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HUMAN ERROR AND MARITIME SAFETY

ΜΑΤΣΙΔΗ ΒΑΣΙΛΙΚΗ

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ABSTRACT

The purpose of this review is to introduce the concept of human error and the maritime safety implemented to control this issue. The following key areas were examined: the influence of human error, human factors leading to human error, common themes of accidents, international legislation, management actions and interventions to make shipping safer.

Chapter 1 specifies the distinction between human factors and human errors and also defines these errors into categories by emphasizing on the circumstances under which each error type occurs.

Chapter 2 presents the human factors that influence safety in the maritime domain leading to human errors. Since the maritime system consists of people, technological, environmental and organizational factors play a vital role in the way people perform. Some of these critical factors analyzed in this review are: complex automation, fatigue, situation awareness, increased cognitive demands, poor communication, cultural diversity, lack of teamwork, insufficient training, inadequate manning, safety culture and safety climate and the working environment with its demanding aspects.

Chapter 3 reviews these issues within a framework that proposes that these individual factors can be contributory causes in accident causation. Since maritime accidents are determined to follow a pattern two accident causation models are presented: The Swiss Cheese Model and The Triangle of Effectiveness which could help us to identify the root causes of accidents and possibly prevent them from happening. In addition, two accidents are analyzed considering the human errors which were involved in their causation.

Chapter 4 considers the current status of attempts to address these human factor issues prevalent in the maritime industry introduced by the international organizations, codes and conventions to ensure safety at sea. The IMO, ISM, SOLAS, ILO, STCW and ISO regulations and recommendations which were established to manage the human capital are presented. Significant recommended practices analyzed it this review are: Just culture, Human Factors Engineering and Ergonomics and Human-Centered Approach which absolve the human element from the blame of accidents and focus instead in their optimal performance by adapting the system to the human and considering structural issues that could potentially enhance shipping safety.

The writing of this dissertation would not have been completed without the support, patience and guidance of my English Professor Mrs. Papaleonida Paraskevi whose wisdom, knowledge and commitment to the highest standards inspired and motivated me. It is to her that I owe my deepest gratitude.

CHAPTER 1: HUMAN ERROR IN THE MARINE DOMAIN

1.1 Introduction

The shipping industry has focused on improving ship structure and the reliability of ship systems in order to reduce casualties and increase efficiency and productivity. We've seen improvements in hull design, stability systems, propulsion systems, and navigational equipment. Today's ship systems are technologically advanced and highly reliable.

Yet, the maritime casualty rate is still high. But why is it that with all these improvements, we have not significantly reduced the risk of accidents? It is because ship structure and system reliability are a relatively small part of the safety equation.

The maritime system is a people system, and human errors figure prominently in casualty situations. About 75-96% of marine casualties are caused, at least in part, by some form of human error. [1]

Studies have shown that human error contributes to:

- 84-88% of tanker accidents [2]
- 79% of towing vessel groundings [3]
- 89-96% of collisions
- 75% of allisions
- 75% of fires and explosions [4]

There are many different kinds of human error. It is important to recognize that human error encompasses much more than what is commonly called operator error. [1] If the errors made by crewmembers are divided into management errors and operational errors, then 71 % of them are management errors. [5] In order to understand what causes human error, we need to consider how humans work within the maritime system [1] as they are at the very centre of the shipping enterprise being the secret of its successes and the victims of its failures. [6]

Experts in the maritime field agree on three basic points:

- Everyone commits errors.

- Human error is generally the result of circumstances beyond the control of those committing the errors.
- Systems or processes that depend on perfect human performance are inherently flawed. [7]

Picture 1: *The shipping industry is run by people.* [6]

1.2 Definitions of human factors and human errors

The terms human factor and human error are often used interchangeably as referring to the cause of an accident which happened because of people, an individual or organization, as opposed to because of a technical fault. The relationship between these two terms is that human factors are the underlying causes of accidents whereas human errors are the immediate causes.

Originally human factors were defined to be the scientific study of the man-machine interaction [8] regarding human abilities and limitations in relation to the design of systems. [9]

More recently human factors also included the effects of individual, group and organizational factors on safety. [8]

Human factors deal with manpower, organization management, allocation of responsibility, automation, communication, skills, training, health, safety, prevention of errors or accidents, and design and layout of equipment and workplaces. [10] Important parameters are safety, efficiency and comfort. [11]

Human error is defined as a result of observable behavior originated from psychological processes on different levels such as, perception, attention, memory, thinking, problem solving, decision making, evaluated against some performance standards, initiated by an event in a situation where it was possible to act in another way considered to be right in order not to cause an accident. [12]

Also sometimes it is described as being one of the following: an incorrect decision, an improperly performed action, or an improper lack of action (inaction). It is also widely accepted that human error is a general term which covers a variety of unsafe acts, omissions, behaviors and unsafe conditions or a combination of these in which the individual should have had acted in a different manner. [1]

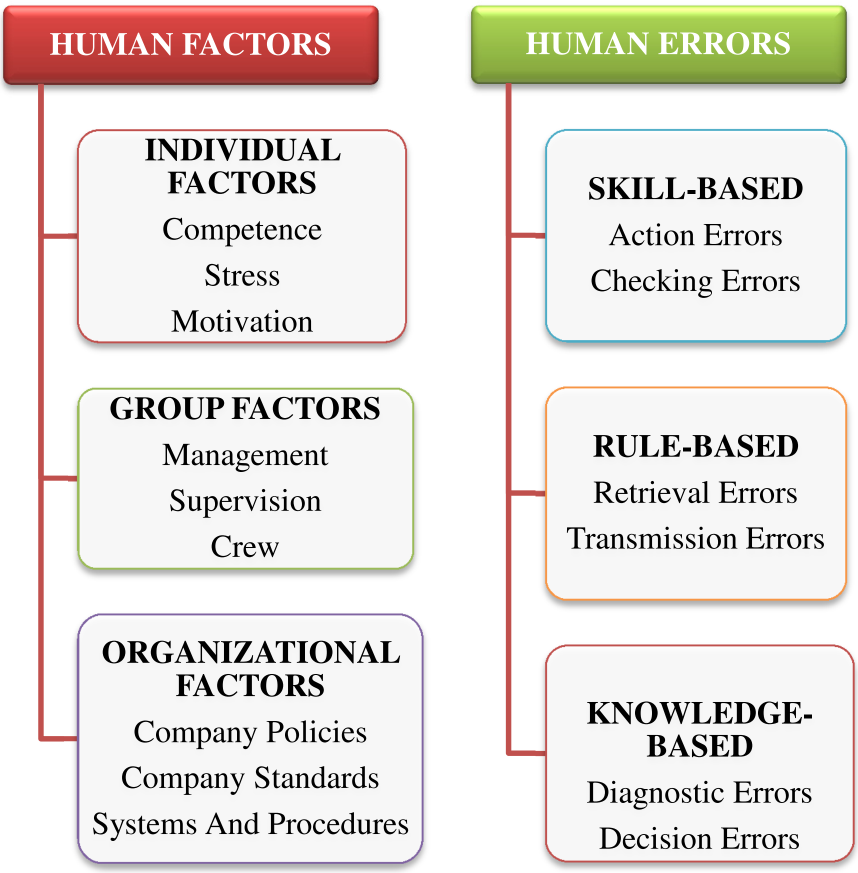

Figure 1: *The relationship between human factors and human errors.* [8]

1.3 Human Error Classifications

Therefore, if we want to make greater strides towards reducing marine casualties, we must begin to focus on the types of human errors that cause casualties. [1]

There are three main sorts of activity in which we make mistakes:

- Skill-based activity: where we are well practised in what we do. Here, because we can work without thinking too much about it, we can find ourselves doing something familiar (e.g. operating a well-used panel switch) when we should be doing something else (e.g. operating a less frequently used, but adjacent, panel switch). Or else, we can suffer a memory lapse (eg we suddenly forget what we were going to do next).

- Rule-based activity: where we have more conscious involvement with the task, and need to apply rules and procedures to what we are seeing and doing. Here, we can make a mistake by failing to apply a rule correctly, or at all (e.g. assuming that give-way vessels will always give way, or not realising we ourselves are the give-way vessel).

- Knowledge-based activity: where we must have even more conscious involvement with our task (e.g. where we are attending a fire and must make decisions in novel circumstances). Here, the kind of mistakes we make often has to do with the way we make sense of the situation. Decisions based on wrong interpretations of complicated or ambiguous information are usually the result of insufficient training or experience, or bad communications. [6]

Human errors are also categorized into four basic error types based on skill-rule-knowledge classification of human performance. These are: skill-based slips and lapses, rule-based mistakes, knowledge-based mistakes and also violations. These four error types are differentiated along several factors. This differentiation is shown below. [13]

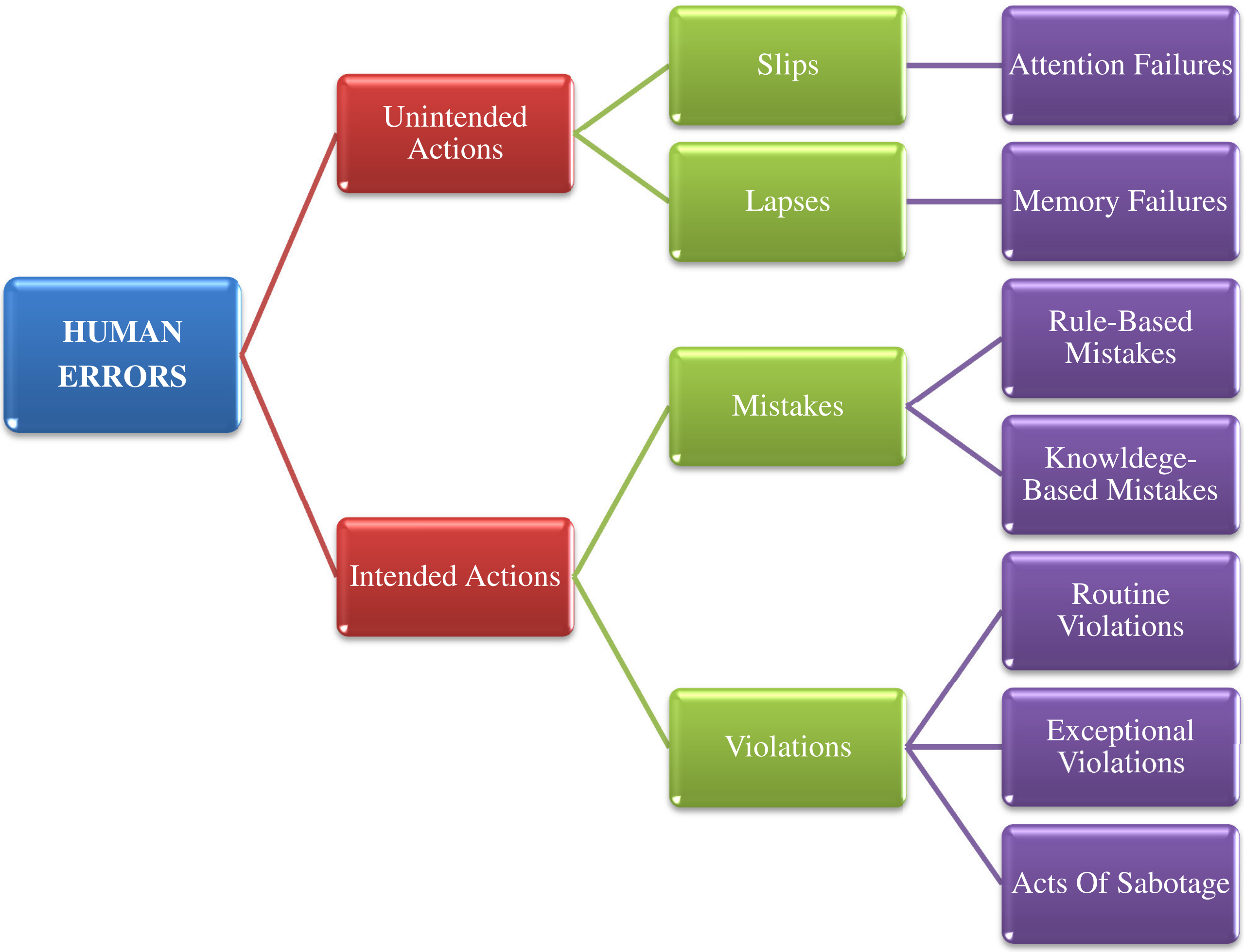

Figure 2: *The distinctions between the error types.* [13]

- Slips and memory lapses: (e.g. accidentally pressing the wrong button or missing out a step or steps in a task) usually occur in tasks which are so frequently carried out that they become automatic. In general, it is not possible to eliminate these errors through instruction or training. The best approach to controlling these errors is through design, by eliminating the opportunity for making them (e.g. through interlock guards and ensuring that components can only be fitted in the correct manner). Where this is not practicable, equipment should be designed or arrangements put in place, to allow errors to be detected and corrected before any adverse consequences occur (e.g. by giving feedback of the results of an action).
- Mistakes: are situations where, despite a genuine attempt to comply with procedures, an error of judgement leads to an inappropriate rule being applied or a step in a procedure being done out of sequence. It is possible to reduce such errors by improving the training and the quality of procedural documentation. However, as the action is completed successfully in the eyes of the individual concerned, it can be difficult to self-detect the error without external

assistance (e.g. improved supervision or independent checks). Mistakes can also occur in novel situations where the individual does not have set rules to apply (e.g. in diagnosing a particularly complex fault). These situations rarely occur, but when they do the likelihood of error is high. These errors can be reduced by improved technical and decision-making training, use of diagnostic aids and improved teamwork to allow crew to obtain the advice of others.

- Violations (non-compliance): is a separate form of human failure that occurs when an individual or individuals deliberately contravene established and known rules. They are therefore fully aware of what they should do but for some reason, consciously decide not to follow the organisation's approved working practices. [14] Examples are: navigational basis (charts) not updated, confusion of buoys and/or landmarks, maneuvering capabilities overestimated, clearance requirements underestimated. [15] Retraining staff in the correct practices cannot be the answer, as they already know what they should do. Violations are addressed by ensuring that crew do not perceive the benefits of non-compliance to be greater than any adverse consequences. [14]

1.4 Origins and occurance of each error type

In an attempt to present the possible origins of these error types and describe how switching between the error levels occurs, we note the following:

Slips and lapses, the errors at skill-based level, occur prior to problem detection and are typically associated to monitoring failures. These can be caused by inattention (e.g. a necessary check is omitted) or by overattention (e.g. an attentional check is made at an inappropriate moment).

Rule-based and knowledge-based errors follow the detection of a problem. Rule-based mistakes arise from the misapplication of good rule, which means using a rule that is beneficial in certain situation in dissimilar circumstances, or from application of bad rules.

Generally humans try to find a solution to a problem at rule-based performance level before resorting to the knowledge-based level. Only after realizing that a satisfactory result cannot be attained by applying stored problem-handling rules, they will move into knowledge- based level and even then, at first, search for cues that remind them of previously successful rules for adaptation to current situation. [13]

ACTION ERRORS	No action taken Wrong action taken Correct action on wrong object
CHECKING ERRORS	Checks omitted Wrong checks made Correct check on wrong object
RETRIEVAL ERRORS	Required information not available Wrong information received
TRANSMISSION ERRORS	No information sent Wrong information sent Information sent to wrong place
DIAGNOSTIC ERRORS	Actual situation misinterpreted
DECISION ERRORS	Circumstances considered but wrong decision made

Figure 3: *Error Categories and their occurence.* [8]

1.5 Active and Latent errors

There are usually multiple causes of an incident, with multiple people and events contributing to its evolution. Studying accidents in detail revealed that there were 7 to 58 distinct causes contributing to each accident, with 50% of the cases having at least 23 causes. Unfortunately we are often very good at identifying the error most immediately linked to an incident.

The accumulation of human errors results in active and latent failures. [16] The effects of active failures are felt almost immediately after the accident as they are directly related to it [17] while latent conditions are error-inducing states or situations that may not be visible but are lying dormant until the proper set of conditions arise which expose their unsafe attributes. [18]

Active errors are the ones made by pilot, control room crew, ship officers and other front-line operators. Designers, high-level decision makers, managers, maintenance personnel etc. are most likely causing latent errors.

Previous accidents have shown that the biggest threat to a complex system's safety comes from latent errors. A disaster may have been lurking in the system long before the accident due to poor design, incorrect installation, faulty maintenance, poor management decisions, etc., and the operator has just added the finishing touch.

Because of this, improvements in the immediate human-machine interface might not have a great impact on improving safety. [13] In this way the human operator is set up to make errors because the latent conditions make the system in which they work error-inducing rather than error-avoiding. [18]

CHAPTER 2 : HUMAN FACTORS TRIGGERING HUMAN ERRORS

2.1 Introduction

As was stated earlier, the maritime system is a people system. People interact with technology, the 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. [1]

Human factors affecting safety can be divided into organizational, group and individual factors. Some examples of organizational factors are management commitment to safety, safety training, open communication, environmental control and management, stable workforce, and positive safety promotion policy. Examples of group factors are linemanagement style, good supervision and clear understanding of own and other team members' roles and responsibilities. Individual factors are related to factors which affect a person's performance such as human-machine interface and competence, stress, motivation and workload of an individual. [8]

2.2 Design Issues

As human beings, we all have certain abilities and limitations. For example, humans are great at pattern discrimination and recognition. 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. Undoubtedly machines can do a much better job.

The design of technology can have a big impact on how people perform. 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. Such designs can lead to inadequate comprehension of the state of the system and to poor decision making. [1]

2.2.1 Automation

Due to reduced manning levels in the maritime industry there is now an emphasis on automation. There has been a cultural shift towards increased levels of automation in tasks, particularly with regard to navigation systems. This increase in automation and decrease in manning levels has changed the role of the seafarer. [19]

Automation can create new attentional demands. The operator has to permanently keep track of the numerous systems, what they are doing and what they will do next, which mode they are operating in and so on, this is termed mode awareness. [20]

The growing amount of automation on bridge has negative effects such as increased cognitive demands and cognitive reluctance on the reduced workforce and contributes to observed human error. [21] Operators have the tendency to monitor less effectively when automation has been installed and even less effectively if the automation has been functioning efficiently for a period of time [22] Unfortunately automation is introduced for that which can be automated, rather than for that which should be automated. [23]

Also accidents may, in the instance of increased automation, be a result of over-reliance on machines. [21] Humans tend to rely on technological aids over own observation, especially if human observation is vague or contradictory. [24]

In a study of co-operation on bridge, operational personnel, authorities, shipping companies and training organizations were interviewed and almost all interviewees found safety threats in using navigation and maneuvering aids, especially in the form of over-reliance and possible equipment malfunctions. [25]

2.2.2 Poor Design

Automation creates new human weaknesses and amplifies existing ones. [22] One challenge is to improve the design of automation. Poor design pervades almost all shipboard automation, leading to collisions from misinterpretation of radar displays, oil spills from poorly designed overfill devices, and allisions due to poor design of bow thrusters. Poor equipment design was cited as a causal factor in one-third of major marine casualties.

Poor design of equipment, user controls and interfaces, or work procedures, increases workload, response times, fatigue and stress levels. It may also promote the invention and use of dangerous short-cuts. [6]

The fix is relatively simple: equipment designers need to consider how a given piece of equipment will support the mariner’s task and how that piece of equipment will fit into the entire equipment suite used by the mariner. Human factors engineering methods and principles are in routine use in other industries to ensure human-centered equipment design and evaluation. The maritime industry needs to follow suit. [1]

2.2.3 Poor Maintenance

A further issue relates to the quality of the maintenance work. Equipment reliability and production can be reduced, and the risk of accidents increased (during or following maintenance), if maintenance work does not meet the desired standard.

As maintenance is heavily reliant on human activity, maintenance quality is largely dependent on the performance of the crew. This increases the risk that maintenance tasks are carried out incorrectly, particularly for complex items, where the need for quality maintenance can be very important.

In addition, when the maintenance is costly or difficult to carry out, there is a greater risk that it will not be carried out as often as it should or that it will not be done at all. This increases the chance of the item failing in service, often with costly consequences. [14]

Finally poor maintenance practices may intensify the design defects [16] and result in a dangerous work environment, lack of working backup systems, and crew fatigue from the need to make emergency repairs. [18]

2.2.4 Inadequate Knowledge of Own Ship Systems

A frequent contributing factor to marine casualties is inadequate knowledge of own ship operations and equipment. Mariners often do not understand how automation works or under what set of operating conditions it was designed in order to work effectively. The unfortunate result is that mariners sometimes make errors in using the equipment or depend on a piece of equipment when they should be getting information from alternate sources.

Several studies and casualty reports have warned of the difficulties encountered by crews and pilots who are constantly working on ships of different sizes, with different equipment, and carrying different cargoes. The lack of ship-specific knowledge was cited as a problem by 78% of the mariners surveyed.

A combination of better training, standardized equipment design, and an overhaul of the present method of assigning crew to ships can help solve this problem. [1]

2.3 Personnel Issues

This section deals with human performance factors or behaviors that may contribute to maritime incidents and evaluates their contribution in accident causation. [29]

2.3.1 Fatigue

Fatigue is not a new issue in the maritime domain. Research has illustrated that there are potentially disastrous outcomes from fatigue in terms of poor health and also diminished performance. [26] Falling asleep on watch or a decrease in alertness because of fatigue is well-known and not a new cause of marine traffic accidents. [27]

However, the conditions in which seafarers work are becoming increasingly demanding. There are shorter sea passages, higher levels of traffic, reduced manning, extended hours of duty and rapid port turn-around. [21] Additional issues such as rolling, pitching, vibrations, and noise only serve to magnify any present effects of shift work based fatigue [29] causing poorer health and safety performance. [31] Decreased alertness and slowed reaction speed caused by fatigue affects situation awareness. It may also have an effect on communication atmosphere on bridge.

When factors contributing to fatigue in bridge work were studied by presenting questionnaires to watch officers, it was found that 17% of respondents had fallen asleep and over 40% had been near nodding off at least once on watch. The most important factors affecting alertness had been the time of day, the length of the previous sleep period and the time since the person had last woken up. [27]

In their research, investigating officers were presented with 98 ship casualty reports and identified in 23% of cases that fatigue was a contributory cause. Despite the introduction of work rest mandates by the IMO, there are still occasions where individuals simply have to work for more than 12 hours with a 6-hour break. For instance, during discharging operations, the chief officer must be present at all times. A tanker with a 300,000 tonnage takes approximately 44 hours to discharge, so this means that the chief officer is required to be awake and present throughout this period.

In a report attempting to address operator fatigue, seafarers were identified out of the occupational groups included to have the second highest number of maximum work hours in a 30-day period, behind rail operators. [28] A further study surveyed 563 seafarers, 50% of whom indicated that they worked more than 85 hours in a week and 66% felt that extra manning was necessary to reduce fatigue. [30]

There are the following fatigue causal factors:

- Workload: The harder people work, the sooner they need time to recover from it. Workload itself is influenced by the design of the tools, equipment and procedures people must use and the expertise they have acquired through training and experience.
- Sleep debt: People need enough sleep of the right sort to recover from their wakeful activities. In its absence, they build up a sleep debt which severely affects their ability to stay alert. Sleep debt causes people to misread situations, overlook key information and fall asleep even when they know it will put them and their colleagues at extreme risk.
- Perceived risk or interest: If people are stimulated by their sense of risk or interest in what they are doing, they can stay awake and alert for longer. However, the time they then need to recover from sustained activity will also get longer. If people are engaged on tedious or boring tasks, they will feel tired sooner.
- Time of day: People live by natural daily rhythms which means that they feel least alert in the small hours of the morning and most alert in the period before midday.
- Environment: People become more fatigued in environments with bad levels of light, noise, vibration, temperature and motion. [6]

These factors have the following effects on human behaviour:

- Decreased attention and vigilance: People become less alert and slower to notice things. They may fail to detect signals or their significance, especially during monotonous tasks or in tedious environments. Tasks requiring sustained attention or surveillance are especially affected by fatigue.
- Communication difficulties: It becomes increasingly difficult to decide what needs to be said, how to say it, or what another person said.
- Inability to concentrate: Maintaining focus on the task at hand, even for a few seconds, is difficult. People cannot follow complex directions or numerical calculations, and are easily confused.
- Omissions & carelessness: People increasingly skip steps, miss checks and make mistakes.

- Slower comprehension & learning: It takes increasingly longer to understand any written or spoken information, or display patterns (e.g. a map or charts).
- Mood changes: Irritability, depression and apathy increases.
- Faulty memory: Recall of recent events or orders becomes faulty. For example, the content of a radio message may be immediately forgotten or recalled incorrectly. [32]

2.3.2 Stress

Stress has been identified as a contributory factor to the productivity and health costs of an organization as well as to personnel's health and welfare. [34] Stress is a physiological response to prolonged situations where the demand on people exceeds their available resources. It is always bad and produces both physical and behavioural signs and symptoms. [33]

Stress produces a complicated series of changes in the body's hormone levels and blood chemistry. Over a prolonged period, this can result in a wide range of adverse physical and behavioural changes in people as well as increased vulnerability to illness.

While stress is a common part of human life, it is not the same as arousal, and is always bad. One of the first signs of chronic stress is difficulty in sleeping, which can then contribute to the development of sleep debt. The inability of people to repay their sleep debt through stress-induced insomnia can itself become a source of stress. This creates a particularly vicious circle in which stress increases sleep debt which increases stress level, with the result that performance levels decline ever faster.

The inability to deal effectively with fatigue can become a source of stress, as can the sleep debt that results. In addition, stress can increase fatigue by stimulating too much production of adrenalin.

Stress can be caused by a large number of factors. Some of these factors are work-related while others may belong to the private lives of the person affected. Seafarers are particularly vulnerable to both sources since their work brings them into contact with many known work-related stressors as well as removing them from their home lives and countries for long periods. Stressors such as constant noise and vibration, domestic, personal and employment worries, social isolation and loneliness can contribute to sleep debt, which turns fatigue itself into a source of stress. [6] Exposure to elevated stress levels for an extended period of time leads to negative mental and physical health outcomes. [35]

2.3.3 Health

Health is one of the factors that influence professional efficiency of seafarers. [36] Physical and mental health problems amongst seafarers are not uncommon particularly if we consider the type and the difficulties of the work that a seafarer has to face onboard.

When thinking of seafarers' health and lifestyle one should always have in mind just few of the following factors:

- Unstable work schedules and long working hours due to operational needs.
- The small community which one should adapt and work with.
- The feeling of being away from home and familiar faces.
- The difficult working environment as well as all the hazards that are involved.
- The restricted medical facilities and limited medical supplies.
- The confined nature of life on board ship.
- The climate of the area where the ship is operating. [37]

Furthermore in some circumstances, psychological problems such as impatience, dissatisfaction and lack of motivation may provoke intolerance between crew members which mostly results in cultural and religion differences. [36]

2.4 Non-technical skills

Non-technical skills are an additional set of competencies that are used integrally with technical shipping skills, such as those to manoeuvre the vessel, or set down the anchor. They encompass both interpersonal and cognitive skills such as situation awareness, communication, team working and leadership. The following analysis focuses on non-technical skills within the maritime domain.

2.4.1 Situation Awareness

Situation awareness means the person's ability to construct a mental model on what is happening at the moment and how the situation will develop. [21] Particularly is the perception of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future. [38]

Situation awareness consists of three levels:

- In the first level individuals must have the correct perception of the elements in the situation in order to form an accurate picture.
- The second level involves the combination, interpretation, storage, and retention of the acquired information to form a picture of the situation whereby the significance of particular objects and events are understood.
- The third level is projection, and occurs as a result of the combination of levels one and two. This stage is an extremely important component of Situation awareness, as it means possessing the ability to use information from the environment to predict possible future states and events, in order to reduce surprise.

In various studies carried out regarding human error in maritime operations it is found that 71% of all human error types on ships are situation awareness related problems. [19]

Situation awareness errors are categorized into three groups:

- Failure to correctly perceive information (59%).
- Failure to correctly integrate or comprehend information (33%).
- Failure to project future actions or state of the system (9%). [21]

2.4.2 Decision making and cognitive demands

The increasing technological sophistication of ship navigation systems may significantly alter the skills, knowledge, and strategies involved in navigating large ships, degrading rather than enhancing maritime safety.

This challenge, combined with the potentially disastrous consequences of incorrect decisions, make the navigator’s job a singularly stressful one. This stress is magnified by the multiple, often competing tasks and responsibilities of navigating a ship, all of which must be carefully coordinated. [39]

While technological innovations seek to ameliorate these difficulties, new navigation technologies may also burden the human operator with increased cognitive demands. Mariners are exposed to an increasing number and diversity of supervisory and decision tasks, needing to divide attention between primary navigation displays and secondary tasks such as engine and cargo functions. [40]

In a review of 100 shipping incidents regarding cognitive demands it was found that as mental workload increased, collision threat increased and there was a detriment in performance on the secondary task resulting to the 70% of observed human errors. This shows the potential consequences of having to monitor numerous pieces of equipment concurrently. [21]

In addition, computer-based decision aids can also introduce new cognitive demands such as the need to monitor more ships during collision avoidance, to form mental models of the new technology, and to perform complex mental scaling and transformations to overcome the limits of electronic versions of paper charts.

While technology has the potential to eliminate many simple tasks, historical data concerning shipping accidents indicate that many navigation errors result from misinterpretations or misunderstandings of the signals provided by technological aids such as collision avoidance systems. [41] Moreover, poor judgment in the use of technological aids contributes to many maritime accidents. Further, navigational knowledge and skills may degrade because they are used only in rare, but critical, instances. [42]

Advanced technologies may also introduce new phenomena that affect mariner decision making, such as over-reliance on a radar display to steer a ship. In this situation, if the display fails to contain the information necessary to specify operator actions, errors will result. [43] Thus, it is clearly important to understand the cognitive tasks involved with advanced navigation technology in order to guide design and training development.

2.4.3 Poor Communication

Human communication is the process of influencing a human receiver to create thought and action that is consistent with, and responsive to, the sender's purpose. [6] Communication is one of the core skills central to effective and safe production and performance in all high-risk industries that also influences team situation awareness as well as team working and effective decision-making. [21]

Communication barriers that occur between seafarers and are presented in all types of ships, especially when there is a multinational crew can cause misunderstandings resulting in marine accidents. [38]

For instance, when there is a pilot on board a ship, an important teamwork relationship between the OOW (officer of the watch), master, and pilot shall be established. On the contrary by incidents sampled, 42% involved misunderstandings between pilot and master or the officer of watch due to lack of effective communication.

Questionnaires were developed to measure teamwork, communication, and to evaluate the master, pilot, and OOW relationship. When asked whether OOW asks for clarification if he/she is unsure of the pilot's intentions, 90% of OOW, 76% of masters, and only 39% of pilots responded that the OOW always or often asks for clarification.

Here appears to be a discrepancy between an individual's self-perception of effective communication and other's interpretations of these interactions. When asked whether bridge officers were reluctant to question a pilot's decision: 92% of masters and 81% of bridge officers said sometimes and 12% of bridge officers said they were always reluctant to question the pilot. These communication issues can often result in errors or accidents.

Although these are fundamentally communication issues, this figure could also reflect deficits in other skills such as lack of situation awareness and poor team working. One factor which could be a contributing cause to these findings, are language problems. [21]

2.4.4 Language and cultural diversity

A common language, context and culture always increase the speed and bandwidth by which intended communications can occur. However, these commonalities do not eliminate the construction of unintended meanings. Many communication failures arise precisely because people fail to recognise that they are exchanging signals that have as many possible meanings as can be constructed by the receiver, and not just the single meaning intended by the sender.

Human communication fails because people do not engage in dialogue that will result in unambiguous agreement about the situation they share and the possibilities that are open to them. There are several reasons for inadequate dialogue:

- People may have inadequate access to common media for the dialogue (e.g. no common language).
- People may have inadequate technical training (e.g. unawareness that communication is necessary).

- People may have inadequate personal skills or cultural awareness training (e.g. unawareness that information content or communication style may be interpreted differently in different cultures).
- People may have inadequate critical abilities (e.g. lack of appreciation of the discipline that successful communication requires). [6]

2.4.5 Lack of Teamwork

Teamwork is the ability to work well with a range of other people, providing mutual support and advice. [14] In a team task, people must work with each other in mutually supportive ways to achieve a shared goal. Many seafaring jobs require people to work with each other as team members, each of whom contributes their effort to an objective that is bigger than any one of them.

In these situations, people need skills that permit not just effective interaction between people, but good teamwork. A team is united by a common goal, with each member having a defined role to play in achieving it. This means that each team member must have not only the technical skills to carry out their role, but the necessary team skills to carry out the role in concert with other team members.

Therefore it requires a unique set of skills and practices to be effective, such as having skills in leading and motivating others, monitoring what each other does, backing up their colleagues, helping the whole team to adapt to changing demands and being receptive to each other’s suggestions. Furthermore, these skills need to be all glued together by similar mental models of the team situation, mutual trust and effective communication between team members. [6]

Based on various reviews and accident case studies it was stated that poor team performance leading to loss of situation awareness was a very common cause of marine accidents. The root causes of poor team performance lies in national, organizational and professional cultures: procedure violations, lack of communication and system understanding between team members. [44]

In a study that was carried out, there were questions evaluating teamwork: 96% of masters, 100% of bridge officers, and 85% of pilots stated that teamwork was often or always as important as technical proficiency. It appears there is a comparative lack of appreciation from the pilots of the importance of teamwork. Pilots were asked if it is possible to establish an effective working relationship with the master and OOW: 45% said it was always possible, and 36% said it was often possible. However, when asked about their experience of the master, OOW, and pilot working as a team, only 51% of masters, 46% of bridge officers, and 38% of pilots stated that they always work as a team. [2]

2.5 Organizational Issues

There is less research on organizational factors, which may mediate relationships between organizational climate and behavior and then propose measures such as accident data. Therefore in order to complete the picture one must consider this element in accident causation to fully address and reduce the level of incidents in this industry. [21]

Organizational factors, both crew organization and company policies, affect human performance. 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. On the contrary, 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. [1]

Unfortunately, these same factors also increase the likelihood that any mistakes will lead to serious consequences. This is because the factors also interfere with the ability to recover from mistakes once made. For example, the same fatigue that prevents a watchkeeper spotting a collision course can also interfere with their subsequent response to the emergency situation that develops.

A universal finding is that it is combinations of multiple adverse circumstances that create disastrous outcomes. It is not human mistake-making that is the problem, so much as the existing conditions and history of the organisation in which it occurs. [6]

2.5.1 Insufficient training

Organisations often claim that people are their greatest asset. People form attitudes towards their organisation, and the industry as a whole, about the quality (low or high) of the effort to provide them with the information they need. And whatever people learn, they in turn transmit to others, helping to define and maintain the nature of the overall culture to which they belong.

But if the organisation has not made arrangements for the focused learning and development of its staff, its people may represent an unknown and potentially catastrophic liability and risk to the organisation, rather than an asset.

Poor training or lack of experience may result in attempting to do tasks with insufficient knowledge which is a dangerous thing or else a failure to prevent a dangerous situation developing. Lack of investment in training and structured experience contributes to a poor safety culture by sending strong signals to the workforce that they are not valued.

So the question for safety-critical organisations like the maritime industry is not whether people learn, but what they learn and by what means. The answer to these questions is more or less in the control of their managers and employers for without the right guidance, people learn the wrong things.

As a result, in the absence of effective formal training, people informally learn what their colleagues do, what the shortcuts are, what seems to make sense to them, and what behaviours are rewarded. However, informal learning may or may not result in safe behaviour. [6]

2.5.2 Inadequate manning

Reduced manning is an organisational policy aimed at increasing efficiency. It is often made possible by the introduction of automation. However, increased efficiency usually means a corresponding decrease in thoroughness.

If the numbers of people fall short of what is required to carry out a task, then workload, fatigue, stress levels and sickness are increased, dangerous short-cuts are taken and the safety culture is compromised by demotivation, low morale and absenteeism.

Management efficiencies (in the form of crew cuts) often result in unsafe working efficiencies (short-cuts) and an increase in the number of mistakes, all made worse due to fewer people having less time to prevent those mistakes developing into something worse. [6]

2.5.3 Safety climate and safety culture

The following section details human factors issues arising as a result of decisions or policies made at the organizational level, such as safety climate and safety culture (management values and practices). [45]

- Safety Climate: Interest in safety climate has now diversified into the maritime domain as it will influence whether or not an individual engages in safe behaviours or not. [21] Organization safety climate is like a snapshot of selected aspects of organization safety culture at that particular point in time. [46] Although there is some debate on the definition of safety climate, definitions proposed consistently feature either employee's attitudes or perceptions of safety. [47]

Essentially climate perceptions relate to procedures as patterns, whereby consistent procedures represent patterns that reflect the importance and prioritization of safety over competing goals. In the adoption of a safety climate model, there should be a distinction between two levels: the organizational level of policies and procedures and the group level of supervisory practices in implementation and prioritization of these procedures. [17]

- Safety Culture: Interest was generated in safety culture in the maritime industry after an address of the IMO stated that safer shipping requires a safety culture. Safety culture is defined as the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, safety issues receive the attention warranted by their significance. [21]

The most influential source of a good safety culture is the seriousness with which senior management approaches it via training, crew investment and the implementation of work processes that accommodate the time that safe practices take. Crew mistakes increase not just because of the absence of this investment, but also because of the meaning people attach to the absence of the investment by their senior management. [6]

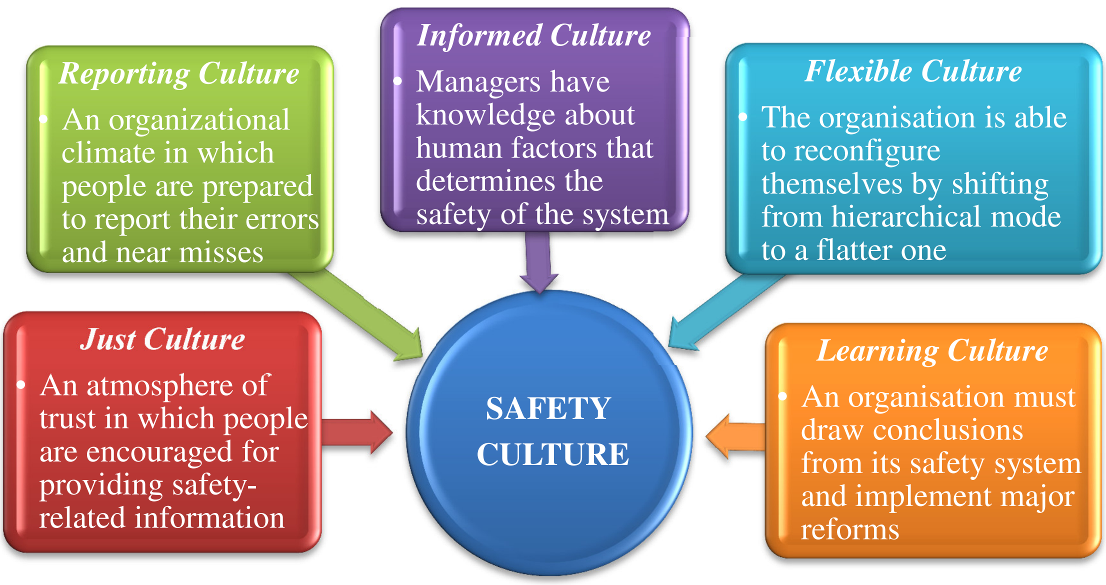

Figure 4: *The components of Safety Culture.* [64]

2.5.4 Complacency

The reasons of maritime accidents can partly be explained by the influence of the notion of Complacency as a special influential socio-psychological factor.

Where rules and procedures collide with the need to be efficient due to economic considerations, people find ways to work around them. If the efficiencies that they use to meet their schedules and targets do not result in an accident over a long time, the organisation may drift, often unnoticed, towards and across safety limits. This is sometimes referred to as complacency. [6]

Inappropriate communication and poor cooperative relationships on board a ship represent one of the basic causes of Complacency that is reflected in inadequate decisions and inefficient action. The genesis of this notion is rooted not only in the model of ship's organisation and management style but also in an interactive relation of the ship to external factors.

From the analysis of different maritime accidents the following autonomous and interactive negative influences of the above mentioned notion have been noted:

- Management Complacency*:* The negative influence of the Shipping Company (Management) expressed through the dominant communication company, ship in which process the crew meet the interests of the Company against their own beliefs and attitudes which are eventually lost, or become passive and transform into submissive attitudes.
- Leadership Complacency: The negative influence of leadership expressed through domination in which case the crew meets the requirements of the authority suppressing personal attitudes and beliefs.
- Self-Induced Complacency: The negative influence of the acquired feeling of superiority and personal significance to the change of personal, previously positive attitudes.

Complacency marks the above mentioned influences such as self-sufficiency or self-satisfaction. In a wider sense, it means too much self-confidence or egoistic pleasure. Complacency is also translated by the consecutive form of its basic meaning as lack of motivation, lack of discipline, lack of concentration, or feeling that somebody and/or something else will take care of the problems on board.

From the psychological point of view the meaning of the notion of Complacency represents a process of gradual change of attitudes that transforms a good seaman into a bad seaman. In this connection, the change of attitudes is caused by the influence of hierarchical authority and subordinating influence of the Company (Management).

In that sense, the change into inhibition begins as a spontaneous reaction to bad communication or unpleasant environment (hierarchical relations) within which the individual can feel insignificant. Such a reaction is visible after a longer period from the way such a person adapts to the circumstanmces. The way of adaptation can be seen through gradual change of personal attitudes that finally results in unconscious refusal of existing knowledge and skills.

Therefore, Complacency applied to the tasks and procedures performed by seamen on board refers to the modified mental state in which the seamen's behaviour derives from unconsciously formed attitudes as the result of adaptation in the conditions of bad communication and unpleasant environment. [5]

"**Complacency** can strike any person in any occupation, where a person feels their skills, knowledge and experience are called into question by superiors. And the result will most likely be changed attitudes caused by gradually hampered creativity."

Wiener (Fahlgren, 2000: 74)

2.5.5 Working Environment

The environment affects performance, too. The marine environment is not a forgiving one. Currents, winds, and fog make for treacherous working conditions. When we fail to incorporate these factors into the design of our ships and equipment, and when we fail to adjust our operations based on hazardous environmental conditions, we are at greater risk for casualties.

The physical work environment directly affects one's ability to perform. For example, the human body performs best in a fairly restricted temperature range. Performance will be degraded at temperatures outside that range, and fail all together in extreme temperatures. [1]

For example, at temperatures of below 16ºC dexterity can be adversely affected. At high temperatures the capacity for physical work reduces with the increasing risk of heat stress. This problem is increased with high relative humidities. The need to wear certain types of PPE can also increase problems of heat stress. The influences of temperature, therefore, need to be considered both in terms of the basic task demands (dexterity and physical workload) and the need for and implications of wearing PPE. [14] High sea states and ship vibrations can affect locomotion and manual dexterity, as well as cause stress and fatigue.

By the term environment we are including not only weather and other aspects of the physical work environment (such as lighting, noise, and temperature), but also the regulatory and economic climates. For instance tight economic conditions can increase the probability of risk-taking (e.g., making schedule at all costs). [1]

CHAPTER 3 : THE HUMAN ELEMENT IN ACCIDENT CAUSATION

3.1 Introduction

Nowadays, shipping and maritime navigation are burdened by lots of contradictions related to technological, economic and organisational development. [5] One way to identify the types of human errors relevant to the maritime industry is to study marine accidents, determine how they happen and possibly trace the development of an accident through a number of discrete events.

Accidents are not usually caused by a single failure or mistake, but by the confluence of a whole series, or chain, of errors. Minor things go wrong or little mistakes are made which, in and of themselves, may seem innocuous. However, sometimes when these seemingly minor events converge, the result is a casualty.

Multiple human errors are made, usually by two or more people, each of whom make about two errors apiece but every human error that is made is determined to be a necessary condition for the accident. That means that if just one of these human errors do not occurr, the chain of events will brake and the accident will not happen.

Therefore, if we can find ways to prevent some of these human errors, or at least increase the probability that such errors will be noticed and corrected, we can achieve greater marine safety and fewer casualties. [1]

3.2 Accident causation models

The majority of accidents happen as a result of unsafe acts and unsafe conditions. Since all hazards are not always possible to be identified and eliminated therefore effective accident investigation programs are essential for collecting critical data.

Maritime accidents are determined to follow a pattern, so they can be prevented just by identifying their root causes, which is possible by accident investigation techniques on human errors providing explanations of why accidents happen and recognizing how hazards in the maritime workplaces cause losses.

Accident causation models have considerably increased the understanding of how accidents happen and have stimulated a strong and powerful emphasis on the role of human error which has resulted into a reasonable place for training and education of mariners in order to develop competencies and safety awareness. [16]

3.2.1 The Swiss Cheese Model

James Reason, a professor of psychology, proposed a framework for accident causation in a complex system constructed of hierarchical components or levels [17] that explains how the many types of contributing factors can converge, resulting in an incident. [18] These levels represent organization's or system's defenses against failure and are the following:

- Level 1: The primary origins of latent failures are fallible decisions made at the manager and designer level, which is the top failure level in "the Swiss Cheese" model. Fallible high-level decision-making can be a result of the difference in two goals that are in short-term conflict such as maximizing both production and safety. These failures are a part of designing and managing process and cannot be totally prevented, but their consequences should be recognized and prevented in time. [13]
- Level 2: The next failure level in the model refers to the supervisors and their safety-consciousness as displayed by the operational decisions they make. For example, a good supervisor will ensure that personnel receive the proper training and mentoring, that work crews have the necessary skills and work well together, and that safety related procedures are used routinely. [18]
- Level 3: Deficiencies at the supervisory level can manifest at the next level, preconditions for unsafe acts. These preconditions are latent states that create potential for unsafe acts. Examples of the preconditions of unsafe acts are stress, inattention and lack of motivation. One deficiency can produce a variety of preconditions, or a single precondition can be a result of multiple deficiencies at line management level.
- Level 4: The next level, unsafe acts, means the actual performances of humans and machines. Unsafe acts can be either unintended or intended. Besides being an error or violation, unsafe act is committed in the presence of a potential hazard that could cause injury or damage. The occurrences of unsafe acts depend on psychological precursors and complicated interactions within the system and with environment. Very few unsafe acts will result in an accident. [13]

- Level 5: The last level in the model is the defense level which is constituted from safeguards such as personal safety equipment, automatic safety devices, warning systems, procedures and training. Inadequate defenses consist of both latent and active failures. [16]

Although organizational accident defenses are seen as obstacles which prevent the hazards from converting into losses, the obstacle and barriers have holes in them as slices of Swiss cheese. Reason called his model "Swiss Cheese" because of these defects in the organizational defenses. [48]

In the picture below the dynamics of accident causation in the Swiss Cheese model are presented, where a trajectory of accident opportunity passes through each level from windows of opportunity. These windows' locations and sizes vary over time and if they line up, an accident occurs. [17]

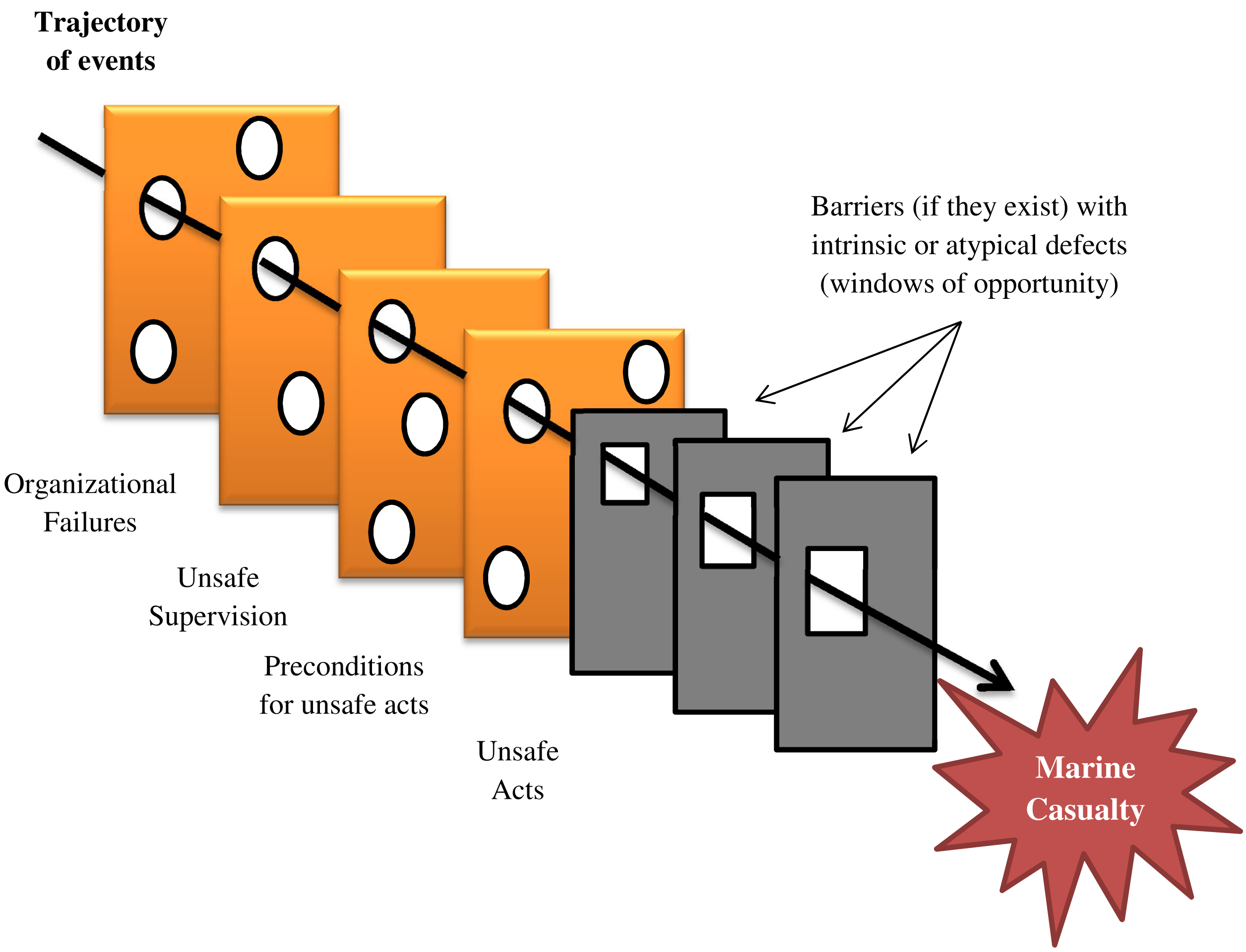

Figure 5: *The Swiss Cheese Model.* [13]

In the Swiss Cheese model, each of the contributing components is necessary for accident occurrence but none of them is sufficient on its own. [13] Each of the errors is a necessary condition for an accident, so if any one of them does not occurr, the accident will not happen. [49]

3.2.2 The Triangle of Effectiveness

Gerry Miller, a human factors engineer, stated that even the most safety-conscious employee will occasionally initiate unsafe acts at the job site and that sometimes these acts are encouraged, led, or even coerced upon the employee by a variety of factors beyond the employee's control. However, these acts can be prevented, or at least the consequences of the acts mitigated, through the application of barriers or safety interventions.

This concept was illustrated through his triangle of effectiveness which presents eight levels of barriers that can be used to prevent or mitigate incidents. Starting at the base of the triangle, these eight elements are:

- <u>Policies and culture:</u> management policies and corporate culture which promote a safe, human-centered work environment.
- <u>Workplace design:</u> ergonomically-designed and arranged equipment.
- <u>Environmental control:</u> keeping lighting, temperature, noise, etc. within human compatible ranges.
- <u>Personnel selection:</u> selecting the right people for the job.
- <u>Training and standard operating procedures (SOPs):</u> ensuring workers have the necessary knowledge and skills to do the job, and that SOPs are correct and consistent with best practices.
- <u>Interpersonal relationships (communication):</u> the exchange of necessary information between team members.
- <u>Job aids:</u> understandable, easy-to-use task instructions and warning placards.
- <u>Fitness for duty:</u> ensuring that workers are alert, focused, and capable of safe job performance.

All eight barriers are important and must be included in a total behaviorally-based safety program. It should be emphasized, however, that the elements at the base of the triangle (i.e., policies & culture, workplace design, and environmental control) have the most significant impact on safety and should form the backbone of a company's safety program.

Interventions based solely on elements at the top of the triangle (such as fitness for duty and job aids) will have the least impact on workplace safety, and therefore should have a lesser emphasis within the company's safety program.

The factors at the top of the triangle depend primarily on the actions of individual workers. Therefore interventions at this level are a less efficient and less effective way of dealing with safety issues. [18]

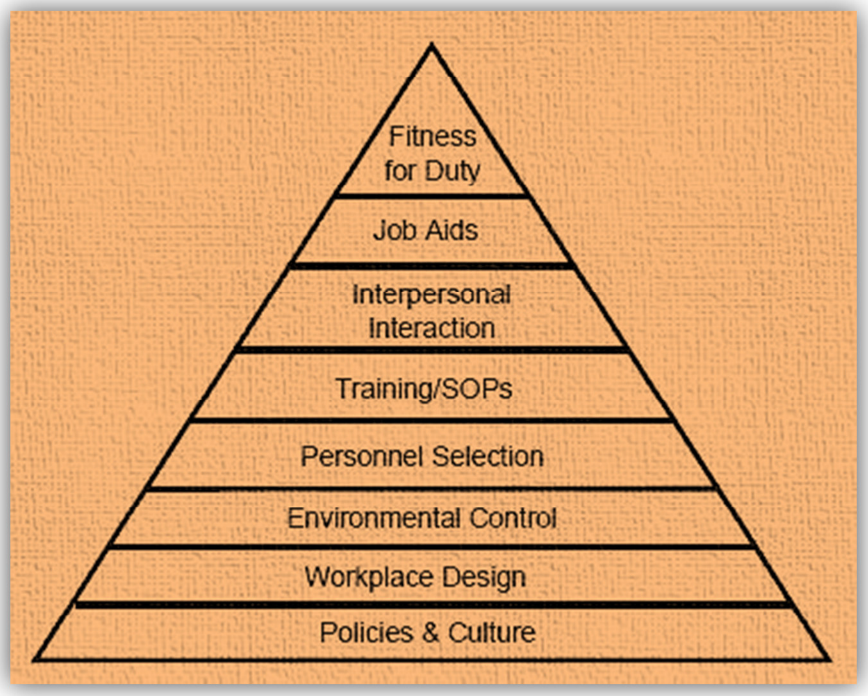

Figure 6: *The Triangle of Effectiveness to Reduce Human Error.* [18]

3.3 Accidents involving human error

3.3.1 The oil spill of Torrey Canyon

The first major oil spill, which was in the English Channel in 1967 and involved the tanker Torrey Canyon, exemplified the environment of high pressure and acute time demands in the maritime industry.

The captain, to save 6 hours, took a more direct route through the Scilly isles to arrive at Milford Haven in time to make the high tide. If he missed this window, his ship would be forced to wait at anchor for five days before being able to enter the bay. The oil in the tanker was moved to different tanks to raise the ship two inches to avoid a potential grounding. When passing through the Scilly Islands, the vessel came across a fishing boat and was unable to turn quickly enough and the ship ran aground, spilling 100,000 tons of oil contaminating a total area of about 300 km along the coast. [17]

At least four different human errors contributed to this accident.

- The first was economic pressure, that is, the pressure to keep to schedule (pressure exerted on the master by management). The Torrey Canyon was loaded with cargo and headed for its deep-water terminal in Wales. The shipping agent had contacted the captain to warn him of decreasing tides at Milford Haven, the entrance to the terminal. The captain knew that if he didn't make the next high tide, he might have to wait as much as five days before the water depth would be sufficient for the ship to enter.

- This pressure to keep to schedule was exacerbated by a second factor: the captain's vanity about his ship's appearance. He needed to transfer cargo in order to even out the ship's draft. He could have performed the transfer while underway, but that would have increased the probability that he might spill a little oil on the decks and come into port with a sloppy ship. So instead, he opted to rush to get past the Scillies and into Milford Haven in order to make the transfer, thus increasing the pressure to make good time.

- The third human error in this chain was another poor decision by the master. He decided, in order to save time, to go through the Scilly Islands, instead of around them as originally planned. He made this decision even though he did not have a copy of the Channel Pilot for that area, and even though he was not very familiar with the area.

- The final human error was an equipment design error (made by the equipment manufacturer). The steering selector switch was in the wrong position: it had been left on autopilot. Unfortunately, the design of the steering selector unit did not give any indication of its setting at the helm. So when the captain ordered a turn into the western channel through the Scillies, the helmsman dutifully turned the wheel, but nothing happened. By the time they figured out the problem and got the steering selector back on manual, it was too late to make the turn, and the ship ran aground. [1]

Figure 7: *The Oil Spill of Torrey Canyon.* [67]

3.3.2 The fatal fire on Scandinavian Star

Early in 1990, Scandinavian World Cruises sold M/S Scandinavian Star, a casino ship, to Vognmandsruten for use as a passenger ferry between Oslo, Norway and Frederikshavn, Denmark.

While en route on 7 April, 1990 an arsonist set a fire on Deck 3 in the passenger section. The brand new crew were mostly Filipino who due to the ship's schedule, had undergone training for the ship's new ferry duties in only 10 days, a good month short of the time they might have expected for orientation and work-up for such a ship.

The fire quickly spread throughout Deck 3 and onwards to Decks 4 and 5 helped by the ventilation fans in the car storage area. It was also assisted by the highly flammable melamine resin laminate that covered many of the surfaces. As it burned, the resin gave off two extremely poisonous gases (hydrogen cyanide and carbon monoxide) which would asphyxiate most of the 158 people who died as the tragedy unfolded.

As the fire spread, the Captain ordered the fire doors on Deck 3 to be closed. But they could not be operated remotely and some had been wedged open. Considering that the fire was being fed by the air conditioning system, he also ordered the system to be turned off. However, the result was that toxic smoke entered the passenger cabins and began to suffocate people who were already trapped by the fire and smoke in the passageways.

Alarms were sounded, distress signals were broadcasted and the order was given to abandon ship. But the alarms were largely unheard and many people did not wake up before they were fatally overcome by toxic smoke. Others could not find their way to the exits.

Unfamiliar with the ship or how to deal with the fire, and unable to communicate with passengers anyway, the largely untrained crew could do little except abandon ship. Unaware of the evacuation progress, the Captain and crew later discovered that many passengers had been left aboard. One third of the passengers died.

It is, of course, indisputable that this disaster would not have happened if there had been no arson. It is also clear that the Captain's assumptions about the role of the Deck 3 exhaust fans and ship's air conditioning system were mistaken or at least incomplete. But it should also be clear that the catalogue of mistakes for this event must include several serious organisational errors, including:

- The design decision to use melamine resin laminates 20 years before, when the ship was built.
- The design decision to require manual fire door operation.
- The design specification for alarm systems that proved to be inadequate when they were needed.
- The design solution for escape routes in the presence of smoke and fire.
- The management decision to hire crew who could not communicate with passengers.
- The management decision to deploy crew unfamiliar with the ship and inadequately trained for responding to fire.

Given the operational and economic pressures to start the ship on its new ferry route, these decisions are clearly the result of trade-offs between efficiency and thoroughness at an organisational level.

Disasters like the one that befell the Scandinavian Star are never attributable to a single error and nor are they only attributable to the people at the sharp end (i.e. the Captain and crew). The organisational culture, operational pressures and prevailing management style all provide a powerful context for the behaviour of the workforce. [6]

Figure 8: *The fatal fire on Scandinavian Star.* [68]

CHAPTER 4 : ENHANCING MARITIME SAFETY

4.1 Introduction

Since the initial adoption of maritime safety standards, the focus was always on the ship's design and equipment. Nevertheless, many studies revealed later that human factors and human error were the main reasons contributing to marine accidents.

The Sinking of S/S Titanic on 1912 was the initial incentive for the international maritime community to set up safety standards in order to reduce accidents at sea, and that resulted in the adoption of Safety Of Life At Sea (SOLAS) convention and later led to the establishment of the International Maritime Organization (IMO).

By the mid 1980's the IMO gave attention to the role of human factors in the maritime accidents by adopting the concept of implanting the safety culture in shipping industry.

The most significant instruments which were introduced to create safety culture and improve human performance in ship operations are the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) convention and the International Safety Management (ISM) code. [7]

Furthermore the International Labour Organization (ILO) focused on seafarers' employment and welfare by setting minimum standards on issues such as seafarers' conditions of employment and accommodation recreational facilities.

Finally the International Organization for Standarization (ISO) focused in the application of ergonomics on board ships to address the human issues and eliminate error-inducing situations.

It is worth mentioning that some of the issues covered in the different conventions overlap since there is an effort to regulate important aspects from different perspectives. I have chosen to present them here depending on their special point of interest, but I do recognize that the regulations are interwined in order to promote safety in a holistic way.

4.2 International Maritime Organization

A resolution adopted by IMO in 1997 elucidates the Organization's approach in human error. It admits that human element is a multidimensional and complex issue and encourages the development of non-regulatory solutions as it believes that regulatory approach creates a culture of compliance which is far from a safety culture.

IMO recognizes 3 types of shipping companies; first those which not only comply with the regulations but take additional steps toward safer shipping, then those which just comply with the requirements but for them safety is not a priority and finally those that do not comply and run substandard ships. Unfortunately adoption and enforcement of regulations do not turn non-compliers into compliers. [7]

4.2.1 Minimum Safe Manning

The principles of minimum safe manning introduced by IMO Resolution A.1047 (27) are sensible and, if followed, should provide a robust foundation to help determine the manning level. The resolution goes on to list the functions on which the safe minimum manning levels should be based, including:

- Size and type of ship.
- Number, size and type of main propulsion units and auxiliaries.
- Construction and equipment of the ship.
- Method of maintenance used.
- Cargo to be carried.
- Mooring and unmooring the ship safely.
- Safe navigational watches to be carried out in accordance with STCW requirements.
- Frequency of port calls, length and nature of voyages to be undertaken.
- The number of qualified personnel required to meet peak workload situations.
- Trading area(s), waters and operations in which the ship is involved.
- Extent to which training activities are conducted on board.
- Applicable work hour limits and/or rest requirements. [54]

4.2.2 Standard Marine Communication Phrases

IMO's Standard Marine Communication Phrases (SMCP) were adopted by the 22nd Assembly in November 2001 by the resolution A.918 (22) recommending that all seafarers and those involved in maritime training shall use a common set of English language phrases.

SMCP have been developed to be a comprehensive body of standardized language, focusing primarily on all predictable communication scenarios relating to health and safety. These include verbal communications made shore-to-ship (and vice-versa), ship-to-ship and on-board communications. The objective was to overcome language barriers among international crew and avoid misunderstandings which could cause accidents.

The IMO SMCP builds on a basic knowledge of English and has been drafted in a simplified version of maritime English. It includes phrases for use in routine situations such as berthing as well as standard phrases and responses for use in emergency situations.

Under the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended, the ability to understand and use the SMCP is required for the certification of officers in charge of a navigational watch on ships of 500 gross tonnage or above.

There's no doubt that SMCP has made a big difference. Having an agreed set of phrases allows seafarers from many different nationalities to communicate with each other predictably, in key areas of health and safety. [55]

4.3 The International Safety Management Code

The high number of maritime incidents prompted IMO to produce a unified safety management code called the ISM code. The ISM guidelines were developed to provide a framework for the proper development, implementation and assessment of safety and pollution prevention management in accordance with industry best practices.

The ISM code is often linked to litigation cases involving maritime incidents. This prompted shipping companies to further understand the legal implication of ISM code and hence it became more evident to companies that full demonstration of the requirements is vital.

The ISM Code establishes an international standard to enhance the value of safety management and operation of ships by focusing on system and structural issues and also addressing human issues so that maritime companies shall operate in a profitable manner and also grow organically.

Almost all-shipboard systems and operations are heavily dependent on human intervention and the human link will constantly remain a weak link in this equation. Therefore these elements of human aspect needed to be continuously managed and improved.

So the implementation of ISM renewed strategies in managing human capital and led to the improvement of work practices that will form the basis for a safer operation of vessels and the economic viability of companies. [50]

4.3.1 Safety Management System

A Safety Management system (SMS) meeting the requirements of the ISM code requires a company to document its management procedures and record its actions to ensure that conditions, activities and tasks that affect safety and the environment are properly planned, organised, executed and checked.

A SMS is developed and implemented by people and clearly defines responsibilities, authorities and lines of communication. A SMS allows a company to measure its performance against set criteria hence identifying areas that can be improved.

The increase in Safety Management skills improves morale and can lead to a reduction in costs due to an increase in efficiency and a reduction in claims. The functional requirements for a safety management system are:

- Safety and environmental policy
- Instructions and procedures to ensure that safe operation of the vessel in compliance with relevant international and flag state legislation
- Defined levels of authority and communication between shore and ship personnel
- Procedures for reporting accidents and non-conformities with the code
- Procedures for responding to emergency situations (drills etc)
- Procedures for internal audits and regular management reviews
- A system is in place for the on board generation of plans and instructions for key shipboard operations. [51]

4.3.2 Near misses

A near-miss is defined as an extraordinary event that could reasonably have resulted in a negative consequence under slightly different circumstances, but actually did not. Essentially, a near-miss is an accident that almost happened. It has been estimated that for every accident, there are about 600 near-misses.

Near-misses and accidents have the same causes, so studying near-misses can help us understand safety problems and make corrective changes before an accident takes place. In addition, since near-misses do not result in full-blown casualties, studying near-misses can help us learn how to develop early-warning systems to detect when conditions have become non-normal and also show us what steps to take in order to avoid the accident. [18]

The ISM Code requires that the safety management system should include procedures ensuring that non-conformities, accidents and hazardous situations are reported to the Company, investigated and analysed with the objective of improving safety and pollution prevention.

Near misses, accidents and incidents shall be reported by everyone without the fear of punishment indicating that companies do welcome incident reports in order to understand the precursors to events that were detrimental to safety and the marine environment and to promote a no blame culture to improve the safety and environmental management on board. [52]

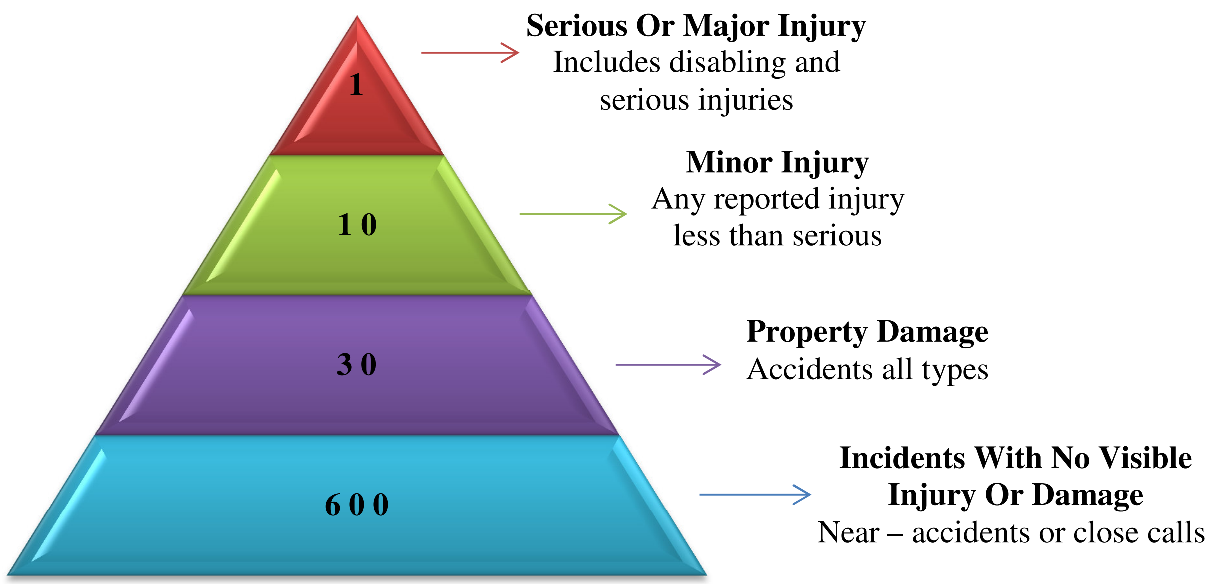

Figure 9: *Accident Ratio Study: For every accident, there are about 600 near-misses.* [52]

4.3.3 Incident investigation and analysis

An incident is defined as including all accidents and all near-miss events that did or could cause injury, or loss of or damage to property or the environment.

Incident investigation and analysis is the study of accidents and near-misses and is squarely in line with the intent of the ISM Code. ISM requires that a company provide for a safe work environment and safe practices in maritime operations and establish safeguards against all identified risks. Incident investigation helps the company to identify its risks and to understand the underlying causes of incidents.

Establishing a human factors incident investigation program in maritime companies and analyzing the data collected, they can learn from incidents and identify how to improve their policies and work practices to achieve a higher level of safety.

These programs often follow well-grounded investigative practices, providing investigation team members with training in the basics of incident investigation, gathering and documenting evidence, and interviewing techniques. An incident database may also be kept so that frequency and trending analysis shall be made.

However, where most of these programs fall short is in the areas of identifying human factors causes and determining how best to correct these problems. While a number of companies attempt to consider operator errors during incident investigations, these operator errors represent only the tip of the human factors iceberg.

Most human factors causes originate further up the organizational chain, taking the form of poor management decisions, inadequate staffing, inadequate training, poor workplace design, etc. Simply identifying the mistake an operator made, and not drilling down to identify the underlying, organizational causes of that mistake, will not help to prevent reoccurrences of the incident.

On the contrary, when a focus on human error is incorporated into existing incident investigation, analysis, and intervention program, it can produce great benefits for a company, including fewer incidents, fewer lost-time accidents, improved employee morale, greater productivity, and an overall improvement in operations. [18]

"Incident investigation and analysis is a vital process for understanding and preventing incidents, both large and small, which can cause untold and often irrecoverable damage to individual lives, equipment, organisational safety culture, company reputation and profit."

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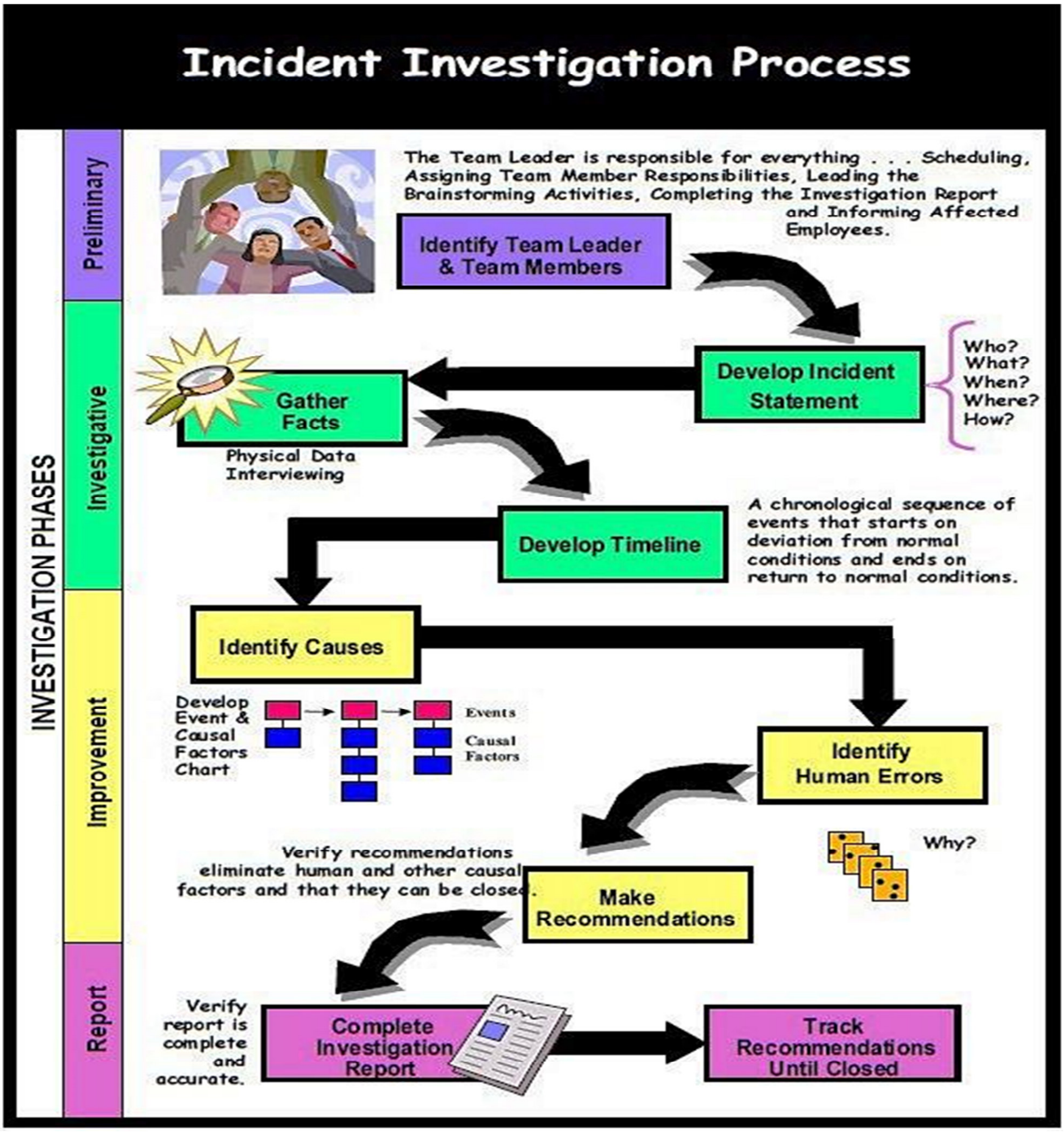


Picture 11: *The different phases of the Incident Investigation Process.* [18]

4.3.4 Internal audits

After July 2010 it became mandatory to carry out internal audits annually under the ISM code. Clause 12.1 of ISM code states that internal safety audits are now required to be carried out on board and ashore at intervals not exceeding 12 months. In extreme exceptional cases it can be extended to 3 months.

The objectives of an ISM internal audit are:

- It acts as a tool to monitor how well the SMS system is implemented on board regarding the safety practices and pollution prevention activities.
- It helps in checking whether company safety and environmental policy is continually in compliance with the requirement of this code. Provides an opportunity to possible changes in the SMS system.
- Shows the evidence of the SMS working and that the procedures are being followed.
- To determine compliance with regulatory requirement.

The internal audit is carried out as per the procedure laid down in company's SMS annually. It is conducted by company's person who is other than the field of audit. By conducting an internal audit the following are checked for proper order:

- Plans/procedures being followed.
- Laws and regulations being followed.
- Records/documentations are being maintained to provide adequate and accurate information.
- Deficiencies are identified and corrective actions taken.
- Personnel are familiar with the use of SMS. [53]

4.3.5 Just culture

It is clear that mistake making is part of normal human behaviour. It is also clear that wider organisational factors play a huge part in helping to create our behaviour including our mistakes. These twin realisations have allowed a new approach to safety management to emerge in recent years.

To increase safety and facilitate the reporting and sharing of safety data, as required by the ISM Code, the maritime industry has identified the need to move towards a no blame culture or a just culture that will allow the accountabilities of individuals at all levels of the organisation to be properly addressed and fairly integrated.

A just culture is founded on two principles, which apply simultaneously to everyone in the organisation:

- Human error is inevitable and the organisations' policies, processes and interfaces must be continually monitored and improved to accommodate those errors.
- Individuals should be accountable for their actions if they knowingly violate safety procedures or policies.

Achieving both of these two principles is enormously challenging. The first principle requires a reporting system and culture that people can trust enough to make the necessary disclosures. The second principle is implemented specifically from the way in which the organisation defines, investigates and attributes accountability for whatever its staff disclose.

Accountability in a just culture is assessed by investigating how actions and decisions made sense to each involved person at all levels of the organisation at the time of the incident, and what changes the organisation could consider to prevent them from contributing to a mistake again.

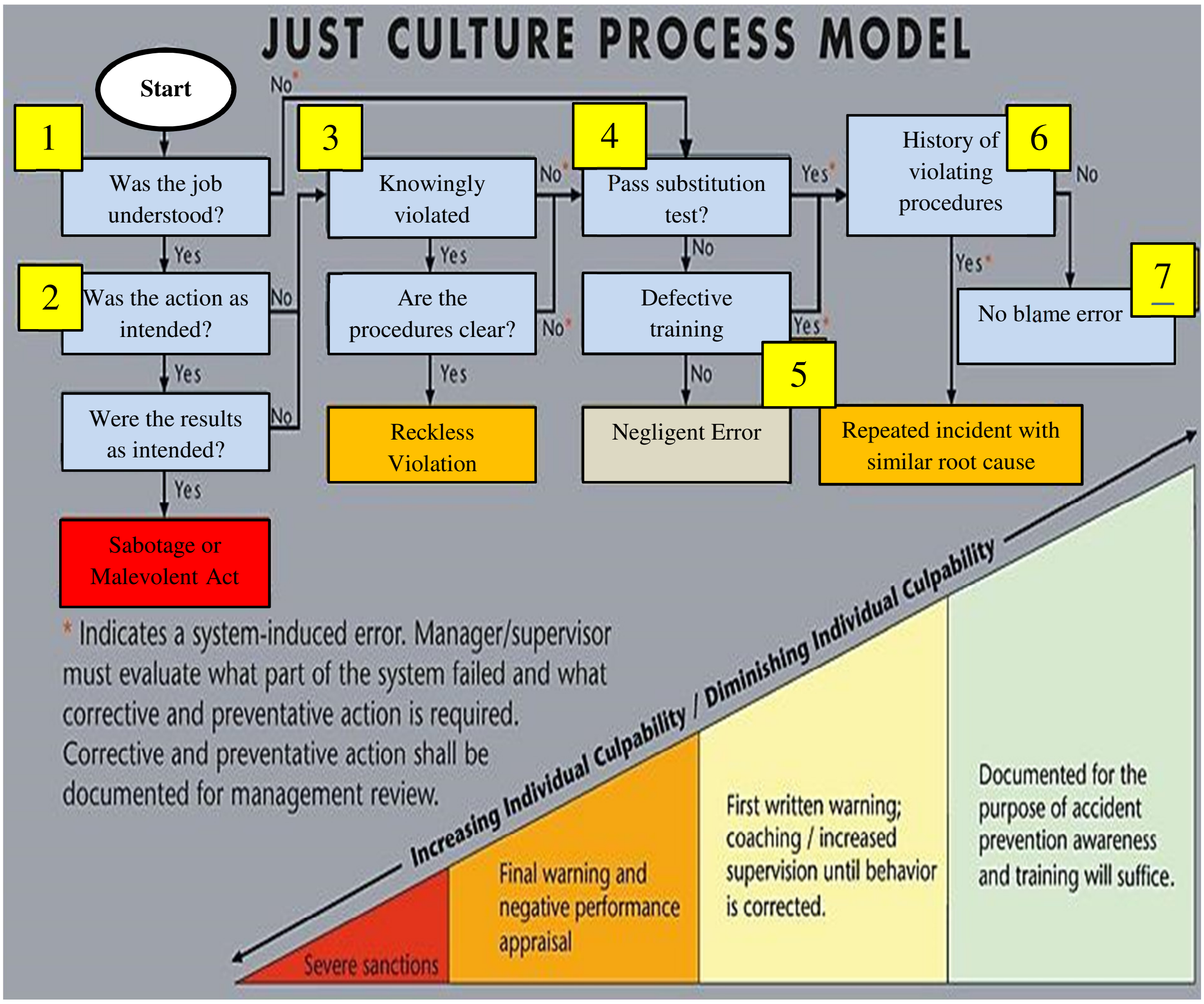
Reporting is supported by debriefing programmes to help cope with trauma. Investigations are conducted by expert practitioners who have deep knowledge of the technical demands of the incident and are schooled in hindsight bias. Techniques such as substitution may be used in which experts can mentally place themselves in the incident to decide what they would have reasonably done.

The different perspectives may then be assembled into a mosaic to form a rich picture of the incident. Note, however, that no-one had this picture at the time of the incident, and it is only useful to help consider what systemic changes might be necessary.

The following benefits of a just culture are anticipated:

- Increased reporting of unsafe incidents and accidents, including trends that indicate future problems developing.
- Increased trust between all levels of the workforce, which accelerates the organisation's journey towards greater safety maturity.
- Decreased actual numbers of adverse incidents and accidents.
- Decreased operational costs due to safer behaviour, higher workforce motivation and morale, and increased productivity.

The journey to a fully mature just culture presents difficult challenges, but promises to create much more effective safety based on genuine attitude change. It also provides the means to transform safety from a cost centre into a profit centre. [6]



__Picture 12:__ A decision tree for determining the culpability of unsafe acts. [65]

4.3.6 The Safety Culture Ladder

A model which was proposed to enhance maritime safety and is related to ISM is the safety culture ladder.

Programmes have been initiated within the maritime industry which describe a journey or ladder, together with supporting tools designed to change the safety attitudes of the entire workforce. The journey is typically depicted as moving through a number of organisational approaches to safety. This may start with the pathological stage, where people don't really care about safety at all and expect someone to get fired if there is an accident. At the end of the journey is the generative stage where people actively seek information, and failures lead to far reaching reforms.

The five stages and their characteristics of the safety culture ladder are:

Level 1: Pathological

- We leave it to the lawyers or regulators to decide what's OK.
- There are bound to be accidents – this is a dangerous business.
- If someone is stupid enough to have an accident, sack them.
- Bad news is unwelcome – kill the messenger.

Level 2: Reactive

- Safety is taken seriously every time there is an accident.
- Managers try to force compliance with rules and procedures.
- Many discussions are held to re-classify incidents.
- Bad news is kept hidden.

Level 3: Calculative

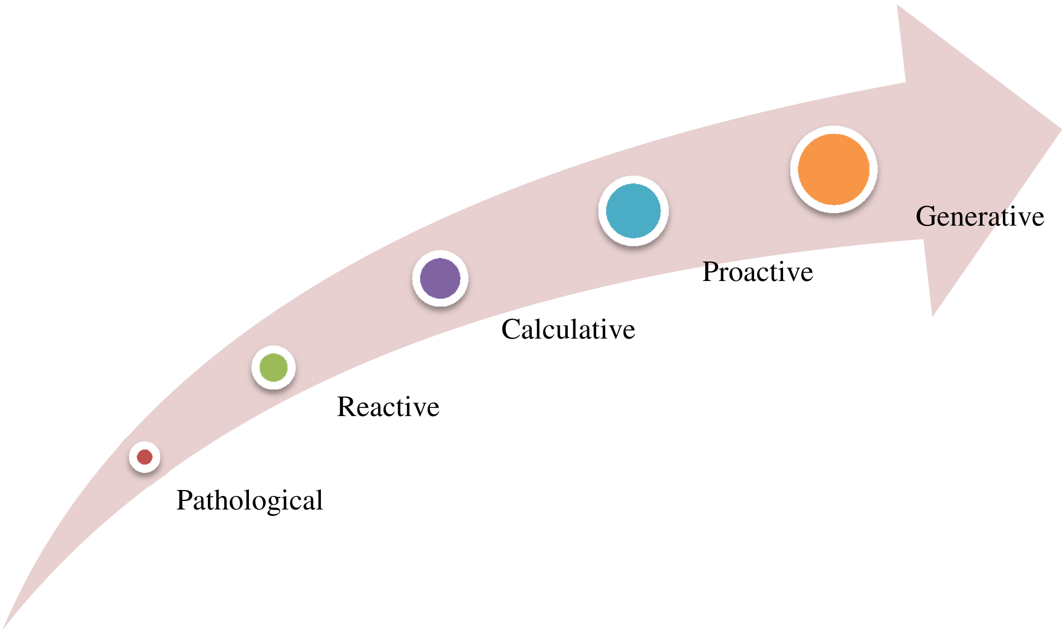
- There are lots of audits and lots of data to describe things.
- The new Safety Management System is assumed to be enough.
- People are surprised when incidents still happen.
- Bad news is tolerated.

Level 4: Proactive

- Resources are allocated to anticipate and prevent incidents.
- Management is open to bad news, but still focused on statistics.
- The workforce is trusted and feels involved in safety.

Level 5: Generative

- Managers know what's happening – the workforce tells them.
- Bad news is sought out so failures can be learned from.
- People are constantly aware of what could go wrong.
- Safety is seen as a profit centre. [6]



Picture 13: *The stages of the Safety Culture Ladder.* [6]

4.4 Safety Of Life At Sea

The first international convention concerning safety at sea was Safety of Life at Sea (SOLAS), prompted by the Titanic disaster in 1911. The convention was first adopted in 1914. SOLAS specifies minimum standards for the construction, equipment and operation of ships compatible with their safety. It is generally regarded as the most important of all international treaties concerning the safety of merchant vessels.

Regarding human error SOLAS set the requirements for the establisment of a common working language on board ships and also introduced the concept of the Bridge Navigational Watch Alarm System (BNWAS) for the elimination of marine accidents caused by human factors which was definitely a step forward.

4.4.1 Common Language

As navigational and safety communications from ship to shore and vice versa, from ship to ship, and on board ship must be precise, simple and unambiguous so as to avoid confusion and error, there is a need to standardize the language used.

This is of particular importance in the light of the increasing number of internationally trading vessels with crews speaking many different languages, since problems of communication may cause misunderstandings leading to dangers to the vessel, the people on board and the environment. Where language difficulties arise, a common language should be used for navigational purposes.

Paragraph 4 of Regulation 14, SOLAS Chapter V requires the establishment of a common working language on board, to ensure effective crew performance in safety matters.

On all ships, a working language shall be established and recorded in the ship's log-book. Each seafarer shall be required to understand and, where appropriate, give orders and instructions and report back in that language. If the working language is not an official language of the State whose flag the ship is entitled to fly, all plans and lists required to be posted shall include a translation into the working language.

English shall be used on the bridge as the working language for bridge-to- bridge and bridge-to-shore safety communications as well as for communications on board between the pilot and bridge watchkeeping personnel unless those directly involved in the communication speak a common language other than English.

The regulation also draws attention to the use of the IMO Standard Marine Communication Phrases. (SMCPs). [54]

4.4.2 Bridge Navigational Watch Alarm System

Navigating a giant vessel is not at all an easy job and when it comes to a situation of emergency, wherein the navigational officer has to make some quick decisions, the safety of the entire ship and its crew depends on that officer and if he is not capable to handle that situation or take a decision at the correct time it can lead to devastating scenarios.

Thus according to the amendments made to SOLAS Chapter V Regulation 19 that were adopted by the IMO on 5th June 2009 in Resolution MSC.282 (86) it was made mandatory to have a Bridge Navigational Watch Alarm System (BNWAS) fitted to all passenger and cargo vessels.

The BNWAS is a safety alarm system that monitors bridge activity and detects operator's disability. The system includes a series of indications and alarms to monitor the awareness of the Officer of the Watch (OOW) and if he is not responding it automatically alerts the Master or another qualified OOW if for any reason the OOW becomes incapable of performing the watch duties efficiently which can lead to maritime accidents. [56]

We could say that BNWAS acts similar to a dead man alarm in the engine room. Additionally, it provides the OOW with a means of calling for immediate assistance if required. [57]

4.4.3 Personal protective equipment

Personal Protective Equipment (PPE) may be defined as "equipment designed to be worn or held by an employee for protection against one or more hazards likely to endanger the employee's safety and health at work, and any addition or accessory designed to meet this objective".

PPE is technically sophisticated, designed, built and tested to exacting standards of performance. The equipment must be properly selected and fitted, and workers must be properly trained in its use, application and maintenance. Its selection demands professional skill, knowledge of the workplace and understanding of the potential hazards.

In fact, there is no replacement for PPE in many situations. And in many others, it is the logical first choice, or an affordable alternative to costly engineering and administrative controls. Because few, if any, workplaces can be cleared of all hazards, PPE is an essential component of any occupational safety and health program.

The use of quality, properly-selected PPE by workers trained in proper fit and use in tandem with other control methods is a time-proven, cost-effective method of protecting workers from hazards in the workplace.

It is the duty of every employer to provide personal protective equipment for use by their employees, where the risks cannot be avoided or sufficiently limited. Thus all employees are obliged to wear the PPE they have been provided with. No person shall intentionally or recklessly interfere with or misuse any appliance, protective clothing or other equipment provided in the workplace for health and safety purposes.

Examples of PPE include such items as safety helmets, gloves, goggles, safety footware, safety harnesses, eye protection, protective hearing devices, respirators and full body suits. [69]

4.5 International Labour Organization

Until recently, little comprehensive statutory (or regulatory) guidance had been offered related to habitability. Although a few class societies had been quite active in this area, compliance with their guidance was optional.

Now we have the International Labour Organization's Maritime Labour Convention (MLC 2006) which covers owner/ operator related management systems and the vessel's accommodations design.

The Maritime Labour Convention 2006 (MLC 2006) has been described as the fourth pillar of maritime regulation covering international shipping setting out seafarers' rights to decent working conditions, covering almost every aspect of their work and life on board. [58]

4.5.1 Habitability

In terms of habitability, minimum standards are established on board vessels constructed after the date that the Convention entered into force for a particular flag state to ensure that any accommodation for seafarers, working or living on board, or both, is safe and decent and are inspected to ensure initial and ongoing compliance.

This relates to:

- The size of rooms and other accommodation spaces
- Heating and ventilation
- Noise and vibration and other ambient factors
- Sanitary facilities
- Lighting
- Hospital accommodation

Looking at habitability from a human factors perspective, designing for appropriate levels of ambient environmental factors is crucial to work task performance, whether that task is communicating on the bridge, viewing displays in a control room, or resting.

Here are some reasons why:

- Noise: Inappropriate levels of noise can degrade vigilance during watchkeeping tasks, interfere with complex mental tasks, delay the onset of sleep or awaken one from sleep, and generally interfere with rest.
- Whole-body Vibration: Controlling levels of whole-body vibration can establish a safe environment with respect to human response to excessive vibration, including; motion sickness, vibration induced injury/illness and motion induce instabilities and interruptions. Vibration can also alter worker perception (e.g., reading text and instruments, depth perception) and influence control movements (e.g., tactile sense, head/ hand movements, manual tracking).

- Indoor Climatic Qualities: The objective here is to provide conditions that are suitable to facilitate human performance with regard to factors such as increases in energy expenditure, decreases in work capacity, reduced hand/arm control manipulation capability, and a decreased capacity for cognitive functioning.
- Lighting: Vision is essential to information transfer, as well as general safety. Inappropriate lighting levels can result in visual task difficulty, distraction, perceptual confusion (such as misreading a display) and failure to detect visual targets. Improperly designed lighting systems can also contribute to eye fatigue, human error, unsafe conditions, and increases in reaction/ response times.

The intent of good habitability design is to apply appropriate criteria or limits that will provide the best overall shipboard or structure conditions for the crew, given design constraints and budget. Additionally, it is crucial that all habitability design characteristics be considered concurrently and early in the design to help meet potential resource constraints.

A psychologically satisfying and desirable work environment leads to the safe performance of tasks and activities as it is a place where the workers are encouraged for performing their best.

Workers are free for participating in identifying and solving work problems. The management system permits their workers to define goals for themselves and also let them innovate methods of achieving their goals. Management can improve the environment of work for workers by managerial techniques, participative methods, setting defined goals for workers etc. [16]

The MLC establishes a new (and improved) baseline related to crew accommodation requirements. Even though it is basically a health and safety conservation standard, it is a definite step forward for seafarers. [6]

4.5.2 Rest hours

The International Labour Organization including the ILO Maritime Labour Convention (MLC) covers seafarers' minimum rest periods to prevent fatigue and ensure that seafarers are fit for duty.

1. The limits on hours of work and rest shall be as follows:

(a) Maximum hours of work shall not exceed:
(i) 14 hours in any 24-hour period
(ii) 72 hours in any 7-day period
or
(b) Minimum hours of rest shall not be less than:
(i) 10 hours in any 24-hour period
(ii) 77 hours in any 7-day period

2. Hours of rest may be divided into no more than two periods, one of which shall be at least six hours in length, and the interval between consecutive periods of rest shall not exceed 14 hours.

Seafarers will need to review and sign a record of their work/rest hours periodically (typically at least once a month) to ensure they comply with the minimum rest hours stipulated. [59]

Similar, but less stringent, requirements regarding minimum hours of rest are contained in Section A-VIII/1 of the International Convention on Standards of Training, Certification and Watchkeeping (STCW) for Seafarers. [6]

4.6 Standards of Training, Certification and Watchkeeping for Seafarers

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (or STCW), 1978 sets qualification standards for masters, officers and watch personnel on seagoing merchant ships. STCW was adopted in 1978 by conference at the International Maritime Organization (IMO) in London, and entered into force in 1984. The Convention was significantly amended in 1995.

The 1978 STCW Convention was the first to establish basic requirements on training, certification and watchkeeping for seafarers on an international level. Previously the standards of training, certification and watchkeeping of officers and ratings were established by individual governments, usually without reference to practices in other countries. As a result standards and procedures varied widely, even though shipping is extremely international of nature.

The IMO Convention on Standards of Training Certification and Watchkeeping for Seafarers adopted a new set of amendments in Manila in 2010 called The Manila Amendments. These amendments were necessary to keep training standards in line with new technological and operational requirements that require new shipboard competencies. The Manila Amendments were effective as of 1 January 2012. There is a transition period until 2017 when all seafarers must be certified and trained according to the new standards.

A detailed review of STCW code section A-II/2 indicates the Mandatory minimum requirements for training and certification that professional mariners must have based on the capacity they serve in the type of vessel they work on. [7]

4.6.1 Training Requirements

It is widely quoted that 80% of transport accidents are due to human error. It is the human element on board ship that can either provide the skills that may prevent a disaster, or the frailty or plain lack of competence that can cause one. And, while the capability, complexity and sheer power of technology seems to be accelerating exponentially, the human element remains a basic component with all its strengths and all its weaknesses.

That is why the international maritime community has now evolved from an approach, which traditionally seeks technical solutions to safety-related problems and is focusing instead on the role of human factors in maritime safety.

The STCW Convention is one of several key initiatives that underpin this new philosophy at IMO. It seeks to establish a baseline standard for the training and education of seafarers throughout the world and, by placing an emphasis on quality control and competence-based training, and practical demonstrations of competency in the form of training record books and assessments conducted by qualified assessors onboard the ship or at maritime schools.

The primary purpose of the STCW 2010 Manila Amendments are as follows:

- To enhance the requirements for refresher training in safety related certificates every five years.
- To require additional security training for all levels of seafarers.

- To require Human Element Leadership and Management Level training for deck and engineering officers.
- To require additional training in Chapter V for tank vessel personnel.
- To require formal training for all officers in modern technology.
- To consolidate the training in Chapter V for all passenger vessels to include RO-RO vessels.
- To introduce modern training methology (e.g. Web-based learning).
- To harmonize the rest periods with the provisions established by the Maritime Labour Convention 2006.

These amendments went into force in January 2012 with a five year phase in and implementation plan and a 1 January 2017 deadline for all mariners. New mariners beginning their sea service after January 2013 must be in compliance with the amendments at the start of their training. [63]

4.6.2 Bridge Resource/Team Management

Weakness in bridge organization and management has been cited as a major cause for marine casualties worldwide. Accidents in operations are frequently caused by resource management errors.

Better procedures and training can be designed to promote better communications and coordination on and between vessels. Bridge Resource Management (BRM) is a first step towards improvement and it was a concept introduced by STCW (Chapter VIII, Part 3-1). [1] BRM reduces the risk of marine casualties by helping a ship's bridge crew anticipate and correctly respond to their ship's changing situation.

Bridge Resource Management (BRM), or as it is also called Bridge Team Management (BTM), is the effective management and utilization of all resources, human and technical, available to the Bridge Team to ensure the safe completion of the vessel's voyage.

BRM focuses on bridge officers' skills such as teamwork, teambuilding, communication, leadership, decision-making and resource management and incorporates this into the larger picture of organizational and regulatory management.

BRM addresses the management of operational tasks, as well as stress, attitudes and risk. It also recognizes that there are many elements of job effectiveness and safety, such as individual, organizational, and regulatory factors, and they must be anticipated and planned for. BRM begins before the voyage with the passage plan and continues through the end of the voyage with the passage debrief.

When BRM is correctly practiced onboard a vessel the result should be a Bridge Team that:

- Maintains its situational awareness.
- Continually monitors the progress of the vessel making appropriate adjustments and corrections as necessary to maintain a safe passage.
- Acquires relevant information early.
- Appropriately delegates workload and authority.
- Anticipates dangerous situations.
- Avoids becoming pre-occupied with minor technical problems and losing sight of the big picture.
- Undertakes appropriate contingency plans when called for.
- Recognizes the development of an error chain.
- Takes appropriate action to break the error-chain sequence. [21]

4.6.3 Computer Based Training

As the maritime industry make efforts to mature in its use of learning technologies, it emphasizes on how to best use the tools that we have at hand, both to maximize efficiency and to optimize training outcomes. One step forward regarding additional training for mariners is the use of Computer-Based Training (CBT) modules (e.g. Seagull) on board ships.

Each CBT module is a dedicated multimedia program consisting of a number of chapters of learning material followed by an assessment section. The final assessment chapter contains a database of multiple choice questions from which final assessment tests can be randomly generated.

Lessons are delivered with a sequential text and normally include a mixture of illustrations, animations and video clips as appropriate to the text. A training session can be interrupted at any time and continued at a later date. However, the final assessment can only be performed once.

The main and overwhelmingly significant strength is the CBT's combination of quality and price. The effect is as if all maritime operators got together to co-fund the creation of a course which is very efficient. [70]

All CBT Courses:

- Are comprehensive industry-based courses.
- Include practical tasks and stimulating visuals.
- Incorporate computer-based assessment.
- Produce records of the training time and the user identification.
- Can be used for self-study purposes or in a trainer-led environment.
- Provide printable certificates showing pass / fail status.
- Allow users to choose their material and study at their own pace. [71]

4.7 International Organization for Standardization

All people are prone to making errors and this is more likely when they are tired, under time pressure, or exposed to distractions and interruptions particularly when carrying out familiar tasks. Ideally the potential for errors should be removed through good design of procedures and equipment. [14]

For systems to operate safely and effectively, they must be designed to support the people who operate them. Human factors are regarded as having an essential contribution during the development and operation of systems.

It is increasingly recognised that human factors issues must be considered as a central part of development thinking. Experience shows that it is ineffective to address them as an afterthought. The risks associated with poor human factors can best be avoided by starting human factors activities as early as possible in the design process and continuing them throughout.

The International Organization for Standarization (ISO) set standards for the application of ergonomics specifing the process of Human-Centred Design in a form that is compatible with modern approaches. [60]

4.7.1 A Human - Centered Approach

While human errors are all too often blamed on inattention or mistakes on the part of the operator, more often than not they are symptomatic of deeper and more complicated problems in the total maritime system. Human errors are generally caused by technologies, environments, and organizations which are incompatible in some way with optimal human performance. These incompatible factors set up the human operator to make mistakes.

Traditionally, management has tried either to cajole or threaten its personnel into not making errors, as though proper motivation could somehow overcome inborn human limitations. In other words, the human has been expected to adapt to the system. This does not work. Instead, what needs to be done is to adapt the system to the human.

An international standard ISO 9241-210: Ergonomics of human-system interaction provides guidance on achieving quality by incorporating user centred design activities throughout the life cycle of interactive systems. With its introduction in 2008, it revised ISO 13407, Human-centred design processes for interactive systems, 1999.

ISO 9241-210 describes user centred design as a multi-disciplinary activity, which incorporates human factors and ergonomics knowledge and techniques with the objective of enhancing effectiveness and productivity, improving human working conditions, and counteracting the possible adverse effects of use on human health, safety and performance.

Human factors are all those things that enhance or improve human performance in the workplace by focusing on their inherent characteristics. [1] The discipline of human factors is devoted to understanding human capabilities and limitations, and to applying this information to design equipment, work environments, procedures, and policies that are compatible with human abilities. [5]

Human factors apply scientific knowledge and principles as well as lessons learned from previous incidents and operational experience to optimise human wellbeing, overall system performance and reliability. [1] In this way we can design technology, environments, and organizations which will work with people to enhance their performance, instead of working against people and degrading their performance.

This kind of human-centered approach (that is, adapting the system to the human) has many benefits, including increased efficiency and effectiveness, decreased errors and accidents, decreased training costs, decreased personnel injuries and lost time, and increased morale and also the development of sustainable and safe working cultures. [5]

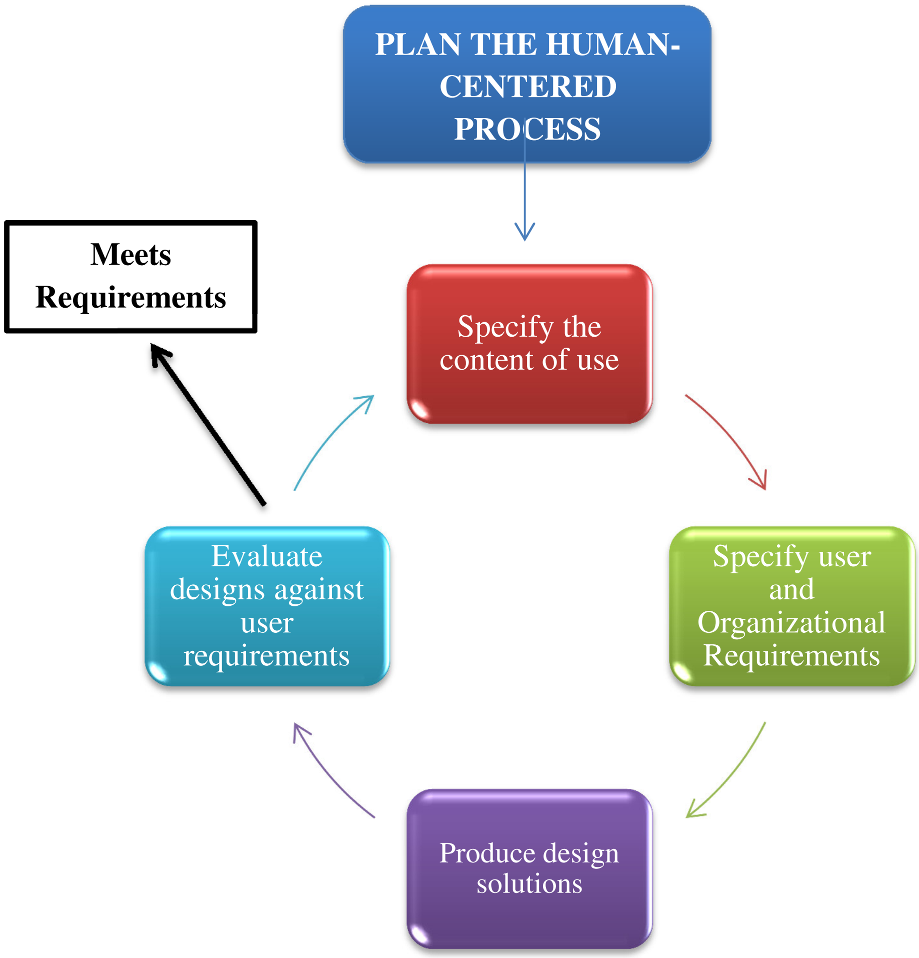


Figure 10: *The interdependence of user-centered design activities.* [66]

4.7.2 Human Factors Engineering and Ergonomics

Designing the interior spaces of any vessel is a challenging task. There are important considerations to keep in mind regarding the adequate use of the space. The end user is the most important element when designing and his/ her anthropometry is the key factor during the design process.

The main goals of designing for habitability are to provide a design that will enhance human performance, mental alertness, the quality of life for seafarers, and quite possibly crew recruiting and retention. [11]

ISO 14738: Anthropometric requirements for the design of workstations at machinery 2002, (including Cor 1:2003 and Cor 2:2005) provides guidance on achieving quality by taking into account the need to include ergonomics and human factors engineering (HFE) considerations in ship's design to affect in a positive way the performance of the crew.

Human Factors Engineering (HFE) focuses on the application of human factors knowledge to the design and construction of socio-technical systems. The objective is to ensure systems are designed in a way that optimises the human contribution to production and minimises potential for design-induced risks to health, personal or process safety or environmental performance taking into account the following:

- Ergonomic body postures
- Avoid static postures
- Body dimensions
- Make way (provide space) for tools and component parts
- Free access to machinery and equipment
- Visibility
- Circulations
- Accesses without obstacles and enough space
- Technical organisation of the space

Human Factors Engineering has an important contribution to make to ensure the quality, safety and fitness for purpose of equipment and facilities used and support efficient, reliable and safe human performance. [14] Improvements in all these areas will help to reduce crew fatigue and increase overall safety, as well as quality of life.

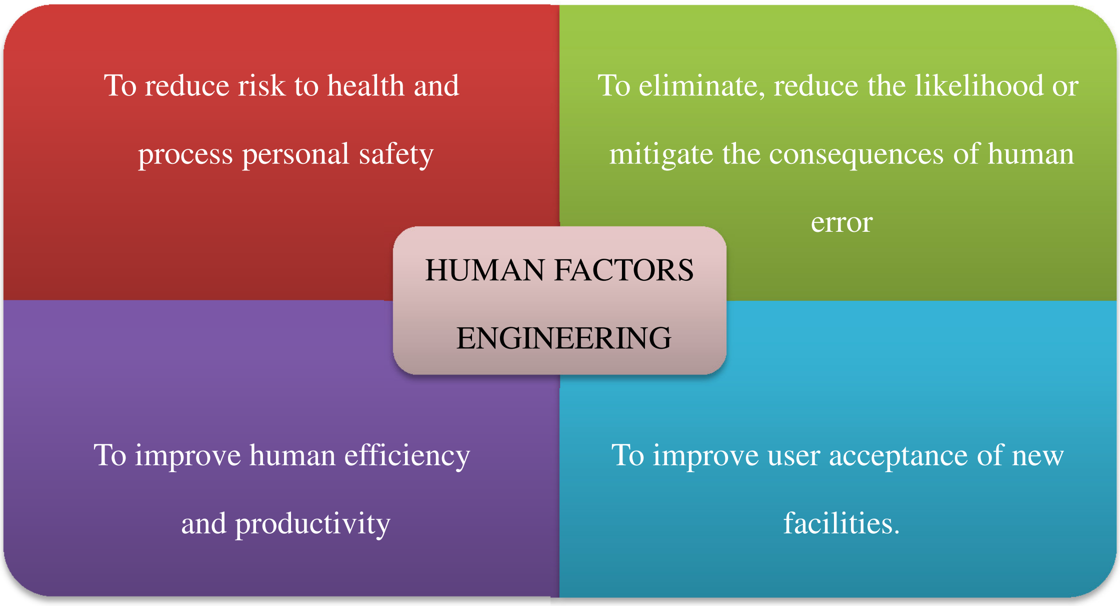


Figure 11: *The purpose of implementing Human Factors Engineering.* [11]

The most important space for HFE interventions is the Bridge. Improvements to the Bridge design focuses on the redesign of the main console. The goal is to assure an easy reach access of the vessel controls and appropriate placement of displays within the crew member's primary field of view. Another important element is the helmsman's console seat design, to include height and fore and aft, and adjusting mechanisms to accommodate the anthropometric differences of different users, for example, women.

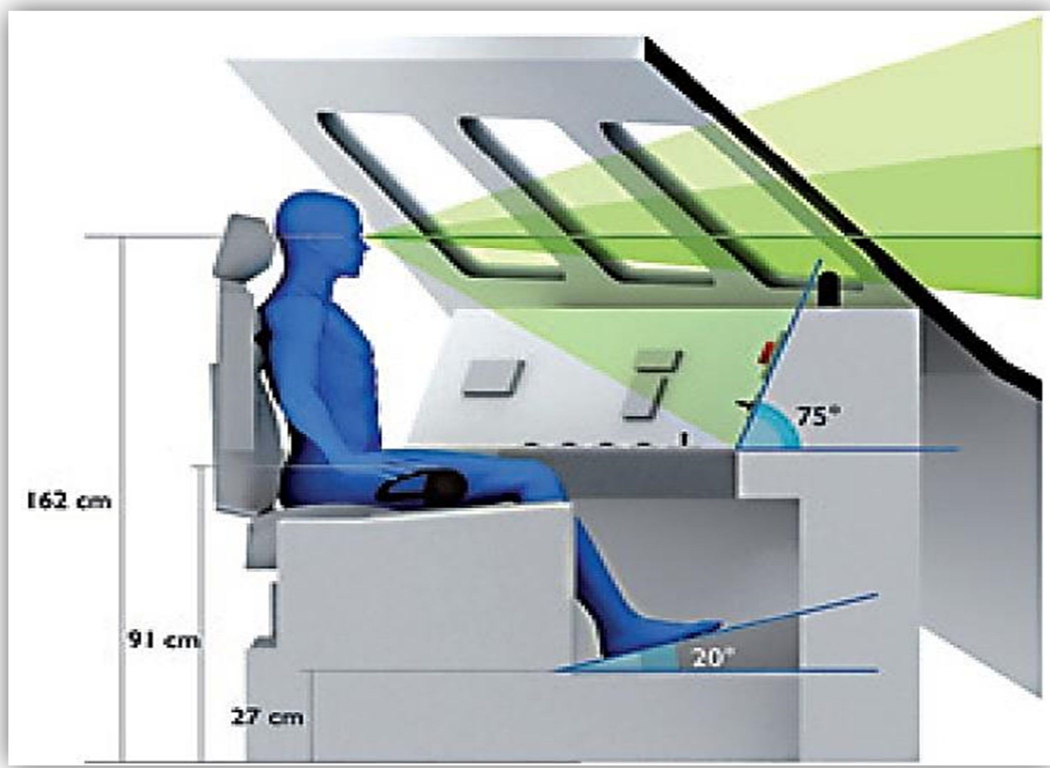


Figure 12: *Human element design considerations.* [14]

Good Habitability always comes from a good design process that acknowledges the importance of the human being in the safe and effective operation of the vessel as it allows for improvement of productivity, morale, safety, and comfort as well decreasing the potential for fatigue and human error. [11]

4.7.3 Risk Assessment Matrix

ISO 31000 was published as a standard on the 13th of November 2009 with the purpose to provide generic guidelines for the implementation of risk management. [61]

Risk assessment is an effective means of identifying process safety risks and determining the most cost-effective means to reduce them. Risk assesment uses a matrix that has ranges of consequence and likelihood as the axes. The combination of a consequence and likelihood range gives an estimate of risk or a risk ranking.

An effective risk assesment matrix should have the following characteristics:

- Be simple to use and understand.
- Not require extensive knowledge of quantitative risk analysis to use.
- Have clear guidance on applicability.
- Have consistent likelihood ranges that cover the full spectrum of potential scenarios.
- Have detailed descriptions of the consequences of concern for each consequence range.
- Have clearly defined tolerable and intolerable risk levels.
- Show how scenarios that are at an intolerable risk level can be mitigated to a tolerable risk level on the matrix.
- Provide clear guidance on what action is necessary to mitigate scenarios with intolerable risk levels.

Construction of a risk matrix starts by first establishing how the matrix is intended to be used. Some typical uses for risk ranking are process hazard analyses, facility siting studies, and safety audits. A key initial decision that has to be made is to define the risk acceptability or tolerability criteria for the organization using the matrix. Without adequate consideration of risk tolerability, a risk matrix can be developed that implies a level of risk tolerability much higher than the organization actually desires.

Another key aspect of risk matrix design is having the capability to evaluate the effectiveness of risk mitigation measures. The risk matrix should always allow the risk ranking for a scenario to move to a risk tolerable level after implementation of mitigating measures. Otherwise it may be difficult to determine the effectiveness of mitigation measures.

The next step is to define the consequence and likelihood ranges. A typical risk matrix is a four by four grid. First determine what the consequences of interest are. These can include personnel safety, public safety, environmental impact, property damage/business interruption, corporate image and legal implications. Each consequence of interest may have a different definition for a specified consequence category consequence range. [62]

Dealing with safety risks includes:

- Avoiding the risk by deciding not to start or continue with the activity that gives rise to the risk

- Accepting or increasing the risk in order to pursue an opportunity
- Removing the risk source
- Changing the likelihood
- Changing the consequences
- Sharing the risk with another party or parties (including contracts and risk financing)
- Retaining the risk by informed decision. [61]

The key to risk management is to identify risks that are intolerable and to mitigate them to a tolerable level. The benefit of using a risk matrix is that it identifies those risks that need to be mitigated and therefore allows for more cost-effective risk mitigation. This is becoming increasingly important as companies have reduced their operating budgets and have limited resources to manage risk.

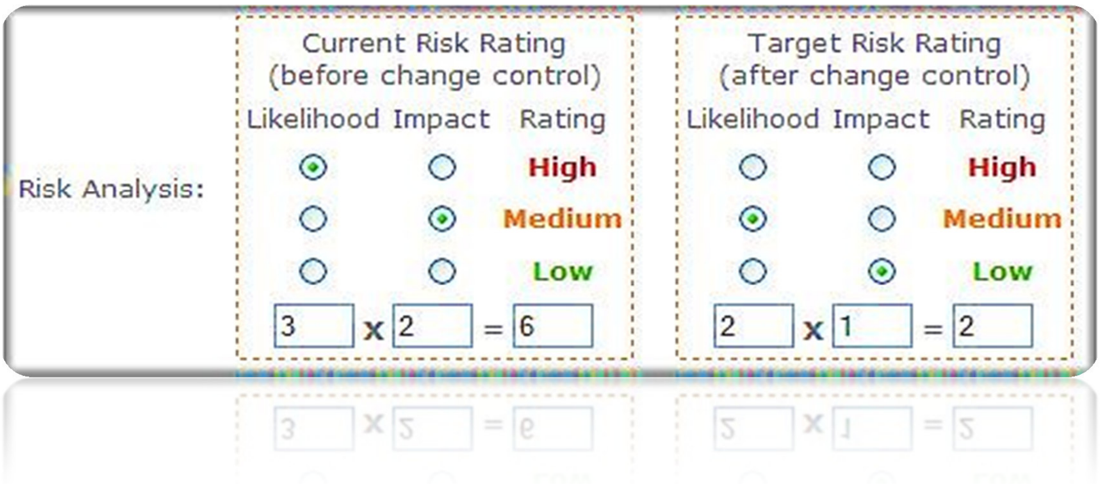
	CONSEQUENCES					LIKELIHOOD				
						A	B	C	D	E
	PEOPLE	ASSETS	ENVIRONMENT	REPUTATION	GENERATION/ FINANCIAL	Practically impossible	Not likely to occur	Could occur or I've heard of it happening	It is known to occur or "it has happened"	Common or occurs frequently
1	First Aid Injury	Slight Damage (<$10k)	Slight effect	Slight impact	Slight impact on revenue/ finances (<$10k)	Low	Low	Medium	Medium	High
2	Medical treatment Injury	Component level replacement/ repair ($10k-$100k)	Minor effect	Limited impact	Partial output reduction or equivalent ($10k-$100k)	Low	Medium	Medium	High	Extreme
3	Lost Time Injury less than 7 days	Equipment level replacement/ repair ($100k-$5m)	Localised effect	Local area impact	Unit off line <4hrs or equivalent ($100k-$5m)	Medium	Medium	High	Extreme	Extreme
4	Lost Time Injury more than 7 days or fatality	Unit level damage ($5m-$50m)	Major effect	State wide impact	Unit off line >4hrs or equivalent ($5m-$50m)	Medium	High	Extreme	Extreme	Extreme
5	Multiple Fatalities	Multiple unit capability damage (>$50m)	Massive effect	National impact	Multiple units off line (>$50m)	High	High	Extreme	Extreme	Extreme

Figure 13: *Risk Assesment Matrix for the identification of safety risks.* [62]

<u>Consequence</u> = Potential Consequence of an incident/injury given current level of controls.

<u>Likelihood</u> = What is the potential of an incident or injury occuring giventhe current level of controls.

<u>Risk Classification</u> = The intersection of the chosen column with the chosen row.



<u>RISK SCORE</u>

LOW – Tolerable: Monitor and Manage.

MEDIUM: Monitor and maintain strict control measures As Low As Reasonable Practible (ALARP).

HIGH: Review and introduce additional controls to mitigate to ALARP.

EXTREME: Intolerable, STOP work and immediately introduce further control measures.

CONCLUSION

Recapitulating, this review has introduced the concept of human error and the maritime safety regulations established to deal with this issue and possibly eliminate the occurrence of accidents.

We have seen that human error (and usually multiple errors made by multiple people) contributes to the vast majority (75-96%) of marine casualties, making the prevention of human error of paramount importance if we wish to reduce the number and severity of maritime accidents.

Many types of human errors were described, the majority of which were shown not to be the fault of the human operator. Rather, most of these errors tend to occur as a result of technologies, working environments and organizational factors which do not sufficiently consider the abilities and limitations of the people who must interact with them, thus setting up the human operator for failure.

Therefore, it was presented that human errors could be reduced significantly by implementing the regulations introduced to control human error and adapting recommended practices to deal with this issue.

To summarize with, it is of vital importance to keep the human operator uppermost in our minds and design technologies, working environments, and organizations which support the human operator and foster improved performance and fewer accidents.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonable Practible
BRM	Bridge Resource Management
BTM	Bridge Team Management
BNWAS	Bridge Navigational Watch Alarm System
HFE	Human Factors Engineering
ILO	International Labour Organization
IMO	International Maritime Organization
ISM	International Safety Management code
ISO	International Organization for Standarization
MLC	Maritime Labour Convention
M/S	Motor Ship
MSC	Maritime Safety Committee
OOW	Officer Of the Watch
PPE	Personal Protective Equipment
SMCP	Standard Marine Communication Phrases
SMS	Safety Management System
SOLAS	Safety Of Life At Sea
SOP	Standard Operating Procedures
S/S	Steam Ship
STCW	Standards of Training, Certification and Watchkeeping for Seafarers

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