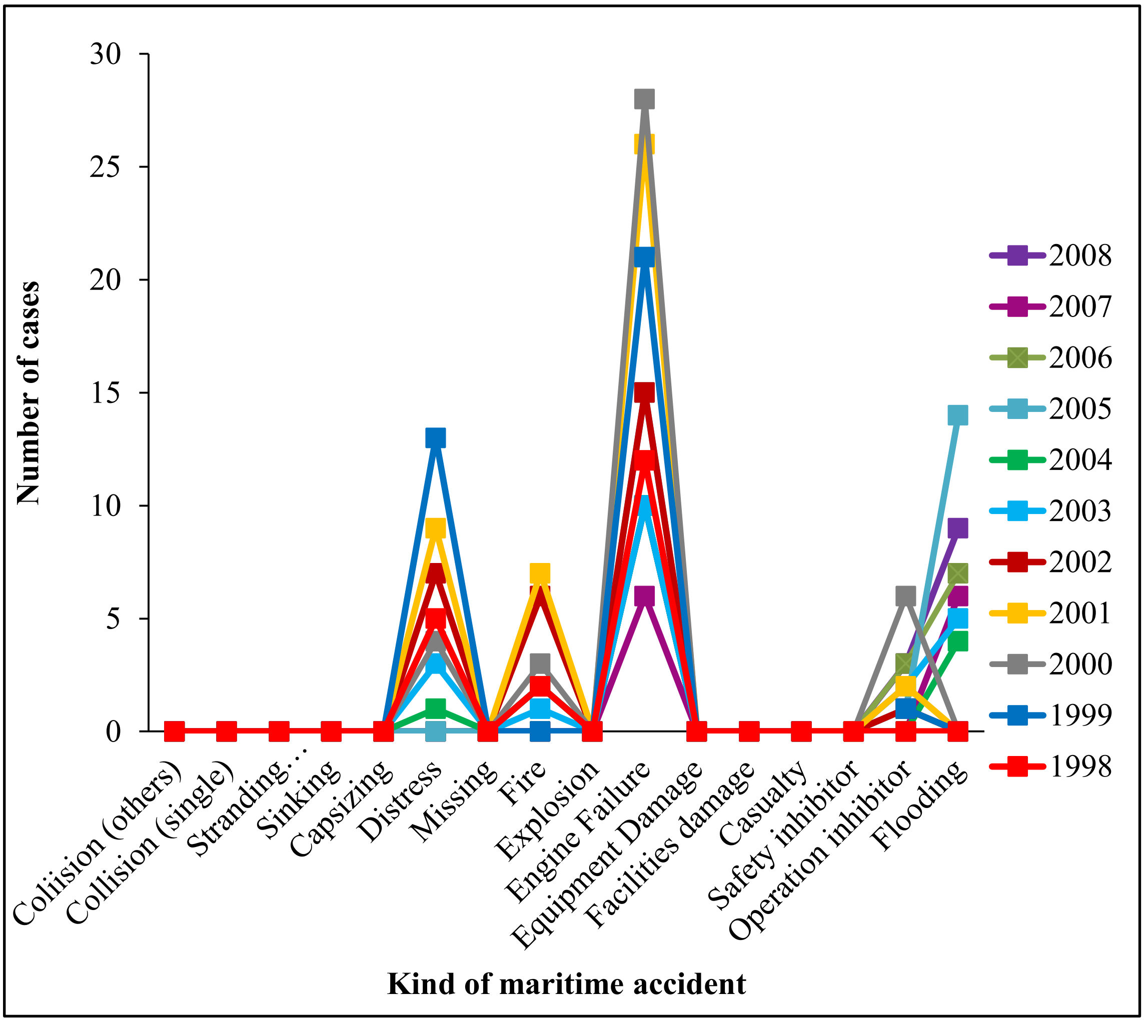


Fig.5.20 Auxiliary engine failure in 1998-2008

20. Poor management of lubricant oil

Fig. 5.21 shows number of cases probability that unsafe actions such as poor management of lubricant oil lead to engine failure, operation inhibitor, fire, and equipment damage are cases reach highest number of maritime accidents. One of root cause is decreased quality that poor management of lubricant oil needed practices and procedures for ensuring that the standby lubricating oil filter was ready for service, for monitoring lubricating oil filter performance and for changing over to the standby filter were adequate [66].

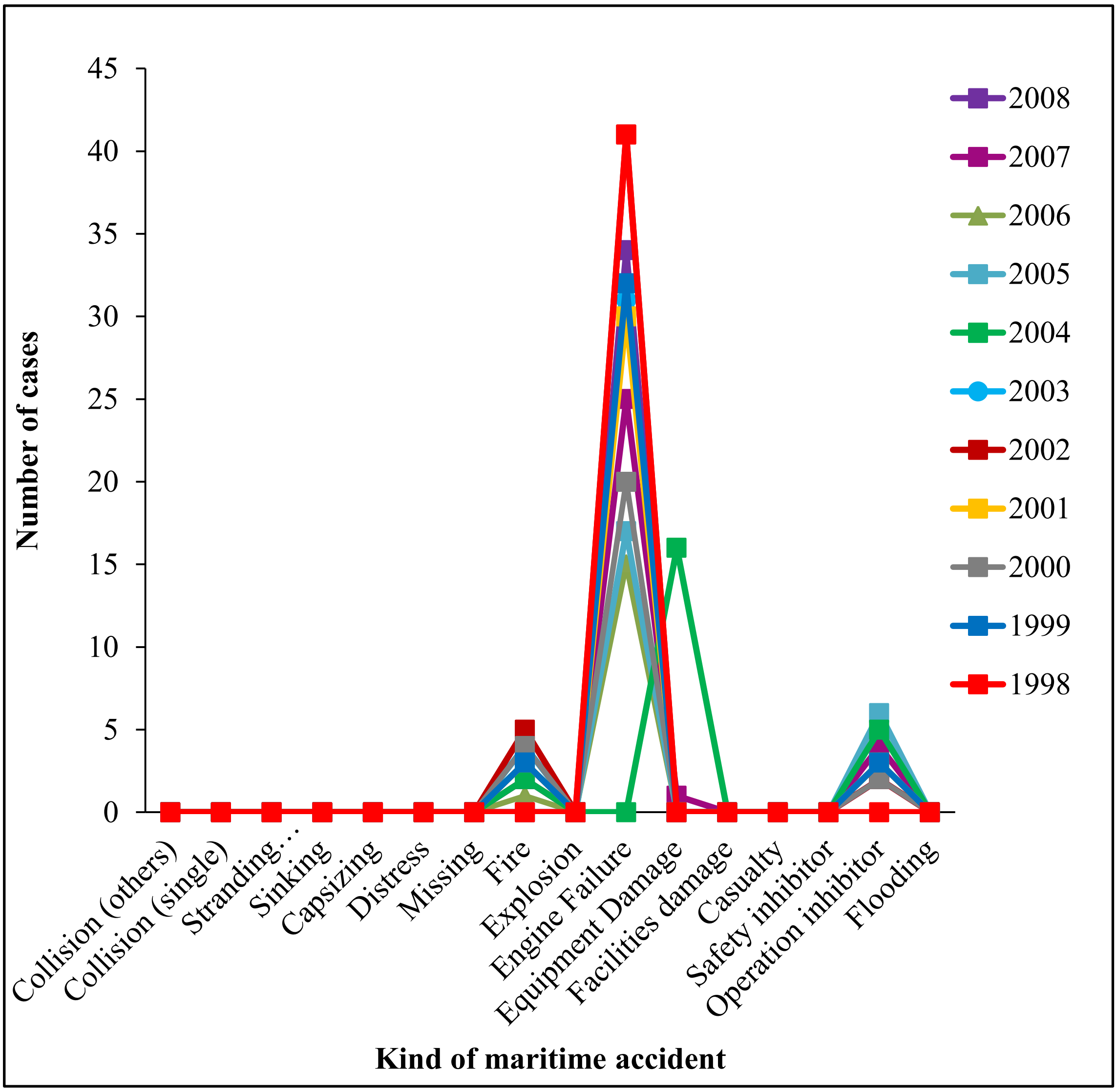


Fig.5.21 Poor management of lubricant oil in 1998-2008

21. Poor management of electrical equipment

Fig.5.22 shows number of cases probability that unsafe actions such as poor management of electrical equipment lead to fire, operation inhibitor, engine failure and casualty are cases reach highest number of maritime accidents. One of root cause is poor management of electrical equipment that ship steering systems are commonly electro-hydraulic, with the 'electro' parts requiring continual good checking. Regulations exist to control the construction, installation, operation and maintenance of electrical equipment so that danger is eliminated as f.ar as possible. Minimum acceptable standards of safety are issued by various bodies including national governments, international governmental conventions (e.g. SOLAS), national and international standards associations (e.g. BS and IEC), learned societies (e.9. IEE), classification societies (e.g. Lloyds), etc. Where danger arises it is usually due to accident, neglect or some other contravention of the regulations. Thus, preventive as well as corrective maintenance is required [67].

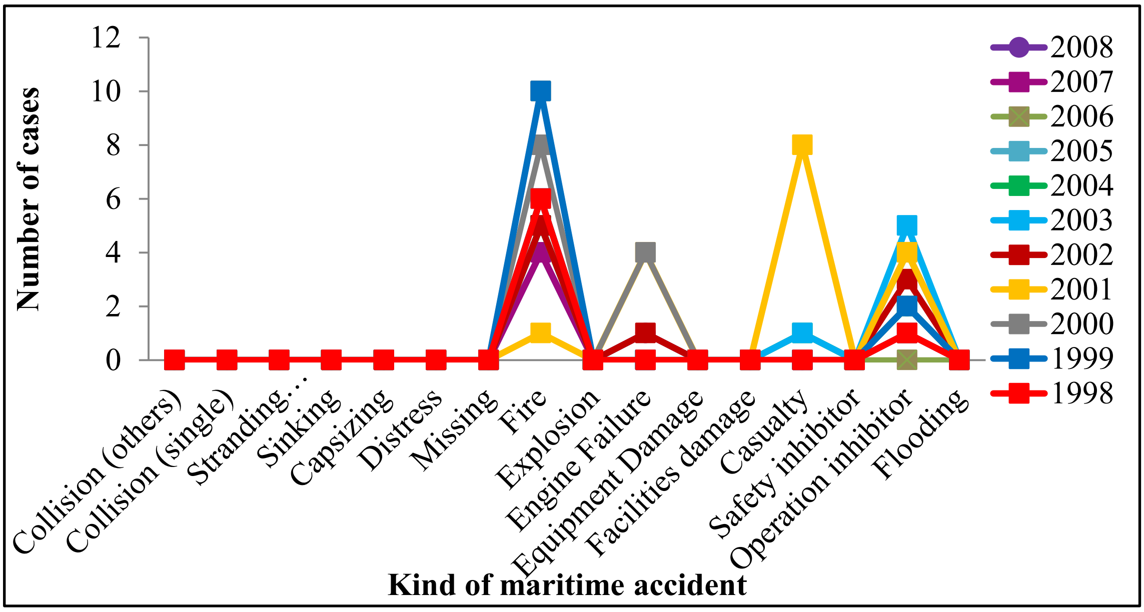


Fig.5.22 Management of electrical equipment in 1998-2008

22. Improper handling and other task

Fig. 5.23 shows number of cases probability that unsafe actions such as improper handling and other task lead to human casualty, capsizing, fire and sinking are cases reach highest number of maritime accidents. One of root cause is referred that largely a matter of common sense and is necessary for the care and protection of objects such as to know workplace equipment, a seaman need to be trained in the proper use and limitations of the equipment they operate. However, good handling techniques are not always obvious.

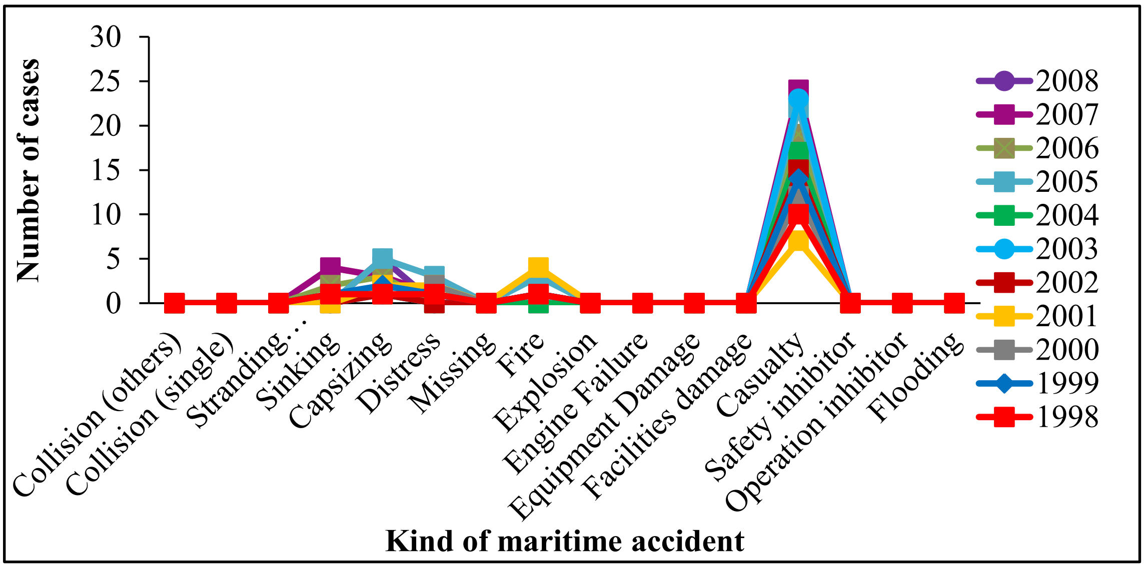


Fig.5.23 Improper handling and other task in 1998-2008

23. Improper fishing work

Fig. 5.24 shows number of cases probability that unsafe actions such as improper fishing work lead to casualty and capsizing are cases reach highest number of maritime accidents. One of root cause is decrease quality of practical understanding of the basic types of small fishing vessel is construction including common terminology. A fishing vessel encumbered by her nets or trawl cannot keep out of the way of other vessels and Rule 26 directs all other vessels to keep out of the way of fishing vessels. Conversely, it is the duty of encumbered fishing vessels to keep their course and speed. The rule as to indicating the position of the nets by a second light should be strictly observed.

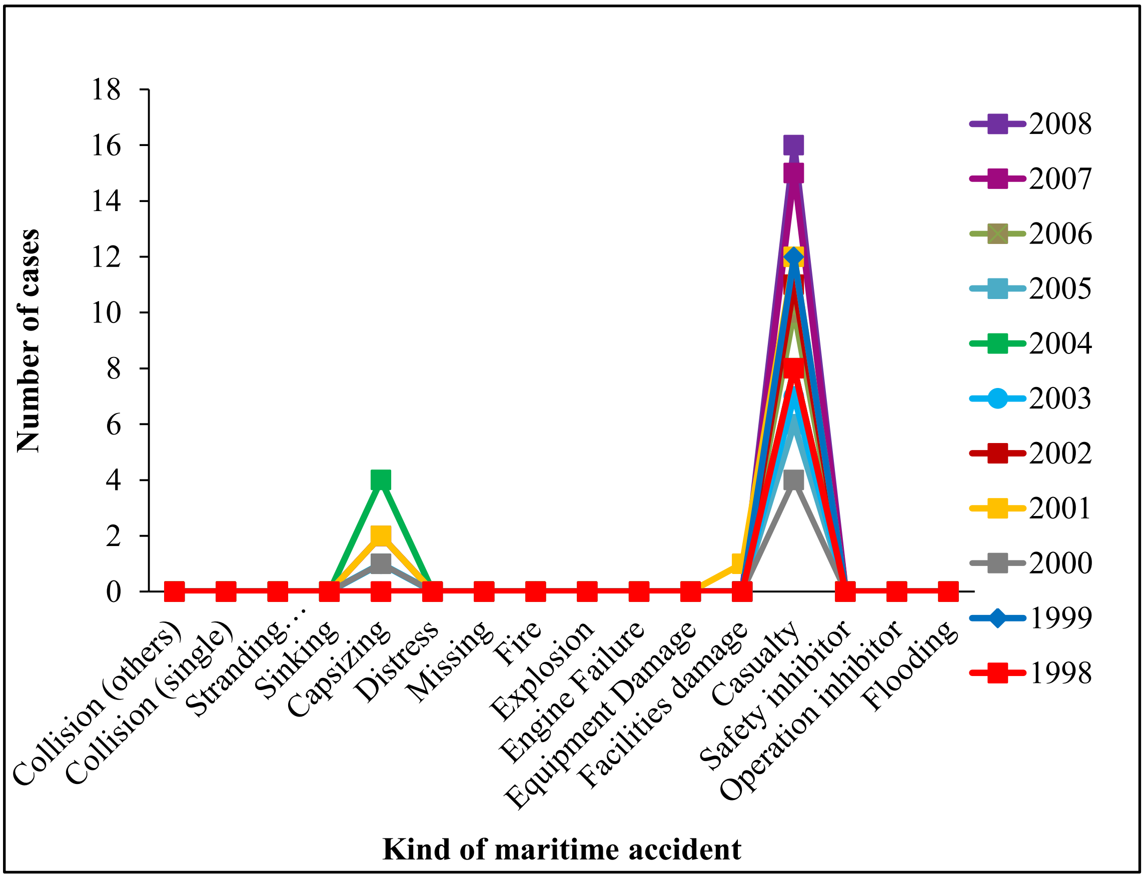


Fig.5.24 Improper fishing work in1998-2008

24. Poor management of passenger and cargo loading

Fig. 5.25 shows number of cases probability that unsafe actions such as improper fishing work lead to casualty and sinking are cases reach highest number of maritime accidents. One of root cause is decrease of quality that a common problem for ships and crews is the miss-declaration of shipping container weights and contents. It is of the utmost importance to recognize that actions taken when containers are stuffed may have direct implications for the stability and safety of containerships, the lives of seafarers on board and the safety of others throughout the transport chain. It is vital to adhere to weight restrictions, and correct procedures for loading and securing cargo, to ensure the safe distribution of weight and that cargoes inside containers do not move or shift when at sea, compromising the safety of the ship. Un-stable position of the ship will be impacted to accident. The IMO/ILO have guideline on the Packing of Cargo Transport Units, provides a common global resource for information on container stuffing.

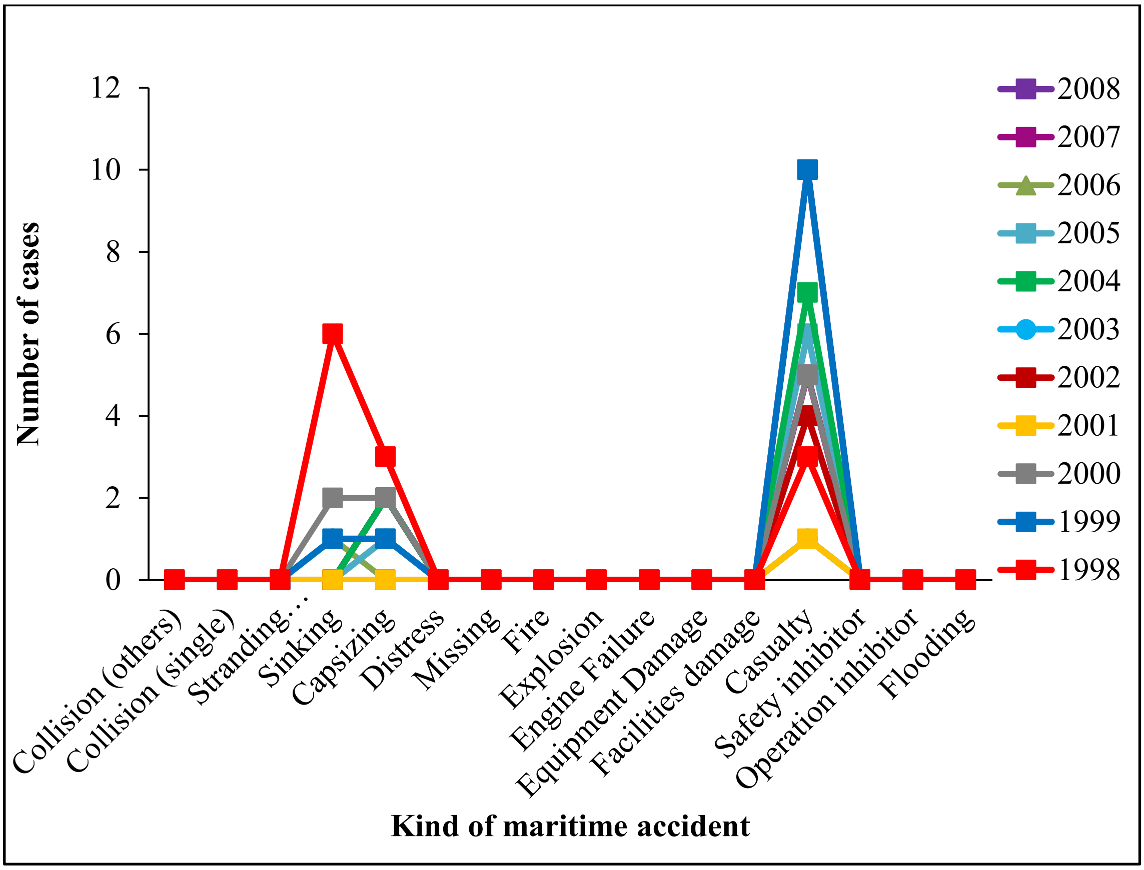


Fig.5.25 Poor management of passenger and cargo loading in 1998-2008

25. Inadequate supervision of working on board

Fig. 5.26 shows number of cases probability that unsafe actions such as inadequate supervision of working on board lead to collision (others) and stranding/grounding referring to casualty are cases reach highest number of maritime accidents. One of root cause is decreased quality that inadequate supervision of work on board, where much equipment and systems are highly specialized, can lead to costly malfunctions. The vessel is only one element of a large project and a disciplined project management approach is required to ensure smooth dovetailing with the overall economics and design plan. Time or cost over runs can eliminate projected margins, making it critical that projects are completed on time with no compromise on cost or quality. Close supervision by qualified experts is therefore of critical importance, right from a vessel's inception on the drawing board, through its sea trials to final delivery and continue monitoring during of sailing by giving a certain period of time. Inadequate supervision will get many problems.

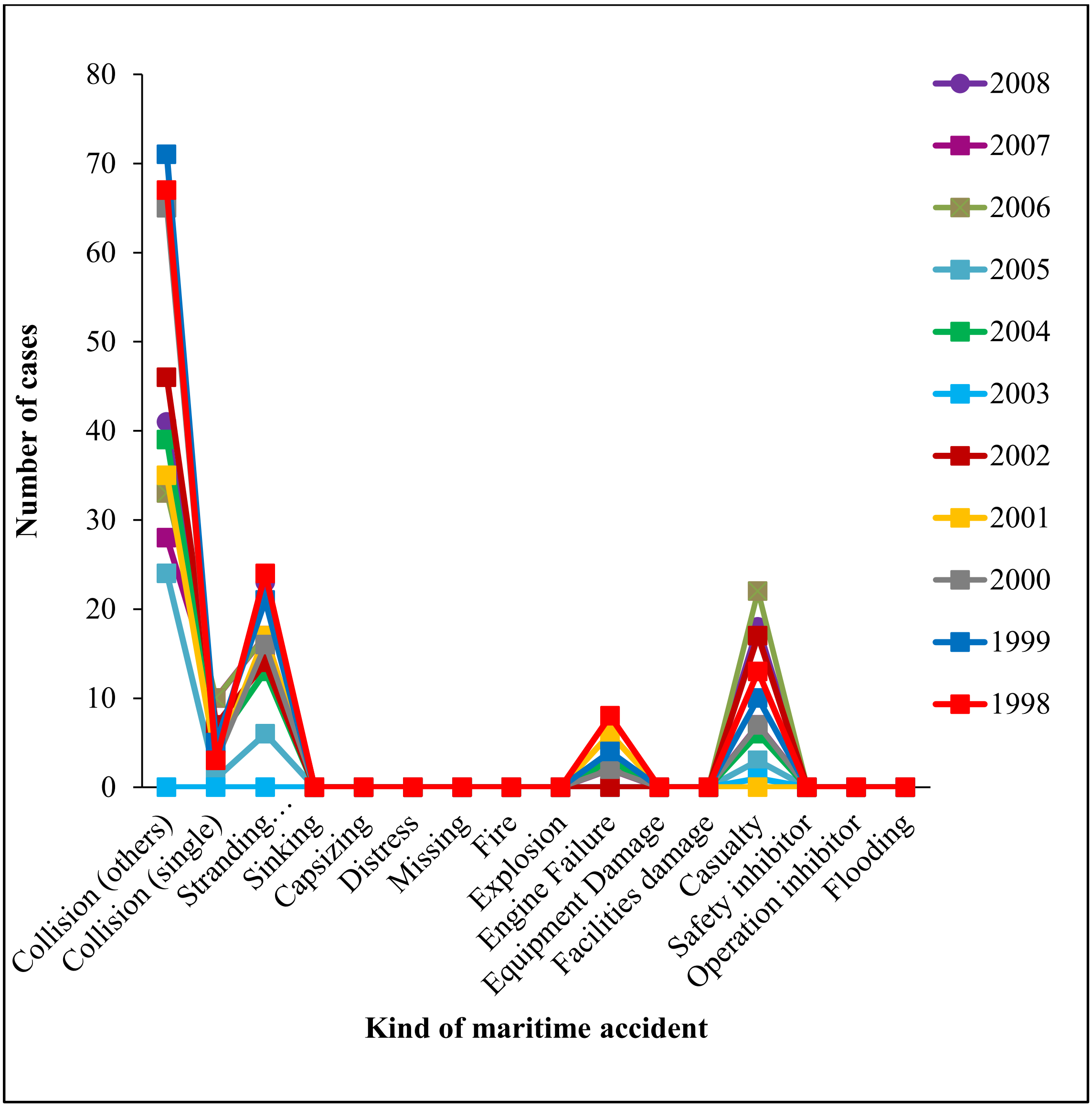


Fig.5.26 Inadequate supervision of working on board in1998-2008

26. Inadequate report taking over watch

Fig. 5.27 shows number of cases probability that unsafe actions such as Inadequate report and taking over watch lead to collision (others), collision (single), stranding/grounding and casualty are cases reach highest number of maritime accidents. One of root cause is decreased quality that inadequate seamen on taking over the watch the relieving officer should satisfy himself as to the vessel estimated or true position and confirm its intended track, course and speed and should note any dangers to navigation expected to be encountered during his watch [68]. The seamen are unable to exclude the possibility of the officer of the navigational watch being affected by fatigue caused by an excessive workload due to a watch system which is inadmissible for a vessel of this size and area of operation as well as the course of the voyage.

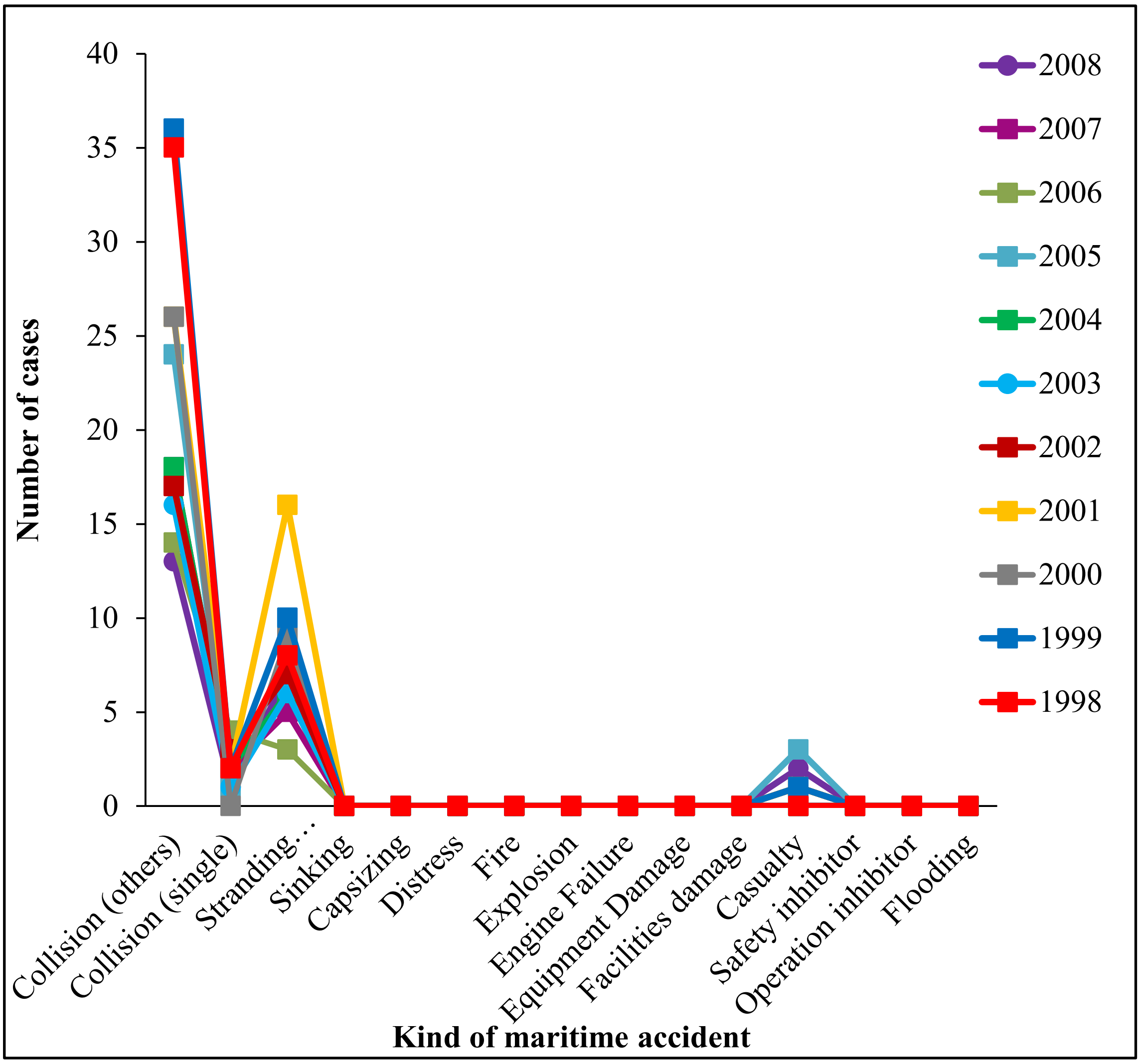


Fig.5.27 Inadequate report and taking over watch

27. Poor management fire

Fig. 5.28 shows number of cases probability that unsafe actions such as poor management fire lead to fire and explosion are cases reach highest number of maritime accidents. One of reason is decreased quality that management to prevent fire on ship is discovery of a fire at sea can expect to be rapidly followed by the sounding of the fire alarm. This would alert personnel to move towards their respective fire stations, inclusive of the Navigation Bridge and the Engine Room. Each scenario will be influenced by various factors, not least the nature of the fire, and what is actually burning. In the event of an engine room fire, where the total flood CO_2 employed, while the ship will immediately become a 'dead ship'. Such as situation of fire lead to explosion would invariably leave the vessel at the mercy of the weather conditions (see in fig.5.28). This situation may dictate need to engage with an ocean-going tug at a later time, once the fire is out [69]

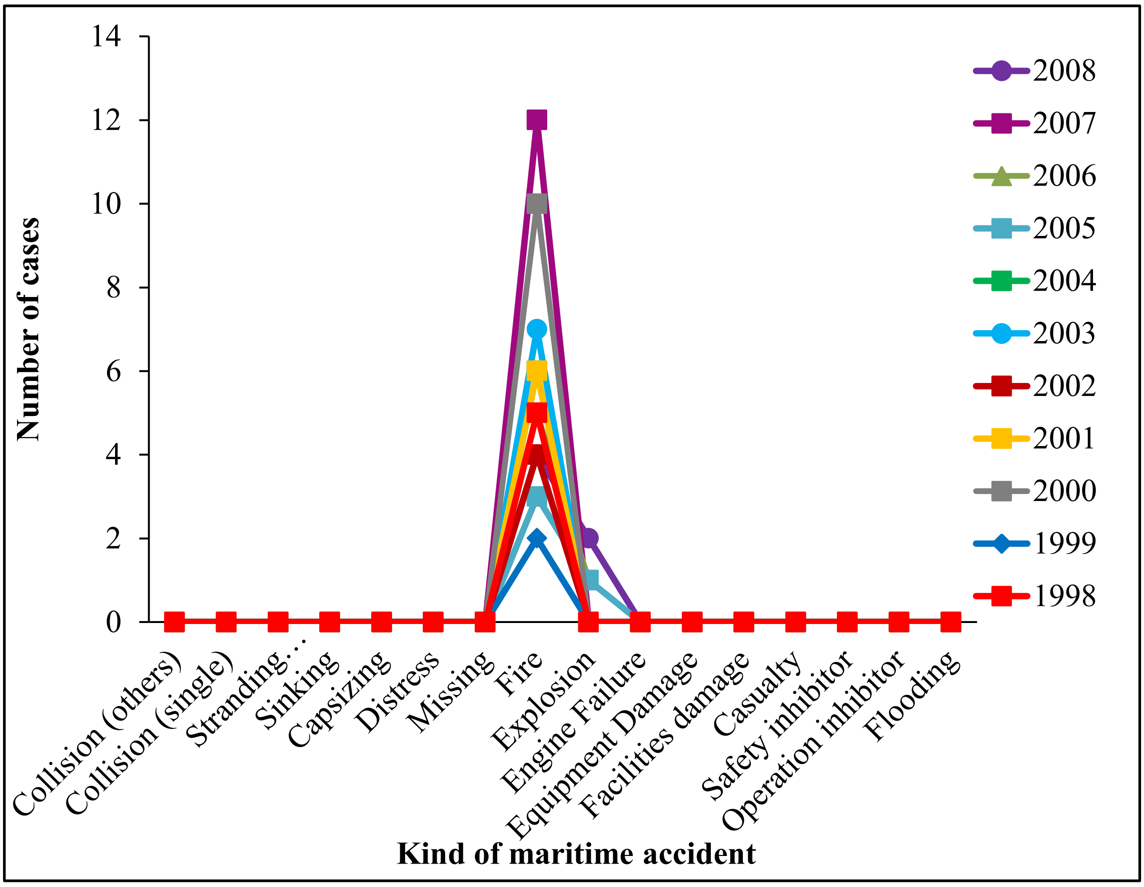


Fig.5.28 Poor management fire in 1998-2008

28. Force Majeure

Fig. 5.29 shows number of cases probability that unsafe condition such as force majeure lead to capsizing, distress, engine failure, casualty are cases reach highest number of maritime accidents. One of reason is force majeure sometimes called others forces and external forces. Generally its unsafe conditions is which have externality, un-predictability. The reason unpredictable situation will occur as where non-performance is caused by the usual and natural consequences of external forces, describes in the fig. 5.29.

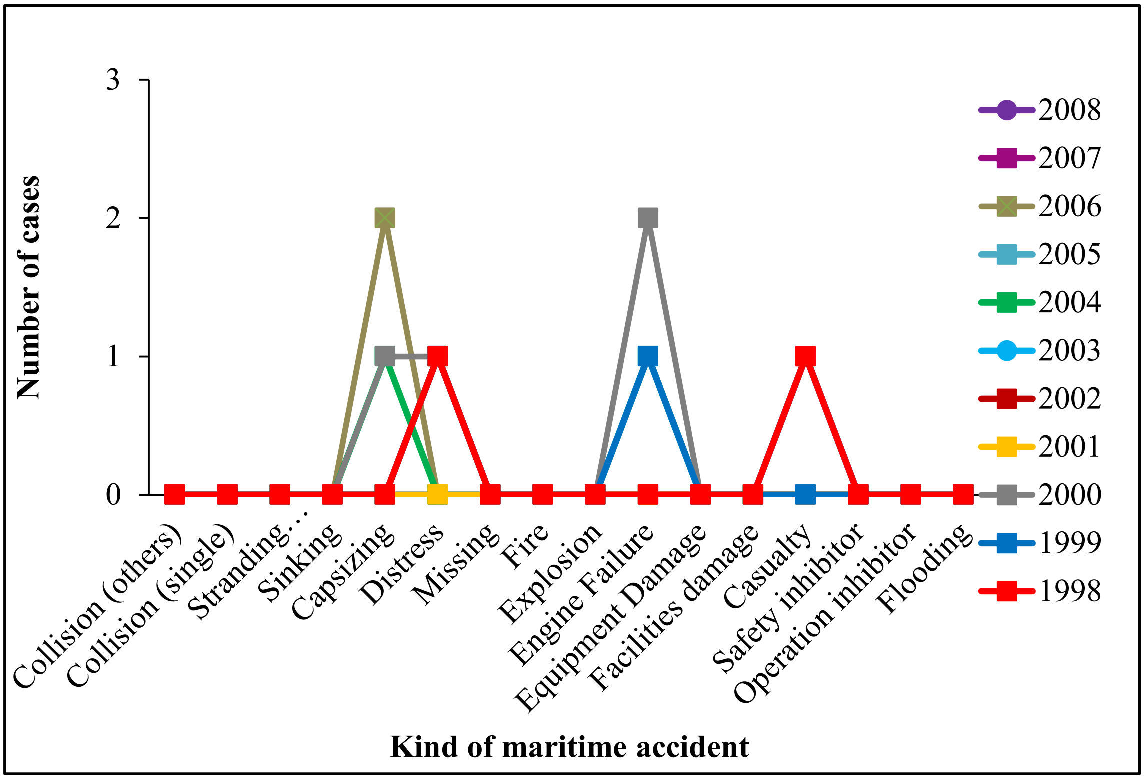


Fig.5.29 Force Majeure in 1998-2008

29. Others

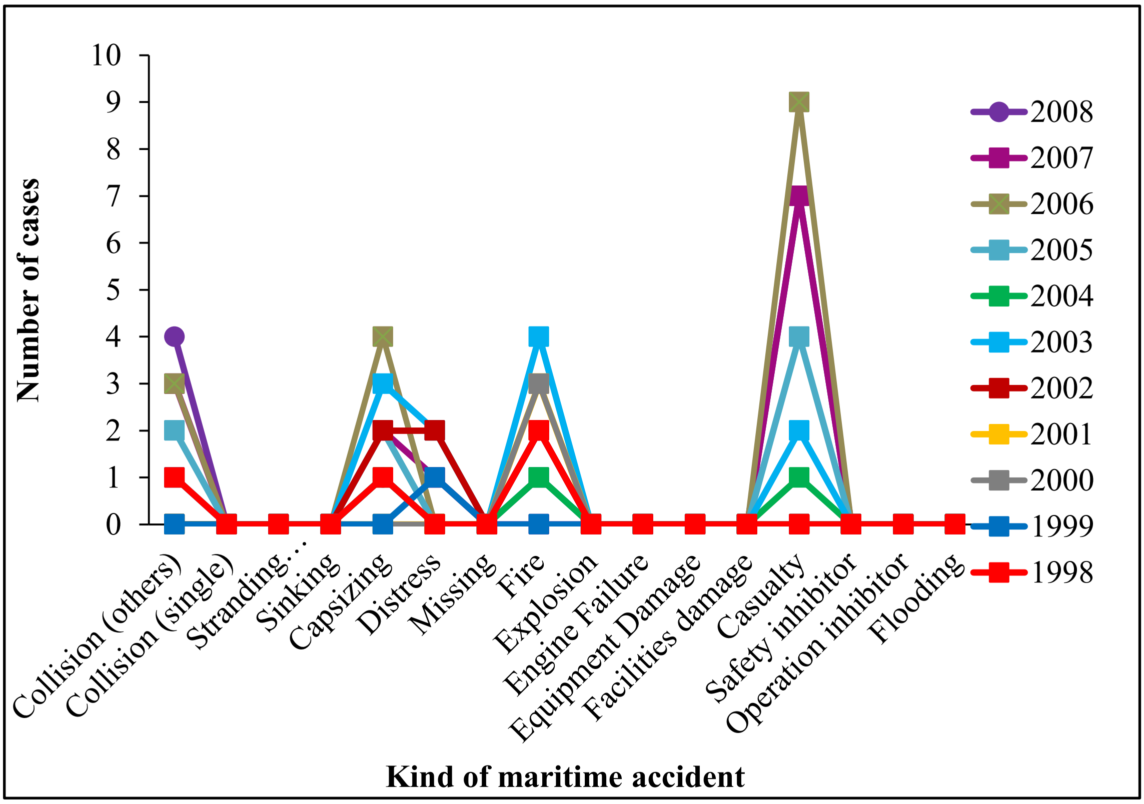


Fig.5.30 Others in 1998-2008

5.4 Risk Level Term in Safety Standard

Generally, any unsafe actions are contains a risk. A risk is a consequence that will happen. Further definition of risk is mentioned by R. de la Campa Portela [70] in table 5.2.

Table 5.2 Definition of risk

Definition of risk	Author/Organization	Year
A combination of hazard level and (1) likelihood of the hazard leading to an accident and (2) hazard exposure or duration.	Nancy Leveson, Massachusetts, US.	1995
A function of the probability of a hazard developing into an accident and the expected consequence of the accident if it did occur.	Redmill and Rajan, UK	1997
The risk remaining after protective measures have been taken is the residual risk.	ISO/IEC Guide 51; Geneva, Switzerland.	1999
Combination of the probability of occurrences of harm and the severity of that harm.	ISO/IEC Guide 51; Geneva, Switzerland.	1999
The probable consequence of that outcome.	Robert O'Connor, New York, US.	2000
A combination of the probability of occurrence of harm and the severity of that harm.	IEC 61508-4 is an International standard of rules applied in industry;	2002
Risk is a combination of the frequency of occurrence of harm and the severity of that harm	IEC 61511-1;	2003
The effect of uncertainty on objectives.	ISO 31000; ISO Guide 73;	2009

5.4.1 Risk Level Determination

The level tolerance of any consequence from every case is going to happen, different. As it is well known, risk level which give idea of the general importance of a specific hazard, can be comprised amongst one of three assumptions Kuo [71]:

A. Intolerable risk level: the risk level is too high to be justified and that it should be reduced regardless of the costs associated with the measures needed to bring the risk down to a tolerable level.

B. Tolerable risk level: risk levels that are assessed to be below the intolerable limit are regarded as tolerable provided it can be demonstrated to be ALARP (As Low As Reasonable Practicable). In order to demonstrate that the risk level is ALARP, cost effectiveness assessment of available risk control options must be performed. If cost effective risk control options are available, the risk level will not be ALARP and thus not regarded as tolerable until these are implemented.

C. Negligible risk level: the risk level is assessed to be so low that no further risk reduction measures are required.

Campa Portela was corrected in probability level. In this case, to determine the risk level of the studied factor implement to use in a risk matrix, which parameters have probability of happening of such a factor in a maritime accident and its consequences, both data derived from the analysis done in step 1. To elaborate the risk matrix, that can be seen in fig. 1.1 and 1.2, will be processed to establish five levels of probability and five levels of consequences in table 5.3.

Table 5.3 Probability levels of risk

Over	**Under**	**Description**
0 % –	**10 %**	very low probability risk level
10 % -	**40 %**	low probability risk level
40 % -	**60 %**	half probability risk level
60 % -	**90 %**	high probability risk level
90 % -	**100 %**	very high probability risk level

Consequence levels could be established as:

1. Disastrous consequences: people death, very serious damage to maritime, environment, sinking or any other accident which results in the ship total lost.
2. Serious consequences: people serious injuries, maritime environment serious damage, fire, collision, grounding or any other accident which results in very serious damage to ship structure.
3. Moderate consequences: moderate injuries to people, moderate damage to maritime environment or any other accident which results in moderate damage to ship structure.
4. Minor consequences: minor injuries to people, minor damage to maritime environment, or any other accident which results in minor damage to ship structure.
5. Negligible consequences: very little damage to ship structure (see in table 5.4).

Table 5.4 Risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

5.4.2 Unsafe Actions in Risk Matrix

Based on the results of data collection has been described by table 5.1 in section 5.2, and the risk assessment and investigation which has been described, the risk level analysis for unsafe actions follows below:

1. Improper management for ship operation(X1) = 1.5 % in risk matrix

Unsafe actions such as improper management for ship operation have minor, moderate, serious, disastrous consequences and negligible and tolerable risk level. It means the risk level is assessed to be so low but need assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures too that no further risk reduction measures are required based on 1.5 % is very low probability of risk level (table 5.5) and fig.5.2 are number of cases serious tolerable . Considering is needed awareness (as explained sub chapter 4.2.2) as greatest accidents to casualty or injured in operational. Other kind of maritime accidents such as engine failure and collision as result to risk..

Table 5.5 Improper management for ship operation=1.5 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

2. Poor repair condition on ship structure(X2) = 0.9 % in risk matrix

Unsafe actions such as poor repair condition on ship structure have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 0.9 % is very low probability of risk level (table 5.6) and fig.5.3 are number of cases serious tolerable. Monitoring is needed in procedure maintenance (as explained sub chapter 4.2.2) because greatest accidents lead to engine failure in operational. Other kind of maritime accidents such as casualty and collision are highest accidents will be occurred to risk.

Table 5.6 Poor repair condition on ship structure =0.9 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

3. Poor preparation for sea(X3) = 0.5 % in risk matrix

Unsafe actions such as poor preparation for sea have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 0.5 % is very low probability of risk level (table 5.7) and fig.5.4 are number of cases serious tolerable. Monitoring is needed in procedure (as explained sub chapter 4.2.2) because greatest accidents lead to operation inhibitor during operational. Other kind of maritime accidents such as stranding/grounding, collision and casualty can be occurred to risk.

Table 5.7 Poor preparation for sea = 0.5% in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

4. Improper hydrographic survey (X4) = 2.4 % in risk matrix

Unsafe actions such as improper hydrographic survey is have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.4 % is very low probability of risk level (table 5.8) and fig.5.5 are number of cases serious tolerable. Reasoning is needed action (as explained sub chapter 4.2.2) that procedure to improve hydrographic surveys and monitoring because greatest accidents lead to stranding/grounding in operational. Other kind of maritime accidents such as facilities damage and collision are two highest numbers of cases to risk.

Table 5.8 Improper hydrographic survey = 2.4 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

5. Inadequate passage planning for ship's (X5) = 2.2 % in risk matrix

Unsafe actions such as inadequate passage planning for ship's have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.2 % is very low probability of risk level (table 5.9) and fig.5.6 are number of cases serious tolerable. Considering is needed action (as explained sub chapter 4.2.2) that procedure knowledge and skills will affect to performance of the seaman because greatest accidents lead to stranding/grounding in operational. Other kind of maritime accidents such as facilities damage and casualty are cases reach highest to risk.

Table 5.9 Inadequate passage planning for ship's = 2.2 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

6. Improper ship handling(X6) = 2.8 % in risk matrix

Unsafe actions such as improperly ship handling have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.8 % is very low probability of risk level (table 5.10) and fig.5.7 are number of cases serious tolerable. Controlling is needed action (see in sub chapter 4.2.3) for training about fundamental skill of professional seamen ship is being able to maneuver vessel with accuracy and precision because greatest accidents lead to collision. Other kind of maritime accidents such as facilities damage and casualty are cases reach highest to risk.

Table 5.10.Improper ship handling = 2.8 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

7. Unconfirmed ship position (X7) = 4.2 % in risk matrix

Unsafe actions such as unconfirmed ship position have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 4.2 % is very low probability of risk level (table 5.11) and fig.5.8 are number of cases serious tolerable. Controlling is needed action (as explained sub chapter 4.2.3) training about less to knowledge and skills about incorrect vessel heading because greatest accidents lead to collisions. Other kind of maritime accidents such as stranding/grounding and facilities damage are cases reach highest to risk.

Table 5.11 Unconfirmed ship position = 4.2 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

8. Improper look-out (X8) = 31.1 % in risk matrix

Unsafe actions such as improper look-out have moderate consequences and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 31.1 % is cost effectiveness assessment of available risk control options must be performed (table 5.12) and fig.5.9 are number of cases serious tolerable. Monitoring is needed to control behavior attitude (as explained sub chapter 4.2.2) implemented rules of International COLREGs because greatest accidents lead to collision. Other kind of maritime accidents such as casualty and facilities damage are cases reach highest to risk.

Table 5.12 Improper look- out = 31.1 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

9. Fatigue (X9) = 6.5 % in risk matrix

Unsafe conditions such as fatigue have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 6.5 % is very low probability of risk level (table 5.13) and fig.5.10 are number of cases serious tolerable. Monitoring is needed good coordination due to how the motion of the ocean can affect one's balance, coordination because greatest accidents lead to stranding/grounding. Other kind of maritime accidents such as collision (others) and collision (single) are cases reach highest to risk.

Table 5.13.Fatigue = 6.5 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

10. Insufficient maintenance and wrong handling of steering systems and nautical instruments(X10) =0.2 % in risk matrix

Unsafe actions such as insufficient maintenance and wrong handling of steering systems and nautical instruments have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 0.2 % is very low probability of risk level (table 5.14) and fig.5.11 is number of cases serious tolerable. Monitoring is needed awareness (as explained sub chapter 4.2.2) that maintenance operation because greatest accidents lead to collision (single), collision (others) and stranding/grounding

Table 5.14 Insufficient maintenance and wrong handling of steering systems and nautical instruments =0.2 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

11. Poor attention to meteorological and oceanographical (X11) = 2.1 % in risk matrix

Unsafe actions such as poor attention have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.1 % is very low probability of risk level (table 5.15) and explained in fig.5.12 are number of cases serious tolerable. Considering is needed monitoring and controlling (as explained sub chapter 4.2.2) that maritime weather and ocean conditions for adequate planning of marine activities because greatest accidents lead to capsizing, stranding, collision (single), distress.

Table 5.15 Poor attention to meteorology and oceanography = 2.1% in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

12. Improper anchoring and mooring (X12)= 1.1 % in risk matrix

Unsafe actions such as improper anchoring and mooring have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 1.1 % is very low probability of risk level (table 5.16) and fig.5.13 are number of cases serious tolerable. Monitoring is needed good coordination due to how to selected good anchor and do not drag anchor in operational because greatest accidents lead to collision (others). Other kind of maritime accidents such as stranding/grounding and distress are the most influence to risk.

Table 5.16 Improper anchoring and mooring = 1.1 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

13. Inadequate preparation for rough at sea (X13) = 0.8 % in matrix

Unsafe actions such as inadequate preparation for rough at sea have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 0.8 % is very low probability of risk level (table 5.17) and fig.5.14 are number of cases serious tolerable. Monitoring and controlling are needed good coordination due to how to do in rough weather situations within limited time because greatest accidents lead to capsizing. Distress and stranding /grounding are the most influence to risk.

Table 5.17 Inadequate preparation for rough at sea = 0.8 % in matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

14. No indication of navigation lights and shapes (X14) = 1.2 % in risk matrix

Unsafe actions such as no indication of navigation light have serious consequences and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 1.2 % is cost effectiveness assessment of available risk control options must be performed (table 5.18) and fig.5.15 are number of cases serious tolerable. Monitoring is needed awareness (as explained sub chapter 4.2.2) that maintenance operation because greatest accidents lead to collision (single). Other kind of maritime accidents such as collision (others) are the most influence to risk.

Table 5.18 No indication of navigation lights and shapes = 1.2 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

15. Signaling failure (X15) =5.9 % in risk matrix

Unsafe actions such as signaling failure have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 5.9 % is very low probability of risk level (table 5.19) and fig.5.16 are number of cases serious tolerable. Monitoring is needed awareness (as explained sub chapter 4.2.2) that failures are interpreted the signal because the greatest accident lead to collision (others). Other kind of maritime accidents such as collision (single) and casualty as result to risk.

Table 5.19 Signaling failure =5.9 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

16. Improper ship's speed (X16) =2.5 % in risk matrix

Unsafe actions such as improper ship's speed have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.5 % is very low probability of risk level (in table 5.20) and explained in fig.5.17 are number of cases serious tolerable. Considering is needed controlling and monitoring (see in sub chapter 4.2.2) that check speed on a ship taking into account the situation in and situation moving towards because the greatest accident lead to collision (others). Other kind of maritime accidents such as collision (single) and casualty as result to risk.

Table 5.20 Improper ship's speed =2.5 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

17. Ignoring COLREGS (X17) =11.0 % in risk matrix

Unsafe actions such as no obeying COLREG have serious consequences and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 11.0 % is cost effectiveness assessment of available risk control options must be performed (table 5.21) and fig.5.18 are number of cases serious tolerable. Considering is needed action (see in sub chapter 4.2.2) that keep remind mariners of the basic of COLREGs because greatest accidents lead to collision (others).

Table 5.21 Ignoring COLREGS =11.0% in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

18. Main engine failure (X18) = 4.3 % in risk matrix

Unsafe actions such as main engine failure have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 4.3 % is very low probability of risk level (table 5.22) and fig.5.19 are number of cases serious tolerable. Considering is needed controlling periodical (as explained sub chapter 4.2.2) in maintenance because greatest accidents lead to engine failure. Other kind of maritime accidents such as flooding and operation inhibitor, fire as result to risk.

Table 5.22.Main engine failure = 4.3 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

19. Auxiliary engine failure (X19) = 2.1 % in risk matrix

Unsafe actions such as main engine failure have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.1 % is very low probability of risk level (table 5.23) and fig.5.20 are number of cases serious tolerable. Considering is needed controlling periodical (as explained sub chapter 4.2.2) that maintenance and cleanliness procedures because greatest accidents lead to damage to engine failure. Other kind of maritime accidents such as operation inhibitor, fire as result to risk.

Table 5.23 Auxiliary engine failure =2.1 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

20. Poor management of lubricant oil (X20) = 2.5 % in risk matrix

Unsafe actions such as poor management of lubricant oil have moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.5 % is very low probability of risk level (in table 5.24) and explained in fig.5.21 are number of cases serious tolerable. Considering is needed monitoring (as explained sub chapter 4.2.2) periodical in lubricant oil and cleanliness procedures because greatest accidents lead to damage to engine failure. Other kind of maritime accidents such as operation inhibitor, fire and equipment damage are result probability of risk.

Table 5.24 Poor management of lubricant oil =2.5 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

21. Poor management of electrical equipment (X21) = 0.8 % in risk matrix

Unsafe actions such as poor management of electrical equipment have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 0.8 % is very low probability of risk level (table 5.25) and fig.5.22 are number of cases serious tolerable. Considering is monitoring (see in sub chapter 4.2.2) that continual good checking, testing and maintenance as indeed do all electrical systems on board a ship. Other kind of maritime accidents such as fire, operation inhibitor, engine failure and casualty are result probability of risk.

Table 5.25 Poor management of electrical equipment = 0.8 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

22. Improper handling and other task(X22) = 1.8 % in risk matrix

Unsafe actions such as improper handling and other task have minor, moderate, serious, disastrous consequences and negligible and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 1.8 % is cost effectiveness assessment of available risk control options must be performed (table 5.26) and fig.5.23 are number of cases serious tolerable. Considering is awareness (as shown sub chapter 4.2.2) that continual good handling techniques not always obvious because improper handling as a matter of common sense and necessary for the care and protection of objects and fatality greatest led to disastrous such human casualty, capsizing, fire and sinking.

Table 5.26 Improper handling and other task = 1.8 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

23. Improper fishing work (X23) = 0.9 % in risk matrix

Unsafe actions such as improper handling and other task have minor, moderate, serious, disastrous consequences and negligible and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 0.9 % is cost effectiveness assessment of available risk control options must be performed (table 5.27) and fig.5.24 are number of cases serious tolerable. Considering is attitude and action (as shown sub chapter 4.2.2) that the rule as to indicating the position of the nets by a second light should be strictly observed to avoid fatality led to disastrous such human casualty and capsizing.

Table 5.27 Improper fishing work = 0.9 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

24. Poor management of passenger and cargo loading(X24) = 0.6 % in risk matrix

Unsafe actions such as poor management of passenger and cargo loading have minor, moderate, serious, disastrous consequences and negligible and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 0.6 % is cost effectiveness assessment of available risk control options must be performed (table 5.28) and fig.5.25 are number of cases serious tolerable. Considering is attitude and action (as shown sub chapter 4.2.2) that to recognize that actions taken when containers are stuffed may have direct implications for the stability and safety of containerships, the lives of seafarers on board and the safety of others throughout the transport chain to avoid fatality greatest led to disastrous such human casualty and sinking as result to risk.

Table 5.28 Poor management of passenger and cargo loading =0.6 % in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

25. Inadequate supervision of working on board (X25) = 6.5 % in risk matrix

Unsafe actions such as supervision of working on board have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 6.5 % is very low probability of risk level (table 5.29) and fig.5.26 are number of cases serious tolerable. Considering is controlling/monitoring (as explained sub chapter 4.2.2) during of sailing by giving a certain period of time because will be greatest led to collision (others) and stranding/grounding referring to casualty.

Table 5.29 Inadequate supervision of working on board= 6.5% in risk matrix

Consequences / Probability (Over – Under)	Negligible	Minor	Moderate	Serious	Disastrous
0-10 %	Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %	Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %	Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %	Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %	Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

26. Inadequate report and taking over watch on board (X26) = 2.4 % in risk matrix

Unsafe actions such as supervision of working on board have minor, moderate consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 2.4 % is very low probability of risk level (table 5.30) and fig.5.27 are number of cases serious tolerable. Considering is controlling (as explained sub chapter 4.2.2) in to arrange and manage operational on ship because the greatest accident lead to collision (others). Other kind of maritime accidents such as collision (single), stranding/grounding and casualty are result probability of risk.

Table 5.30 Inadequate report and taking over watch on board = 2.4 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

27. Poor management fire (X27) = 0.5 % in risk matrix

Unsafe actions such as poor management fire have serious consequences and tolerable risk level. It means the risk level is assessed to be ALARP (As Low As Reasonable Practicable) risk reduction measures are required based on 0.5 % is cost effectiveness assessment of available risk control options must be performed (table 5.31) and fig.5.28 are number of cases serious tolerable. Considering is attitude (see in sub chapter 4.2.2) that to prevent fire on ship and to expect to be rapidly dictate need to engage with an ocean-going tug at a later time, once the fire is out because the greatest accident lead to fire and explosion.

Table 5.31.Risk level poor management on fire = 0.5 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

28. Force majeure (X28) = 0.1 % in risk matrix

Force majeure sometimes called others forces and external forces. Generally its unsafe conditions is which have externality, un-predictability. The reason unpredictable situations have minor, moderate and serious consequences and negligible risk level. It means the risk level is assessed to be so low that no further risk reduction measures are required based on 0.1 % is very low probability of risk level (table 5.32) and fig.5.29 are number of cases serious tolerable. Considering is controlling/monitoring (as explained in sub chapter 4.2.2) that unpredictable situation will occur as where non-performance is caused by the usual and natural consequences of external forces, because the greatest accident lead to distress, engine failure, capsizing and casualty.

Table 5.32 Force majeure = 0.1 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

29. Others(X29) = 0.8 % in risk matrix

The reason unpredictable situations have minor, moderate and serious, disastrous consequences and negligible and tolerable risk level. Monitoring is condition in awareness, action, attitudes for control behavior (as explained sub chapter 4.2.2) that unpredictable situation should be strictly observed to avoid fatality greatest led to disastrous such human casualty, fire and capsizing, collisions (other) are probability of risk.

Table 5.33 Others = 0.8 % in risk matrix

Consequences		Negligible	Minor	Moderate	Serious	Disastrous
Probability						
Over	Under					
0-10 %		Negligible	Negligible	Negligible	Tolerable	Tolerable
10-40 %		Negligible	Negligible	Tolerable	Tolerable	Intolerable
40-60 %		Negligible	Tolerable	Tolerable	Tolerable	Intolerable
60-90 %		Tolerable	Tolerable	Tolerable	Tolerable	Intolerable
90-100 %		Tolerable	Intolerable	Intolerable	Intolerable	Intolerable

From the analysis of the risk level determination unsafe actions, found that:

1. Any unsafe actions have different characteristics that lead to kind maritime accidents.
2. Result problems that risk report by consequences level have consist of (Appendix-D):

a. Minor-Moderate-Serious-Disastrous is five unsafe actions such as improper management for ship operation (X1), improper fishing work (X23), poor management of passenger and cargo loading (X24).

b. Minor-Moderate-Serious such as poor repair condition on ship structure (X2),poor preparation for sea (X3), inadequate passage planning (X5), improper ship handling(X6),improper ship speed (X16), poor management and electrical equipment(X21), inadequate report and taking over watch (X26), force majeure(X28).

c. Moderate-Serious such as improper hydrographic survey before sailing (X4), unconfirmed ship position (X7), improper look-out (X8), fatigue (X9), insufficient maintenance and wrong handling of steering systems and nautical instruments (X10), poor attention to meteorological and oceanography, improper anchoring and mooring (X12), inadequate preparation for rough sea (X13), ignoring COLREGS (X17), main engine failure(18), auxiliary engine failure (X19), poor management of lubricant oil (X20), inadequate supervision of working on board(X25).

d. Serious such as no indication of navigation light and shapes (X14), poor management fire (X27).

CHAPTER 6
LOGIC OF PATTERNS IN RESPONSE TO UNSAFE ACTIONS

6.1 Introduction

In chapter 3 is described that Safety Response Model (SRM), of which one important element is decision making. Decision making can be regarded as the cognitive process resulting in the selection of a course of action among several alternative scenarios. The start of every decision is making a procedure for the final choice output and that depends on the time limit and information as pointed out Maritime Coast Guard Agency (MCA) [73]. The output can be an action or an opinion of choice. The seafarer can make more efficient decisions by shaping performance from response to unsafe conditions or unsafe actions through analysis scenario in an event. When actions are as a choice with time in the background, ubiquitous and often inconspicuous properties both, physical and psychological appear (described by red line in fig. 5.1). Scheduling to shape response decisions should be modeled on input, process and output. However, although processes necessarily unfold in time, this is not of itself a property of primary scientific interest. Identification of shaping factors in the taxonomy of errors on each individual, such as the seafarer, can be aimed at minimizing human injuries, from minor to fatal, that could be created in the formation of a safety culture. The name of this method is Personal Identification (PIN) Safe. Regarding this method it was described in chapter 4 and more detail implemented in the following sub chapter 6.

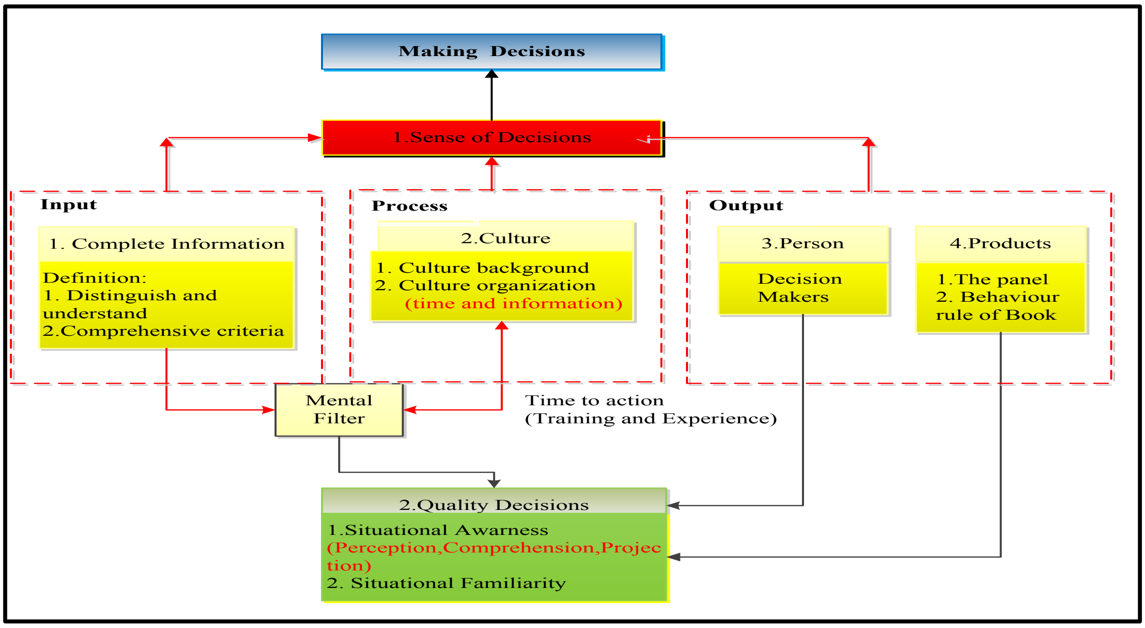


Fig.6.1 Decision-making scheme

6.2 Quality Decisions Scheme Human Element in Maritime Transport Systems

The maritime transport system is a very complex and large-scale socio-technical environment system consisting of human actions that interact with each other and operate in a physical environment. The main elements of the system are objects of transport, infrastructure, and facilities; these are linked by an information system and transport-related activities Zhejiang,L.[74].The human element is very important it designs, develops, builds, operates, manages, regulates, and interacts with other elements of the system. These elements are embedded in very complex, interdependent, and dynamic relationships have been modified (as show in fig.6.2).

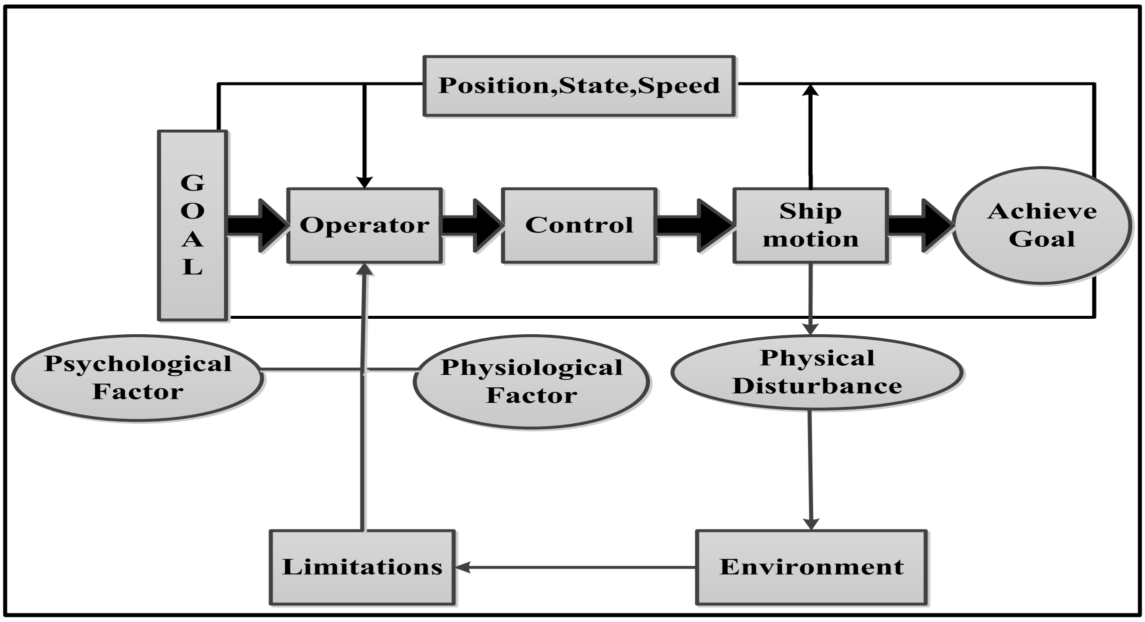


Fig.6.2 Relationships amongst operator, environment and ship

Knowledge of the working environment is vital in order to decrease the risk value of an individual ship. Every risk will culminate in an accident. Considering it has the probability accident which the ship determined by time, location and information Decreasing the steps to reach of accident level, the author is using the fact that every accident has probability for an individual ship, which fact is determined using exposures and a casualty rate. The exposures are the number of potential casualty sensitive situations in which the ship can be involved that could lead to an accident. For example, the exposure of collisions is an encounter between two ships. By relating these exposures with the actual casualties from the accident database, the casualty rates for the different accident types are derived. When observing boating accidents, the failure probabilities are distinguished from the corresponding exposure, as has been explained in chapter 4. Any exposure has its own characteristics of accident.

6.3 Characteristics in Every Perception

One alternative approach is to study unconscious perception based on the relative sensitivity of direct and indirect measures to conscious perceptual information. By considering the relative sensitivity of direct and indirect to conscious perceptual information, it is possible to use the disassociation paradigm to study unconscious perception and to make only one a priori assumption. Obviously it is desirable to minimize a priori assumptions, and we propose that only the following reasonable, but minimal working assumption is required by the logic of paradigm as logic of pattern.

6.3.1 Logic of Patterns in Qualitative Method

Critical events are consequences that potentially lead to accidents. Every accident that occurs during interaction with the human element will have its own characteristics. These characteristics need to be determined for evaluation by management. Identifying and analyzing the consequences are important to establishing evaluation strategies. Analyzing combinations of individual protection, management protection, structural calculations, and system damage, and their effects on safety culture can provide opportunities to enhance safety at sea. Some researchers have studied and many qualitative models have been used to analyze the risks of accidents or incidents, such as Bayesian models of plan recognition Charniak,R.,P.,G [75], taxonomy reliability Ross et al. [76], and risk based approaches in CREAM by Marseguerra et al.[77].

Finite model theory by Istiarto [78] with sample S gives the group a real number with a value of 0–1 that is called weighting or probability; this allows the odds of the occurrence of an event to be calculated.

- Each sample point in the sample universe is given a value denoting its probability; the sum of all probabilities for all sample points is equal to 1.
- To calculate the odds for event A, all the events that make up sample A are added together. A is the number of these probabilities, which is denoted by P(A). Thus, the probability set ∅ is 0, and S is 1.

$$0 \leq P(A) \leq 1 \qquad (6.1)$$

$$P(\emptyset) = 0 \qquad (6.2)$$

$$P(S) = 1 \qquad (6.3)$$

- When an experiment has N different experimental results, each has the same possibility of occurrence, and n is all of the results of this experiment that contain event A, the probability of event A is

$$P(A) = n/N \qquad (6.4)$$

The next step of the compound set events is as follows:

- The compound set events are for a combination of two events. If A and B are two sets in a universe or sample S, then the union of A and B is a new set that consists of members of A and B (as shows in equation 6.5):

$$A \cup B = \{x \in S \mid x \in A \text{ or } x \in B\} \qquad (6.5)$$

Venn Diagram

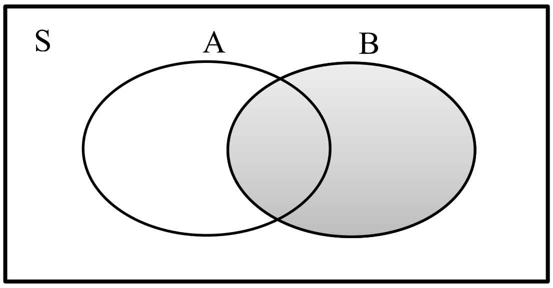


Fig. 6.3 Venn diagram of compound sets

6.3.2 Behavior of Condition Response

Conditioning response is a behavior of the body to process occurrences due to the effect of some antecedent stimulus or agent in condition at a system. Information system in memory will be processed depending on situation of body. Everybody has a different perception in that condition or situation. Generally, a dynamic situation becomes quite difficult for making decisions and taking action. Analyzing the subject matter will be helped comprehensively when investigating uses classification system or taxonomy as a way of organizing performance. The taxonomies that emphasize observable behaviors are primarily of practical value. The taxonomy error by the UK P & I Club, has been modified. In fig. 6.4 is demonstrated various schemes for classifying error based on stages of information processing.

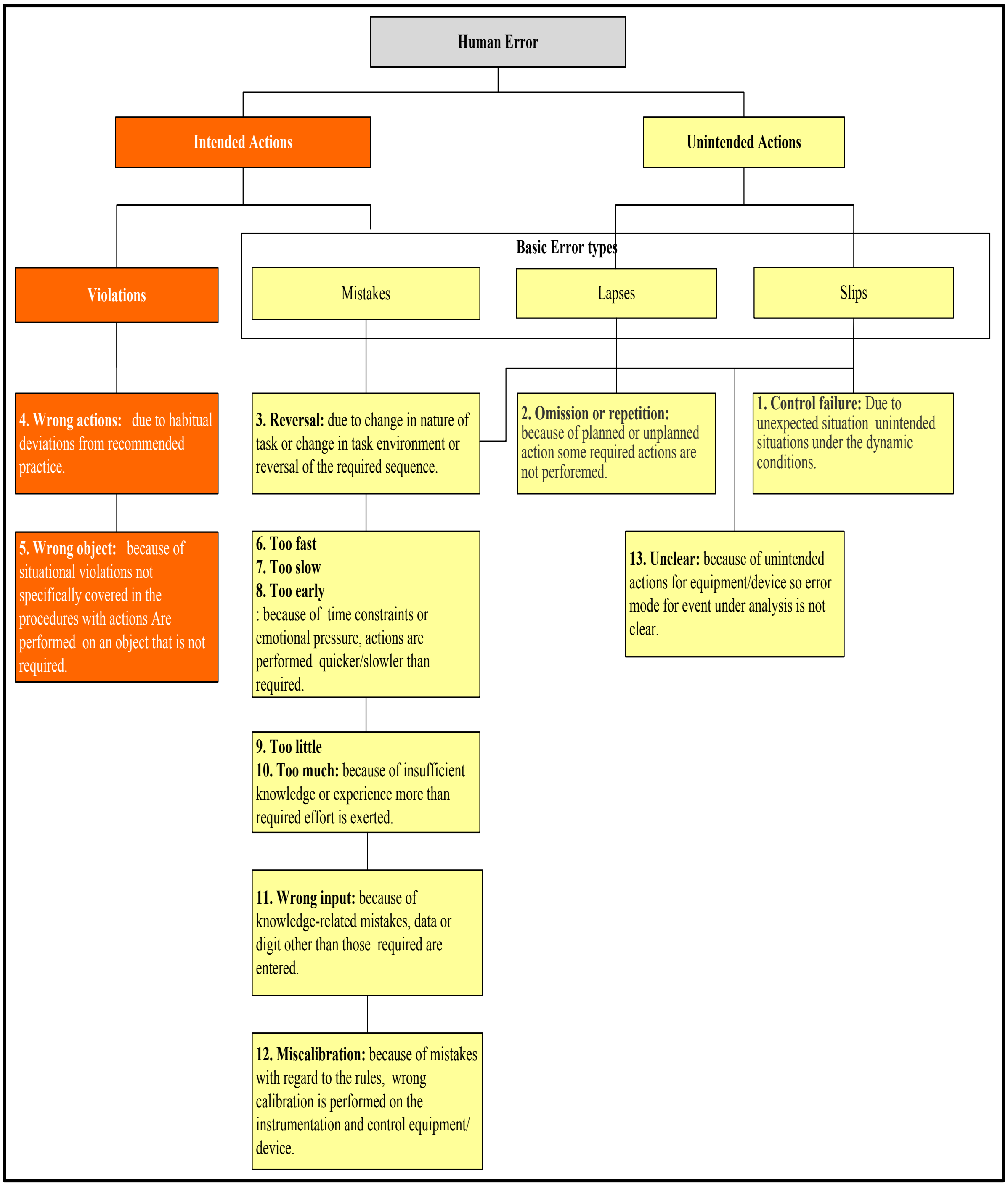


Fig.6.4 Modified taxonomy error modes from cognitive functions

Analyzing information processing is identified which involves the use of rules. These rules may have been learned as a result of interacting with the plant, through formal training, or by working with experienced process workers. The level of conscious control is intermediate between that of the knowledge and skill based modes. In the skill-based mode, the individual is able to function very effectively by using ‘pre-programmed’ sequences of behavior which do not require much conscious control. It is only occasionally necessary to check on progress at particular points when operating in this mode. Analyzing information to operation is needed in a system, including the failure to operate the information. A failure will happen when an accumulation of unsafe actions occurs. Failures will occur to one of the subsystem in mal function.

6.4 Extent Condition of Maritime Sector in Japan

6.4.1 Information Data of Maritime Accidents

The average number of accidents per year of vessel at sea in Japan was 67.11 from 1991-2008. Further analysis on the causes accident by unsafe actions are enough known that there is a serious concern about effort to minimize accidents that is occur such as human casualties. Data collected by the Marine Accident Inquiry Agency (MAIA) have shown that human casualties in maritime accidents around Japan have shown an increasing trend over the last ten years (fig. 6.5).

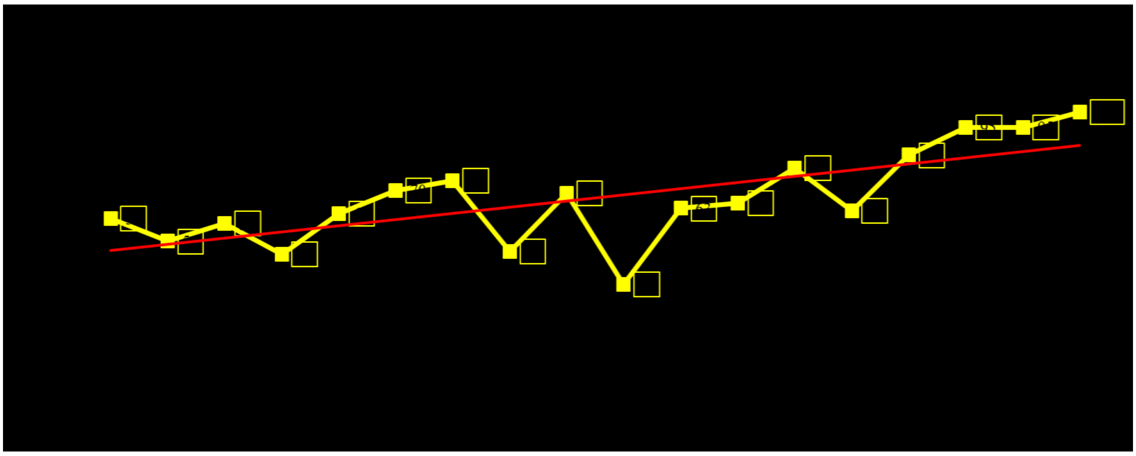


Fig.6.5 Example casualty accidents reported in 1991–2008

Moreover, the characteristic of maritime accidents since 1998-2008 is as follows:

The collision is about 68 percent of all maritime accidents that were due to human errors such as improper look-out, ignoring COLREGS, signaling failure, inadequate supervision, fatigue, improper ship's speed, inadequate report and taking-over watch, improper ship handling, no indication lights and shapes and unconfirmed ship position were ten of the highest frequency unsafe actions that occurred in the previous eleventh-year period (as shown in table 6.1).

Table 6.1 Unsafe actions reported in 1998−2008

Causes of collision	Variable	Year											Total of
Unsafe action		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	number causes
Improper management for ship operation	X1	5	8	3	2	5	4	4	8	1	14	12	66
Poor repair conditions of ship structure	X2	1	0	0	0	0	1	3	1	1	5	3	15
Poor preparation for sea	X3	0	0	0	0	0	1	5	3	0	0	0	9
Improper hydrographic survey before sailing	X4	1	4	5	3	4	5	3	1	6	3	4	39
Inadequate passage planning	X5	3	2	6	6	11	4	7	5	8	5	10	67
Improper ship handling	X6	21	24	22	15	21	21	11	14	18	21	11	199
Unconfirmed ship's position	X7	13	10	17	17	8	9	11	9	16	9	8	127
Improper look-out	X8	441	415	444	457	504	502	417	398	360	358	389	4685
Fatique	X9	28	31	34	36	38	40	26	36	32	30	39	370
Insufficient maintenance and wrong handling of steering systems and nautical instruments	X10	2	1	2	0	0	2	0	1	1	0	5	14
Poor attention to meteorological and oceanographical	X11	5	9	7	6	10	4	0	8	2	6	5	62
Improper anchoring and mooring	X12	2	3	2	3	1	3	3	1	2	6	2	28
Inadequate preparation for rough sea	X13	0	0	0	2	0	0	1	0	2	3	1	9
No indication of navigation lights and shapes	X14	21	30	16	31	21	18	15	13	8	6	10	189
Signalling failure	X15	90	89	100	72	83	86	79	99	66	68	63	895
Improper ship's speed	X16	62	47	56	54	5	23	27	42	21	9	5	351
Ignoring COLREGS	X17	178	194	178	148	164	180	142	150	119	115	115	1683
Main engine failure	X18	1	1	1	2	1	1	0	2	0	0	1	10
Auxiliary engine failure	X19	3	2	5	1	3	2	1	2	1	2	0	22
Poor management of lubricant oil	X20	0	0	0	0	0	0	0	1	1	0	3	5
Poor management of electrical equipment	X21	0	1	0	0	0	0	0	1	2	2	0	6
Improper handling and other task	X22	0	0	2	1	0	0	0	1	1	1	1	7
Improper fishing work	X23	0	0	0	0	0	0	0	0	0	0	0	0
Poor management of passenger and cargo loading	X24	0	0	0	0	0	0	0	0	0	1	1	2
Inadequate supervision of work on board	X25	70	76	68	38	53	45	44	51	43	38	45	571
Inadequate report and taking over the watch	X26	37	38	26	28	20	17	20	25	18	20	14	263
Poor management fire	X27	0	0	0	0	0	0	0	0	0	0	0	0
Force majeure	X28	1	0	0	0	0	0	0	0	0	0	0	1
Others	X29	1	0	1	0	0	1	0	3	4	5	6	21
		986	985	995	922	952	969	819	875	733	727	753	9716

(Remarks: yellow color means remarkable and higher number of causes)

6.4.2 Identification of Unsafe Actions in Analysis Scenario

As is shown in fig.4.1 that human error immediately link when got deviation or failure combination between substandard practices of operator and/or substandard working condition of operator. It is basic errors and other is violations.

In the analyzed data report Japan over the period 1998–2008 it was found that from 29 conditions such as unsafe actions or unsafe conditions there were 9,716 cases described as collision (single) and collision (other) accident (table 6.1). The table 6.2 has listed as summary one of root cause maritime accidents (chapter 5) then broken down to determine as scenario of root causes of maritime accidents. The substandard practices of operators are assessed, particularly decisions made without reference to the normal conditions of the system or applicable rules. Decision errors are an activity or behavior that proceeds as intended, yet the plan proves inadequate or inappropriate for the situation. These unsafe actions are performed by individuals who either did not have the appropriate knowledge or simply made a poor choice. Unsafe actions in a given scenario are analyzed as follows:

Table 6.2 Unsafe actions by X1–X29 for collision cases from 1998 to 2008

Unsafe Action	Root cause of condition	Total cases
Improper management for ship operations (X1)	Communication is important during operation.	66
Poor repair conditions of ship structure (X2)	Less detailed checks and trials of applicable ship parts to identify problems.	15
Poor preparation for sea (X3)	Knowing the times of the tide and obtaining an up-to-date weather forecast (especially expected wind conditions).	9
Improper hydrographic survey before sailing (X4)	The work of a hydrographic survey technician can be broken down into several main job functions. Within each category, there are a series of various tasks that must be performed.	39
Inadequate passage planning (X5)	Courses have not been selected to take advantage of weather and currents and most efficient routes.	67
Improper ship handling (X6)	Ships handling in confined waters, particularly narrow waterways, has received a great deal of attention. Lack of adequate training and experience by officers.	199

Unconfirmed ship position (X7)	The basics of navigation as commonly practiced by every sailor are not adhered to.	127
Improper look-out (X8)	Every vessel shall maintain a proper lookout by sight and hearing at all times. Look-out must be dedicated job, i.e. no other-job. Under-manning and fatigue undermine this most vital work.	4685
Fatigue (X9)	The combination of wind and waves can cause sea sickness, which affects motor skills and the ability to think clearly. Generally induced by overwork and lack of rest. Regulations require more stringent rest/work hours but these are frequently ignored. Fatigue robs the person of adequate mental and physical abilities.	370
Insufficient maintenance and wrong handling of steering systems and nautical instruments (X10)	There is a strict PMS (Planned Maintenance Systems) on ships and tests and checks should be carried out on the Steering gear and Nautical equipment. Daily. The root cause of not being done is inadequacy in the ship's and Ship owner's Safety Management System.	14
Poor attention to meteorological and oceanographically information (X11)	Poor attention to meteorology and oceanography lowers the quality of meteorological forecast and warning services that support the safety of life and property at sea (SOLAS). Root cause: poorly trained ship staff that lack sufficient incentives to improve.	62
Improper anchoring and mooring (X12)	Generally, improper anchoring and mooring owing to unsafe actions that do not select good anchorage and drag the anchor. Incorrect anchoring in tidal waters must be minimized to prevent accidents on a ship. Inexperienced Master and deck officers.	28
Inadequate preparation for rough sea (X13)	It is very important for a seafarer to know what to do in rough weather so that mistakes can be avoided when quick decisions need to be made; the ship can be prepared for rough sea by taking precautions such as steering control and machinery control.	9

No indication of navigation lights and shapes (X14)	Root cause: lack of leadership and seamanship.	189
Signaling failure (X15)	Refers to improperly interpreting relevant signals from the ship whistle when making maneuvers.	895
Improper ship speed (X16)	Every vessel shall at all times proceed at a safe speed to take proper and effective action to avoid collision and stop within a distance appropriate to the prevailing circumstances and conditions.	351
Ignoring COLREGS (X17)	Not obeying Collision Regulation (COLREGs) can be put down to misinterpretation, even though the rules are quite clear. It also stems from deliberate actions not to obey the rules.	1683
Main engine failure (X18)	Main engine failure is generally due to a lack of cylinder overhauling, which means lapses in the routine maintenance program, lack of spare parts, and inadequate technical management from ship owner. Bad quality fuel also causes big problems.	10
Auxiliary engine failure (X19)	Primary engine failure requires troubleshooting the marine auxiliary diesel engine. Improper maintenance damages the machine or system, which affects the operational system that is not running and triggers failures such as fire.	22
Poor management of lubricant oil (X20)	Proper practices and procedures are needed to ensure that standby lubricating oil filters are available. Ships generally carry a log-book of all lubes carried and used on board. Stowage/usage of lubricant oil is important.	5
Poor management of electrical equipment (X21)	A ship steering systems are commonly electrohydraulic; the “electric” parts require continual checking, testing, and maintenance as all electrical systems on the ship do. Ship has an ETO – Electro-technical Officer (previously an Electrician) on board. With the correct parts a good ETO can manage all but – within the PMS again.	6
Improper handling and	Proper handling and other tasks are largely a matter	7

other tasks (X22)	of common sense and necessary for the care and protection of objects. Seafarers need to know the workplace and be trained in the proper use and limitations of the equipment they operate.	
Improper fishing work (X23)	Practical understanding of the basic types of small fishing vessels, including common terminology, is required. A fishing vessel encumbered by her nets or trawl cannot keep out of the way of other vessels; Rule 26 directs all other vessels to keep out of the way of fishing vessels.	0
Poor management of passenger and cargo loading (X24)	Root Causes: incorrect declaration of weights, contents and MSDS (Marine Safety Data Sheets) of all types of cargo, not just containers. Passengers? – Lack of tuition and practice drills of SOLAS lessons on personal safety. Recognizing that actions taken when containers are stuffed may have direct implications on the stability and safety of ships.	2
Inadequate supervision of work onboard (X25)	Close supervision by qualified experts is of critical importance, starting from a vessel's inception on the drawing board through its sea trials to final delivery and continued monitoring during sailing.	571
Inadequate reporting and taking over the watch (X26)	The officer of the watch should not hand the watch over to the relieving officer if he has a good reason not to do so. Root cause: Master must ensure his OOW's (Officer of the Watch) are competent to stand a watch and to hand over the watch. Root cause: Master is not doing his/her job.	263
Poor fire management (X27)	Each scenario is influenced by various factors; not least the nature of the fire and what is actually burning. In the event of an engine room fire, where the fire is completely flooded with CO_2, the ship immediately becomes a "dead ship." All seafarers, from Captain down to galley-boy, undergo strict Fire Prevention and Fire Fighting training. Practice drills are held weekly. Poor fire management can only come from the ship's Safety Officer – and from	0

	the Captain.	
Force majeure (X28)	Force majeure is sometimes called other forces and external forces; and, unforeseeable circumstances. In contrast to unpredictable situations, nonperformance is caused by usual and natural events. (Often termed Act of God). Root cause? – Mother Nature.	1
Others (X29)		21

6.5 Evaluation Response

6.5.1 Response of Unsafe Actions in Taxonomy Error

Any accident that occurs is a union of several events where unsafe actions were taken. An unsafe action is an erroneous decision or action made by a human. Data on unsafe actions were previously recorded by MAIA (table 6.2), then developed the data were analyzed to determine the possible root causes of the unsafe actions in PIN Safe model. The author is took a variety of sources and determined as one of root cause to overcome the limited data.

The next step is understood the root cause of unsafe actions in each scenario; the taxonomy error (fig.6.4) presented by the UK P&I Club was implemented as a sample set (see eq. 6.4) of event probabilities.

By theory of probability, the conditions of each human factor that shapes the performance of a seafarer can be implemented as follows:

$$S = \{\text{taxonomy error}\} \quad (6.6)$$

where S is the sample universe of human error:

$$S = \{1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13\} \quad (6.7)$$

where 1–13 are codes for the taxonomy error (see figure 6.4) in equation (6.7).

$$N(S) = 13; \text{ N is the number of members in a sample} \quad (6.8)$$

$$\text{Not influenced: } P\{S\} = 0/13 \quad (6.9)$$

$$\text{Influenced: } P\{S\} = 1/13 \quad (6.10)$$

The taxonomy error is developed by applying the combined analysis of root cause of unsafe actions for every incident that has caused maritime accidents. According to the MAIA, one of the most common causes of maritime accidents over the last eleven years is collisions. The analysis is as follows:

If X1 and X2 are two sets in universe S, then the union of X1 and X2 is a new set whose membership consists of members of A and B (see eq.6.5):

$$\mathrm{X1} \cup \mathrm{X2} = \{x \in S \mid x \in X1 \text{ or } x \in X2\} \quad (6.11)$$

Venn Diagram

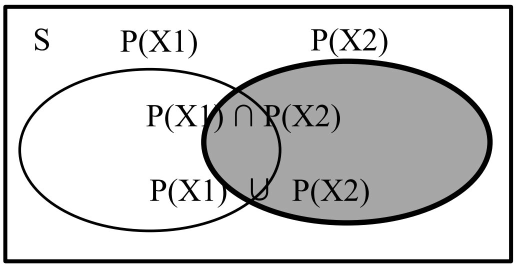


Fig.6.6 Venn diagram of compound sets in unsafe actions

For every event, an unsafe actions occurred; the compound set in equations 6.5 shows the chances of collision accidents on the basis of the probabilities of unsafe actions such as X1–X29 in the taxonomy error (equations (6.4)–(6.11)) in Rivai, et al. [79] as listed in table 6.3:

Table 6.3 Counting unsafe actions in taxonomy error

Unsafe action	Taxonomy Error Code													n (x)	P(Xi)= n(x)/13; i=1,2,…,29	Pattern	P(Xi) =n(Xi)/13; i=1,2,…,29
	1	2	3	4	5	6	7	8	9	10	11	12	13				
Improper management of ship operations (X1)	x			x		x	x	x	x	x	x		x	9	9/13	A	0.69
Improper hydrographic survey before sailing (X4)	x	x		x	x				x	x	x	x	x	9	9/13		0.69
Poor attention to meteorological and oceanographical information (X11)	x	x	x	x		x	x	x			x		x	9	9/13		0.69
No indication of navigation lights and shapes (X14)	x		x	x	x	x	x	x			x		x	9	9/13		0.69
Main engine failure (X18)	x	x	x	x		x	x	x				x	x	9	9/13		0.69
Improper handling and other tasks (X22)	x	x	x			x	x	x	x	x			x	9	9/13		0.69
Inadequate passage planning (X5)	x			x		x				x	x	x	x	7	7/13	B	0.54
Unconfimed ship's position (X7)	x	x	x						x	x	x		x	7	7/13		0.54
Improper anchoring and mooring (X12)	x			x	x		x	x	x				x	7	7/13		0.54
Improper ship speed (X16)	x			x		x	x	x			x		x	7	7/13		0.54
Poor management of electrical equipment (X21)	x	x							x	x	x	x	x	7	7/13		0.54
Improper fishing work (X23)	x			x	x				x	x	x		x	7	7/13		0.54
Inadequate reporting and taking over the watch (X26)	x	x	x			x	x	x					x	7	7/13		0.54
Poor repair condition of ship construction (X2)	x	x	x			x	x	x				x	x	8	8/13	C	0.62
Poor preparation for sea (X3)	x		x	x	x				x	x		x	x	8	8/13		0.62
Inadequate preparation for rough seas (X13)	x	X		x	x	x	x	x					x	8	8/13		0.62
Signaling failure (X15)	x			x		x	x	x	x	x			x	8	8/13		0.62
Auxiliary engine failure (X19)	x	x	x	x	x						x	x	x	8	8/13		0.62
Insufficient maintenance and wrong handling of steering systems and nautical instruments (X10)	x	x	x								x	x	x	6	6/13	D	0.46
Poor management of passenger and cargo loading (X24)	x	x	x	x	x								x	6	6/13		0.46
Inadequate supervision of work onboard (X25)	x	x				x	x	x					x	6	6/13		0.46
Fatigue (X9)	x	x	x	x	x	x	x		x	x	x	x	x	12	12/13	E	0.92
Ignoring COLREGS (X17)	x	x	x	x	x	x	x	x	x	x		x	x	12	12/13		0.92
Poor management of lubricant oil (X20)			x						x	x			x	4	4/13	F	0.31
Poor fire management (X27)	x			x	x								x	4	4/13		0.31
Improper ship handling (X6)	x		x	x	x	x	x	x	x	x	x		x	11	11/13	No pattern	0.85
Improper look-out (X8)	x	x		x	x	x	x	x			x	x	x	10	10/13		0.77
Force majeure (X28)	x												x	2	2/13		0.15
Others (X29)	x	x	x	x	x	x	x	x	x	x	x	x	x	13	1		1.00
(P(X1∩X2∩X3∩X4∩X5∩X6∩X7∩X8∩X9∩X10∩X11∩X12∩X13∩X14∩X15∩X16∩X17∩X18∩X19∩X20∩X21∩X22∩X23∩X24∩X25∩X26∩X27∩X28∩X29))	x												x	2			

Remarks: $\boxed{x}$ = influenced one error;
1= control failure; 2 = omission or repetition; 3 = reversal; 4 = wrong action; 5 = wrong object; 6 = too fast; 7 = too slow; 8 = too early; 9 = too little; 10 = too much; 11 =wrong input; 12 = miss-calibration; 13 = unclear.

6.5.2 Response Unsafe Actions in 4M Factors

Responding to an event then looking at the root cause of the problem is one comprehensive solution in minimization of unsafe actions leading to maritime accident. In SRM (Safety Response Model), that root cause of problem is viewed from 4 M (Man, Machine, Media and Management) Factor which has been described in chapter 2 and more be explained within collision accidents in below:

Table 6.1 shows that there are 10 (tenth) unsafe actions are a major cause of maritime accidents due to collision.

In mathematics, an element, or member, of a set is any one of the distinct objects that make up that set Schechter [80]. The relation "is an element of", also called set membership, is denoted by the signature $\in$. Writing is

$$X \in A \qquad (6.12)$$

means that "X is an element of A". Equivalent expressions are "X is a member of A.
In this research, the elements covered are four categories of maritime transport system for the safety known as Man, Machine, Media, and Management.

$$X_i \in \{\text{Man or Machine or Media or Management}\} \qquad (6.13)$$

The number of elements in a particular set is a property known as cardinality; informally this is the size of a set. In the above the cardinality of the set for all four elements man, machine, media and management is determined from the total numbers of each cause and perspective of the causes of induction using 4M factors.
Table 6.4 illustrates that the next stage has been done by reconstructing the relationships from the total number of collision in the maritime transport systems in relation between the root causes of every unsafe action with relation of 4 M Factor, and there is a more detailed explanation of this in section 6.5. 2
In condition:
Tenth (X6,X7,X8,X9,X14,X15,X16,X17,X25,X26) are variable causes of collision as independent and higher number of causes.
Four factors are (Man (Y1), Machine (Y2), Media (Y3), Management (Y4)) which are variables in maritime transport system wherein dependency is determined, by Rivai, et al. [81].

Table 6.4 The relationship of 4M Factors with unsafe actions in variable X1-X29

Related unsafe action	Variable causes of collision	Total number of causes	Relation of maritime transport system				Related unsafe action	Variable causes of collision	Total number of causes	Relation of maritime transport system			
			Man (Y1)	Machine (Y2)	Media (Y3)	Management (Y4)				Man (Y1)	Machine (Y2)	Media (Y3)	Management (Y4)
Improper management of ship operation	X1	66	●	●	●	●	**Signaling failure**	**X15**	895	●	●		
Poor repair condition of ship construction	X2	15	●	●		●	**Improper ship's speed**	**X16**	351	●	●	●	
Poor preparation for sea	X3	9	●	●	●	●	**Ignoring COLREG**	**X17**	1683	●		●	●
Improper hydrographic survey before sailing	X4	39	●	●	●	●	Main engine failure	**X18**	10	●	●		●
Inadequate passage planning	X5	67	●			●	Auxiliary engine failure	X19	22	●	●		●
Improper ship handling	X6	199	●	●			Poor management of lubricant oil	X20	5	●	●		●
Unconfirmed ship's position	X7	127	●	●	●		Poor management of electrical equipment	X21	6	●	●		●
Improper look-out	X8	4685	●		●		Improper handling and other tasks	X22	7	●			●
Fatique	X9	370	●		●	●	Improper fishing work	X23	0	●	●	●	●
Insuffient maintenance and wrong handling of steering systems and nautical	X10	14	●	●		●	Poor management of passenger and cargo loading	X24	2	●			●
Poor attention to meteorology and oceanography	X11	62	●		●		**Inadequate supervision of work onboard**	**X25**	571	●			●
Improper anchoring and mooring	X12	28	●	●	●	●	**Taking over watch**	**X26**	263	●			●
Inadequate preparation for rough seas	X13	9	●	●	●	●	Poor fire management	X27	0	●	●	●	●
No indication of navigation lights and shapes	X14	189	●		●	●	Force majeure	X28	1	●	●	●	●
							Others	X29	21	●	●	●	●

(Remarks: Bold fonts means remarkable and higher number of causes)

(▭ Not having relationships between causes of collision and one of 4M Factors)

(● Having relationships between causes of collisions and one of 4M Factors)

Fig. 6.7 describes the "relationship causes" of maritime accidents, such as collision in the maritime transport systems. To complete this analysis graphically, the relationships between the causes of collision in the maritime transport system were reached by inserting the resultant values from equation (6.12), (6.13) in the table 6.4.

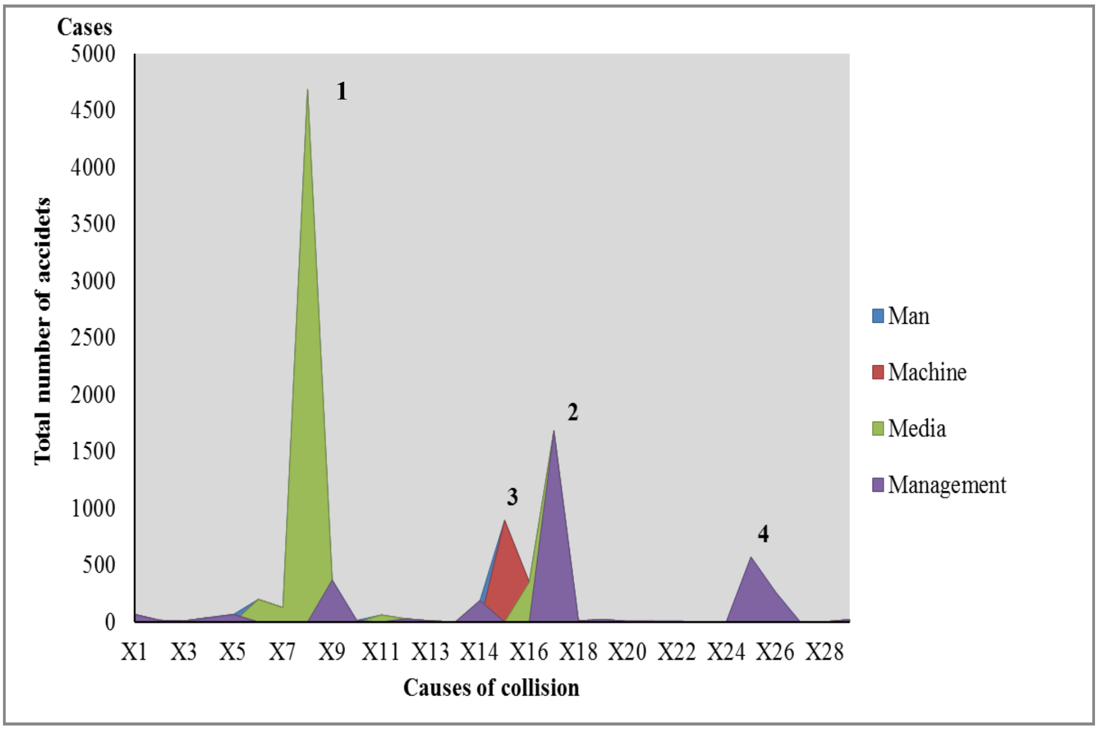


Fig.6.7 Relationships of unsafe actions of collision in 4M Factor

Fig. 6.7 illustrates the highest influences of the relationships as causes of collision in the maritime transport system. All together the following results can be drawn:

(1) Relationship between man, media and management influenced by variable X8 (improper look-out), and X9 (fatigue).

(2) Relationship between man, media and management influenced by variable X16 (improper ship's speed), X17 (ignoring COLREG).

(3) Relationship between man, machine, management influenced by variable X14 (no indication of navigation light and shapes) and X15 (signaling failure).

(4) Relationship management influenced by variable X25(inadequate supervision), and X26 (taking over watch).

CHAPTER 7
CONSIDERATION AND CONCLUSION

7.1 Result

The objective of this dissertation is to identify the human elements involved in maritime accidents and the countermeasures for reducing the impacts of the human elements involved. For this purpose the following tasks have already been completed:

- ✓ Studying the background literature, documents and reports relating to the human elements in maritime casualties' accidents at sea. Preparing information and materials needed for the research work.
- ✓ Working out the research plan and determining the methods and approaches used in this research by the qualitative method.
- ✓ Establishing a classification for classifying and storing the human elements involved in the maritime accidents.

  The risk ranking is determined by combining frequency ranking and consequence ranking and then implementing 3A behavior (Appendix-D) as one way of overcoming the decrease of quality performance of seafarers. By viewing some aspects of the data that has been researched, there can be obtained as follows:

  1. Minor-Moderate-Serious-Disastrous such as improper management for ship operation (X1), improper fishing work (X23), poor management of passenger and cargo loading (X24).
  2. Minor-Moderate-Serious such as poor repair condition of ship structure (X2), poor preparation for sea (X3), poor course selection and course-keeping (X5), improper ship handling (X6), improper ship speed (X16), poor management of electrical equipment (X21), inadequate reporting and taking over the watch (X26), force majeure (X28).
  3. Moderate-Serious such as improper hydrographic data checking before sailing (X4), unconfirmed ship positions (X7), improper look-out (X8), fatigue (X9), insufficient maintenance and wrong handling of steering systems and nautical instruments (X10), poor attention to meteorology and oceanography, improper anchoring and mooring (X12), inadequate preparation for rough sea (X13), not obeying COLREGS (X17), main engine failure (X18), auxiliary engine failure (X19), poor management of lubricant oil (X20) and inadequate supervision of work on board (X25).
  4. Serious, such as no indication of navigation light and shapes (X14), poor management of safety and fire (X27).

✓ Identifying effective and practical counter measures for reducing the human elements' involvement by studying the patterns that have the same value of one kind of taxonomy error models that have been developed in order to get the performance shaping factors. The patterns are as follows:

5. Pattern A had a weight of 9/13 and contained unsafe actions such as improper management (X1), improper hydrographic data before sailing (X4), poor attention paid to meteorological and oceanographical information (X11), no indication of navigation lights and shapes (X14), improper handling and other tasks (X22), and main engine failure (X18).
6. Pattern B had a weight of 7/13 and contained unsafe actions such as poor course selection (X5), unconfirmed ship positions (X7), improper anchoring and mooring (X12), improper ship speed (X16), poor management of electrical equipment (X21), improper fishing work (X23), and inadequate report and taking over the watch (X26).
7. Pattern C had a weight of 8/13 and contained unsafe actions such as poor preparation for sea (X3), inadequate preparation for rough seas (X13), main engine failure (X18), and auxiliary engine failure (X19).
8. Pattern D had a weight of 6/13 and contained unsafe actions such as insufficient maintenance and wrong handling of steering systems and nautical instruments (Y10), poor management of passenger and cargo loading (X24), and inadequate supervision of onboard work (X25).
9. Pattern E had a weight of 12/13 and contained unsafe actions such as fatigue (X9) and not obeying COLREGS (X17).
10. Pattern F had a weight of 4/13 and contained unsafe actions such as poor management of lubricant oil (X20) and poor management of safety and fire (X27).
11. Analysis of the taxonomy error found that the root causes of control failure and unclear situations were mostly human error.

✓ The methods in use for this dissertation mainly consist of: collecting actual unsafe actions data from current written accident reports; establishing a classification of the human element for collecting and storing the data picked up from the written reports; designing a simple mathematical model for analyzing the data collected from data reports. The main findings and achievements are:

12. For identifying the human elements involved in accidents at sea, in the classification for collecting and storing the data relating to the human element involvement in maritime accidents, this has been proposed by the qualitative model.

13. The method is reasonable to apply. Using this qualitative model, the author could find relationship causes of accidents in the term of maritime transport system.
14. Flexible data. Using one variable as independent can find relationships to other data. Logic of pattern has been used. Sources are from both printed theories and from opinions of experts, as well as root causes from unsafe actions.
15. Sampling weights by AND/OR within taxonomy error (Appendix-E) in maritime system (4M factors) as alternative qualitative model. Using this model, a second opinion in the decision-making for management improvement can be done.

✓ The written accident report is currently the most useful and available source to develop one method for minimizing accidents and improving safety of life at sea by PIN Safe model. This model provides more detailed information regarding human performance in characteristics of accident which is a value from the unsafe action involved. Developing PIN Safe model, because:

16. PIN Safe model analyzes unsafe actions in the root causes of accidents within the human element and thus the basic data for safety assessment can only be identified by the application of an accurate and structured method that accounts for the cognitive and social processes involved in the management of a system.
17. The framework for qualitative assessment combines the taxonomy error in the set of a system, which is a union of unsafe actions that have occurred. This method is one way to recognize patterns of unsafe actions.
18. PIN Safe as anticipation of engineering controls is anticipated of all human factors. Initiating events could lead to process deviations. Measurement parameters in all operations by approaching logic of pattern can help to suggest for improved motivation of self; and censoring of equipment by ergonomic design is useful to help to reach good performance in the working environment with probability of exposure and casualty rate. During observation of boating accidents, the failure probabilities are distinguished from the corresponding exposure.
19. PIN Safe as the pattern of unsafe action in risk monitoring is realized as critical events have consequences, which have potential impact to accidents. Every accident that occurs has been interacted within unsafe actions of the seafarer in the working environment. Interactions of them will have their own characteristics or pattern. Risk is the probability and severity of loss from exposure to the hazard. The third key aspect of exposure, which is the number of personnel or resources affected by a given event or over time by repeated events, is called in controlling taxonomy error within 4M Factors, the comprehensive

monitoring information processing database. Those are needed for the role of management to evaluate. Combinations of them in analysis can help result in minimal exposure on mishap, to improve protective capacities in psychological factors based on IMO investigation of human factors. Further aspects that can help self-regulation are encouraged where possible as a part effort to help develop a safety culture in the industry, because:

20. Root cause analysis of the taxonomy error found that control failure and unclear situations are mostly caused by human errors due to unintended actions, which mainly stem from a lack of information or from misinformation.
21. In the case of mistakes, the mistakes tend to be very resistant to contravening evidence. People tend to ignore feedback information that does not support their expectations of the situation. This is one reason that it was needed to produce a database to qualitatively assess the attributes of unsafe actions to improve safety culture.
22. PIN Safe could be done because the database information management organization initial, basic level is unsafe actions when interacting with the other systems.
23. The PIN Safe model is a database management system which needs integration and continuity at all levels of the seafarer to gain protection management. This information model gives advice to the seafarer for improving shaping factors by approaching social culture without judgments. Taking from this information of the seafarer is a consideration for specific training to enhance individual protection in the safety of life at sea.
24. The PIN Safe model is encouraged as self-regulation should be done as part of the efforts to develop a safety culture in the industry. This encourages every worker to take responsibility for areas of safety they can influence, and encourages them to own and operate companies that give safety the highest priority in their working practices with recognition of taxonomy error of self.

7.2 Consideration

1. Developing reports

   Currently available accident reports provided valuable information about the cause of the accident, the scene and the factors that led to the accident. But most of them fail to provide more information in all maritime aspects between man, machine, media and management about the underlying human element.

2. Trial application of codes error

   Trial application of codes error is realized in order to be aware of human weakness and inherent dangers posed by different situations and they may be beneficial as guidelines on what to do and the effectiveness when assessed. If necessary, further amendments are needed. There are a few things that were developed in this pattern, among others:

a. Machine for technology

   Counteracting pattern A involves developing appropriate technology for human capabilities to mitigate the low visibility and restricted maneuvering in bad weather conditions and in narrow waterways in Japan. For identification purposes, lights have individual characteristics in terms of color, intensity and operation system according to the different perceptions of seafarers.

b. Relations of all crew

   Counteracting pattern B involves improving collaboration by operation arrangements and maintaining interpersonal communications (mental, physical, skill sharing) with other seafarers on the ship.

   Unsuitable interpersonal relations are a cause that the attention is not drawn to tasks, which should be fulfilled, but to other directions. The consequences are irritation, over-sensitiveness, feeling of discomfort, stress, dissatisfaction and higher incidence of illness and injuries. The influence of psychosomatic aspects on the reliability and safety of working performance is equally important than the effect of action of physical factors, whether directly as an objective source of workload or through a response in the psychical sphere as a subjective source of workload. Depending on the quality of these factors of work environments, optimal or not optimal, excessive workload will occur or the employee is able or not able to cope with this situation, or avoid it.

c. Management of training in critical situations

   Counteracting pattern C involves cooperating between management and seafarers on special issues such as critical situations at sea; moreover, engine conditions should be improved. Critical situations are the decreased reliability of the system technology which is important as a consideration. The improvements in structural integrity and the reliability of machinery and electrical systems by recognizing failures is a good correction.

   Recognizing in the classification failures from unsafe actions of the systems when divided into two types, single and multiple failures are produced, based on the impact on all the systems. Failures of unsafe actions are due to the impact of critical situations and classified into single and multiple failures according to the effect they impact. Usually any unsafe action that leads to a single or to multiple failures can be addressed by looking into the culture so long as the human failure can be distinguished from the components of mechanism.

d. Design of ship

Counteracting pattern D involves mitigating ship design problems such as steering, nautical instruments, and control issues for passenger and cargo loading without compromising the safety of the ship. The IMO/ILO/UNECE Guidelines on the Packing of Cargo Transport Units provides a common global resource for information on container stuffing.

e. Seafarer performance

Counteracting pattern E involves maintaining the physical and mental conditions of the seafarers to create a culture of safety. When the body and mind are fatigued, non-compliances can occur, and rules may not be obeyed. Team cooperation is needed to minimize rule violations. Seafarers should be reminded of the basics of the COLREGS.

Safe operating procedures are continuously being amended to prohibit specific actions that were implicated in some accident, incident or near miss. The result is that the scope of allowable action shrinks as the system or technology matures. But the range of actions necessary to get the job done under less than ideal circumstances need not diminish. This creates the conditions necessary for situational violations. That is, non-compliance that is committed simply in order to get a particular job done. It means a response to the challenge.

f. Management of operation in breakdown of equipment and in non-standard situations

Counteracting pattern F involves comprehensive database management technology for the maintenance engine so as to aid human decisions. The development of monitoring technology for database management will mitigate poor human decisions such as neglecting lubricant oil, which contribute to engine failure. Poor monitoring of lubricant oil prevents moving components from working smoothly; friction would quickly destroy these surfaces and cause engine failure which in turn could lead to fire. In terms of operational safety it is important to train employees not only in the professional area, i.e. to gain knowledge, skills and habits, but also to prepare individuals in the psychical area, i.e. to maintain their adequate performance in non-standard and stress situations.

3. Keep continuous casualty investigation

IMO adopted the code for the investigation of marine casualties and incidents in 1997. For further addressing the human elements in casualty investigation, IMO amended the code by adding the guidelines for the investigation of human factors in marine casualties and incidents into its Appendix (IMO, 1997 November 27, 2000a). The guidelines offer methods and techniques for the collection and analysis of information, which help the investigator to methodically identify human factors leading to the accidents. The objective of the guidelines is to alert the seafarers to the contributory role of human elements in causing maritime accidents.

4. Effectiveness of actions

   The reliable effectiveness of actions is to be developed in critical situations, and the steps such as developing a safety culture in the working environment should be shown to be effective in reducing the impact of the unsafe actions in collisions and other accidents. Through taxonomy error based on the self, it is recommended that initially all relevant parties of maritime safety should actively try to find ways to develop new a safety culture and make it a positive and integral part of all personnel activities.

5. Prescriptive regulation

   Prescriptive regulation plays an important and active role in improving the level of safety at sea, but to create more rules to eliminate human error in maritime industry is not a good and effective way. Knowing the pattern of deviations from unsafe actions, then to provide enhanced training and specific education to make trainees aware of human limitations and inherent exposure by different situations may be more beneficial.

6. Providing considerations on future work to reduce the effects of human elements

   The further research which will be performed in order to improve safety culture are presented as follows:

   A) In depth analysis of the root causes of any unsafe actions is still needed to be improved upon in order to obtain the validity of the method PIN Safe as a model of innovative interaction in real implementations for all seafarers.
   B) Design of questionnaires as related to the taxonomy errors, and developed the scope of 4M Factors, could be implemented in the finite element method as one alternative in a qualitative procedure.
   C) Monitoring and evaluation of the uses of PIN Safe databases as a consideration for all seafarer to encourage self-regulation.

7.3 Conclusion

According to the explanations of all chapters, some of the following can be concluded:

1. Everyone has limitations

   Limitations are deviations from combinations, like a union, of failures between substandard practices by operators and substandard working conditions of operators in the term of human errors implemented, such as memory, workload, attitude, personality traits, experience, knowledge and training based on IMO 2000. Anyone can have limitations in that everyone has different unsafe actions because of the influence of various factors that affect the characteristics of unsafe actions. Some examples between relations from unsafe actions are, as the author has proposed, as aligned by the following relationships – the relationship between man and media influenced by variable X8 (improper look-out), and X9 (fatigue); between media and management influenced by variable X16 (improper ship's speed), X17 (not obeying COLREG) and X18 (main engine failure); between man and machine influenced by variable X14 (no indication of navigation light and shapes) and X15 (signaling failure); between management influenced by variable X25 (inadequate supervision), and X26 (inadequate report).

2. Everyone can have different characteristic of unsafe actions

   Everyone has a unique character and each of us requires self-recognition in order to accept and overcome the unsafe actions we make. Every one of us needs to accept the specific training required to develop our skills in order to obviate our unsafe actions. And - everyone needs to maintain the specific education and training methodology. The specific education and training should be given based on the characteristics of human performance. It could be recognized as a kind of "control mapping", as is created in good management.

3. Strong management

   Strong management is required to tackle every characteristic of unsafe actions in establishing the evaluation strategies. Evaluation of taxonomy error, as implemented in 4M (man, machine, media and management) factors, is a strategy to develop the performance shaping factors of seafarers to reach protective capacities.

4. Monitoring and controlling operations in breakdowns

   Monitoring and controlling of all factors should be done to avoid critical situations and to minimize human casualties. In chapter 5, we saw the result that the highest cases of human casualty come from unsafe actions such as improper management for ship operation, mismanagement of electrical equipment, improper handling and other tasks, improper fishing work, poor management involving passengers and cargo loading; and others. So, keeping up with specific training in the time allotted is vital to halt any unsafe actions. Knowing the kind of control needed in unsafe actions can help to develop a unique approach for improving human performance.

5. Safety culture in all parties

   The ideology of implementing 3A (Awareness, Action, Attitude) in control behavior can be realized. Initiating events of unsafe actions could lead to process deviations. Measurement parameters in all operations by approaching logic perspective can help to suggest methods for improved motivation of the self, and censoring of equipment by ergonomic design is useful to help reach good performance in the working environment.

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APPENDIX-A Data Report from JTSB, Kind of maritime accidents, 1991-2008

Table A Data Report from JTSB, Kind of maritime accidents, 1991-2008

Year	Collision (Others)	Collision (Single)	Stranding/ Grounding	Sinking	Capsizing	Distress	Fire	Explosion	Engine Failure	Missing	Equipment Damage
1991	1166	34	272	6	31	42	28	4	143	0	0
1992	856	65	225	17	17	32	24	7	148	0	1
1993	710	46	204	46	15	5	30	6	223	0	0
1994	861	70	191	18	41	50	25	4	213	0	0
1995	912	44	248	9	27	28	28	1	230	0	0
1996	766	84	201	15	27	39	37	13	211	0	0
1997	879	64	203	7	33	34	25	0	138	0	0
1998	922	64	206	17	21	14	25	2	123	0	0
1999	919	66	187	8	26	31	20	1	139	0	0
2000	911	84	167	10	31	25	32	3	130	0	0
2001	836	86	189	3	29	26	25	1	117	0	4
2002	871	81	212	7	35	35	27	3	91	0	2
2003	898	71	211	2	39	11	30	0	114	0	0
2004	748	71	176	11	25	9	19	0	108	0	0
2005	803	72	160	9	34	18	21	3	111	0	1
2006	647	86	205	12	39	14	20	2	81	1	0
2007	646	81	196	12	33	12	24	6	100	1	0
2008	673	80	197	9	51	10	13	2	111	0	4

Year	Facilities damage	Casualty	Safety inhibitor	Operation inhibitor	Flooding	
1991	11	59	0	17	0	
1992	16	50	2	10	0	
1993	32	57	0	5	0	
1994	22	45	1	13	0	
1995	26	61	0	31	0	
1996	31	70	0	22	0	
1997	19	74	0	28	0	
1998	14	46	1	8	0	
1999	23	69	0	8	0	
2000	30	33	1	12	0	
2001	28	63	0	21	0	
2002	20	65	0	11	0	
2003	14	79	1	19	12	
2004	14	62	1	18	14	
2005	24	84	1	19	27	
2006	23	95	0	19	11	
2007	23	95	0	19	11	
2008	32	101	0	23	23	
Total	434	1309	8	326	98	27,511

APPENDIX-B Personal Identification Safe in Logic of Patterns

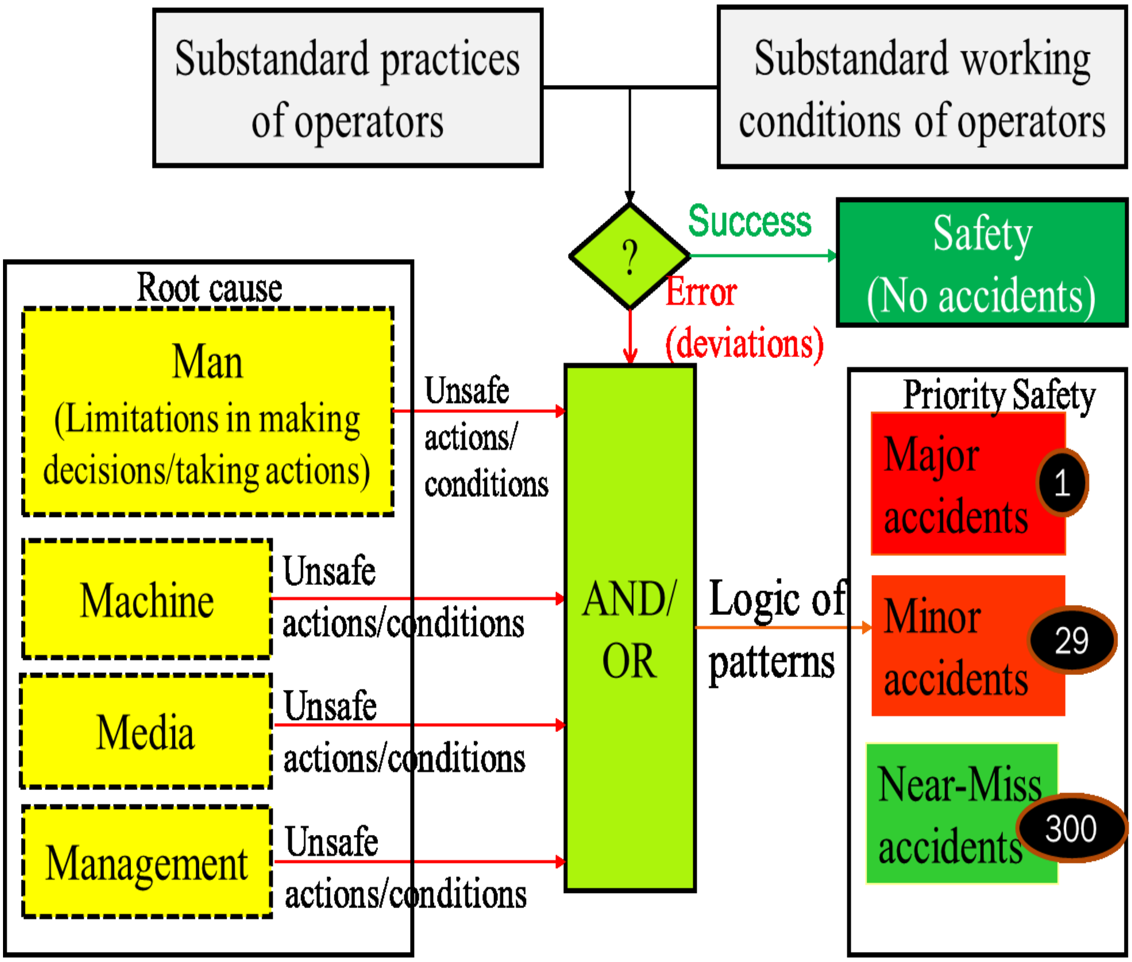


Fig. B Flowchart strategy of Personal Identification (PIN) Safe model in working environment

APPENDIX-C Personal Identification Safe in Probability Weight

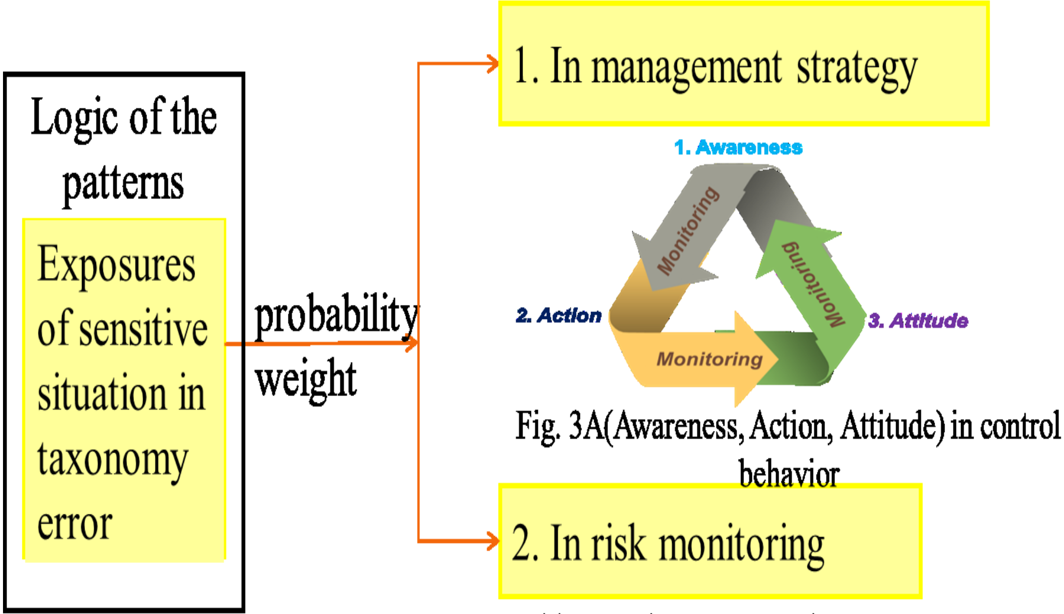


Table 4.2 3 keys in control of exposures

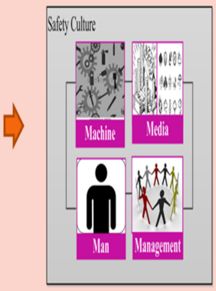
Controlling	Features	Expressed	Comprehensive aspect
Controlling 1	Hazard exposures monitoring	proximity; volume, repetition	
Controlling 2	Severity monitoring	potential impact on the people; equipment; mission;	
Controlling 3	Probability monitoring	determined through unsafe actions in actual numbers;	

Fig. C Strategy of Personal Identification (PIN) Safe model as features of safety

APPENDIX-D Consequences in Risk and PIN Safe Evaluations

Table D.1 Consequences level minor-moderate-serious-disaster

Consequences Level	Unsafe actions/conditions	PIN Safe Evaluations
Minor-Moderate-Serious-Disaster	Improper management for ship operation (X1)	Awareness
	Improper handling and other task(X22)	Awareness
	Improper fishing work (X23)	Attitude and action
	Poor management of passenger and cargo loading(X24)	Attitude and action
	Others (X29)	Monitoring

Table D.2 Consequences level minor-moderate-serious

Consequences Level	Unsafe actions/conditions	PIN Safe Evaluations
Minor-Moderate-Serious	Poor repair condition on ship structure(X2)	Monitoring
	Poor preparation for sea(X3)	Monitoring
	Inadequate passage planning for ship's (X5)	Action
	Improper ship handling(X6)	Controlling
	Improper ship's speed (X16)	Controlling and monitoring
	Poor management of electrical equipment (X21)	Monitoring
	Inadequate supervision of working on board (X25)	Controlling/ monitoring
	Inadequate report and taking over watch on board (X26)	Controlling
	Force majeure (X28)	Controlling/ monitoring

Table D.3 Consequences level moderate-serious

Consequences Level	Unsafe actions/conditions	PIN Safe Evaluations
Moderate-Serious	Improper hydrographic survey (X4)	Monitoring
	Unconfirmed ship position (X7)	Controlling
	Improper look-out (X8)	Monitoring
	Fatigue (X9)	Monitoring
	Insufficient maintenance and wrong handling of steering systems and nautical instruments(X10)	Monitoring is needed awareness
	Poor attention to meteorological and oceanographically (X11)	Monitoring, controlling
	Improper anchoring and mooring (X12)	Monitoring
	Inadequate preparation for rough at sea (X13)	Monitoring, controlling
	Signaling failure (X15)	Monitoring is needed awareness
	Ignoring COLREGS (X17)	Action
	Main engine failure (X18)	Controlling
	Auxiliary engine failure (X19)	Controlling
	Poor management of lubricant oil (X20)	Monitoring

Table D.4 Consequences level serious

Consequences Level	Unsafe actions/conditions	PIN Safe Evaluations
Serious	No indication of navigation lights and shapes (X14)	Monitoring
	Poor management fire (X27)	Attitude

APPENDIX-E Sampling Weights of Each Pattern

Table E.1 Sampling weights of pattern A

Unsafe action	Taxonomy Error Code													n (x)	P(Xi)= n(x)/13; i=1,2,…,29	Pattern
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Improper management of ship operations (X1)	x			x		x	x	x	x	x	x		x	9	9/13=0.69	
Improper hydrographic survey before sailing (X4)	x	x		x	x				x	x	x	x	x	9	9/13=0.69	
Poor attention to meteorological and oceanographical information (X11)	x	x	x	x		x	x	x			x		x	9	9/13=0.69	A
No indication of navigation lights and shapes (X14)	x		x	x	x	x	x	x			x		x	9	9/13=0.69	
Main engine failure (X18)	x	x	x	x		x	x	x				x	x	9	9/13=0.69	
Improper handling and other tasks (X22)	x	x	x			x	x	x	x	x			x	9	9/13=0.69	

x = influenced one error.

1= control failure; 2 = omission or repetition; 3 = reversal; 4 = wrong action; 5 = wrong object; 6 = too fast; 7 = too slow; 8 = too early; 9 = too little; 10 = too much; 11 = wrong input; 12 = miss-calibration; 13 = unclear.

Table E.2 Sampling weights of pattern B

Unsafe action	Taxonomy Error Code													n (x)	P(Xi)= n(x)/13; i=1,2,…,29	Pattern
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Inadequate passage planning (X5)	x			x		x				x	x	x	x	7	7/13=0.54	
Unconfimed ship's position (X7)	x	x	x						x	x	x		x	7	7/13=0.54	
Improper anchoring and mooring (X12)	x			x	x		x	x	x				x	7	7/13=0.54	
Improper ship speed (X16)	x			x		x	x	x			x		x	7	7/13=0.54	**B**
Poor management of electrical equipment (X21)	x	x							x	x	x	x	x	7	7/13=0.54	
Improper fishing work (X23)	x			x	x				x	x	x		x	7	7/13=0.54	
Inadequate reporting and taking over the watch (X26)	x	x	x			x	x	x					x	7	7/13=0.54	

Table E.3 Sampling weights of pattern C

Unsafe action	Taxonomy Error Code													n (x)	P(Xi)= n(x)/13; i=1,2,…,29	Pattern
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Poor repair condition of ship construction (X2)	x	x	x			x	x	x				x	x	8	8/13=0.62	
Poor preparation for sea (X3)	x		x	x	x				x	x		x	x	8	8/13=0.62	
Inadequate preparation for rough seas (X13)	x	x		x	x	x	x	x					x	8	8/13=0.62	**C**
Signaling failure (X15)	x			x		x	x	x	x	x			x	8	8/13=0.62	
Auxiliary engine failure (X19)	x	x	x	x	x						x	x	x	8	8/13=0.62	

x = influenced one error.

1= control failure; 2 = omission or repetition; 3 = reversal; 4 = wrong action; 5 = wrong object; 6 = too fast; 7 = too slow; 8 = too early; 9 = too little; 10 = too much; 11 = wrong input; 12 = miss-calibration; 13 = unclear.

Table E.4 Sampling weights of pattern D

Unsafe action	Taxonomy Error Code													n (x)	P(Xi)= n(x)/13; i=1,2,…,29	Pattern
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Insufficient maintenance and wrong handling of steering systems and nautical instruments (X10)	x	x	x								x	x	x	6	6/13=0.46	D
Poor management of passenger and cargo loading (X24)	x	x	x	x	x								x	6	6/13=0.46	
Inadequate supervision of work onboard (X25)	x	x				x	x	x					x	6	6/13=0.46	

Table E.5 Sampling weights of pattern E

Unsafe action	Taxonomy Error Code													n (X)	P(Xi)= n(Xi)/13; i=1,2,…,29	Pattern
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Fatigue (X9)	x	x	x	x	x	x	x		x	x	x	x	x	12	12/13=0.92	E
Ignoring COLREGS (X17)	x	x	x	x	x	x	x	x	x	x		x	x	12	12/13=0.92	

Table E.6 Sampling weights of pattern F

Unsafe action	Taxonomy Error Code													n (x)	P(Xi)= n(x)/13; i=1,2,…,29	Pattern
	1	2	3	4	5	6	7	8	9	10	11	12	13			
Poor management of lubricant oil (X20)			x						x	x			x	4	4/3=0.31	F
Poor fire management (X27)	x			x	x								x	4	4/3=0.31	

x = influenced one error.

1= control failure; 2 = omission or repetition; 3 = reversal; 4 = wrong action; 5 = wrong object; 6 = too fast; 7 = too slow; 8 = too early; 9 = too little; 10 = too much; 11 = wrong input; 12 = miss-calibration; 13 = unclear.