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WORLD MARITIME UNIVERSITY

Malmö, Sweden

ACCIDENT ANALYSIS AND PREVENTION:

**Application of HFACS in Maritime Casualty
Investigation reports of Ecuador**

DAVID GUEVARA HARO

Ecuador

A dissertation submitted to the World Maritime University in partial
fulfillment of the requirements for the reward of the degree of

MASTER OF SCIENCE

in

(MARITIME SAFETY AND ENVIRONMENTAL ADMINISTRATION)

2020

Declaration

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

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



.....

Malmö, October 23th, 2020

Supervised by: Dr. Jens-Uwe Schröder-Hinrichs

Professor World Maritime University

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Abstract

Title of Dissertation: **Accident Analysis and Prevention: Application of HFACS in Maritime Casualty Investigation Reports of Ecuador.**

Degree: **Master of Science**

This dissertation is a study of the information contained in marine casualty reports sent by Ecuador to the International Maritime Organization (IMO). The study analyses eleven reports of casualties conducted primarily using the Reason's methodology also known as the Swiss cheese model to identify more detailed information about human and organizational factors in relation to the Human Factor Analysis and Classification System (HFACS) methodology framework.

The review identified seventy-eight third tier causality factors in the eleven reports analysed, moreover, these causality factors were categorized by ship type and by the year of the accident to determine the quality of the reports and identify some of the most common causes in the investigation process.

In addition, eighteen interviews to surveyors and assessors of the Maritime Authority of Ecuador were carried out to understand the findings in the application of HFACS into the reports and the other problems or issues related to the casualty investigation reports and procedures. Finally, the paper presents some common problems identified in the process and gives recommendations on how to improve the quality of the reports submitted to the IMO by Member States to improve safety and achieve the objective of preventing accidents occurring in the future.

KEYWORDS: Casualty Investigation Reports, HFACS, Accident prevention.

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List of Abbreviations

CIT	Critical Incident Technique
COGUAR	Ecuadorian Coast Guard
DIRNEA	Ecuadorian National Directorate of Aquatic Spaces
GEMS	Generic Error Modelling System
GISIS	Global Integrated Shipping Information System
HFACS	Human Factors Analysis and Classification System
III CODE	Implementation of IMO instruments Code
IMO	International Maritime Organization
ISM CODE	International Safety Management Code
MAIB	Maritime Accident Investigation Branch of United Kingdom
MAIIF	Maritime Accident Investigators' International Forum
MARPOL	International Convention for the Prevention of Pollution from Ships
MINDEF	Ecuadorian Ministry of Defense
MSC	Maritime Safety Committee
NTSB	National Transport Safety Board of United States
ROCRAM	Operational Network for Regional Cooperation of Maritime Authorities of the Americas
SOLAS	The International Convention for the Safety of Life at Sea
STCW-F	The International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel
UNCLOS	United Convention of the Law of the Sea

Chapter 1 Introduction

“Safety is noted more in its absence than its presence”

Dr. James Reason

The analysis and prevention of maritime casualties has been a worldwide concern for many years. The investigations conducted into the major casualties have helped to develop international standards and instruments for international shipping, ensuring safety and contributing to the reduction of accidents around the world.

The *Titanic* is an early example of a major accident that demonstrated the importance of minimum safety standards required in the construction, equipment, and operation of ships worldwide. In the follow-up to this accident, it was realized that such an issue could only be effectively addressed on an international level. This accident therefore triggered the creation of the first version of the International Convention for the Safety of Life at Sea (SOLAS) in 1914. This is only an example of all major instruments addressing maritime safety that were adopted in the follow-up of accidents. While the follow-up of accidents was often initially done in technical terms and new technical regulations, the capsizing of the *Herald of Free Enterprise* vessel in 1987 demonstrated the necessity to assess the human factors involved in management and operations in shipping and leading to the establishment of the International Safety Management (ISM) Code.

Nowadays, in the age of digitization where casualty investigation information, standards, models and the like are easily accessible, the International Maritime Organization (IMO) has adopted a casualty analysis procedure and a report system that gathers accident and incident statistics from all Member States promoting cooperation, which will prevent accidents from happening in the future.

The safety of the shipping industry and the protection of the marine environment can be enhanced by delivering high quality reports produced by each Member State, which identify the circumstances and causes of all marine casualties and incidents at all levels. It is commonly believed that human error in relation to the performance of the operators/actors on site has contributed to 80% of all accidents. However, systems seldom fail because of the mistakes made only by the operators/actors. The organizational context in which accidents occur is quite significant. Negligent shipping companies and IMO member States struggling with their obligations in terms of implementation and enforcement can significantly contribute to the number of accidents that occur as they influence the latent operating conditions in maritime systems.

Reports developed following investigations represents a potential to learn from every accident and should be explored accordingly. Therefore, the Human Factor Analysis and Classification System (HFACS) is a methodology and tool that helps to identify the human and organizational factors that are included in accident reports at different organizational levels.

Each flag State has an obligation to conduct accident investigations under the United Convention of the Law of the Sea (UNCLOS) and other IMO Conventions such as the International Convention for the Safety of Life at Sea (SOLAS), 1974, under Regulation I/21, the International Convention for the Prevention of Pollution from Ships (MARPOL), 1973, under articles 8 and 12, and the International Convention on Load Lines, 1966, under article 23. In addition, to Resolution of the Maritime Safety Committee MSC.255 (84) on 16th May 2008, the IMO adopted the Casualty Investigation Code, with international standards and recommended practices for a safety investigation into marine incidents with the primary objective to prevent accidents from happening in the future by ensuring safety and environmental protection (IMO, 2008).

In 2012, Ecuador ratified and became a member of UNCLOS, which Convention is considered to be the key instrument for maritime safety and environment protection (United Nations, 1982). In regards to the IMO instruments, Ecuador had ratified 29 out of the 52 Conventions of the IMO, including key Conventions and Codes related to maritime casualty investigations compliance and enforcement such as SOLAS, MARPOL, Load Line Convention, IMO Implementation of IMO Instruments Code (III Code) and Casualty Investigation Code among others.

Moreover, Ecuador has the Maritime Police Code (Ecuador, 1958), that makes mandatory the investigation into all accidents with ships flying their flag or of those in their jurisdiction. The analysis of the Casualty Investigation reports in Ecuador and its submission to the IMO is the responsibility of the Maritime Authority of Ecuador (DIRNEA¹) under and Executive Decree No. 723 (Ecuador, 2015).

1.2 Problem Statement

According to Stoop (2003), even in having a worldwide network of regulations covering human and technical aspects of shipping operations, maritime accidents still occur causing casualties among crews, raising public concern about the safety of the maritime sector and advocating for additional efforts to improve safety. From 2011 to 2018, a total of 1,377 investigations were carried out by the European Union investigation bodies around the world, which revealed that 25,614 ships were involved in causing maritime casualties, 230 ships were lost, 23,073 injuries and incidents were reported and of those 665 were very serious and resulted in 7,694 persons injured and 696 lives lost (European Maritime Safety Agency, 2019).

¹ DIRNEA: [Dirección Nacional de los Espacios Acuáticos] is a specialized institution of the Navy of Ecuador designed as a National Maritime Authority for compliance and enforcement of Flag State and Coastal State responsibilities under Executive Decree No. 1111 (Ecuador, 2008).

In Ecuador, between 2011 and 2018, 104 maritime accidents were reported to the Ecuadorian Maritime Authority, 30 people lost their lives, 12 people were injured, 5 people disappeared, 36 ships suffered damage, and 46 ships capsized or were destroyed. (DIRNEA, 2019). In the same period, Ecuador reported 23 maritime accidents to the IMO, which reports are available on the Global Integrated Shipping Information System (GISIS).

By analysing these reports and applying the HFACS framework, the author will provide a benchmark in understanding more detailed human and organizational causal factors of accidents as well as recommendations to improve the quality of accident reports. Additionally, with the help of interviews to Officers of DIRNEA, this study will provide recommendations to adopt by the Maritime administration or similar institutions of other States in the process of accident investigations.

1.3 Research aims and objectives

The objectives of the research are to:

- Evaluate the current processes and methods used in the investigation of maritime casualties and incidents in Ecuador, more specifically, its purpose, methodology and recommendations.
- Identify gaps relating to Ecuador's compliance with the Casualty Investigation Code and the quality of the reports through the application of the HFACS framework into selected reports.
- Conduct interviews with surveyors and administrative personnel of DIRNEA to analyse the results of the application of the HFACS framework in the accident reports of Ecuador and discuss best practices to improve them.
- Provide recommendations and proposals for conducting maritime accident and casualty investigations and analysis based on identified best practices.

1.4 Research questions

The following research questions will be analyzed in the dissertation:

- Is legislation in Ecuador adequate and sufficient enough to comply with the Maritime Casualty Investigation Code of SOLAS?
- Are the current processes and methods for the investigation of maritime casualties and incidents adequate for Ecuador?
- How can marine casualty investigation reports be improved?
- What should be adopted as best practices for improving ship safety and for reducing the risk of future maritime casualties in Ecuador?

1.5 Research methodology and methods

The principal methodology to be employed in this research will be through a qualitative methodology of semi-structured interviews with surveyors and assessors of DIRNEA that are responsible for investigating incidents/accidents in Ecuador and analyse reports received.

The study will consist of the following chapters:

Chapter One is the introduction to the study, which will comprise of the problem statement, objectives, and scope of the study.

Chapter Two outlines the background of the process of casualty investigations in Ecuador, including a review of the international and national regulatory framework of marine casualty investigations as well as analyzing the procedures of maritime accident investigations and statistics from the last ten years in Ecuador.

Chapter Three will focus on improving the current marine casualty model applied in Ecuador using the HFACS methodology in eleven reports submitted by Ecuador to the IMO to identify more in detail causal factors and the quality of the reports.

Chapter Four will describe the results of the interviews applied to surveyors and assessors of DIRNEA to answer the research questions and their opinion about the results of the application of HFACS methodology.

Chapter Five will describe the findings of the research as well as the discussion of the findings.

Chapter Six will provide conclusions, recommendations, limitations of the study and areas for further research.

1.6 Outcomes

The expected results of this research are to identify and analyse more in detail causal factors of accidents in the casualty investigation reports submitted by Ecuador to the IMO to observe gaps, and make recommendations for improvements in the process of casualty investigation to ensure the compliance with the IMO Instruments, particularly, the Casualty Investigation Code and ultimately to reduce and prevent marine casualties and accidents occurring in the future.

Chapter 2 Background

2.1 Overview of Ecuador and the statistics in Maritime Accidents

2.1.1. Location and Shipping industry

Ecuador is a small country situated in the northwest of South America, it is located close to strategic international traffic routes such as the Panama Canal which connects Europe with the Pacific Ocean and Asia as can be seen from Figure 1 below. There are 23 ports in Ecuador and 90% of trade is carried by sea. The Galapagos Islands is located 500 miles from the continent, and is another important part of the country with regards to tourism, in 2015 there were approximately 225,000 visitors from cruise ships, an increase of 14% per year (Pizzitutti et al., 2017).

Figure 1

Ecuador location on the world map.



As regards the movement of ships, the last data available indicates that in the year 2018 there were a total of 3,764 international ships that called the ports of Ecuador, 56% of which arrived in different ports of Guayaquil, 16.4% in Esmeraldas, 12.2% in

Bolivar, 9.2% in Manta and 6% in other cities. The national shipping industry is composed of 35 cargo ships, principally tankers that carry oil produced by the country, and 15 cruise ships working in the Galapagos Islands.

The fishing industry is the most representative in quantity of national ships, composed of 650 high seas vessels representing 92,8% of the national fleet and 3,983 artisanal fishing vessels measuring less than 24 meters. Therefore, is expected that maritime accidents with this kind of vessels are the most common in the national waters.

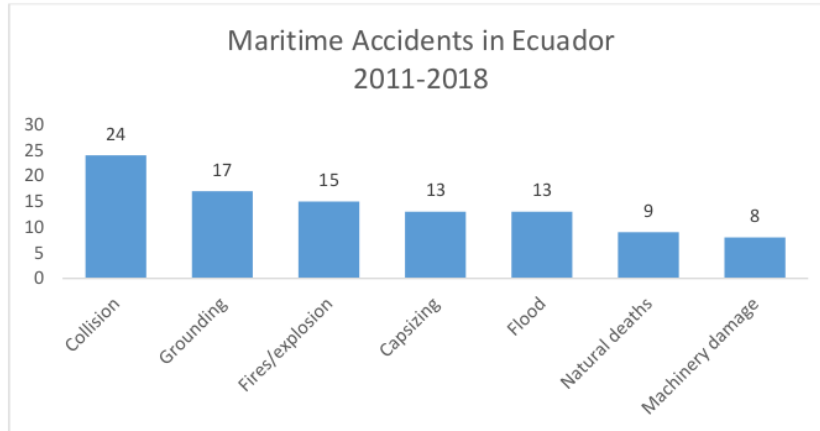
2.1.2. Maritime accidents in Ecuador between 2011 and 2018

Between 2011 and 2018, 104 maritime accidents were reported in Ecuador, the report includes all kinds of ships and accidents. (DIRNEA, 2019). The principal cause of the accidents were collisions, with 24 of the 104 accidents, 15 of them were with artisanal fisher boats; as a result, 12 boats were damaged and 3 boats sank, 13 people died, and 1 person was seriously injured. Nine collisions were recorded between industrial fishing ships, cargo ships, passenger ships, and tankers; as a result, 8 ships were damaged, 2 people died, and 1 ship sank.

After collisions, grounding was the second most common cause of accidents with 17 reported cases, 9 ships were lost, and 8 were destroyed by propulsion and hull damage. Fires and explosions were the third most common cause of accidents and during the said reporting period there were 15 cases, resulting in the death of 3 people , 6 were injured, 8 ships were seriously damaged, 5 ships lost and 2 ships sunk. Most of the cases occurred in the Galapagos Islands (DIRNEA, 2019).

Figure 2

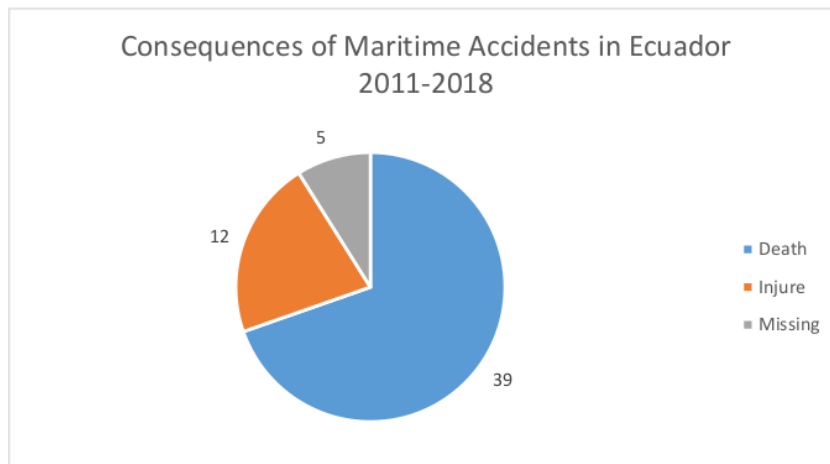
Type of Maritime Accidents in Ecuador. (DIRNEA, 2019)



As can be seen from Figure 3, the maritime accidents that occurred in the stated period resulted in the death of 39 people, 12 people were injured, 5 people disappeared, 36 vessels suffered damage and 46 vessels sank or were destroyed.

Figure 3

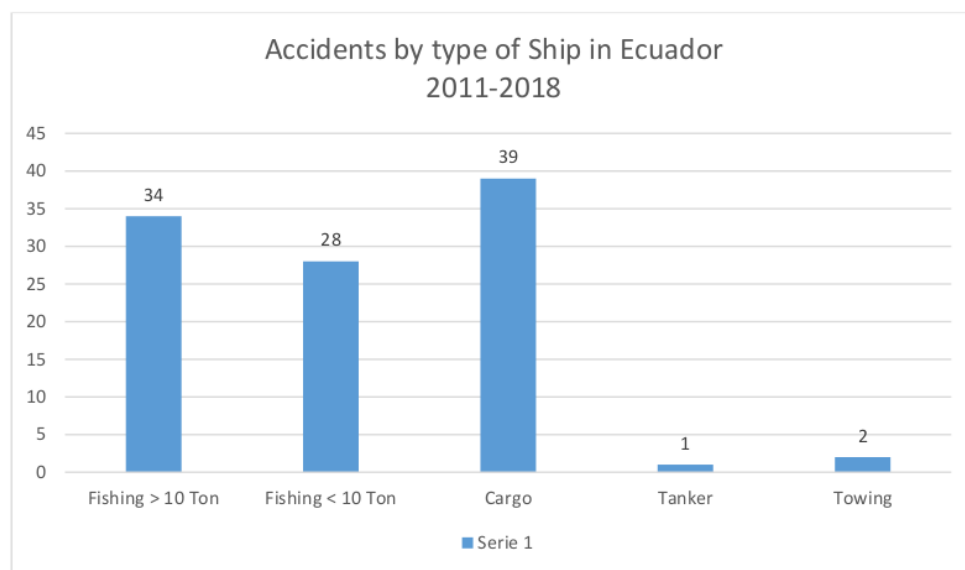
Consequences of Maritime Accidents in Ecuador 2011-2018. (DIRNEA, 2019)



The type of ships involved in the highest number of accidents were cargo ships with 39 cases, followed by fishing vessels weighing more than ten tones with 34 cases, and fishing vessels carrying less than 10 tons with 28 cases. The cargo vessel accidents usually occurred between Ecuador and the Galapagos Islands, and fishing vessel accidents mainly occurred along the coast of Manta and Guayaquil (DIRNEA, 2019).

Figure 4

Accidents by type of ship in Ecuador 2011-2018. (DIRNEA, 2019)



2.2 Regulatory framework of Ecuador related to Maritime Accidents

2.2.1 International Regulations

2.2.1.1. UNCLOS

Ecuador was the 163rd State to become a part of the United Nations Convention of the Law of the Sea on 24th August 2012. According to article 94 of UNCLOS, a flag State has an obligation to investigate a marine casualty on the ships flying their flag or in

their jurisdictional maritime zones (UN General Assembly, 1982). In paragraph 7 of the same article this obligation extends to a flag State to nominate a qualified person or persons to investigate an accident when nationals of another State die or suffer serious injuries as well as when the accident causes damage to ships or installations of another State or to the marine environment.

2.2.1.2. IMO Conventions

The mandatory instruments that Ecuador is a part of as an IMO Member State for casualty investigations matters are:

- SOLAS Convention
- MARPOL Convention
- Load Lines Convention
- Casualty Investigation Code
- III Code

2.2.1.3. Regional Cooperation Organizations

Ecuador is part of two important regional organizations related to the cooperation in the investigation of Maritime Accidents:

The ROCRAM² is a regional organization for the cooperation between maritime authorities created in 1983, composed of thirteen states: Argentina, Bolivia, Brazil, Chile Colombia, Cuba, Ecuador, México, Panamá, Paraguay, Peru, Uruguay, and Venezuela. Regarding casualty investigations. The organization was created in 2015 by a group of experts to share relevant information on maritime casualties or incidents

² ROCRAM: [Red Operativa de Cooperación Regional de Autoridades Marítimas de las Américas] is a regional organization for cooperation among Maritime Authorities of America continent.

of the member states through a web platform to accumulate experiences on this matter (ROCRAM, 2020).

The Maritime Accident Investigators' International Forum (MAIIF) is a non-profit organization dedicated to the exchange of ideas, experience and information acquired in maritime accident investigations to promote and improve marine accident investigation, foster cooperation and communication between investigators (MAIIF, 2019).

2.2.2. National Regulations in Ecuador

The main maritime regulation in Ecuador, is the Maritime Police Code (Ecuador, 1958), under Chapter VI of the Code; the Port Captain is the local maritime authority responsible for the investigation of casualties under his jurisdiction regardless of a ship's Flag State or nationality of the people involved. This investigation has to be based on the causes and circumstances of the accident and can be used to determinate civil or administrative responsibilities.

Based on this Code, the Maritime Authority passed a resolution (DIRNEA, 2010), expanding this obligation of Captains of Port in accordance to the Casualty Investigation Code normative and allowing them to be replaced by surveyors qualified designated by the DIRNEA to accomplish safety investigations.

Currently there is a new Bill entitled the Navigation Law that is in process of being adopted by the legislative authorities in Ecuador. This is a replacement of the Maritime Police Code of 1958 concerning mandatory national and international regulations for the country. It is expected that the Navigation Law will be approved by 2021, that is, before the IMO Audit Scheme in Ecuador that is scheduled for 2022 will be conducted.

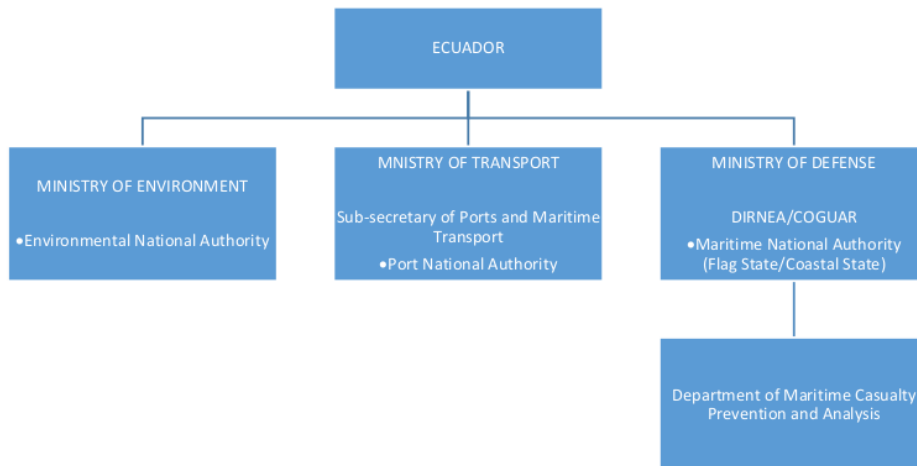
2.3 Overview of Casualty Investigations procedures in Ecuador

2.3.1. Maritime Administration

The Figure 5 shows, the Maritime Administration responsibilities in Ecuador, which are divided into three entities: The Ministry of Environment which is the environmental national authority in charge of environmental regulations and the environmental protection of the seas; The Ministry of Transport and its agency the Sub-secretary of Ports and Maritime Administration is the Port State authority in charge of port State regulations and the control of safety in national ports. The Ministry of Defence and its agencies the National Direction of the Maritime Spaces (DIRNEA) and the Ecuadorian Coast Guard (COGUAR) are military institutions working together as the Maritime Authority for compliance and enforcement of Coastal and Flag State regulations and obligations.

Figure 5

Organigram of Government bodies and areas of responsibility in Ecuador



The Maritime Authority of Ecuador created in 2017 a department for purposes of maritime accident prevention and analysis as well as to collect data for casualty investigations, create statistics, analyse, and make recommendations to prevent accidents happening in the future.

2.3.2. The process of Maritime Casualty investigations in Ecuador

According to the national regulatory framework, the process of casualty investigations is an obligation of the Captain of each port. The surveyors act under the authority of the local maritime authority (Port Captain) with the responsibility to investigate the causes and circumstances of an accident and analyse the causality factors of them and to take corrective and preventive measures. The reports and recommendations are submitted by the Port Captain to the DIRNEA to evaluate and then submitted to the IMO (DIRNEA, 2010).

2.3.3. Casualty Investigation Department

In 2017, the DIRNEA established a department for Analysis and Prevention of Maritime Casualties and Incidents with a mandate, to collect all reports, analyse the data and make recommendations to improve safety at sea. The department is also responsible for submitting reports to the IMO through the GISIS report system in compliance with the Casualty Investigation Code.

In addition, the stated department maintains statistics and classifies reports to produce informative bulletins for seafarers and share lessons learned from different types of accidents. The first bulletin was created in 2018, collected information on the accidents that occurred between 2011 and 2018 and is available on their web page (DIRNEA, 2019).

2.3.4. Casualty investigation surveyors

Currently, Ecuador has approximately 100 surveyors trained in maritime casualty investigations; these surveyors are active or retired navy officers. The National Marine Academy organizes a two-week course each year for 20 surveyors according to National and International Regulations. The courses are based in the IMO model courses 3.11, 2014 edition (IMO, 2014).

The surveyors are called to do an inspection after an incident, which is a requirement of the local maritime authority, and with the approval of the National maritime authority, in the case of significant accidents, a group of surveyors can work together depending on their previous experience.

2.3.5. Casualty investigations reports

The procedure to make a report for maritime accidents is aligned to the national and international legislation: more specifically the Ecuadorian Maritime Police Code (Ecuador, 1958), Casualty Investigation Code (IMO, 2008) and a Guideline to assist investigators in the Implementation of the Casualty Investigation Code (IMO, 2014). All reports follow the Reason's methodology, commonly known as the “Swiss Cheese” model. The reports contain the following mandatory parts:

- General information
- Details of the accident
- Material tests
- Event analysis
- Conclusions and recommendations

National legislation requires reports to be completed within 30 days for minor and serious cases and within 45 days for very serious cases, however this does not apply to technical reports or reports where international ships are involved. If the maritime accident is very serious, a group of investigators can be assigned to the process and

given more technical assistance to surveyors in regard to human or organizational factors or technical matters. In the last ten years, there were 23 accidents reported by Ecuador to the IMO.

Chapter 3 Application of HFACS in accident investigation reports of Ecuador

3.1 Models for accident investigations

According to Hollnagel (2016), accidents are preventable but only if they are correctly described and understood. Several models and factors can be considered in accident investigations, however the choice of model used to analyse them is crucial because it will determine the analyst's perspective and therefore guide the conclusions and the preventive measures needed to be taken. (Chauvin et al., 2013). Accident causation models basically answer two questions: why does an accident occur?, and how does it occur?.

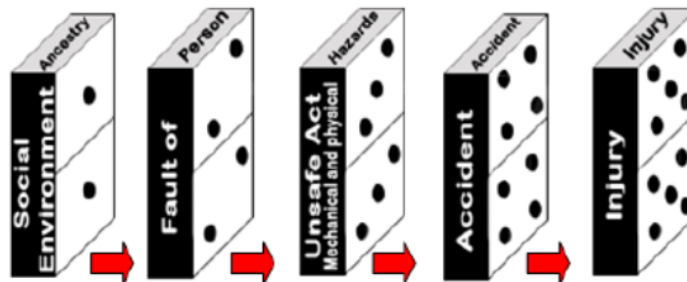
Accident models and thinking about accidents have changed over time. Today modern ships with complex systems require new sophisticated accident models and investigation methods. The current accident causation models (approximately 29 models) consist of qualitative and quantitative analysis and will develop in the future for dynamic analysis, accident prediction and intelligence comprehensive analysis (Fu et al., 2020). According to Hollnagel (2004), current accident models can be classified into three major categories: 1) simple linear system models (cause-effect models), 2) complex linear system models (epidemiological models) and, 3) complex interactions (systemic models).

Simple linear models such as Heinrich's domino model presented in Figure 6, was popular in the 1930s with the industrial revolution, consisting of a linear propagation of cause-effect links, corresponding to an event chain. In this model, accidents can be prevented by fixing or eliminating the weak "domino" piece or placing a barrier between two pieces. The unexpected event is usually an unsafe act, with human error involved (Heinrich, 1941). The limitation of this model is that it does not address the

causal relationships between the human or organizational aspect of the accident (Fu et al., 2020).

Figure 6

Heinrich domino's model. (Klockner, 2015)

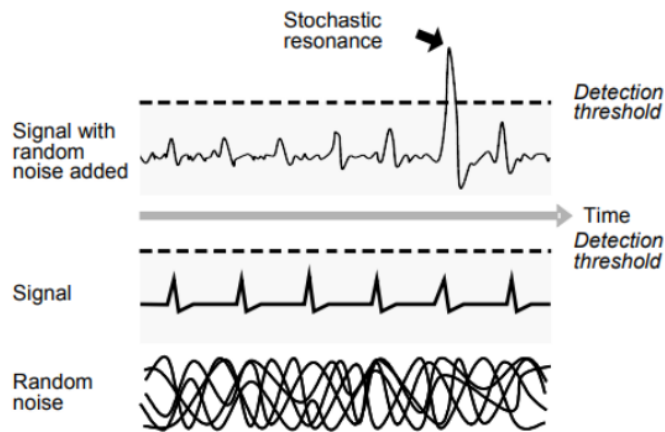


Complex linear system models such as Reason's model emerged in the 1990s and consist of linear combinations of active failures and latent conditions, corresponding to several event chains (Reason, 1990, 1997, 2008; Hollnagel, 2004). Active failures are considered as unsafe acts and latent conditions as unsafe conditions that trigger those unsafe acts. This model focuses more on the organizational contributions to the accident however, it does not explain why these conditions were seen as normal or rational before the accident. (Reason et al., 2006)

Finally, complex interaction models such as Hollnagel's functional resonance model consist of interdependent functions whose performance depends both on other functions and on different factors. (Lundberg et al., 2009) In this model, accidents are seen to emerge from unexpected combinations or stochastic resonance as shown in Figure 7 below, of normal variability in the system rather than action failures, which combine, or resonate, with other normal variability actions. The benefit of this model is that it provides a more complete understanding of the event because of the contributing interactions, latent conditions and organizational weaknesses can be identified. (Hollnagel & Goteman, 2004)

Figure 7

Stochastic resonance in the Functional Resonance Accident Model. (Hollnagel & Goteman, 2004)



3.2 From Human to Organizational Factors

The basis for conducting any accident investigation is to understand all the factors involved in the process such as the organizational, cultural, or technical factors. The role of factors varies between different models and each model will give a different result depending on the factors considered. Lessons learned from this experience in accident investigations indicate which factors are important and which are not. In addition, some methods may miss factors that others deem important.

Nowadays it is well known that the human factors represent more than 80% of maritime accidents. After analysing 30 years of maritime accidents, the IMO amended the Casualty Investigation Code with the Resolution A.884(21) in 1999, to progress from an approach which focuses on technical requirements for ship design and equipment to one which seeks to recognize and more fully address the role of human factors in maritime safety (Eriksson & Mejia, 2003).

Human error, which is apparently the cause of the accidents, is just the tip of the iceberg seen where latent conditions can be present and built from organizational and strategic decisions and a lack of authorities' control. Several authors have highlighted the importance of considering human and organizational factor for maritime safety (e.g. Chauvin, 2011; Hetherington et al., 2006; Schröder-Hinrichs, 2010, as cited in Chauvin et al., 2013).

Figure 8

Organizational causes of accidents. (Reason, 2016)

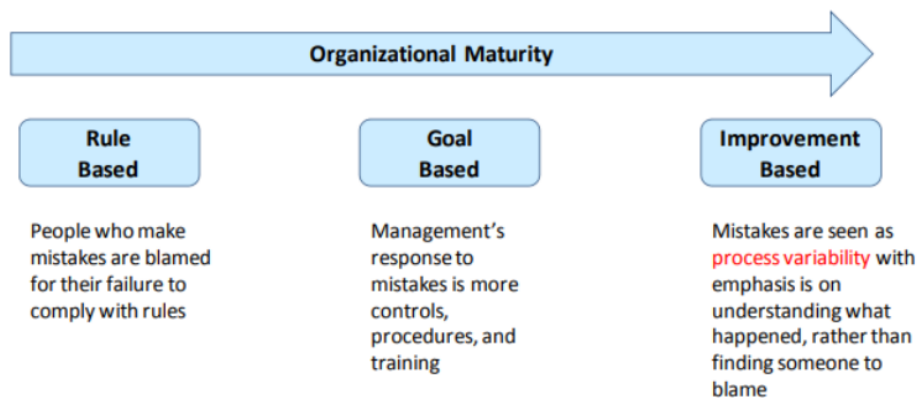


Latent conditions are always present in complex system such as ships, and sometimes cannot be eliminated from the management systems, because they are part of the cultural biases in strategic decisions (Reason, 1997). Figure 8, illustrates an example of latent conditions produced by a heavy work as an organizational factor in the base of the pyramid. This pass to a local workplace factor in the form of stress in the workplace and can trigger an active failure or precursor to the worker cutting corners. At the end if barriers fail, the unsafe act could result in an incident or accident.

The difference between active failures and latent conditions is that the first one have immediate and relatively short-lived effects and the second can lie dormant, until they interact with local circumstances to defeat the systems' defenses. This local circumstances could be inadequate tools or equipment, time pressure, insufficient training, poor supervision, low pay poor communications. Another difference between active failures and latent conditions is that active failures are committed by the "sharp end" personnel (a master of a ship or part of the crew) and latent conditions are produced by the top management personnel (shipowners) or regulatory and governmental authorities.

Figure 9

Organizational maturity. (Department of Energy, 2012)



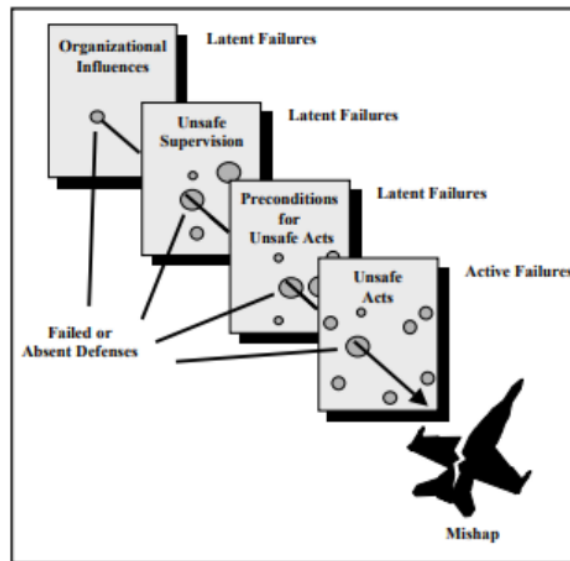
For this reason, the Figure 9 shows the components of an Organizational Maturity, that is needed when an accident occurs to understand the causal factors of the accident by not blaming the worker and increasing enforcement but also move backwards to the goal based response from managers and rule based response from government authorities and see if those process need improvement.

3.3 Reason's Model for accident investigations

Reason's model, emphasised the organizational dimension of major accidents. As shown in Figure 10, it describes four levels of human failure from active action from latent conditions, each influencing the next: 1) unsafe Acts, 2) preconditions for unsafe acts, 3) unsafe supervision, and 4) organizational influences (Reason, 1990). The organizational or latent conditions that arise from unsafe acts of humans can arise from strategic and top-level decision made by governments, maritime administrators, shipowners and organizational managers. (Chauvin et al., 2013)

Figure 90

"Swiss cheese" model of human error causation.(Wiegmann and Shappell, 2000).



Reason's model has revolutionized common views of accident causation, however according to Wiegmann and Shappell (2000) it is a simple theory with few details of how to apply it in a real-world setting. The "holes in the cheese" are not defined in the model and cannot be identified during the accident investigation process or cannot be detected and corrected before an accident occurs, however, such specificity was never

the original intention. The model is a generic tool that can be used in any domain and the details of the conditions permitted to exist depend on each investigator (Reason et al., 2006).

3.3 HFACS Methodology for Maritime accident investigations

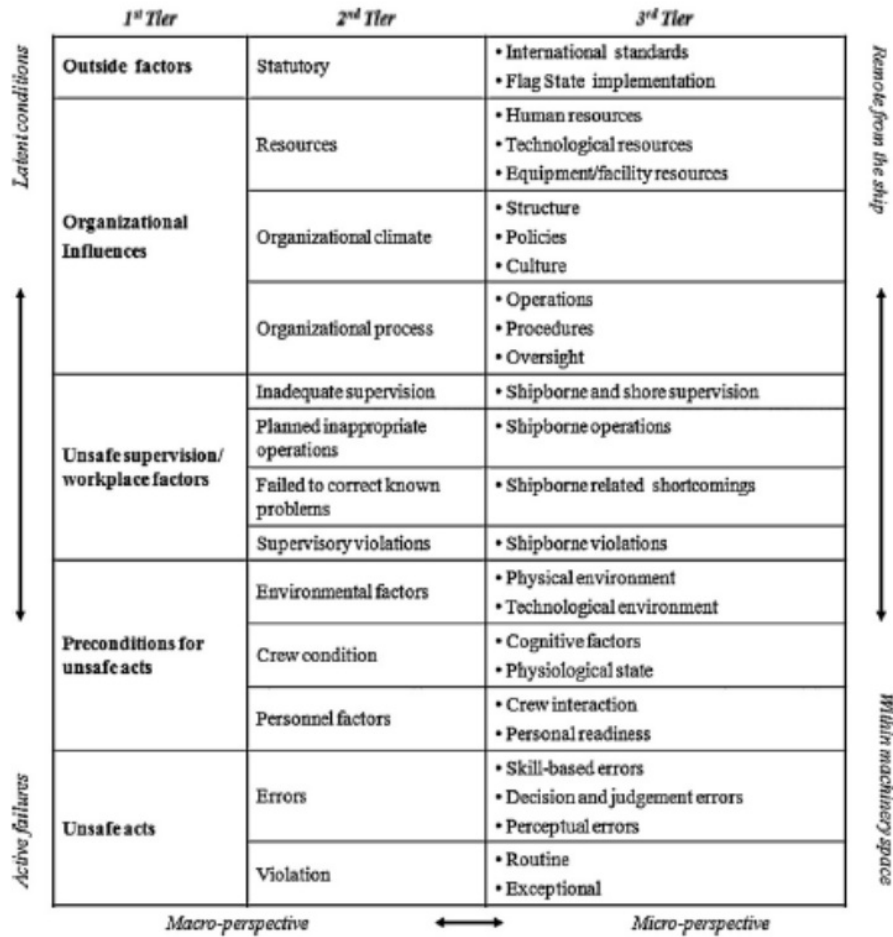
The HFACS framework was developed in 2000 by Wiegmann and Shappell to analyze underlying human and organizational causal factors present in military aviation accidents (Shappell and Wiegmann, 2001, 2003, 2004). After that, the HFACS methodology was also used in the analysis of accidents in other means of transport and different industries such as the railway industry (Reinach and Viale, 2006), the mining industry (Patterson and Shappell, 2010), becoming one of the most widely used human factor accident analysis frameworks (Li et al., 2008; Fu et al., 2020).

In the maritime sector, HFACS methodology has also been used and adapted by different authors (e.g. Celik and Cebi, 2009; Chen et al., 2013; Rothblum et al., 2002; Schröder-Hinrichs et al., 2010; Xi et al. 2010) as it supplements Reason's model with a framework to analyse maritime casualties reports. This study is based in the Human Factor Analysis and Classification System-Machinery Spaces on Ships (HFACS-MSS) framework proposed by Schröder-Hinrichs et al. (2010) presented in Figure 11 below.

The adaptations in the mentioned framework, primarily focuses on the fifth level on top of organizational influences, called outside or external factors, with a statutory level, created to capture the influence of safety regulations in shipping and their enforcement by maritime authorities. In the adaptation the third tier factors are called *International standards* (e.g., rule making process) and *Flag State implementation* (e.g., class and statutory surveys). (IMO, 2010)

Figure 11

Human Factor Analysis and Classification System-Machinery Spaces on Ships (HFACS-MSS) framework. (Schröder-Hinrichs, Baldauf, and Ghirxi, 2010)



The use of the HFACS methodology in this study is based on its success in identifying in the reports the active failures and latent organizational conditions in a macro and micro perspective way, obtaining a comprehensive insight into the accident and a clear means for summarizing the analysed accident. (Chen et al., 2013). Nowadays, HFACS is often used in accident analysis and prevention in combination with other models

(Daramola, 2014; Zhan et al., 2017; Li et al., 2019a; Zarei et al., 2019, as cited by Fu et al., 2020).

Therefore, the use of HFACS methodology can help in the identification of some common and more detailed factors present in accidents analysed by Ecuador that the Reason's model cannot identify and work in recommendations that are more specific. Moreover, Reason's model has been used by Ecuador to compile accident investigation reports since 2014.

3.4. Application of HFACS methodology in accident investigation reports

For the HFACS analysis, eleven accident investigation reports were selected from the 23 reports submitted by Ecuador to IMO through the GISIS. The Table below presents the details of the accidents selected. The main rationale was to select the latest accidents where the Reason's model was applied. The time frame within which the selected accidents occurred was between 2012 and 2020 except for one accident that occurred in 2001. Most of the reviews of the accidents were classified as very serious, with only one case of a serious accident and one classified as less serious.

Regarding the type of ship and type of accident, the reports were selected randomly trying to analyse a variety of accidents to understand common failures instead of focusing on a specific type of ship or type of accident. Finally, it is important to mention that from the 23 reports submitted to the IMO, some reports were incomplete and discarded to avoid distortion of analysis. The table below summarizes the characteristics of the reports selected.

Table 1

Accident reports selected for HFACS analysis

No	Incident Date	Type Ship	Gross tonnage	Type of Casualty	Type of Accident
1	2020-02-03	Fishing Vessel	1000	Very Serious	Intoxication with gas
2	2020-01-23	Fishing Vessel	344	Serious	Fire/Explosion
3	2019-06-02	Fishing Vessel	228	Very Serious	Capsizing
4	2019-05-31	Passenger Ship	227	Less serious	Grounding Sinking
5	2015-01-28	Passenger Ship	1475	Very serious	Grounding
6	2014-11-17	Cargo Ship	893	Very serious	Capsizing
7	2014-05-09	Cargo Ship	2279	Very serious	Grounding
8	2014-04-23	Fishing vessel	229	Very serious	Machinery Damage
9	2013-01-06	Fishing vessel	323	Very serious	Fire/explosion
10	2012-04-04	Fishing vessel	242	Very serious	Capsizing
11	2001-01-16	Tanker	835	Very serious	Grounding

3.4.1. The methodology of the review

The review of the accident reports was undertaken with the assistance of the supervisor of this dissertation. The reports made by Ecuador consisted of general information, details of the accident, material evidence, event analysis, conclusions and recommendations. The material evidence and event analysis sections were useful to understand the facts involved in the accident and classified them in the HFACS framework. The author of this thesis reviewed each accident report and coded it accordingly. Thereafter, findings were discussed with the author's supervisor who reviewed the coding results by studying the original accident investigation reports.

The coder and the supervisor primarily only coded information that was identified in the accident investigation reports, however, sometimes findings like the lack of a

safety culture were not always included in the reports even though sufficient evidence was presented in the reports to deduce that fact. If such a situation existed, the coder and the supervisor agreed to include such finding in the coding results.

This may have added a subjective view to the overall coding, nevertheless, any such instances were very carefully discussed and only considered for inclusion when sufficient evidence was available to draw such conclusions, and if deemed necessary, the new and extended finding was included in the analysis. It is assumed that this procedure limits the subjective aspects of the coding to the least extent possible.

3.5 Results of the application of HFACS in the accident investigation reports

The review result in the determination of 78 third tier factors in the eleven investigation reports analyzed. Table 2 summarize the identified factors in the HFACS framework. For the first tier factors, *Organizational influences* was the most represented factor, with 23 causes and 29.5% of the occurrences followed by *Preconditions for Unsafe Acts* with (19-24.4%), *Unsafe supervisions* with (15-19.2%), *Unsafe acts* with (14-17.9%), and finally *Outside factors* with (7- 9%). These results are similar to those observed in the accident reports when investigators apply the Reason's model.

Table 2

Identified third Tier HFACS causal factors in the accident investigation reports reviewed.

<u>First tier</u>	<u>Second tier</u>	<u>Third tier</u>	<u>Total</u>	<u>%</u>
Outside factors			7	9,0
	Statutory		7	9,0
		International standards	0	0,0
		Flag State implementation	7	9,0
Organizational Influences			23	29,5
	Resources		14	17,9

	Human resources	2	2,6
	Technological resources	2	2,6
	Equipment facility resources	10	12,8
Organizational climate		2	2,6
	Structure	0	0,0
	Policies	0	0,0
	Culture	2	2,6
Organizational process		7	9,0
	Operations	2	2,6
	Procedures	2	2,6
	Oversight	3	3,8
Unsafe supervision/ workplace factors		15	19,2
	Inadequate supervision	6	7,7
	Shipborne and shore supervision	6	7,7
	Shipborne operations	3	3,8
	Shipborne related shortcomings	1	1,3
	Supervisory violations	5	6,4
	Shipborne violations	5	6,4
Preconditions for unsafe acts		19	24,4
	Environmental factors	4	5,1
	Physical environment	3	3,8
	Technological environment	0	0,0
	Economic environment	1	1,3
	Crew condition	9	11,5
	Cognitive factors	7	9,0
	Physiological State	2	2,6
	Personnel factors	6	7,7
	Crew interaction	4	5,1
	Personal readiness	2	2,6
Unsafe acts		14	17,9
	Errors	9	11,5
	Skill-based errors	1	1,3
	Decision and judgment errors	6	7,7
	Perceptual errors	2	2,6
	Violation	5	6,4
	Routine	4	5,1
	Exceptional	1	1,3
TOTAL		78	100

Despite the small quantity of reports analysed in this study, it is notable that high quantity of Organizational factors and Outside (Statutory) factors were observed in the reports.

For the second tier factors, *Resources* are the most represented factor with 14 events and 17.9% of the occurrences, followed by *Errors* and *Crew Conditions*, both with (9-11.5%), *Organizational process* and *Statutory* both with (7-9%) of the factors analyzed. This presents a more detailed explanation of the common factors presented giving some small peaks of information about the findings when reports are analysed more in detail.

Finally, for the third tier factor, the most represented numbers are shown in the Table 3 below. *Equipment facility resources* were observed 10 times and represented 13% of the factors found, followed by *Flag State implementation* with (7-9%), *Cognitive factors* with (7-9%), *Shipborne and shore supervision* with (6-8%) and *Decision and judgment errors* with (6-8%).

Table 3

Highest-ranking HFACS third tier factors.

First tier	Second tier	Third tier	Number	%
Organizational Influences	Resources	Equipment facility resources	10	13%
Outside factors	Statutory	Flag State implementation	7	9%
Preconditions for unsafe acts	Crew condition	Cognitive factors	7	9%
Unsafe supervision/ workplace factors	Inadequate supervision	Shipborne and shore supervision	6	8%
Unsafe acts	Errors	Decision and judgment errors	6	8%
Unsafe supervision/ workplace factors	Supervisory violations	Shipborne violations	5	6%
Preconditions for unsafe acts	Personnel factors	Crew interaction	4	5%
Unsafe acts	Violation	Routine	4	5%
		TOTAL	49	63%

Equipment facility resources is a factor generally brought about by financial problems of the top managers or shipowners. In the HFACS methodology, it refers to the use of poor quality equipment or inadequate equipment purchased by managers as well as deficiencies in the maintenance of equipment and workspaces due to financial problems of the shipowners (Shappell & Wiegmann, 2000).

For this study, *Equipment facility resources* was observed in six of the eleven reports analysed, although in one report it was observed three times. This factor presented in the reports analysed showed that when the specific equipment needed for the bridge or propulsion machinery were reported as damaged or inoperative and stayed in this condition until the occurrence of the accident. For example, in one report the secondary radar, one GPS and the rudder indicator were reported as inoperative and the ship continued to sail with these problems on many occasions so the crew adapted to this unsafe condition.

The second more common factor observed refers to Flag State implementation regulations that the Maritime Authority fail to enforce. As an example there was a case, where the plimsoll disc was observed as not being painted in the correct position in an annual inspection and the ship did not correct it immediately, allowing the ship to continue to overload cargo, which resulted in the ship capsizing when weather conditions affected her stability.

Cognitive factors are the third most common factors observed in this study and are linked to the other factors mentioned because safety and training are often the first areas to be cut in organizations experiencing financial difficulties. It was generally observed in accidents in the Galapagos Islands that the crew were not qualified for their position or they were required to do other tasks that they were not qualified to do because they did not want to hire new personnel.

Thereafter, the other factor uncovered was active failures normally present in accidents such as errors and violations combined with inadequate supervision from the Master's or ship supervisors, but due to the small quantity of these occurrences and the small quantity of accidents analysed it is not necessary to discuss same in details.

3.5.1 HFACS for the type of ship accident

The eleven reports were separated by type of ship to see the number of factors in each group, fishing vessels with five reports analysed presenting 30 causal factors, three accident reports of cargo ships resulted in 28 causal factors, two accident reports of passenger ships present 13 causal factors and one tanker with seven causal factors. Therefore, the average of causal factors by type of ship is Cargo ships (9.3), Tanker (7), Passenger ship (6.5), and Fishing vessel (6).

If the analysis focusses just on fishing vessels, the Table 4 below shows the results. *Equipment facility resources*, and *Flag State implementation* factors appears at the top of the table, this could be an indicator that the organizational and statutory problems mentioned above refers mainly to these types of vessels and further studies with more accident reports can be done to confirm this hypothesis. For the other type of ships the quantity of reports analysed is not sufficient to make a proper classification or codification.

Table 4*Number of third tier HFACS found in fishing vessels accidents*

First tier	Second tier	Third tier	Number	%
Organizational Influences	Resources	Equipment facility	4	5%
Outside factors	Statutory	Flag State implementation	4	5%
Unsafe supervision/ workplace factors	Inadequate supervision	Shipborne and shore supervision	4	5%
Preconditions for unsafe acts	Crew condition	Cognitive factors	3	4%
Unsafe acts	Errors	Decision and judgment errors	3	4%
Unsafe supervision/ workplace factors	Planned inappropriate op	Shipborne operations	3	4%
TOTAL			21	27%

3.5.2 HFACS for the year of ships accident

If the reports are separated by the year of the accident investigation, in the five reports completed after 2017, it was found 32 causal factors with an average of 6.4 factors per report were found. Furthermore, in the six reports analysed before 2017, 46 causal factors with an average of 7.6 factors per report were found.

The above results indicates that in reports analysed after 2017, the information provided is more complete and for that reason less causal factors were identified, which is expected because, the Maritime Authority of Ecuador created the Department of Analysis and Prevention of Maritime Casualties and Incidents after 2017 to, amongst others, collect all reports and monitor the work of surveyors.

3.6 Summary and Conclusions

The application of the HFACS framework in the accident investigation report of Ecuador resulted in the identification of 78 causal factors for eleven accidents analyzed. *Organizational* and *Statutory* factors and were the principal factors found in reports. Be that as it may, if one classifies the reports by type of ship, organizational and statutory factors were mostly observed in fishing vessels in comparison to other type of ships.

This is expected to be found on these kinds of vessels especially as such vessels are not required to comply with the International Safety Management Code (ISM Code) or the International Convention on Standards of Training, Certification and Watchkeeping for Fishing Vessel Personnel (STCW-F) Convention, which stipulates where the inspections should be focused. Under these organizational factors, the *Equipment facility resources* were the most common factor in the accidents reviewed which means that shipowners or fishing companies do not assign the necessary financial resources to correctly equip and maintain their ships equipment and workspaces.

In addition, the HFACS review found seven *statutory* factors identified as *Flag State implementation* responsibilities. This factor refers to deficiencies observed in surveys or inspections carried out and not addressed by the ship managers. This problem could be caused by the lack of a policy that provides cooperation for safety enforcement inspections between the two institutions in charge of them, one for ports and another for coastal and flag state obligations.

In addition, the review presented 7 *Cognitive* factors, which are considered as an active failure caused by the lack of qualifications or instruction to the crew, complemented by *inadequate supervision* as six factors and *decision and judgment errors* as another six factors. All these factors are commonly the reason for accidents

occurring and are part of the human error factors caused by the confidence of the crew or master or a lack of training and qualifications for the duties assigned.

The next chapter will discuss these findings with surveyors and administrative personnel of the Maritime Administration of the country with interviews conducted to understand if these factors were observed in the surveys and how the Maritime Authority can obtain recommendations from this analysis.

Chapter 4 Interviews to the Maritime Authority of Ecuador

4.1 Introduction

The application of the HFACS methodology during the analysis of the accident investigation reports helped to identify some common, underlying organizational factors. These could be caused by latent conditions, common problems, or other root causes that have to be taken into consideration by the DIRNEA in its efforts to improve the overall maritime safety of its national fleet. Therefore, 18 qualitative semi-structured interviews were conducted in addition to the previous analysis to achieve the research goals and collect data about the previous results.

4.2 Selection of interview techniques and methods

The selection of the correct method for the interview was important to interpret the results obtained before in Chapter 3. There are four types of interviews used in social research: 1) Structured interview, 2) semi-structured interview, 3) unstructured or focused interview, and 4) group interview and focus group. The group interview method was discarded because it was difficult to arrange a group meeting with all surveyors at the same time.

In individual interviews, the structured method allows for a better standardization and comparability of the answers because questions are clearly defined, and short answers are expected. On the other hand, the unstructured method allows the participants to answer questions within their own frame of reference, talking more about their own knowledge and experiences. The semi-structured method is in between the focused and structured methods and utilizes techniques from both questions that are specified, but the interviewer can explain their answers without affecting the standardization and comparability needed for the analysis (May, 2011).

Therefore, semi-structured interviews were used in this study to standardize and compare the answers from the surveyors and at the same time allow them to talk freely about their opinions about the findings using the HFACS methodology. Therefore this enabled the researcher to compare the answers obtained and at the same time to select the best interviews in terms of the quality of the information obtained and present the results.

The CIT was developed by Flanagan (1954) to collect specific and significant behavioural facts of the persons doing operational procedures and what their experiences have been and how they felt about being interviewed about a job or task that they did before (in this case, the accident investigation). According to Kuada (2012), CIT allows people to be interviewed and to freely describe their experiences and unreservedly express their feelings. For that reason, the critical incident technique (CIT) was used in order to understand the experience of the surveyors that made the accident reports and to get an idea of the process they engaged in.

Inevitably, with this method and technique, some interviews provide more information than others. A comparison of the two methods (structured and focused interviews) is necessary in order to be fully understood, and in the end, each interview will add to the final study (Gerson and Horowitz, 2002). Therefore, accident investigators were encouraged to talk with an emphasis on the incidents or accidents they were involved in, and considered critical because of the outcome or the severity of the accident obtaining the most important information about accident investigations encountered by the surveyors.

4.3 Selection of participants and questions

All the participants selected for the interviews were active Navy Officers currently working in DIRNEA. It is important to mention that in Ecuador, Navy Officers employed by DIRNEA must successfully complete a course specialising in either coast guard or maritime affairs at the beginning or during their careers.

Moreover, their work can be related to the application and enforcement of National Maritime Legislation as a Port Captain, Flag State, and Port State inspector, surveyor, and assessors in the Maritime Authority departments. For this study, all the surveyors interviewed had the Coast Guard specialization and had completed the IMO model courses 3.11 (Safety Investigation into Marine Casualties and Marine Incidents), and IMO model course 3.09 (Port State Control Officer). In addition, 40% of the surveyors interviewed completed the advanced course in Accident investigations.

Two groups of questions were prepared to conduct the interviews. The Annexes provides the details of the questions asked according to the interview. The first group of questions to surveyors, as detailed in Annex A attached hereto, were structured in a standardized format to surveyors. The questions were related to their qualification, different courses related to the topic, experience as a surveyor in regard to the number of investigations accomplished in the last five years, type of accident, type of ships, and methodology used in their job.

After that, the interviewer presented the results of the HFACS methodology explained in Chapter 3, and briefly explained the methodology and results to the interviewees, more specifically, in the findings of organizational and statutory factors. Thereafter, surveyors were free to give their opinions about the study, and experiences of their investigations and some recommendations about the process. In some cases, the interviewer sought both clarification and elaboration of the answers. Finally, the interviewees were asked about the problems or issues they faced in fulfilling their tasks and the recommendations for improvement.

Originally, the intention of this study was to interview only surveyors that did the reports that were analysed. However, it was difficult to find all surveyors in Guayaquil, and the information provided by other investigators was also important. Moreover, after finishing this group of interviews, the author realized that it was necessary to

continue the interviews with the maritime administrators and assessors in charge of the subsequent process after the reports were submitted to the Maritime Authority.

Therefore, assessors were requested to answer the second group of questions listed in Annex B hereto in order to understand the further analysis and process of investigation reports submitted to DIRNEA and the entire process leading up to submission of the reports to the IMO. The assessors interviewed either work or worked in a senior position of the Maritime Authority with the responsibility to receive the reports, analyse them, and make policies or resolutions with the information obtained from the accident reports.

The time taken in each interview and the information obtained depended on the participant; in general, each interview took between 20 to 45 minutes. The questions were related to these topics:

Group one (surveyors)

- a) Forming, training experience, and expertise in accident investigations.
- b) Methodology and methods used in performing accident investigations.
- c) Human and organizational factors found in the investigation process.
- d) Statutory factors found in the investigations process.
- e) Application of the “Stopping rule” in accident investigations.
- f) Recommendations obtained and the follow up process.

Group two (assessors)

- a) Responsibilities and experience in the Maritime Authority.
- b) Opinions about HFACS factors found in accident reports submitted to the IMO.
- c) Opinions about Statutory factors found in accident reports submitted to the IMO.
- d) Opinions about process and methodology applied to accident investigations.
- e) Opinions about being in the same institution to issue certifications and make accident investigations.

f) The subsequent process with recommendations obtained from the surveyor working in accident reports.

4.4 Interview Instrument and ethics statement

The interviews were recorded for further analysis; all participants were volunteers, did not receive any payment for the interview, and consented to the use of the information provided for the study. The quotations used in the results do not have names, positions, and hierarchies of interviewees to maintain anonymity and confidentiality of the information gathered for purposes of the study. Further, to ensure the quality of the interviews, the approval of the Ethics Committee of the World Maritime University was obtained and the Committee certified that all the information used for purposes of the study is verified and trustworthy.

4.5 Data analyses

4.5.1 Interviews to surveyors

For surveyors, six groups of questions were asked. The first group of questions were related to the experience of the interviewees in the maritime sector, their courses, experience as a surveyor concerning the number of accident investigations accomplished by type of ships, and type of accidents.

The results were that all the surveyors receive the courses to be Port State Inspector (IMO model course 3.09) and Surveyor for Safety investigations (IMO model course 3.11); 40% of them completed an advanced course in Accident Investigations; 80% of the interviewees have more than 15 years of experience in the maritime sector, and 70% of the interviewees have more than five years of experience as surveyors (see Figures 12 and 13). In addition, 60% of the surveyors participated in at least one very serious accident investigation in the last five years.

This information indicates that the process and qualification of surveyors according to the National and International legislation, have the experience, background, and foundation studies necessary to successfully carry out their mandate, duties and responsibilities.

Figure 102

Surveyors interviewed experience in the Maritime sector

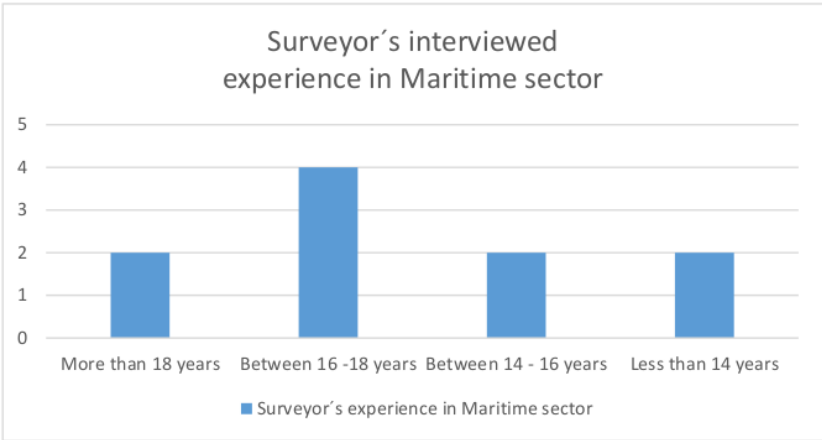
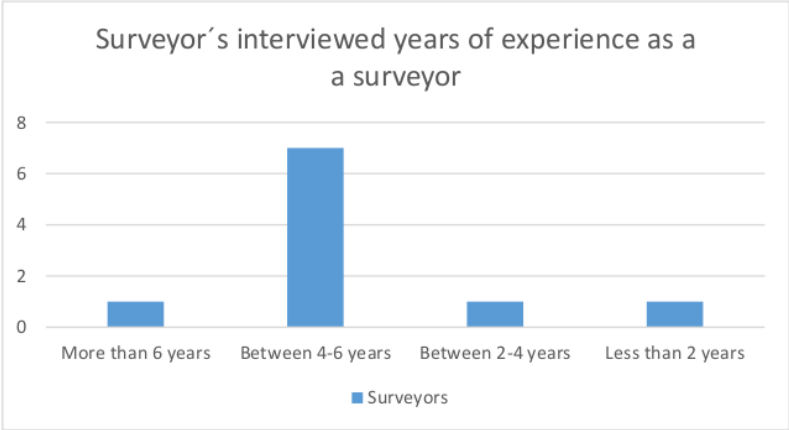


Figure 13

Surveyors interviewed years of experience as a surveyor



The second group of questions were related to the techniques, methodology, and methods used to perform accident investigations. All the surveyors indicate that they applied the Maritime Accident Investigation Manual (DIRNEA, 2014), which is a Guideline created by DIRNEA in 2014 and aligned to the Guidelines of the following two Manuals: 1) The IMO Guideline to assist investigators in the implementation of the Casualty Investigation Code (IMO, 2014), and 2) The Maritime Accident International Investigation Forum Investigation Manual (MAIIF, 2014).

Investigators also advised that before this Manual, they applied the Standards for the Investigation of Maritime Accidents resolution taken by DIRNEA (DIRNEA, 2010), which is based in the Casualty Investigation Code Parts I and II (IMO, 2008).

In general, the surveyors followed the Reason's methodology in combination with a Causal factor charts analysis and the Generic Error Modelling System (GEMS model) to the classification of the basic human error type. Therefore, the author concludes that all surveyors are familiar with Reason's method, and it was easier to explain the HFACS methodology to them.

The third group of questions were related to the findings of 78 3rd tier HFACS factors in the investigation reports analysed by the author and the opinion of surveyors about these findings. The author asks for their opinion about the high quantity of organizational factors found in only eleven reports and whether they found similar factors in the investigations they have carried out.

All surveyors agreed that Human and Organizational factors were commonly observed in accidents investigated before, with the exception of one surveyor that pinpointed organizational factors in the reports. On the other hand, recommendations to address these factors were not mentioned by all the surveyors in the reports. When the question about the reasons for not including recommendations related to organizational factors was asked, some answers were:

"The investigation was directed to the Port Captain with only assumptions of what could happen and it is not the duty of a surveyor to determinate blame or responsibilities of the accident." (Surveyor, four years of experience)

"I found some recommendations related to organizational factors and training (ISM code and STCW Code), but it is not applicable for fishing vessels, so it was not mentioned in the report" (Surveyor, eight years of experience)

These answers demonstrate that surveyors can identify organizational factors but do not put them in their reports because they think that everyone knows the underlying problems (e.g., fishing vessels are not obliged to comply the ISM Code or STCW-F Convention) or they think their job is not important enough and reports are not taken into account.

The next question was related to the *Statutory* factors found in the HFACS analysis. All surveyors also agreed on the importance of identifying these factors in the accident investigation reports, but only 30% of the surveyor's referenced them in the report, and only one resulted in a new resolution being passed by the Maritime Authority and that emanated from the findings of the accident. Some of the answers related to this question were:

"The responsibility of the accident was on the Captain, there was a problem found in a port inspection, but the Captain knew that his ship has this problem, and he solved it" (Surveyor, five years of experience)

"I found a lack of a resolution from the Maritime Authority related to the ship inspection in port, so it was recommended and ended with a new resolution from the Maritime Authority" (Surveyor, one year of experience)

Similar to the question asked before, in this case, surveyors also understand the problems related to the Flag State implementation and enforcement, but they do not put them in the report because they are not seen as part of the institution or they do not trust the process followed after reports are submitted and prefer not to mention those problems to avoid drawbacks.

The next question was related to the application of the "Stooping rule" for the investigation. The "Stopping rule" is a constrain that could be preventable and appears when the investigator stops the investigation too early at the first thing that they find that's gone wrong rather than continuing to investigate other factors or possible causes that provoked that failure. Lundberg et al., (2010) mention this as a deviation of the ideal, *what-you-find-is-what-you-fix* principle for what you are able to fix depends on what you find.

To answer this question, all surveyors indicated that even when the national legislation established a time period for the investigations to be completed (30 days for less serious cases and 45 days for very serious accidents), under the Casualty Investigation Code (2008), they can take more time and it depends on the type of ship and the type of accident. However, it is normal to take the same time (30 and 45 days) because they cannot neglect other obligations. This happens because the surveyors are not in a specific department. Therefore, they continue with their normal jobs in the different Maritime Authority departments while completing the investigation, and they try to finish the investigation as soon as possible so they can continue with their other responsibilities.

In addition, other answers were related to the pressure from the media or shipowners for the application of insurance policies to finish the investigation as soon as possible. This is because the same investigation can have two different purposes, one for

liability and others for safety due to the lack of surveyors available to accomplish investigations. Some of the answers to this question were the following:

"Investigations under National legislation determinate blame or responsibilities and under the Casualty investigation Code are carried out at the same time and sometimes by the same surveyor so at the end there is pressure from the media or insurance companies to finish them as soon as possible" (Surveyor, one year of experience)

"Surveyors are Officers working in the Maritime Authority, and they are selected to carry out surveys when an accident occurs so they have to finish the investigation as soon as possible to continue with their normal obligations and cannot take more than two weeks for an investigation" (Surveyor, six years of experience)

Finally, the sixth question was related to the recommendations obtained after the investigation and the follow-up process of these recommendations. Surveyors interviewed indicated that reports and recommendations are sent to the Port Captain in compliance with the national legislation, and after that, their work is finished because the following process is a task of DIRNEA and the Department of analysis and prevention of accidents in the Maritime Authority. Moreover, all surveyors interviewed agreed to put all the information from their survey available to all interested persons. The answers to this question were:

"The report has recommendations, but it was directed to the Port Captain in line with the National Legislation, after that, it is supposed that the Port Captain has to send the reports to DIRNEA to analyze the recommendations, so in the end, I don't know if the recommendation was taken into account" (Surveyor, five years of experience)

For this reason, it was necessary to continue the interviews with the Officers of DIRNEA who received these reports, analysed them, and made policies or normative to complete the process.

4.5.2 Interviews to assessors

In the second group, eight assessors were interviewed for their opinions concerning the accident investigation process and the problems associated with this process. All assessors are active Navy Officer in senior positions in the Maritime Authority of Ecuador, with more than 20 years of experience in the sector.

Chapter two mentioned the process followed after the surveyor sends reports to the Port Captain. After that, the reports are submitted to DIRNEA, and they are collected in the Accident Investigation Department, whereafter, the Maritime Safety Committee of DIRNEA have monthly meetings to analyse the recommendations made in reports, and these recommendations can result in a new resolution being passed or policy created for the Maritime Authority.

The assessors interviewed are part of this process because they work or worked in one of the following Departments: General Direction, Seafarers Department, Accident Investigation Department, Technical advisory Department, Planning Department, Training Department, and Maritime Safety Committee.

The first question was related to the Human and Organizational factors HFACS identified by the author in the reports analysed more specifically in the findings of organizational factors, and the results presented in Chapter 3. The interviewees agreed on the importance of identifying and addressing the Human and Organizational factors needed in the accident prevention process. Some remarks made by the interviewed were:

"Human Factors are observed by surveyors but not mentioned with an emphasis in the reports affecting the quality of the reports, and this high quantity of factors could be produced by the lack of the mandatory application of the ISM Code in fishing vessels in the country." (Assessor, Seafarers Department)

"There is a lack of experience of surveyors in the investigation of latent conditions in accidents, and the methodology needs to be updated with seminars for the actualization of knowledge at least every five years." (Assessor, training Department)

The answers about fishing vessels are the same as surveyors; they understand that the ISM Code has to be implemented in fishing vessels as well as the STCW-F Convention as soon as possible. They also remark that surveyors need seminars to update their knowledge in the process of investigations, and the surveyors selected for accident investigations should be qualified in the last five years or less.

The second question was related to the opinion about Flag State implementation factors found in the Accident investigation reports and why surveyors did not mention these factors in the conclusion and recommendations. In general, the assessors mentioned that the cause of this problem is the lack of policies and legislation updates for the maritime sector and the coordination difficulties with the institutions in charge of the enforcement of the Flag State and Port State obligations. For example, this was the answer of one assessor that was interviewed:

"There are some statutory problems in the legislation. Safety inspections are divided between two state institutions; DIRNEA makes the inspections for Flag State Obligations and Port State obligations if the ship is at sea. The Sub secretary of Port and Maritime Transport make the inspections for Port State

obligations only if the ship is in port. Therefore the monitoring and control of safety regulations is affected” (Assessor, Planning Department)

The third question was related to the opinion about the process and methodology applied to accident investigations and the problems identified by surveyors who made investigations at the same time to accomplish National regulations and investigations under the Casualty Investigation Code (safety investigations). The answers to this question differed, but mainly confirmed the lack of human and financial resources to be the principal cause of these problems:

“The ideal situation is to do different investigations, but there is a lack of human and financial resources. The process and methodologies are the same, so the same surveyor can carry out the investigation to a certain point, after that he/she can make different reports one for liability and one for the Safety recommendations” (Assessor, Technical advisory Department)

"The Department of Accident investigation in DIRNEA was created in 2017; this was the first step, now we need to amend the National legislation and make different investigations because they have different purposes." (Assessor, Accident investigation Department)

The fourth question was related to the opinion about how Safety is affected if the same institution is in charge of issuing certifications and making accident investigations. In general, the interviewees understood that this is a problem, and there could be a conflict of interest. However, they mentioned that currently, the Navy is a suitable institution with the personnel and resources to accomplish this obligation, and internal changes could help to address this problem. The answers to this question were:

"At the moment, there is no other institution in the country that can assume those responsibilities. We have the experience and personnel qualified to do

both activities. To solve this problem, we use the most experienced and highly ranked Officers in accident investigations and they cannot be inspectors at the same time.” (Assessor, Safety Committee)

“The ideal situation is to have different institutions, but there is no economic or political support to do that. We can issue authorizations to a Recognized Organization, but at the moment, there are not organizations qualified for accident investigation in the country.” (Assessor, Technical Advisor Department)

The next question was related to the application of the "Stopping Rule" too early by surveyors in the accident investigations. The assessors remarked that accident investigations do not have a time limit, but during the investigations surveyors have to continue with their normal work, so the investigation is affected. The answers to this question were:

“The investigation under the Casualty Investigation Code does not have a limit of time, the investigation for accidents under the National Legislation has a time limit so at the end, if we undertake different investigations, the time limit for the first investigation does not apply (Assessor, Accident investigation Department)

“An investigation of an accident cannot have be time bound because there could be new evidence or new technology that helps to clarify the current facts. Therefore an investigation can be reopened or should not continue until all the facts are clarified” (Assessor, Training Department)

The last question to assessors was related to the process followed with recommendations obtained from the surveyors in accident reports. The interviewees advised that all the reports that are submitted to the Department of Maritime Casualties

Prevention and Analysis in DIRNEA are analysed in the Maritime Safety Committee and are important because it assists in the making of new resolutions and policies to solve Safety problems of the country after that they can be submitted to the IMO if it is necessary or required. The answers to this question were:

"DIRNEA is in charge of receiving all the reports, analysing them in the Safety Maritime Committee (of DIRNEA), and if necessary to make new resolutions and submit the reports through GISIS to the IMO. This process is working, and there is an information bulletin with some recommendations obtained from past years." (Assessor, Safety Committee)

"98% of the recommendations provided should finish in a new regulation. The problem is that only one institution by itself cannot make these regulations, bureaucracy affects the process, and we need at least four months for a single resolution" (Assessor, Planning Department)

4.6 Summary and Conclusions

The author in Guayaquil-Ecuador developed eighteen semi-structured interviews with active Navy officers working in Maritime Administration. These interviews helped to clarify and understand the findings of the application of HFACS in the accident investigation reports of Ecuador and some problems related to the investigation procedures. For the data analysis, the interviewees were divided into two groups, the first group consisted of ten surveyors and the second group consisted of eight assessors.

All surveyors and assessors interviewed identify human and organizational factors as important and contributing factors in maritime accidents. This point of view is in line with the IMO, which recognizes organizational factors as major safety factors in maritime accidents. (IMO 2008)

In addition, the interviews helped to understand some organizational and statutory problems and root causes that confirm the HFACS results presented in Chapter 3. These findings and the discussion of the author are presented in the next Chapter.

Chapter 5 Research findings and Discussion

5.1 Research Findings

The research findings (RF) of the study are:

RF1: The Purpose of Safety Investigations is not clear for surveyors

The interviews and literature review demonstrate that surveyors of Ecuador are well trained and qualified to do safety investigations and in theory they understand their purpose, however, when they do their job they act as inspectors with an enforcement view. In some cases, they observe human and organizational causal factors but do not mention them or do not give recommendations to address those problems in the reports. From the eleven reports analysed only one surveyor proposed a new regulation for fishing vessels, it means that in the last 10 years only one report resulted in a new regulation to the Maritime authority of Ecuador.

Safety investigations have the potential to propose a complete change in the law or can motivate and justify the adoption of a new international regulation for the State (e.g. ISM Code or STCW-F Convention for fishing vessels). The reports can also improve the legal standards of domestic legislation and regulations, which is clearly a problem in Ecuador. Moreover, safety investigations can support the process that the DIRNEA is following for the actualization of the maritime laws and policies of Ecuador.

The Maritime Accident Investigation Branch (MAIB) of the United Kingdom for example made 24 recommendations in 2019, of which 20 were promptly and fully accepted, demonstrating the importance of the target of the branch in UK. (MAIB, 2020). In this case, recommendations are sent to change the regulator body, other government departments, merchant vessel industry, fishing vessel industry and many

of those recommendations relate to creating new regulations or amendments to the existing laws and regulations.

RF2: Surveyors are not dedicated solely to marine safety investigations duties.

Safety investigators of Ecuador, are currently part-time investigators, they are assigned to perform safety investigations duties without being replaced in their normal work. This erodes the effective outcomes of investigations because investigators do not carry out their investigator duties properly, as they have to continue with their normal work as soon as possible. The MAIIF Manual (MAIIF, 2014) suggest that “it may be appropriate that suitable personnel should be identified and trained in marine safety investigation techniques prior to being assigned to marine safety investigation duties”.

The interviews conducted indicate that the said state of affairs is caused by a lack of resources and personnel to accomplish this job. However, without the necessity of more resources or personnel, the current process could continue for other kind of investigations (enforcement, liability) and safety investigations could be done by an external department (depending on the Maritime Authority or the Inspector and audit body of the Navy) with one or two surveyors assigned to this task. This department can focus only on the most serious cases (3-5 cases for surveyor per year) and surveyors can be trained and specialize in a specific kinds of accidents.

Moreover, the surveyors of Ecuador can be specialised in accident of fishing vessels, which represent 90% of the national fleet. This is also aligned with the current proactive approach that the IMO is taking on an international level in enhancing fishing vessels safety to save lives and Ecuador could take a proactive action in the IMO proposing changes in accordance with their fishing vessel accidents and investigation experience.

As an example it can be mentioned, the United States where the US Coast Guard has the authority and jurisdiction to investigate all maritime accidents or incidents in their waters or with ships flying their flag. Additionally, the National Transport Safety Board (NTSB), which is a specialized agency that belongs to the Ministry of Transport, has the authority to select the most important maritime accidents and investigate them, analysing an average of 30 maritime accidents per year.

RF3: Independence of Safety is not ensured

Safety investigations expect a higher degree of information to be provided, openness and honesty from witnesses of an accident. Currently in Ecuador, there is not a clear division in the process of safety investigations. The same surveyor is allowed to conduct investigations for actions in civil and administrative proceedings and safety investigations until a certain point. This is due to a lack of qualified personal and economic resources or the perception of the unimportance of safety investigations affecting the outcomes and the reputation of the Maritime authority.

In addition, this process is not adhering to the Casualty Investigation Code (IMO, 2008) Chapter 1.2 about the independence of safety investigations, Chapter 2.11 about the definition of a marine safety investigation, consequently could end in an observation/finding at the III Code audit scheme planned for the country in the year 2022.

Moreover, if surveyors undertake the same investigation with other purposes until a certain point, the people interviewed will provide less information about the causes and circumstances of the accident because they understand that they could be blamed. This can cause the omission of some details involved in the accident.

For example in the United States, the US Coast Guard does investigations as part of the enforcement responsibilities of the country, and the NTSB make Safety Investigations, and both run parallel.

RF4: Outcome of Safety investigations

In Ecuador, investigators submit the reports to the Port Captain as a local maritime authority in accordance with the National legislation and maritime authority resolutions. Captain of Ports are considered a local law enforcement body and are sometimes also active Navy officers with a higher rank than surveyors, therefore the surveyors do not feel comfortable to describe all the causes of the accident because that could affect the reputation of the local maritime authority.

In addition, according to the Chapter 11 of the Casualty Investigation Code, the State shall ensure that investigators carrying out a safety investigation are impartial and objective without interference from any persons or organizations that may be affected thereby.

RF5: Legislation and Maritime Authority

Other contributing factors related to the National legislation and policies that were discovered in the research and affect the quality and depth of the investigation process are:

Safety investigations depend on a National Resolution of the Maritime Authority because the National legislation related to accident investigations is currently being developed and approbation by the legislation authorities of the country.

The Maritime Authority of the country is divided into three institutions dealing with Safety of the shipping industry and environmental protection. Therefore, law

enforcement inspections and surveys are divided between the Sub-secretary of Ports and DIRNEA affecting the law implementation and enforcement.

Fishing vessels are not forced to comply with the ISM Code or STCW-F Convention. Moreover, the National legislation is not updated for this kind of vessel, causing a high rate of accidents related to the training of personnel, human and organizational factors regarding these type of vessels.

5.2 Discussion

Chapters 3 of this study presented the analysis of eleven reports submitted by Ecuador to the IMO with the Human Factors and Classification System methodology. The reports demonstrate the presence of high level of *Organizational* causal factors (29.5% of the total factors. See Table 2). Under-reporting of Organizational factors is a common problem in the maritime sector (Hetherington et al., 2006) but this was not the case in the reports analyzed in this study.

These results are the same to other previous studies with HFACS conducted by students of the World Maritime University from Indonesia (Nurwahyudy, 2014) where the factor of *Equipment facility resources* was a common issue, and Kenya (Osongo, 2017) with 20% of *Organizational* causal factors from the total factors, but differs from the results of Korea (Kang, 2017), where organizational factors represent the third causal factor with 17.7% of the total factors. However, those studies were focused on passenger vessels.

Chapter 4 of this study presented the results of 18 semi-structured interviews done to surveyors and assessor of the Maritime Authority of Ecuador to understand the problems and root causes that cause the high number of these factors in the analysis. There are not other studies that combine the HFACS methodology with interviews. In this study all surveyors and assessors interviewed agreed with the findings identifying

organizational factors such as important and contributing factors to maritime accidents.

Chapter 6 Conclusions and Recommendations

6.1 Conclusions

The application of the HFACS methodology in eleven accident investigation reports from Ecuador resulted in the finding of seventy-eighth third tier causal factors. A high level of organizational factors were observed despite the small quantity of reports analysed.

The results of this study were presented to ten surveyors and eight assessors in the Maritime Authority of Ecuador and helped to understand the problems and root causes of the overall process of investigations.

This chapter presents the conclusions of the study answering the research questions proposed (RQ):

RQ 1: Is legislation in Ecuador adequate and sufficient enough to comply with the Maritime Casualty Investigation Code of SOLAS?

The national legislation of Ecuador needs to be amended; the safety investigation process is regulated by a Resolution of the Maritime authority created in 2010. This resolution is based on the Marine Police Code of Ecuador created in 1958, which provides for procedures to accomplish other type of accident investigations (liability, enforcement). Therefore, the process is affected and safety investigations do not fully comply with the Maritime Casualty Investigation Code of SOLAS.

In the interviews, it was observed that there were some gaps in the independence of safety investigations (Chapter 1.2 and 2.11 of Casualty investigation code). Another gap discovered was in relation to the impartiality and objectivity of the investigation (Chapter 11).

Accidents in fishing vessels need to be analysed in a different context to that of other types of accidents. In Ecuador these types of vessels represent more than 90% of the national fleet and the country is not a signatory member of important international conventions that promote safety in this sector such as the STCW-Fishing Convention or ISM Code applicable for fishing vessels.

RQ 2: Are the current processes and methods for the investigation of maritime casualties and incidents adequate for Ecuador?

The method and process of accident investigations in Ecuador are based on old and outdated resolutions of the IMO. The HFACS methodology demonstrates the need to observe the causal factors in more detail that contribute to the occurrence of an accident to address not only the active conditions that trigger the accident but also the organizational and statutory influences that induce latent conditions for the accidents occurrence.

RQ 3: How can marine casualty investigation reports be improved?

Maritime Safety investigation should be made with the only purpose of preventing similar accidents occurring again in the future. The recommendations of the reports have to be aligned with this purpose, and the findings of the investigations depend on the quality, effort, and methodology used by investigators.

Maritime Accident investigators should be trained and qualified in techniques for safety investigations, the experience and background of the investigators are also important, and finally, to do their job according to the requirements needed, they must have the resources and time necessary to make the investigation.

RQ 4: What should be adopted as best practices for improving ship safety and for reducing the risk of future maritime casualties in Ecuador?

The current accident investigation department and processes can continue in the country for other kinds of accident investigations. The safety investigations department should be separate from the Maritime authority and this department should depend on the Inspector directorate of the Navy. Two or three surveyors should be qualified to handle safety investigations for the most important cases of Ecuador specialized in fishing vessels, merchant vessels and passenger vessels.

The application of the Reason method combined with HFACS in all probability will help to identify organizational causes of accidents and propose more preventive measures or barriers to avoid accidents in all the chain or errors.

6.2 Recommendations

The recommendations for improving the Safety and Accident prevention in Ecuador have different levels: Political-Strategic, Operational-Tactical. However, in this dissertation, the intention is not to mention the high-level recommendations or most relevant requirements that depends on the approval of national legislation by the Government and Maritime Authorities.

The principal recommendations in the Operational-Tactical level for improvement of the accident investigation methodology in the country or other countries with similar problems are:

- 1) Maritime safety investigations should identify not only the active causal factors but also failures that may be present in the whole chain of responsibility. In Ecuador, it is necessary to use a methodology to identify human and organizational factors in the accident investigation process and reports. The HFACS methodology applied to the

Reason's model is an example of this study but also academia has developed and continue developing other models and methodologies that can also help in improving the overall process.

2) The sole objective of a safety investigation into an accident shall be the prevention of future accidents through the discovery of its causes and circumstances. Do not to combine safety investigations with other kinds of investigations in maritime accidents because they differ from their purpose and objectives. Safety investigations have to be done in accordance with the Casualty Investigation Code 2008, which promotes and provides a common approach for the investigation of maritime casualties.

3) Investigations should be conducted by competent, well-trained investigators with the support of an administrative structure. Investigators should work in an independent department of the Navy that reports only to the head of the institution. Safety accident reports should not be sent to the local maritime authority (Port Captain) and when assigned to a maritime safety investigation, such personnel should be relieved of their regular duties, in the context of the investigation, be free from external direction (Casualty Investigation Code, Ch. 11). Finally, they must not conduct an investigation where they themselves may have a conflict of interest.

6.3 Limitations and future research

The main limitation of this study was to the low number of accidents analysed and the high quantity of variables involved. As the quantity of reports submitted by the State to the IMO are limited, it is difficult to identify more patterns of contributing factors when in eleven reports it was found that there were four different kinds of ships and five different types of accident. Future research into the specific types of ship or types of accident is needed in order to confirm the results of this study. However, this study could add value or contribute the current academia despite the limited number of reports analysed.

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Annex A

Questionnaire for interviews with Maritime accident investigators

Topics

- a) Forming, training experience, and expertise in accident investigations.
- b) Methodology and methods used performing accident investigations.
- c) Human and organizational factors are found in the investigation process.
- d) Statutory factors found in the investigations process.
- e) Application of the “Stopping rule” in the accident investigations.
- f) Recommendations obtained and follow up process.

A. Training information.

- 1.- Are you a qualified maritime accident investigator?
- 2.- Where and in what year did you receive the training to be a maritime accident investigator?
- 3.- What approximate time did the training took?
- 4.- Have you completed additional training related to the investigation of maritime accidents?

B. Experience information.

- 5.- How many investigations of maritime accidents have you carried out?
- 6.- What type of ships has carried out investigations?
 - National / International.
 - Tankers / Bulk Cargo / Containers / Fishing
 - Over 300TRB / Over 500 TRB / Over 1000 TRB
 - Over 24 meters long / over 50 meters long / over 100 meters long
- 7.- Have you been part of any international delegation to investigate maritime accidents?
- 8.- What type of marine accidents have you investigated?
 - Very serious / serious / minor

C. Information from investigations conducted

9.- Did you have any limitation / problem regarding resources and means to carry out your investigation?

10.- Did you have any limitation / problem regarding interviews to carry out your investigation?

11.- Did you have any limitation or problem regarding the time to carry out your investigation?

12.- Did you have any limitations regarding material or evidence to carry out your investigation?

D. Analysis of facts found during the investigation

13.- What kind of accident causation models for maritime accident investigations do you know?

14.- What kind of accident causation models do you use for your investigations?

15.- Where an investigator applies the stopping rule for the analysis?

16.- Did you consider organizational factors for your analysis? Why or why not?

17.- Did you consider Flag State factors for your analysis? Why or why not?

E. Results of the investigations

18.- Do you consider that your investigation fulfilled the stated purpose?

19.- What recommendations did you get from your research?

20.- The recommendations were applied?

21.- Do you consider that the investigation found all the causal factors of the accident?

22.- Do you consider that an investigation can be reopened if necessary?

23.- Do you consider that there could have been other external factors to the ship and conditions that could have caused the maritime accident? HFACs

F. Recommendations

24. Are there any recommendations in the marine accident investigation process from your experience as an investigator?

25.- Is there any recommendation on the preparation of reports of maritime accidents?

26.- Do you consider that the reports of maritime accidents should be published to the general public, taking care of the anonymity of those involved?

27.- Do you consider that the country should have a better training process for maritime accident investigators?

28.- Do you consider that maritime incidents (not accidents) should be reported and filed as information for statistics?

29.- Do you consider that the country should have a better statistical analysis process for reports of maritime accidents?

30.- Do you have any other comment or suggestion for the maritime accident investigation process?

Thanks for your cooperation

Annex B

Questionnaire for interviews with Maritime administration Assessors

Topics

- a) Responsibilities and experience in the Maritime Authority.
- b) Opinions about HFACS factors found in accident reports submitted to the IMO.
- c) Opinions about Statutory factors found in accident reports submitted to the IMO.
- d) Opinions about process and methodology applied to accident investigations.
- e) Opinions about being the same institution to issues certifications and make accident investigations.
- f) The process to follow with recommendations obtained from the surveyor in accident reports.

A. Experience information.

- 1.- What is your experience as Maritime Administration Assessor?
- 2.- Do you have responsibilities regarding accident investigation reports and further analysis?

B. HFACS

- 3.- What is your opinion about the HFACS methodology applied in casualty investigation reports of Ecuador and the results obtained in regard to Organizational factors?

C. Statutory factors

3.- What is your opinion about the HFACS methodology applied in casualty investigation reports of Ecuador and the results obtained in regard to Statutory Factors?

D. Methodology

4.- What is your opinion about the process and methodology applied by Ecuador to make accident investigations and how can this be improved?

5.- What is your opinion about being the same institution to issues certifications and make accident investigations. Can this affect the purpose of the investigation?

E. Recommendations

6.- What is the current process followed with recommendations obtained from the surveyor in accident reports. How can this be improved?

Thanks for your cooperation