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ΣΤΗΝ

ΝΑΥΤΙΛΙΑΚΗ ΔΙΟΙΚΗΤΙΚΗ

RISK MANAGEMENT IN SHIPPING INDUSTRY

Χαράλαμπος Γρηγορίου

Διπλωματική Εργασία

που υποβλήθηκε στο Τμήμα Ναυτιλιακών Σπουδών του Πανεπιστημίου Πειραιώς ως μέρος των απαιτήσεων για την απόκτηση του Μεταπτυχιακού Διπλώματος Ειδίκευσης στην Ναυτιλιακή Διοικητική

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Contents

Abstract

The present paper aims to present basic and widely accepted methods of risk-assessment. Using papers from industry’s professionals along with pure academic sources, it gets clear that methods used, both qualitative and quantitative, do not require scientific back-round to be followed. Taking into account the international regulatory basis and the market’s reality, the industry has adopted the prerequisite standards. Those standards need to be monitored and implemented. To this purpose, internal audit is the tool for constant reviewing and improvement of the safety procedures. The establishment of a safety culture includes the potential incidents’ investigation and the root cause analysis as well. It would be useless to monitor the safety matters without being willing to review and document the changes. However, while times passes, new challenges towards risk-assessment are arising. In that respect, the existing practices must adjust to the new conditions always according to the company’s Safety Management System (SMS).

Περίληψη

Σκοπός της παρούσας εργασίας είναι να παρουσιάσει βασικές και ευρέως αποδεκτές μεθόδους αξιολόγησης κινδύνου. Χρησιμοποιώντας μελέτες από τους επαγγελματίες του κλάδου σε συνδυασμό με ακαδημαϊκές πηγές, καθίσταται σαφές ότι οι χρησιμοποιούμενες μέθοδοι, τόσο ποιοτικού όσο και ποσοτικού περιεχομένου, δεν απαιτούν επιστημονικό υπόβαθρο για την εφαρμογή τους. Λαμβάνοντας υπόψη το διεθνές κανονιστικό πλαίσιο και την πραγματικότητα της αγοράς, ο κλάδος έχει υιοθετήσει τα απαιτούμενα πρότυπα εργασίας. Τα πρότυπα αυτά πρέπει να παρακολουθούνται και να εφαρμόζονται. Για το σκοπό αυτό, ο εσωτερικός έλεγχος είναι το εργαλείο για τη συνεχή επανεξέταση και τη βελτίωση των πολιτικών ασφαλείας. Η εμπέδωση μιας νοοτροπίας ασφάλειας περιλαμβάνει την έρευνα των πιθανών περιστατικών και την ανάλυση των αρχικών αιτιών των γεγονότων αυτών. Θα ήταν άνευ ουσίας η παρακολούθηση των θεμάτων ασφάλειας χωρίς να είναι δεδομένο ότι οι πρακτικές ασφάλειας θα μεταβληθούν ως επίσημες διαδικασίες. Ωστόσο, στο συνεχώς μεταβαλλόμενο περιβάλλον της ναυτιλίας, προκύπτουν νέες προκλήσεις που απαιτούν εκτίμηση κινδύνων. Από την άποψη αυτή, οι υπάρχουσες πρακτικές πρέπει να προσαρμόζονται στις νέες συνθήκες πάντα σύμφωνα με το Σύστημα Διαχείρισης Ασφάλειας (SMS) της εταιρείας.

1.0 Introduction

Maritime means of transportation of cargo are present in history since the ancient times. Regions like ancient Greece, Southeast Asia, China, Middle East and Norther Europe are some examples of how sailing has not only been a great part of their historic presence but also how much has influenced the civilizations that were having access to sea. During the second half of the twentieth century and after many decades of trade and accidents, safety regulation began to getting established. However, in the insurance sector, the term risk and risk assessment were first introduced. Human casualties and environmental damage could no more be tolerated without legal, financial and fame consequences for whoever was the causal factor for the accident. Immediate reactive actions and most significantly proactive actions were regulated with absolute application towards the shipowners as well as to other parties of the industry.

The scope of the present paper is to introduce risk's analysis framework for maritime transportation in which the term "uncertainty", "risk" and "hazard" are of central importance. The theoretical basis of risk is presented as extensively possible as it could be. The point is not to analyze risk assessment methods from a scientific perspective but to describe the methods widely used in the industry, both qualitative and quantitative.

Many definitions of the risk concept exist, including subcomponents like probability, uncertainty, possibility, frequency, incidents, accidents events and/or consequences. In the current application, risk is understood as referring to the possible but uncertain occurrence of a condition in which something valuable (like health) is in danger. Realism and constructivism consider risk as something different. Realism defines risk as something that is absolute and in the end places something at stake where constructivism believes that risk is considered as it be because of the pre-established perception of it. Currently, risk is not perceived like an ongoing situation but a personal belief shared by a specific industry and accessible through available sources. So, it not something always present but it could easily occur at any time given the circumstances. Regarding the regulatory framework, in terms of legislation in practice, the marine industry has suffered a lot and in the past producing complex, conflicting regulations, mainly responding to disasters including large number of loss of life, culminating in the destruction of the Piper Alpha installation in UK waters in 1988. Based on Mather (2000) the Piper Alpha tragedy proved to be the catalyst for a radical change in the way the industry was both certified and regulated. The accident in the Gulf of Mexico which was the explosion on 20 April 2010 on board the Deepwater Horizon, an offshore drilling platform working on a well one mile below the surface of the Gulf of Mexico, has led to a major oil spill TNYT 2010). Lack of compliance with safety practice and mistakes in proper inspections have been found as main root causes for both cases. The legislation in its own cannot rule the industry. It defines the ways to perform and the consequences against those not complied. Thus, legislation exist but what actually risk assessment does and how contributes to the general term “safety” is presented. Risk-assessment is practically applied as a tool during the decision-making process. While options are evaluated, it is important to be stated the level of risk that comes with every single option. The analysis can be based on financial risks, health risks, safety risks, environmental risks and other types of business risks like the public image, corporate social responsibility etc. An appropriate analysis of these risks will provide the necessary elements that are critical towards proper and thorough decision making, and will might set on track the decision to be received. The information generated through risk assessment should be transferred to the rest of the company in order to aid possible interested parties on understanding the factors which have led to the decision. Risk assessment is the process of collecting evidence and combining information to proceed to an understanding of the risk of a specific option. More specifically the present paper starts obviously with the introduction and then the methodology along with literature review follows. Afterwards, there is presented the initial regulatory framework and its evolvements at is it currently. IMO, ISM, ISPS, FSA and SMS are presented and shortly analyzed in relation with risk and risk assessment. Then, the fundamentals of risk assessment are explained. Following those, risk-assessment methods are presented and analyzed through tables and examples in order to gain a fair opinion them and a short review of them is within the above. Moreover, a small analysis/debate follows about how deeply a scenario-analysis should het. Going on, risk-assessment and reality are described. Furthermore, the procedure of internal audit is described as a measure towards ongoing monitoring and reviewing of the company's management safety systems. Then, additionally to internal audit procedure, the "incident investigation and root cause analysis" is presented, as an extra measure to the establishment of safe practices and safety culture. Conclusion and references follow the above.

2.0 Literature review and methodology

Risk assessment mainly consists of two components. These are risk analysis and risk evaluation. In the case of risk analysis, different risks are concentrated, listed and presented in both qualitative and quantitative spectrums, through the use of many different tools and techniques, mostly based on statistics, since the possibility of accident occurrence is presented in percentages. The goal of the procedure is to correlate different risk factors and determine those among them that are the most crucial to mitigate, based on the possibility of accident occurrence deriving from them. In the shipping industry, every-day operations are the most common activities and risky ones. Past evidence of offshore and shipping transportation activities has revealed that a small, initializing event during and specific operation may lead to a disaster.

Various sources like ABS, Maclachlan 2004, Mather 2009, OCIMF 2004, Sutton 2010, UKHSE 2010 indicate that literature in the offshore industry which mainly relates to the legislation and safety, Health and Safety at Work Act (HSWA) 1974, STCW are some examples. All of them have discussed thoroughly the issues such as safety cases and safety reports; Safety Management System (SMS); Formal Safety Assessment (FSA); Health, Safety and Environment (HSE); ISPS Code; safety case regulations; Quantitative Risk Assessment (QRA); the concept of As Low As Reasonably Practicable (ALARP) in judging the level of acceptable risk. During the past two decades, many journals and articles have risen the topic of safety via risk assessment.

Ten fundamental steps to risk analysis exist, according to Arben Mullai. First, the scientific team must establish a certain background, determining the context in which the different types of risk will be assessed. Second, a preliminary risk analysis procedure should take place, as a way to list different hazards in more generic categories, so that the goals of the research can gradually become more specific as it advances. The third step of risk analysis is none other than the formation of an adequately skillful risk analysis team, comprised primarily of specialists in the field of maritime risk assessment, but also of scientists of different backgrounds who can provide valuable input to the research. The fourth step is practically complementary to the third step. It includes the identification of third parties, such as policy makers, shipowners, charterers and consumers of maritime transportation services. The fifth step appears to be one of the most crucial, since it serves as a means to specify the content of the research. Concluding this step, the scientific team must already have formed a catalogue with all possible risk-inducing activities that are unavoidable in the maritime sector, yet still threaten every shipping company. the sixth step adds problem identification to the equation. This procedure differs in nature from the previous one, since its structure is mainly scenario-based. The seventh step could possibly prove to be the most critical among them, since it describes the identification of the goals of the risk analysis. the eight step includes the boundaries of the analysis. These boundaries describe natural limitations of the research that will never cease to exist. Ninth, the risk analysis team is now ready to decide upon the tools and methods to be applied in the research, depending on the nature and quantity of the data collected and concluding, the data collections itself.

Hazard identification is the most critical part of risk assessment and a thorough level of research during that process is required (Hyatt N, 2003, p.87). There are certain methodologies used for hazard identification. When more generic information concerning major hazards is requested, the author indicates the PrHA (Primary Hazard Analysis) method.

Another aiding approach would be HAZOP (Hazard and Operability Analysis). HAZOP (Hyatt N, 2003) is fundamentally useful to the current research, since it is conducted during later stages of risk assessment process and can mitigate hazards deriving from human performance gap. This method also excludes the application of assumptions, reassuring the team that all data collected derive from proven facts.

Also, useful model for the risk assessment process is the “Failure Mode and Effects Analysis” (FMEA) (Hyatt N, 2003, p.92). Based on the above-mentioned author, FMEA is widely used in order to detect possible hazards leading to incidents, estimates and classifies their effects and place them in a hierarchical position, depending upon the intensity of severity of those consequences.

Douglas J. Landoll ("The Security Risk Assessment Handbook- a complete guide to performing Security Risk Assessments", 2nd edition, 2011), writes that threats connected to relevant risk estimation must always be classified. The PIC of risk-assessment decides on which categories of threats must be included in the research and which of those should be abandoned as irrelevant to the specific task. According to the author, there are four basic steps to every security risk assessment. Those are the analysis of threats, the valuation of assets, an analysis of vulnerability, and finally the security risk evaluation.

Recent scientific progress has proven that human performance gap towards risk can indeed be quantified (Hurst W.N., 1998, p.49). According to Nick W. Hurst, the process of quantification of human performance, reviews the phenomenon as a source of risk, leading to accidents or incidents. The quality of a company's safety culture can be measured according to the employees' perception and behavior within the system the operate (Hurst, N.W., 1998, p.56). The staff's opinion could be collected using surveys and questionnaires. The significance of quality which is "grading" a company's safety culture is highlighted through B. Turner's accident causation model, titled "Man Made Disaster" (Oltedal, H.A., 2011, p. 43). According to that model, time and changes in the environment cause shifts in the chain of events finally leading to accidents or disasters. Moreover, according to data form the Royal Institution of Naval Architects (Berman J., Nikki B.C., Pennie D., 2007, p.4), human errors rely mostly on organizational scheme and modus operandi. In addition, human errors are provoked due to bad weather, complexity of documentation leading in misinterpretation of safety procedures as well as improper planning which leads to poor management. In terms of maintenance, distractions prevent maintainers from successfully completing their duties. Improper maintenance can diminish the equipment's life expectancy and performance significantly. If the machinery under improper maintenance is reserved as emergency equipment, an accident could become fatal.

The RINA (Berman J., Nikki B.C., Pennie D., 2007, p.6), indicates that the vessel's design could provoke malfunction upon hull and machinery, due to infiltration of debris during maintenance procedure. Therefore, the naval architect's responsibility is to contribute to risk-assessment through production of the most practical and safe architectural patterns.

The above studies indicate that there is more a scientific approach than before of course in combination with actual results. In fact, access to real evidence regarding certain incidents are difficult. However, the scope of the present paper is to present a wide framework for risk assessment and not real evidence or case-studies. The description of the methods is presented along with explanatory examples. The research is based on existing primary research fact that enhances the credibility of the methodology used, as the examples presented are widely accepted and used.

3.0 Regulatory Framework

There is a broad regulatory framework concerning shipping industry. The International Maritime Organization-IMO is the main regulatory body of the industry. It consists a specialized agency of United Nations that deals exclusively with the maritime sector and it was funded in 1948. Its main objective is the prevention of oil pollution and the improvement of maritime safety. IMO is focused on promoting the implementation of tools for the continuous establishment of safety and prevention. That can be achieved through the regulations produced. To that end, there are certain conventions which promote the scopes of the Organization. The key conventions are the following:

- International Convention for the Safety of Life at Sea (SOLAS), 1974.
- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto and by the Protocol of 1997 (MARPOL).
- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) as amended, including the 1995 and 2010 Manila Amendments.

Moreover, there are three main comities. The first one is the Maritime Safety Committee (MSC) which mainly focuses on *"navigation, construction and equipment of vessels, manning from a safety standpoint, rules for the prevention of collisions, handling of dangerous cargoes, maritime safety procedures and requirements, hydrographic information, log-books and navigational records, marine casualty investigations, salvage and rescue and any other matters directly affecting maritime safety".* The second one is the Marine Environment Protection Committee (MEPC). The MEPC, *"is empowered to consider any matter within the scope of the Organization concerned with prevention and control of pollution from ships".* Also, there is the Legal Committee *which "is empowered to deal with any legal matters within the scope of the Organization"*.

3.1 The International Safety Management (ISM) Code

The International Safety Management (ISM) Code was established to set an international standard regarding the safe management and the safe operation of ships as well as for pollution prevention. In 1987 the IMO Assembly adopted resolution A.596(15), which called upon the Maritime Safety Committee to develop guidelines concerning shore-based management to ensure the safe operation of ro-ro passenger ferries. Because of the poor operating practices, the negligent safety conditions and the accidents occurred without further investigation afterwards, IMO, in 1987 and after the 'Herald of Free Enterprise" disaster, adopted the resolution A.596(15) describing guidelines on management for the safe operation of ships and for pollution prevention. The ISM Code in its current, erga omnes, form was adopted in 1993 by resolution A.741(18), in 1994 was incorporated into SOLAS and finally entered into force on 1 July 1998. The Code "establishes safety-management objectives and requires a safety management system (SMS) to be established by "the Company", which is defined as the owner or any other organization or person, such as the manager or bareboat charterer, who has assumed responsibility for operating the ship and who, on assuming such responsibility, has agreed to take over all duties and responsibility imposed by the

Code". The Company is then required to establish and implement a policy for achieving these objectives. This includes providing the necessary resources and shore-based support. The company has to establish a policy towards those objectives, providing the resources required to shore and ashore personnel. In each company, there is a role of the highest importance, the role of the designated person ashore, who is the link between the personnel ashore with the management. What ISM requires, must be documented and organized in the Safety Management Manual, as a part of Safety Management System. The Manual must also be kept on board the vessel.

3.2 The International Ship and Port Facility (ISPS) Code

The ISPS Code entered into force and incorporated in SOLAS, on July 2004. It has set the standard for a thorough and binding security framework for the shipping industry. According to the Code, its purpose is summarized in the following five sentences:

- establishment of an international framework that fosters cooperation between Contracting Governments, Government agencies, local administrations and the shipping and port industries, in assessing and detecting potential security threats to ships or port facilities used for international trade, so as to implement preventive security measures against such threats;
- determining the respective roles and responsibilities of all parties concerned with safeguarding maritime security in ports and on-board ships, at the national, regional and international levels;
- to ensure that there is early and efficient collation and exchange of maritime security-related information, at national, regional and international levels;
- to provide a methodology for ship and port security assessments, which facilitates the development of ship, company and port facility security plans and procedures, which must be utilized to respond to ships' or ports' varying security levels; and
- to ensure that adequate and proportionate maritime security measures are in place on board ships and in ports.

Furthermore, the irrespective to IMO, the International Labor Organization-ILO has introduced the Maritime Labor Convention in 2006-MLC 2006. The Maritime Labor Convention is an international agreement which defines seafarers' rights regarding conditions of work. It is called the 'Seafarers' Bill of Rights'. It applies to every one of the seafarers, including those with jobs in passenger services on cruise ships and commercial yachts.

Besides the central, intergovernmental regulatory bodies, the industry has set some ground rules, that every company related to the industry should follow, in order to survive through raising their commercial value. The "Tanker Management Self-Assessment" was introduced by the Oil Companies International Marine Forum (OCIMF), in order for the tanker vessels companies to follow specific rules, in order for theirs' vessels to be chartered by the Oil Majors. Regarding the gas carriers, there is the Society of International Gas Tanker & Terminal Operators Ltd-SIGTTO. SIGTTO's purpose is the promotion of shipping and terminal operations for liquefied gases which are safe, environmentally responsible and reliable. Also, there are ISO 9001, ISO 14001 and OHSAS 18001, the integrated management systems, that promote quality of services, health and environmental protection.

All of the above, at a higher or lower rate, have impact on the industry. There is always the debate about overregulation and how it limits the potential of the industry. On the other hand, through those regulations, the practices have been improved, the services have been improved as well and the safety issues seem to have been reduced. In combination, both IMO's proactive measures like FSA, and Industry's regulations have saluted a safer future.

3.3 Formal Safety Assessment

Formal Safety Assessment (FSA) as per IMO is a "*structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost-benefit assessment*". FSA ensures that proper action has been made before an accident occurs. In the direction of reducing the risks lying in the shipping industry and especially after the "Piper Alpha" disaster in 1988, where 167 people were killed, IMO decided to

implement the FSA. The Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process were approved in 2002 (MSC/Circ.1023/MEPC/Circ.392). The Guidelines have since been amended by *MSC/Circ.1180-MEPC/Circ.474 and MSC-MEPC.2/Circ.5*. The above Guidelines have now been superseded by *MSC-MEPC.2/Circ.12/Rev.2*.
The Guidelines in their current condition, indicate the importance of data gathering on incident reports, description of near misses as well as operational failures, to be reviewed and assessed in order not to reoccur in the future. The conditions, limitations and assumptions regarding the data gathering should also be defined.

3.3.1 The five stages of FSA

The first stage is concerned with the identification of hazards, of alternative accident scenarios as well as the potential consequences. The hazard may be a situation such as fishing vessel because it may collide with own vessel. It may be an activity like crane operations because the loaded cargo might drop. It may even be material such as oily rag because it might catch fire. In practice, the term "hazard" is often used for the combination of a physical situation with particular circumstances that might lead to harmful consequences. For example, a collision with fishing vessel, a dropped load of cargo or an oily rag fire. It is difficult to declare completeness of a hazard's identification process, and hence hazard identification should be periodically reviewed. Risk assessment in general and hazard identification in particular is a team work. The second stage is about assessment of risks thus the evaluation of risk factors. Safety is related to the degree of absence of risk. Because no activity is free of risk, an activity is considered safe when the level of risk is within acceptable limits. But how do we know if the risk is acceptable or not? We should be able to calculate the risk and we should know how much risk is acceptable? In short, we should know how to calculate or estimate risk. IMO defines risk as 'the combination of the frequency and the severity of the consequence' (*MSC Circ 1023/MEPC Circ 392*). Here the frequency is 'the number of occurrences per unit time (e.g. per year) and consequence is 'the outcome of an accident". In the real world, risk has two components: How likely is this to happen? – likelihood of occurrence (frequency) and how bad the results would it be if this did happen meaning the severity of the consequences. We would need both the above components for estimating the Risk. A reliable equipment would mean that there are little chances of it breaking down. That is frequency (likelihood of occurrence) is low. But to estimate the risk we also need to consider the severity of consequences if the equipment fails. We need to combine both these factors to get a fair estimation of risk involved in using this equipment. Traveling by a plane has far more severe consequences than traveling by road. Though, the frequency and finally the risk as per statistics is far less. However, it is a matter of fact that the perception of risk is higher than the actual risk in case of travel by a plane. This is perception of risk against actual risk. Even though we think the risk for traveling by air is higher than traveling by road, but still we travel by air. This is the basis of Risk assessment and is called 'As low as Reasonably Practicable' or ALARP. If we travel by car, there is some cost, time and effort involved. These would be disproportionate to the benefits of risk reduction that we would achieve. So, when deciding the practicability of how much risk reduction is enough, we compare a hazard with three things: a) Cost, b) time, c) effort involved. It is possible that we avoid traveling by air but it is not practicable (Possibility vs Practicability). The fundamental principle of risk management acknowledges that the risk cannot always be eliminated. The solution possible is to reduce the risk at a level that is ALARP. This is the level where the risk is tolerable as reasonably practicable and where risk reduction measures would be in place. So, we can estimate the risk by combining frequency and severity of consequences. This combination of Frequency and Severity of Consequence can be completed in many ways. Each company may have different method which you will get in company's safety management manuals. A company may decide to prepare a Risk Estimator matrix with Likelihood and consequences on the y and x –axis respectively. The likelihood and consequence are to be estimated with existing controls in place and a resultant risk calculated from the matrix. The company SMS should identify the level of risk for which additional controls will be required before the job is started. For example, the company might decide that additional controls are required if the risk level is Moderate or above as per below example of risk matrix. Another methodology is to give values to Frequency and Consequence and then calculate the risk by Multiplying the two values i.e. Risk = Frequency x Consequence. Remember, the likelihood and consequence are to be estimated with existing controls in place. The company SMS has to identify the Risk value for which additional controls are required. Few company SMSs recognizes that the risk depends more on consequence than the frequency. In this case they calculate risk as below: Risk = Frequency x Consequence squared (F x C^2). What method we need to follow to calculate the risk would depend upon your company's SMS. The **third** stage is about risk control options. This is the step in which we evaluate options for controlling the estimated risks. The principle of controlling the risk is simple. We should aim to remove the risk. But even if we cannot remove it completely, we must reduce it to as low as reasonably practicable (ALARP). There are four way we can handle the identified risk. I) Avoid the risk altogether Not a likely option if the work or operation has to be completed. But this may be necessary at times for safety. For example, in emergency if we have to abandon the ship in rough weather, we cannot avoid it though it would be risky. ii) Reduce the potential impact of the risk This involves reducing either the likelihood (frequency) of a loss occurring or the consequence (severity) or both. This can be achieved by taking extra precautions. When we take extra precautions, it is important to evaluate what is decreasing. Likelihood, consequence or both. Usually it is the likelihood that will decrease, as decreasing consequence at times is not practical. But there can be times when the consequence alone or both will reduce. An example can be working aloft on a mast. Using a safety harness will reduce the likelihood of falling down because if at all the person falls, the consequence will be same. The consequence can be reduced if we rig a net below the mast.iii) Transfer the risk to another party. It is not a common option for seafarers but can involve the use of specialists or technicians. For example, a contractual transfer of risk to a third party by hiring a third party to do the work. Retain the risk with no planning Off course it is not the best option to retain the risk and proceed with the work. The fourth stage is about cost and benefit assessment through determining cost effectiveness of each risk control option. The fifth stage is about recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options is provided). During the course of work, many factors could change. It is important that those in charge, continually monitor, review, evaluate and modify the first three steps in the process. We also need to properly document and provide feedback by the end of the procedure. Within the feedback, it should be mentioned if the control measures taken for the job were enough or not. This feedback then can be used next time similar procedure is planned. The adoption of FSA was the first step from a reactive approach towards accidents, disaster or risk, to a proactive approach, where the minimization of risk is the key to compliance with ISM's principals and within the regulatory framework regarding shipping industry.

3.4 Safety Management Systems (SMS)

The management of the company through the SMS establishes what is has to be done in order for the safety criteria to be met. The SMS aims to safe operation of vessels and to protection of the environment. The ISM code is fundamental for the establishment of the SMS. There is a number of elements that should be contained in an SMS. First, the commitment of taking action when necessary. Second, a plan should be defined and as well as capability to act in favor of the objectives described. Finally, evaluation, learning and improvement are basis of prevention. Every situation that is described as unsafe or non-conformities or even accident, should be identified, reported and prevented from happening again.

A proper SMS system leads to better safety performance by identifying the possible root cause of an incident or an accident. Immediate corrective as well as preventive actions must be made. Through an SMS, both qualitative and quantitative criteria are indicated. Firstly, planning what to do and actually doing it, in a proper way, is απόδειξη of a functional SMS. However, the fact that no error is detected, does not mean that everything is clear. The relevant department, must conduct investigations, building on alternative scenarios and assumptions, in order to be prepared for any case. The performance must be measured and monitored, through internal audits and pre-audits and through reporting, Of course, the inter allia communication is a must, otherwise no improvement could be feasible. The objectives of safety and environmental management are achieved through regulatory compliance, emergency preparedness based on continual improvement of work practices. It is only natural that, as in every workplace, some hazards may exist. Especially, in marine industry, some hazards could be occurred from the operations of tank cleaning, of fueling, of cargo handling or of every-day vessel maintenance. The point of safety, is trying to classify those risks as low as reasonably practicable. The risk based on this model is classified in three categories: unacceptable, tolerable and acceptable. The unacceptable risks are those which cannot be justified unless something extreme happens. The tolerable ones as those which its degradation is impracticable due to cost matters. Finally, the acceptable are those which through risk assessment are low in terms of probability and consequences.

4.0 Risk's fundamentals

In the industry there are many technical terms that in order to be familiarized with them someone either has to be a professional or has an academic back-round. It is very useful to clarify some really fundamental terms. The term "hazard" is a situation or condition that it could produce potentially undesirable outcomes. Some maritime hazards are produced by thermal energy (hot or cold environments, materials), kinetic energy (motion of objects or shipboard equipment) and acoustic energy(noise). Those are only some examples. Moving to term "incident", we mean the unplanned sequence of events, which may contain equipment matters, human errors or bad weather conditions. The incidents are in a state that can be confronted without consequences or at least serious consequences. An incident, if the response is not successful, it can be turned into an accident that provokes undesirable consequences. Some accidents could be collision, fire or explosion, grounding sinking, personnel injury, exposure to radiation and many more. The consequences are negative effects that can contain from personnel injury to death, from damage of property to total loss of it. Even the brand name could be seriously degraded at a point that the company could go out of business.

What is risk? How can we approach the term and at the end "dismantle" it? To begin with, in order to confront the risks, we need to be able to respond to three questions. The first one is deals with what can it go wrong during a situation. The second one is about how likely is something to happened during the specific situation and the last one is about what would be the impact if actually something had gone wrong. To response to the first question, the ones in charge must build a library of possible risks, looking into historical data describing accidents already happened, brainstorming about disaster that have not happened yet. In general, alternative scenarios must be defined and for every one of it, an appropriate response. Concerning the second one, to determine if the risk is credible or not, a full understanding of the problem must be achieved. For example, the danger of grounding is always present, but when the vessels pass by deep waters that never a same incident had happened, the chances are low. Regarding the third question, thus the impacts, those must be assessed, classed by magnitude and finally, it should be cleared if the possible effects are tolerable or not. If tolerable, at what stage it could transformed into not tolerable?

Having being told that risk is a potential exposure to loss of several kinds with possibility of causing consequences, it is only rational to deduct that uncertainty Is a key factor of the industry. Risk though is classified into both categories: the residual risks and then managed risks. The residual ones are those risks that are not managed or manageable, which however are accepted or tolerated by the shipping company. The managed risks are those which are practically eliminated or reduced a maximum level through preventive measures. Those two combined, consist the total risk that a company must affront. The mathematical relation of risk is:

*Risk= frequency*consequences*

*R=f*c*

The “frequency” refers to the events per unit of times, usually per year and indicates how many times such a risk is occurred. The “consequence” refers to the impact per such an event, expressed in financial, environmental or even human casualties. It is upon the company’s SMS to what kind of risks will be more or less exposed. There the risks that are of a higher frequency but with lower consequences and there are those with low frequency but with higher consequences. For example, a risk of high frequency is the bad weather conditions which through years, experience and proactive measures has been mitigated, threatening no more the human life. On the opposite, the risk of collision is not that frequent but when it occurs, the consequences can be very serious. Following that, a risk can be absolute or relative. The absolute kind of risks estimates the frequency of a risk i.e. enclosed spaces risk of fumes occur $5*10^{-2}$ per year and based on practice, personnel on board visits enclosed spaces every single day. Calculating how many deaths have been provoked the last years and taking into account other parameters like sea route, ship type, educational back-round and experience of crew, an estimation is being made regarding how many possible deaths might occur the upcoming time frame. The relative risk is the opposite approach where the estimation of risk is based on assumptions. Adding to the above, the term of "risk" has a profound quantitative approach in order to deduct fruitful deductions. The experience indicates that it is not a priori absolute or punctual an assumption based on quantitative research. Also, the fact that it is not required to be an expert on the subject matter, proves that the experience and the general practice are really fundamental factors. There are three ways to conduct quantitative research upon the risks. The "point risk estimate" approach, the "categorization" approach and the "probability distributions" approach. The first approach, estimates the risk based on the relation

$$Risk_{scenario} = F_{accident\ scenario} * C_{accident\ scenario}$$

where

$$F = F_{initiating\ event} * P_{safeguard\ 1\ failure} * P_{safeguard\ 2\ failure} * etc.$$

where

F= frequency of occurrence, C= consequences and P= probability of occurrence.

4.1 Risk Assessment Methods

Let us consider for example the of the "AZB shipping company".
AZB, is currently building on the scenarios of risk assessment using the "risk point estimate approach". All three below scenarios are having as a consequence an economic loss of $100.000. The first scenario is a boiler leaking that happens once a year. The flow does not stop and any alarm is activated. The probability of those to

occur is 0.1 per year. As a result, the scenario frequency is 0.001 per year. The second scenario contains a mooring tail damage, which happens once a year. The reason are the bad maintenance and the false certificate of expiration. The probability for those two is 0.2 per year as well. Thus, the frequency of that scenario is 0.04 per year. The last scenario includes a sudden magnetron damage which happens 0.5 times per year. That is caused due to negligent maintenance and replacement beyond the manufacturers' instructions. The frequency of occurrence regarding the above is 0.5 respectively. As result, the frequency of such a scenario is 0.125 per year. Taking the worst-case scenario, that all three will occur, is reach to the following conclusion. By adding the three scenario frequencies and multiplying by the financial damage of each one, AZB knows that the financial impact will be the outcome of the above relation.

$$\text{Scenario } 1_{0.001/y} + \text{Scenario } 2_{0.04/y} + \text{Scenario } 3_{0.125/y} * \$100,000 = \$16,600$$

No matter how useful this method is, the "point risk estimation" presents certain limitations. Regarding the accuracy of the method, it depends upon the punctuality and completeness of the different scenarios, which are also depended upon the accuracy of data (likelihood and consequences) of each event happened, something that requires transparent information, usually not accessible. Also, the method could also be considered subjective due to the fact that those in charge of implementing it, analyze the data from their own perspective.

The "risk categorization" approach, is generally efficient to be applied and the information which can be provided include most of the types of risk based-facts. The following tables are indicative of how this approach is implemented.

Types of consequences

Severity	**Safety Impact**	**Environmental Impact**	**Property Loss**	**Business Impact**
Major	One or more deaths or permanent disability	Releases provoking long-term damage to ecosystem	≥ \$3M	≥ \$3M

		or exposure to health risks		
Moderate	Hospitalization or loss of work days due to injury	Releases provoking short-term damage to ecosystem	≥ $100 and < $3M	≥ $100 and < $3M
Minor	First aid to injury required	Pollution with minimal impact on health or environment	≥ $100K and < $10K	≥ $100K and < $10K

Risk Assessment Score

Score	**Death & Injury**	**Economic Impact**	**Environmental Impact**
3 Catastrophic	Numerous loss of life or injuries	Major or long-term national economic impact	Destruction of area's ecosystem
2 Significant	Multiple loss of life or injuries	Major regional economic impact	Long-term partial damage of area's ecosystem
1 Moderate	Little or no loss of life or injuries	Minimal economic impact	Minor environmental damage

Frequency Category	**Description**
Very Frequent	*From 10 to 100 events per year in the fleet*
Frequent	*From 1 to 10 events per year in the fleet*

Occasional	*From 1 event every 10 years to 1 event per year in the fleet*
Infrequent	*Less than 1 event every 10 years in the fleet*
Rare	*Not expected to occur in the fleet*

Frequency Categories

		Vulnerability Score		
		1	2	3
Consequence Score	3	Consider	Mitigate	Mitigate
	2	Document	Consider	Mitigate
	1	Document	Document	Consider

Risk Matrix

Frequency				
	Very Frequent	Marginal	Unacceptable	Unacceptable
	Frequent	Acceptable	Unacceptable	Unacceptable
	Occasional	Acceptable	Marginal	Unacceptable
	Infrequent	Acceptable	Acceptable	Marginal
	Rare	Acceptable	Acceptable	Acceptable
		1	2	3
		Severity of Consequences		

Risk Acceptability for Spills

Scenario	Frequency and Severity Estimates			Risk Acceptability
	Level 3 Severity	Level 2 Severity	Level 1 Severity	
Scenario 1: Hose leak or rupture during tranfer	Very Frequent (Risk M)	Inrequent (Risk A)	Rare (Risk A)	M
Scenario 2: Tank rupture during a grounding	Occasional (Risk A)	Occasional (Risk M)	Infrequent (Risk M)	M
Scenario 3: Tank overfill during a transfer	Very Frequent (Risk M)	Infrequent (Risk A)	Rare (Risk A)	A

Scenario	Frequency and Severity Estimates		
	3 ($100k to $10k) Average Consequence: $3K	2 ($10k to $3m) Average Consequence: $300K	1 (>$3m) Average Consequence: $5m
Scenario 1: Hose leak or rupture during transfer	Very Frequent 10/yr to 100/yr	Infrequent 0/yr to 0.1/yr	Rare o/yr
	Occasional 0.1/yr to 10/yr	Occasional 0.1/yr to 10/yr	Infrequent 0/yr to 0.1/yr

Scenario 2: Tank rupture during a grounding			
Scenario 3: Tank overfill during a transfer	Frequent 1/yr to 111/yr	Infrequent 0/yr to 0.1/yr	Rare o/yr
Frequency Summary (by severity level)	11.1/yr to 111/yr	0.1/yr to 1.2/yr	0/yr to 0.1/yr
Expected Losses (by severity level)	Using the average consequence: $33k/yr to $333k/yr	Using the average consequence: $30k/yr to $360k/yr	Using the average consequence: $0k/yr to $500k/yr

Despite the fact that "Risk Categorization" is widely applied, its results are not quite objective, as the frequency and the severity are estimated and rated based on personal perspectives and attitude. The case is, that each shipping company implements differently each method for risk estimation, as the parameters of doing business are not the same. Factors such as Owning or chartering, long-term or short-term, less ships or more ships, the state of the shipping circle and more, are contributing upon the estimation of risk.

The quantitative approach of risk estimation is also enhanced by probability distributions. In probability theory and statistics, a probability distribution is a mathematical function that provides the probabilities of occurrence of different possible outcomes. A probability distribution is specified in terms of an underlying sample space, which is the set of all possible outcomes of the random phenomenon being observed. The discrete probability distribution is implemented in shipping, applicable to every scenario that has a discrete outcome i.e. if boiler has a broken gasket, leakage of steam and hot water will cause serious injury to whoever is near it. However, continuous probability distribution is also used, in order for ranges of different variables to be set. To be more specific, in shipping it is crucial to set a range, in order to detect the frequency of initiating events. Also, the range of safeguards failure probabilities and the range of consequences are fundamental for a thorough risk assessment procedure. The uncertain outcomes linked with different parameters can be modeled, providing different ranges of outcomes, for different set of parameters. The subjective element is eliminated as the data exported are specific with any personal views included.

Apart from the quantitative type of risk estimation, there is as above mentioned the qualitative type. It has been characterized as easier and faster than the qualitative type, as the data gathered are not numerical. These data have been characterized as "categorical" as parameters like nationality, language, academic back-round are included in order to define larger sets of data. Some basic types of qualitative types are the "subject prioritization, the "basic scenario ranking" and the "criteria based-scenario ranking". The "subjective prioritization" focuses on identifying potential accidents scenarios using structured risk assessment techniques. The categorization of scenarios us conducted subjectively according to their perceived level of risk. The following table is an example of the above method.

Scenarios	Priority 1	Priority 2	Priority 3
Natural Hazard-Severe Storm		x	
Natural Hazard-Severe river and lake icing			x
Natural Hazard- 100-year flood			x
Support System Outrage-Inadequate icebreaking		x	
Support System Outrage-Pandemic	X		
Support System Outrage-Telecon. Loss	X		
Support System Outrage- anchorage block		x	
Accident—Oil spill		x	
Accident-Toxic release			x
Accident- Landside fire		x	

The “basic scenario ranking” method focuses on identifying potential accident scenarios. It set a score per scenario based on type and number of events. The priority given is based on each score per event. The following table is a relevant example. The low score indicates a high risk that a certain event achieves.

Criteria	Abbreviation	Score
Any event expected to occur regularly	EE	1
For each human error that contributes to accident	HE	2
For each active equipment failure that contributes to accident	AEF	3
For each infrequent external event that contributes to accident	IEE	4
For Each passive equipment failure that contributes to accident	PEF	5

The above is the basis for an actual scenario that could possibly lead to an accident like a cargo tank rupture.

Rank	Accident Scenario	Type of events	Score
1*	Operator leaves valve an open; operator leaves valve B open and operator fails to verify that valves A and B are closed before introducing hazardous material into the tank	HE, HE, HE	6
2	Major External impact	IEE	4
3	Mechanic improperly calibrates the relief valve on cargo tank A, and pressure control valve for cargo tank A stocks closed	HE, AEF	5
4	Catastrophic rupture of cargo tank A	PEF	5
5	Operator fails to open the isolation valve under the relief valve on cargo tank A after maintenance of the relief valve, operator fails to detect improperly positioned valve during monthly status checks of special	HE, HE, HE, HE	8

	valves, operator inadvertently misdirects a high-pressure feed stream into cargo tank A and operator fails to detect and mitigate rising pressure		
6	Operator fails to open the isolation valve under the relief valve on cargo tank A after maintenance of the relief valve, operator fails to detect improperly positioned valve during monthly status checks of special valves, operator inadvertently misdirects a high-pressure feed stream into cargo tank A and operator fails to detect and mitigate rising pressure	HE, HE, AEF, HE	9

*The scenario is ranked as more important than three other scenarios with lower scores because the analyst identified strong dependencies among the three human errors associated with this scenario

The above method presents certain limitations. The general prioritization of the scenarios is the first one. Also, the scoring guidelines are not objectively accurate as they are based on personal perspective alongside with real evidence. Moreover, the common cause failures like human error are difficult to exactly defined.

The “criteria-based scenario evaluation” method derives straight from the “basic scenario ranking”. That method does not include numerical scores to “rank” the scenarios. The criteria are used to tolerate or reject the perceived risk associated with the scenario. Recommendations are provided for the scenarios that are risk associated. It is efficient to implement and follow and an effective screening tool. The following are pre-established criteria for evaluation.

Type of Criteria	Examples
Number of safeguards that must fail before a specific accident of interest occurs (i.e., the number of events in each scenario)	There may not be any one-event scenarios capable of causing a major explosion in an engine room. Two safeguards must be in place to prevent a release of oil from entering the water.
Types of safeguards that must fail before a specific accident of interest occurs (i.e., the types of events in each scenario)	There, may not be a situation in which a high-pressure excursion in a boiler could occur without at least one equipment failure in addition to the equipment failure or human error that initiated the high pressure (i.e., no completed dependence on human response

	to the upset condition). An active and passive equipment protection, or two passive equipment protections, are required for any scenario capable of causing a catastrophic consequence
Combinations of the number and types of safeguards that must fail before a specific accident of interest occurs (i.e., the number and types of events in each scenario)	Single event scenarios are only acceptable if the vent is passive equipment failure and the worst-case effect would not be catastrophic. Scenarios involving multiple passive equipment failures are considered practically impossible unless there is some dependency (i.e., common cause) between the failures.

The limitation of the above procedure is that it presents fundamental subjectivity and inaccuracies which occur due to the personal perspective of the person in charge.

The bellow relation as mentioned before express how the frequency of an incident and its consequences lead to risk

$$Risk_{scenario} = F_{accident\ scenario} * C_{accident\ scenario}$$

Risk Equivalence

- 1000 events/year at cost of $10/event =$10000/year
- 100 events/year at cost $100/event =$10000/year
- 10 events/year at cost $1000/event =$10000/year
- 0.1 events/year at cost $100000/event =$10000/year

Because risk addresses potential future exposures achieving high certainty is often difficult using point estimates. Providing coarser estimates by expanding the bounds in which the actual value could can increase the certainty of the estimate.

Because of uncertainty in estimating risk that term is often represented as ranges and not specific values. The sponsor of the risk assessment should agree to the categorizations and be understood by all who participate in risk analysis meetings. A consequence table should have benchmarks. Those must be clear, with concise descriptions for each level of each type of consequence. The descriptions should be as detailed as needed for the sponsor and the participants in the risk analysis to understand what is meant by the category.

Consequence Level	Consequence Type	
	Safety/Health	Economic
Catastrophic	Any injury or illness results in fatality or permanent total disability	Vessel recovery is impractical, vessel cannot be repaired economically or catastrophic failure of critical systems takes vessels out of service. Cost of reportable property/equipment damage is $1000000 or greater
Major	Any injury or illness results in fatality or permanent total disability. Fire or more people are inpatient hospitalized	Casualty to vessel systems makes performance marginal. One or more phases of vessel operations affected. Use of vessels without repair greatly impact route service. Cost of reportable property/equipment damage is $200000 or more, be less than $1000000
Moderate	A nonfatal injury or illness results in loss if time from work beyond the day shift or shift in which it occurred. A passenger is required to alter his/her schedule to seek medical attention and recuperate	Casualty to vessel systems degrades operational performance. Continued use of vessel without repair impacts route service. Cost of reportable property/equipment damage is $25000 or more but less than $200000
Minor		

	A nonfatal injury or illness occurs that does not meet the criteria above. A person is overboard or an electrical shock occurs, neither of which meets the criteria of a higher classification	Casualty to vessel systems has limited immediate impact on operational performance. Continued use of vessel without repair does not affect route service. Cost of property/equipment damage is less than $25000

If the table has more than one type of effect, it must be determined if the sponsor wants to each level to represent an equivalent level. Those can be difficult to accommodate and may not be advisable for certain effects. Some effects that are measurable like property/equipment loss or loss of revenue are accurate. Effect that can not be measured as the above variables are harder to be defined. Also, taking under consideration that some effects might be socially criticized, are harder to equate.

4.2 How deep does a scenario has to go?

The above question is a fundamental issue in the industry. The basic rout of a scenario is the following: causes + hazards→accidents→immediate effects→long term effects. The timing of the effects must be defined in order to be consistent in estimating scenario risks. I.e., an undetected loss s of oil pressure caused by a failed oil pressure indicator and alarm could

- Damage the main engine
- Delay the completion of the voyage
- Spoil a perishable high-value cargo
- Loss of a client future business

Initiating Event	Immediate Effects	Long-Term Effects

Allision of LNG carrier	Vessel hull damaged. LNG released. Fire/explosion occurs	All crew members fatally injured
Leaking fuel oil tank	Fuel oil leaking into sump.	Delays vessel leaving port and vessel misses delivery schedule
Relief valve for tank inoperable	Tank has no overpressure relief but no immediate consequences	Vessel ruptures when pressure increases and relief valve does not open. Fire destroys engine room
Leaking cargo hatches (not properly secured)	Water enters the cargo hold	Water damages the bags if cement in the hold. Loss of 5% of cargo
Rogue wave capsizes fishing vessel	Occupants of vessel enter water. Vessel damaged	$1m vessel lost No fatalities or permanent injuries

The potential consequences can be escalated over time when it comes to environmental impacts and human injuries/deaths. Thus, the level of the analysis made must be assessed and under which circumstances. The consequences' levels analysis should be in three stages. The first level concerns the consequences that are limited to the physical bound of the ship system. The second level concerns the consequences that extend to the physical boundaries of the ship. The last level of consequences extends beyond the physical boundaries of the ship. There can be many possible outcomes for a risk assessment scenario. I.e., an unskilled worker uses a chain saw improperly but is in communication with other who can get him to a hospital. The best-case scenario is a low probability outcome that requires first aid injury. The most probable case is a medium to high probability outcome that leads to a serious injury that requires an outpatient medical attention. The reasonable worst case which is a low probability outcome, leads to a life-threatening injury which must be cared by hospitalization. The worst-case scenario with a low probability outcome is a fatality incident. How a reasonable worst-case scenario is defined? The estimation of the potential consequences in relation to their frequencies must indicate that the risk is just a theoretical scenario without actual possibilities of happening. The use of "categorization" will give a real indication.

	frequency	score
9 daily	continuous	8
8 weekly	very frequent	7
7 monthly	frequent	6
6 quarterly	occasioanl	5
5 annyaly	probable	4
4 decade	improbable	3
3 half-century	rare	2
2 century	remote	1
1 millenium	incredible	0

How does a frequency is estimated? Regarding common concurrencies and events for which historical data exist, it is easier to estimate by participants in risk analyses. On the other hand, infrequent concurrencies are those which are not estimated that easy. I.e., 0.01 events per year per ship equals to:

- 1% chance of it happening in a specific ship within the next year
- 20% chance of it happening in a specific ship during its service life, which is extended until 20 years
- 10% chance of it happening in any ship of a fleet of 10 ships within the next year
- One event happening in any ship of a fleet of 10 ships within the next decade

To estimate low frequencies and in order to help participants in risk analyses to judge more accurately the scenarios, time periods and population references must be used. The question asked must be if the scenario under review or a similar to it ever been experienced within

- The career of the operator aboard the ship?
- The life of the ship?
- The life of the company's current fleet of similar ships?
- The history of the company's fleet of similar ships?
- The current fleet of similar ships under the current flag and class?
- The current global fleet of similar ships?

In reality, there is a fluctuation in the frequencies. The every-day conditions change gradually or rapidly and as a result, there is no stability. The volatility must be affected by reviewing and reviewing the safety systems. Every accident has an initiating event. Thus, the importance of estimating the frequency of initiating events is high. The initiating event frequency is the times that the scenario is performed expressed as a rate. For example, the navigational hazard exposure is expressed as the number of transits per year. The asphyxiant exposure is expressed as the number of confined space entries per year. Also, the frequency of the accident scenario is the number of times that the scenario results in an accident expressed as a rate as accidents per year. It could also be expressed as the initiating event's frequency timing the probability of experiencing the scenario, which is a function of the effectiveness of all existing controls.

As above mentioned, the probabilities consist a significant part of the risk assessment procedure. The probabilities are bounded by 0 to 1.0 and are without dimension. A time frame must be set as a reference like lifetime, year, hour, week etc. Other related time frames are the ship-year, the ships lifetime of the working hours of a seaman.

Range of Probability	Benchmark
0.9 to 1.0	Nearly assured to happen
0.5 to 0.9	Likely to happen
0.1 to 0.5	
0.001 to 0.01	Typical odds
0.0001 to 0.001	Typical human errors under good conditions
0.00001 to 0.0001	
0.000001 to 0.00001	
0.000000.1 to 0.000001	One in a million

Both in quantitative and qualitative research, there are factors that affect the personal perception of the PIC of risk assessment. First, there is the familiarity and the routine. Gradually, people get comfortable with the usual hazards and tend to ignore or underestimate them. Then, there is the likelihood of a risk to occur, when people tend to think that the certain risk is never going to occur. Another factor is being the person in charge. When someone is in charge is feeling safer than being under someone's control. Also, the public opinion changes the way of acting. If something is considered generally safe, the most probable perception is that the specific one is safe. Another very significant factor of ignoring a risk, is the consequences themselves. If the PIC considers the consequences as not harmful, the prevention measures are not that thorough. Following those, many times those in charge are getting asked; how much risk is tolerable? The basic answer is the acceptable is the risk which is as low as reasonably practicable. In other words, if the risk exists but most probably will not harm the crew, the environment or the cargo, it is considered as tolerable. The management is responsible for defining what and how much risk is acceptable.

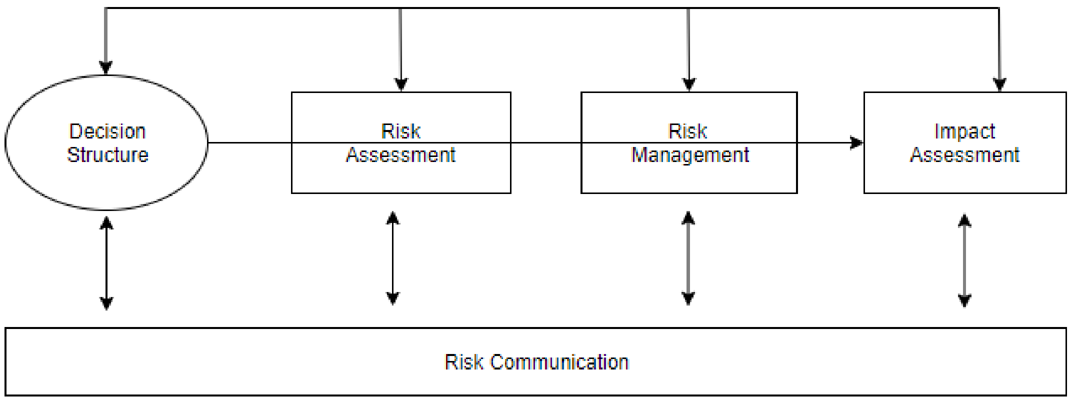
Towards that, there are certain controls that focus on eliminating, substituting and containing the hazards. For the permanent elimination of a hazard, a solution must be examined at the first time that the hazard occurs and before an accident. For example, certain steps in a procedure that might be dangerous could be altered or hazardous to the environment material should be replaced with friendlier ones. The substitution of hazards is in reality the replacement of a hazard with a hazard which is less powerful. The existence of a safer alternative is a prerequisite. For example, using compressed air instead of electricity or purging with inert gas instead of air. In case of not being able to eliminate or substitute the hazards, those can be contained through engineering and administrative controls. The engineering controls consist of mean which limit the dangers. For those to be implemented, structural changes must be conducted over the working environment of the working procedures. The point is the life of the seaman. To prevent any danger, a physical barrier between him/her and the hazard is placed. The administrative controls are productive in terms of implementing safe/safer working procedures. Training, instructions, resources, supervision, rest hours and other measures are tools for containing the hazards. Some examples are the establishment of safety management systems-SMS, the training requirements-STCW and the permit to work system. Moreover, the personal protective equipment-PPE, is a measure of containing the hazards, however is the minimum mean of personal protection. Back-up PPE must be available for every person onboard as well as proper training for using the equipment.

4.3 Reality and Risk Assessment

The reality of risk assessment procedure is depicted in the below quote

“You need a valve which will not leak and you apply everything possible to build one but the available now is a leaking one and you have to determine how much leaking is acceptable and not harmful.”

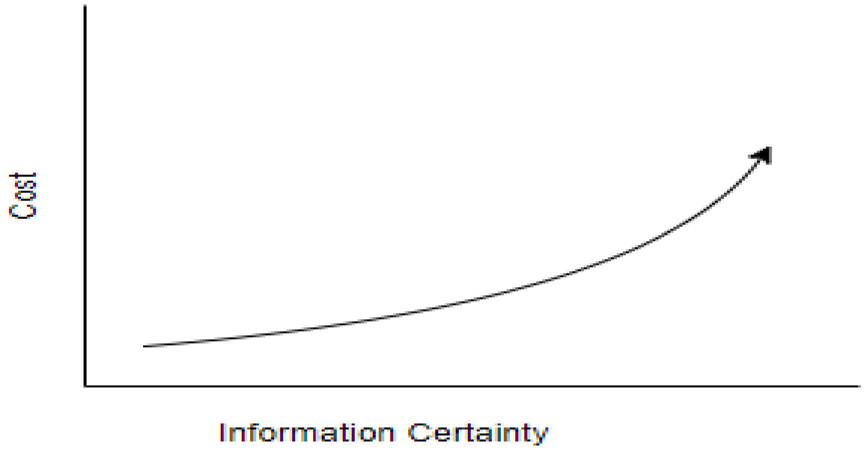
Taking that into account, the decision-making process organizes the information about possibility for one or more unwanted outcomes into a broad, orderly structure that helps decision makers to apply more informed management policies.



During the decision structure, there are certain steps to be conducted. First, the decision's content must be defined. Then, the participants of the decision-making process must be determined. Also, the option available to the decision-makers. Following that, the factors that will influence the decision maker must be also identified. Finally, the factors that influence the stakeholders must be identified and analyzed as well. For example, the fleet management of chartered vessels decision-making procedure. According to the above steps, the decision structure should include the following analysis. At first, the relative risks and benefits of chartering vessels should be presented and taken into account. More specifically, to be decided if it will be long or short-term chartered, what type, what size etc. That's the beginning of establishing a productive-performance fleet. Then, a maximum rate regarding the potential lost operational time because of other external activities like supply chain and logistics support must be set. How much lost time is tolerable? That is the question to be answered. Moreover, the maintenance and inspection plans for the vessels should be examined and defined. Each vessel, along with its specialties should be treated differently but the standards are equal. The same is applied regarding the human resources onboard. Standards about the performance must be set in combination with good working and living conditions. The above are directly connected with the risks rising from different routing options for the vessels. Weather conditions, piracy, shallow sea or a route with historic data of accidents are factors that influence the decision about which route is more viable. In addition, tracking and resolving high risk regulatory compliance issue for the entire fleet is an issue that requires every-day prevention and compliance with the international standards. That, in combination with proper maintenance of critical equipment are is a major issue for having a fruitful, well-known and structured safety policy. If the above measures eventually fail, root cause analysis of major incidents or chronic issues must be conducted, in order not to reoccur or to contain them.

Passing to the second step of risk assessment, a series of activities must be completed. To begin with, answers must be given to the three basic questions; *What can go wrong, how likely is it, what are the impacts*. To answer properly to those question, the risk-related information must as precise and certain as possible. Afterwards, the risk assessment method to be followed must be defined as well as the analytical limits of the method. The example to be used will be the same as above, thus fleet management. Having finished with the decision structure analysis, there are some significant matters to be organized. The first issue is about determining the operational risk of not servicing a ship's system as often as required? In case the vessels' poor maintained components stop functioning, how is this going to be depicted in the operation of the fleet? Then, how could the company I prove its cargo voyage instructions to protect against hazards and mitigate or eliminate undesirable consequences between ship's departure and arrival? Also, what could be the risks of a backlog of non-conformities for the company and how a backlog could be ideally addresses? Are there any repairs required? If yes, all of them or part of them should be funded immediately? Most importantly, has been taken proper actions to resolve the problems which caused major incidents?

A parenthesis is required in order to describe the 'Data Uncertainty" issue. First of all, the below graph explains how gathering information leads to cost increase.



The certainty about a scenario is a matter of gathering information and past experience. When there are experienced losses or near misses, the PIC already has the historical event's summary and by using less resources an acceptable level of certainty is acquired. On the other hand, in order to conduct risk assessment for recognized but not experienced scenarios or even totally unrecognized, more resources are needed in order to reach an acceptable level of certainty. The uncertainty of information cannot be eliminated. Using models to estimate risk, depends on its designed purpose, assumptions, capabilities and limitations. Also, the data uncertainty is a fundamental reason of misinformation. Does the data exist? Are accessible and can be collected the time we need them? Also, many risk parameters are not measured directly. For example, the effectiveness of an engineered safeguards must consider a combination of failure and repair information to produce its probability of failure or safeguard effectiveness data exist for seagoing but the required data is for commuter ferries. Also, the data records might be corrupted, misleading or inaccurate. To be as sure as it can be about the quality of the data, their accuracy and precision must be closely examined. To do so:

- Qualitatively set uncertainty as high, medium or low based on personal experience
- Perform calculations based on best and worst-case situation, setting the bound of likely outcomes
- Perform calculations based on probability distributions with discrete estimates

- Analyze a number of potential situations which provides a robust sample of outcomes

Another relevant issue, is the establishment of the analytical limits of the propagation of losses. In which consequences are we interested in and which consequences are out of the system under examination? Presuming that the vessel is the system under analysis, the consequences might be within the physical boundaries of the vessel, extend to them or even beyond those physical boundaries.

To sum up regarding the methods of risk assessment, there the quantitative ones and the qualitative ones.

Quantitative	**Qualitative**
Fault Tree	Checklist
Event Tree	HAZID
Availability Block Diagrams	Change Analysis
Consequence Analysis	What If
Risk Contours	Failure modes and effects
	Layer of protection analysis

The third step is the Risk management procedure, during which assessment of possible risk management options is conducted according to risk-based information, in order to decide who to manage the potential risk.

Category	**Generic Description**	**Example Management Option**
Spread out	Share the loss exposure with other stakeholders	Invest in insurance
Transfer	Have others in the organization take on loss exposure	Have more capable ship or more experienced master do it
Accept	live with the loss exposure	Sail regardless of the weather conditions to make port on time
Avoid		

	Cancel/delay the activity or don't use the equipment linked to the loss exposure	Don't sail or alter the ship's routing to avoid a severe storm
Reduce	Do something to reduce the loss exposure	Use ergonomic designs to reduce worker injuries

Afterwards, impact assessment must be made. The effectiveness of risk-management options should be identified and ranked. If the effectiveness is insufficient, the management or risk must be reviewed.

Before implementing controls to reduce risk

Frequency	Very Frequent	1		
	Frequent	14		
	Occasioanl	110	4	
	Infrequent	175	10	1
		Low	Moderate	High

Afet implementing controls to reduce risk

Frequency	Very Frequent	1		
	Frequent	14		
	Occasioanl	113	2	
	Infrequent	175	10	-
		Low	Moderate	High

Risk communication is a constant activity through the whole path of decision-making process. Feedback, documentation and constant reviewing are fundamental for retaining productive a safety policy

However, risk assessment and safety culture are functioning in a very dynamic industry like shipping. The constant review and monitoring are fundamental for avoiding incidents, accidents or disasters as well as for avoiding penalties, either financial either “commercial” ones like defamation or even close downs. A fundamental tool against the above is the internal audits.

5.0 Internal audit

IMO defines audit as the “*process of systematic and independent verification through systematic collection of objective evidence, to determine whether the SMS complies with the requirements of the ISM Code and whether the SMS is implemented effectively to achieve the Code’s objectives”*. Thus, the purpose of the internal audit is to verify whether the company’s SMS is complied with industry’s regulations, the safety and pollution prevention activities based on SMS and finally if the systems functions properly.

There are three types of audits; first party, second party and third party. First party audits are the internal audits. The procedure of internal audits follows four phases. The first phase is that of planning. The second is the actual auditing procedure and the third is the reporting of findings after completing the audit. The fourth phase contains the corrective actions if necessary and reviewing. While planning the audit, there must be defined a series of things. Beginning with the purpose and the scope of the audit., how deeply the audits is going to search and why. Also, under which requirements the audit is taking place. The requirements can be either external-ISM either internal-policies. It must also be specified on which part of the company will be under auditing as well as which activities will be audited as well. For example, the department of purchasing could be audited in terms of purchasing proper materials. Moreover, the persons who will be part of the audit team are selected based on their knowledge, experience, credibility and of course availability at that time. The daily audits schedule is also predefined and during the pre-audit meeting, the sequence of events of the procedure are defined along with a formal notification to the auditee. A very important step is the checklist development. The checklist included the processes to be audited, provided consistency and uniformity as well as objective evidence of the audit.

After completing the above, the times comes for the conduction of the audit process. With the initialization of the audit, the audit roles are clarified. Who is the lead auditor, his/her assisting auditor, the top management’s representative and obviously, the audited? Then, the collection of objective evidence is built while the procedure is ongoing. Some elements that must be stated are the location of the evidence (engine room), a notation for each element audited(good/bad). Also, commendations for remarkable performance should be states next to conformities or not conformities detected. Also, observations are to be written along with any physical records, the checklists and the reports to be made. In order to do so, the lead auditor must contain the control of the audit. Experience and knowledge are crucial factors for keeping the procedure in order and formal. During the auditing, meetings are taking place between the team and between the team and the auditee, who is obligatory to be briefed about the progress of the audit. After the physical completion of the audit, it follows the closing meeting. During the closing meeting, a summary of the audit is presented along with commendations and observations. Also, a review of the scope and the audit itself is analyzed without ignoring the nonconformities found. Finally, a draft report is presented to the team and the auditee.

After the completion of the audit, the reporting phase is in place. The nonconformities statements are placed separately as attachment to the audit report. The audit report is a word document with very detailed explanation about the findings. The nonconformity statement cites specifically the requirement violated and the nonconformity provoked. Also, it is remarked as major or minor. Observations are included. In the audit report should in short included the name of the audited and the department/division, the date and location, the scope and purpose, the auditors' names, the summary of the audit results, the reports main core, a functional assessment, commendations, observations, nonconformities, conclusions and recommendations, exhibits and attachments, attendance rosters and the nonconformity reports(separately). However, there are certain things that must not be included in the report. Confidential data, subjective opinions towards improvements, unsolicited observations or fake findings.

Finally, the corrective actions are in order. The corrective actions are responsibility of the PIC of the area audited and not the auditors. The root cause or the nonconformity must be detected and actions to eliminate those must be conducted in order not to reoccur. A specific time frame of implementation of the corrective actions must be clearly stated. After the implementation of the corrective actions, a follow-up verification audits must be conducted in order to identify if the measures received were effective or not. The value of the audit results is unquestionable. An audit can prevent through detection minor or major accidents that could lead to a disaster with significant consequences to those involved. It is an input to the management that can sometimes loose connection with the reality onboard. The ongoing evaluation of the SMS is crucial for establishing a safety culture beyond typical adoption of preventive measures. Thus, for ensuring that existing nonconformities will most probably never reoccur, incident investigation and root cause analysis are the key factor towards this.

6.0 Incident investigation and root cause analysis

Incident investigation and root cause analysis is the mean to avoid a same incident again in the future. To achieve this, the root of the problem, the causality of the initial event is detected and cured. The purpose main purpose in relation to the elimination of a causal root is the protection of the safety and of health of the working force. The preservation of the organization's human and capital resource in monetary terms is a prerequisite in order to build a strong relationship between the internal customers and the company as well as between the external customers and the company. The continuous improvements of quality and reliability of services are coming to enhance the above relationship in combination with regulatory standards and insurance requirements.

IMO's resolution A.849 (20) states that *"each flag State has a duty to conduct an investigation into any casualty occurring to any of its ships when it judges that such an investigation may assist in determining what changes in the present regulations may be desirable or if such a casualty has produced a major deleterious effect upon the environment*." (IMO, 1997). According to the resolution, the purpose is to establish a mutual and common standard of marine incidents' investigation alongside with relative cooperation between States. A marine casualty based on the code are considered the death of, or serious injury to, a person that is caused by, or in connection with, the operations of a ship, the loss of a person from a ship that is caused by, or in connection with, the operations of a ship, the loss, presumed loss or abandonment of a ship, material damage to a ship, the stranding or disabling of a ship, or the involvement of a ship in a collision or material damage being caused by, or in connection with, the operation of a ship or damage to the environment brought about by the damage of a ship or ships being caused by, or in connection with, the operations of a ship or ships. A very serious casualty is considered a damage to a ship which involves the total loss of the ship, loss of life or severe pollution to the environment.

Also, ISM code, in clause 9, includes diligence regarding the implementation of corrective actions and prevention of recurrence. The corrective actions begin with the detection of an actual nonconformity, accident or hazardous situation. The investigation of the circumstances responsible for the nonconformity is in order as well as the gathering of relative records. After the detection of the root cause, the corrective actions are decided which results into a documented system change. The first targets of the corrective actions are to mitigate any damages on humans or environment, taking under consideration other underlying risk.

Tanker Management Self-Assessment, in element 8, suggests the Incident Analysis and Investigation, which is reality is the implementation of the above. The fact that it comes from the market, indicates who strongly it is advised for the procedure to be followed. It is a good business practice, which distincts the responsible companies from those who do not prove through actions their commitment to safety.

6.1 Basics of Root cause analysis (RCA)

RCA investigates two types of undesirable consequences. The first are the accidents. Those are separated into those of high consequences and those of low consequences. High consequence accidents generate too much pain to not determine causes and take actions to prevent recurrences. Low consequence accidents may not appear significant but they consist a burden on fleet’s resources. The second type to investigated, are those which could have provoked series of undesirable consequences but eventually did not. Those are called as near misses. They share similar causes as the accidents but without experiencing losses. The benefit out of it is that experience and knowledge is got without the need of confronting an actual consequence. Taking those under consideration, there are certain common assumptions to be made during the incident investigation. Does the process work as designed or is it problematic? Is the equipment appropriate for the designated use or is inadequate? Does the training of the personnel is adequate of the incident was a result of a performance gap? Are the procedures and the policies clear to the personnel and are properly enforced? These answers must be answered in order for the investigation procedure to be properly initialized. Moreover, the investigation must initiate immediately, even while emergency response activities are still in progress. The loos event and conditions must be defined and the possibility of multiple loss events must be assessed. Respectively, the site of the incident must be secured and the relative data must be collected without being influenced. The proper investigation analysis must classify the event, in order for adequate measures and resources to be taken in action. There are certain typical classifications regarding the vents. The events can be classified based on their process complexity between high, moderate and simple. Also, the type of incidents is another criterion. Is it an accident, a near miss or just an unsafe act? Furthermore, the severity or potential severity of consequences is a remark to the events. Multiple human losses, fatalities, injuries, evacuation measures, just a reportable event or a false alarm are some marking points. Further to those, there is a general principal that an investigation should only conducted if changes are going to be established regarding the specific operation. Otherwise, an investigation without actual changes will be no-credible. A very significant data during the procedure of the RCA is the data gathering and their credibility. Data analysis will product the necessary output for a valid conclusion. The more thorough the data gathering, the more valid the conclusion. However, it can be time and resources consuming so adequate preparation should be made. Data can be derived from several sources. First of all, the statements and interviews of the involved ones are required. The human element is the causal factor to many events. Thus, their perspective is fundamental. In the meantime, physical samples of the event's scene should be gathered if applicable. For example, a spare part of sample of fuel oil. Another important source is the data derived from hard-copy evidence. Logs, records, charts and manuals are still in great position of providing useful facts about the consequential line of the events. Additionally, digital data like correspondence between the crew and the company or third parties is also crucial.

7.0 New Challenges

It is only natural that while time passes, the risks and danger are changing as well or new risk challenges are arising. The industry has to takes measures against new challenges and set new standards and policies towards the potential threats. According to Allianz, there are certain imminent threats which need to be managed and confronted.

In 2018, Europe faced the lowest water levels ever in rivers Rhine and Elbe. As a result, big number of cruise ships were laid up, fact that switched the routes of transportation of the good, from sea to road and rail. The supply chain of Europe’s central industrial area was affected at a point where the freights rates and prices of the commodities (coal, petrochemicals) got higher, leading manufactures and others relative parties to reduce the production rates due to potential shortage of raw materials. to shortages. In the US, Mississippi river’s transportation route has faced same the same issue where due to unpredictable conditions, cargo ships cannot navigate either because of low level waters, either because of high waters. Besides climate change and natural catastrophes, another intense issue is that of cyber security and cyber risks. It goes without saying that living in a digital era has not only affected every-day life but has also add more digital risk. Regarding the shipping industry, where digitalization has been adopted almost entirely by the companies and their vessels, it is crucial for them to set safeguards against their vulnerability and against external malicious parties. Cases like the attacks at COSCO and MAERSK are only indicative of what can be the consequences of such events. In 2017, the International Maritime Organization (IMO) adopted the Maritime Cyber Risk Management in Safety Management Systems resolution. It requires shipping companies to adopt cyber risk management into ship safety measures by 2021. Moreover, classification societies are also providing guidance on cyber security as a part of the offered services. The Guidelines on Cyber Security Onboard Ships, published in December 2018, suggests a structured cyber risk management policy, in order for companies to get prepared. Another issue that is high on the risks' agenda is the political instability. The City of London, where the heart of shipping operates, is under uncertainty with BREXIT to be imminent. Also, sanctions from Usa against China, the permanent embargo again Iran and the political volatility in the Middle East consist a vague scene of doing business. While Turkey invades northern Syria in order confront a potential sovereign Kurdistan, the oil rigs in the area consist a great motive for invasion. The attacks on ARAMCO infrastructure by terrorists' drones reduced temporarily the daily production by almost 6 million barrels per day, fact the led to freight increase and international, temporary shortage. Piracy remain still an issue. According to International Maritime Bureau, piracy incidents have been increased by 12%. The main are of incidents is the Gulf of New Guinea, making the area of Nigeria the most common place of piracy incidents. The hijacking and the kidnapping of the crews for ransoms is a usual event around that are but without total losses. The above are just examples of how risks and hazards are evolving, not allowing mistakes and malpractices.

8.0 Conclusions

This research aimed to identify and present the topic of risk-assessment in the sipping industry. Starting from and introduction to shipping and why risk-assessment became a fundamental tool of the parties involved in the industry, the paper presented the regulatory framework around the topic, either intergovernmental and institutional either commercially imposed. Then, the term risk-assessment was "decomposed" and described in order to be clear what is the topic discussed. Furtherly, widely accepted and used methods for risk-assessment were presented and explained through tables and examples, giving the opportunity to see how they safety matters are worked through. The methods presented are both quantitative and qualitative, fact that indicates how much the both types of conceptual models are useful in order to build a strong point of view of view upon the matter. According to a well-structured safety culture, the safety and health policies of a company must be constantly assessed and monitored. There is no more ideal way to perform so than internal audits. The importance of internal audits is explained along with typical but significant matters during the physical procedure of the audit. Though, an internal audit can be successful and thorough and even so and incident can still occur. In this purpose, incident investigation and root cause analysis are presented. In order to avoid the reoccurrence of such incidents through reaching to the problems root, a series of actions must be conducted. The importance of finding and resolving the root cause is unquestionable. The limitations of the present research are not very different of those when conducting an actual data gathering during an actual risk-assessment. The data available in scientific and industry's sources were present and analyzed at a degree for being easily perceived.

Nowadays, where the need for the protection of the environment, is stronger than ever, companies involved in the shipping industry should by all means stablish specific standards and policies of doing business. Awaiting the implementation of 2020 sulfur's cap, where limiting SOx emissions focuses on improving air quality and protection of the environment, the industry must understand that changes will come, either they believe that are profitable or not. It must not be considered as an overregulation matter but as a reality that must be confronted.

Regarding human safety health, the industry has already moved forward. The Maritime Labor Convention 2006, the STCW and generally IMO have established standards of living, working and training conditions and requirements. Risk-assessment's main purpose is to ensure human safety and health. However, living and working conditions onboard are not just a simple issue. The industry's main purpose is the monetary profits. Many times, the conditions onboard are not ideal. Operations to be completed, drills, inspections and maintenance are designed to preserve human safety and equipment performance. Those, are time-consuming and as a result, the activities are either half-completed either not performed at all. Rest-hours are not possible to be properly followed. Working in the industry and having interaction with seafarers offers a glance inside the real conditions, either living either working ones.

The debate still lies. Do the accusations for high profits against seafarers' health and safety's conditions have a valid basis or the way the industry works is not getting working-friendly at least at a fast pace? The point of the present paper is not to provide groundless advices to the industry's leaders. The presentation of risk-assessment's framework, from the regulatory perspective to the investigation of incidents aims to the consolidation of the safety culture as there are already in place the legal basis and commercial back-round for that to happen.

The new challenges and the evolution of the existing risks and hazards must be thoroughly taken under consideration. The evolution of the technology has undeniably helped the industry. However, the risks involved are too danger to be ignored. Climate change on the other hand is not easy to be restored at this point of time. Nevertheless, the commercial practices can be eco-friendlier taking into account that the responsibility must be equally distributed to both onshore and offshore industries. The fact that the maritime industry is the most dynamic one does not allow complacency at any point. Ongoing changes must be followed up and adjustments should be made to the new conditions of working.

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