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An Application of Human Factors Analysis and Classification System to Identify Organizational Factors in Maritime Accidents

By

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A dissertation submitted to the World Maritime University in partial
Fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE
In
MARITIME AFFAIRS

(Maritime Safety and Environment Administration)

2010

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.

吴文卫

29 August 2010

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ABSTRACT

Title of Dissertation: **An Application of Human Factors Analysis and Classification System to Identify Organizational Factors in Maritime Accidents.**

Degree: **MSc**

In maritime history, the shipping maintains a fairly good safety record generally, but still with a number of major maritime accidents occasionally. Maritime accident investigation as the main means to improve the maritime safety is widely used in maritime practice. The need of a well–structured and –classified accident causation model for directing maritime accident investigation is dictated by growing social pressure for the further improvement on the safety record of shipping and the major reform of understanding of human error, a focus on the organizational factors.

The purpose of this paper is to adapt a proper accident causation model with reference to identification of organizational factors in maritime accidents. In connection with the organizational factors in the ISM Code, the desired causation model is adapted on the basis of the renowned Human Factors Analysis and Classification System (HFACS). By applying the targeted model into two specific maritime cases, observations are made as follows: it is positive to apply the adapted model in specific maritime cases in terms of directing the collection of accident data and sufficient and reliable analysis of the accident. The same principle of the adapted HFACS framework can be also applied by the shipping industry for the purpose of reviewing and benchmarking shipping safety performance. The significance of organizational factors in safety performance is discussed as well. In the end, proper recommendations in relation to how to apply such an adapted framework in maritime practice based on the remarks above are made.

KEYWORDS: Organizational Factors, Causation Model, Human Factors Analysis and Classification System (HFACS), the International Safety Management Code.

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LIST OF ABBREVIATIONS

CMSA	China Maritime Safety Administration
ETTO	Efficiency-Thoroughness Trade-Off
GISIS	Global Integrated Shipping Information System
HFACS	Human Factors Analysis and Classification System
IACS	International Association of Classification Societies
ICS	International Chamber of Shipping
IMO	International Maritime Organization
ISF	International Shipping Federation
ISM	International Safety Management
JAIC	The Joint Accident Investigation Commission of Estonia, Finland and Sweden
PSCO	Port State Control Officer
SMS	Safety Management System
SOLAS	The International Convention for the Safety of Life at Sea
MCA	Maritime and Coastguard Agency
WYLFIWYF	What-You-Look-For-Is-What-You-Find

Chapter 1 Introduction

1.1 Background

It is widely acknowledged that the shipping industry carries 90% of the globe trade. In particular since the 1970’s, the amount of goods actually carried by ships has increased dramatically and reaching 8.02 billion tons of goods loaded in 2007 (IMO, 2009). Strong demand for maritime transport services fuelled by growth in the world’s economy and international merchandise trade is still continuing.

Thanks to the constant endeavours of the rapid development of technology in ship design and navigation aids, the shipping industry still maintains a fairly good safety record, nevertheless, there are a number of challenges for maritime safety (See Figure 1) (Hetherington, Flin & Mearns, 2006). Major maritime disasters occasionally take place around the world, such as the Titanic disaster in 1912, the *TORREY CANYON* in 1967 and the *ESTONIA* in 1994. Perrow (1999) refers to these events as “the normal accidents” with the view that multiple and unexpected interactions of failures are inevitable. The enormous loss of life and property, as well as the environmental damage, involved in shipping casualties, demonstrated the need of constant improvement in maritime safety.

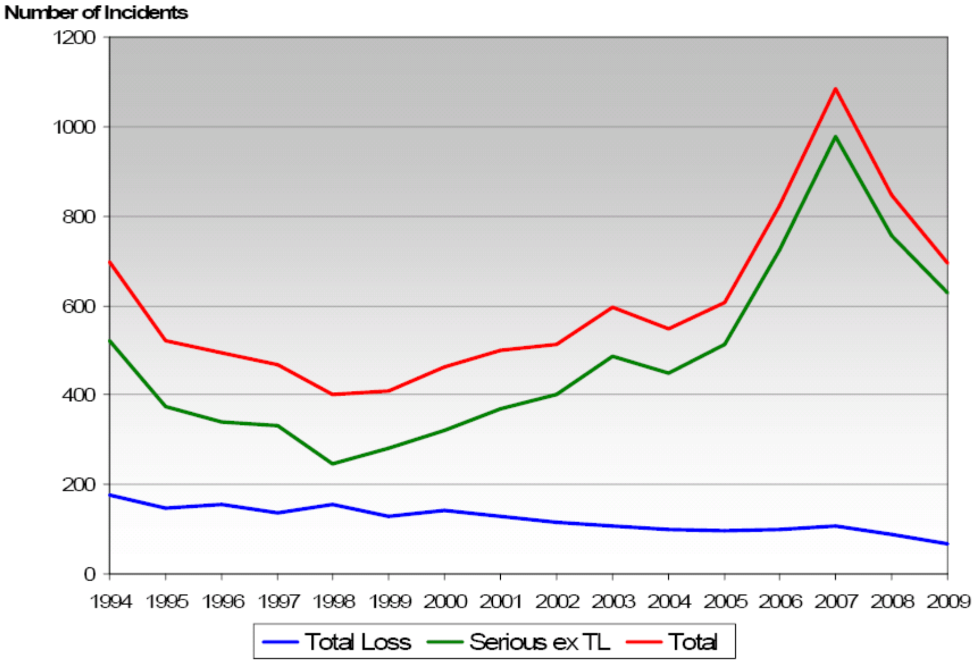

Figure 1 Serious and total loss from 1994 to 2009 by number (Ships over 500 GT)

Source: International Union of Marine Insurance, 2010.

There are numerous diverse approaches to be applied to improve safety performance on board. Accident investigations, as required by the Casualty Investigation Code (IMO, 2008a) and implemented by the majority of states (such as the United Kingdom by the Merchant Shipping Act 1995), is one of several widely utilized approaches to achieve safety (Harms-Ringdahl, 2004). According to Harms-Ringdahl's argument, accident investigation is the "collection and examination of facts related to an occurred specific event". By this definition, we clearly see the purpose of accident investigation is to diagnose what occurs in the system. Even more meaningfully and pragmatically is that the lessons learned from accident investigation should be conducive to prevention of reoccurrence, as stated in the Casualty Investigation Code (IMO, 2008a). Along with this useful and positive function, most major improvements or modifications to a maritime legislative system, criticized as the "disaster-driven system", are often carried out after lessons learned from major accidents (Jalonen & Salmi, 2009). In addition, from the risk assessment point of view, the analysis of an accident plays an indispensable role for setting priorities and identifying hazardous sources (Swedish Rescue Services Agency, 2000). Albeit its passive pattern, the lessons learned from accident investigation contribute a lot to the safety record of the maritime industry. However, most of the current maritime accident investigation systems encourage investigators to determine what happened during an event and how the event occurred, rather than question why the event occurred (ABS Consuliting, 2005). This negative aspect of the current system discourages investigators to search for underlying factors behind the accident (Schröder, Baldauf & Ghirxi, 2009). To shun this negative influence, a better understanding and workable analysis causation model to direct accident investigation methodology is an alternative need.

On the other hand, in order to better understand the concept of “human error” or “human factor” and the accident, the need for an appropriate accident causation model becomes clear. It is generally recognized that human error is attributed to the majority of maritime accidents (Harrald et al, 1998; Trucco, Cagno, Ruggeri & Grande, 2008). Each year in the maritime industry, financial loss caused by human error is far more than 400 million pounds in the forms of ones’ loss business, jobs and ruining reputation, or even spending the rest of life in prison (UK P&I Club, 2003).It is easy to off-hand attribute the accident occurrence to the human error or human factor. However, the terms “human error” and “human factor” are often exchanged in the safety industry but without distinguishing the meanings of these labels. Even to the professional accident investigators among transportation administrations, there is no such thing as a professional usage of the human factor but a spectrum of meanings (Korolija & Lundberg, 2010). The negative way people understanding human error or the human factor always pushes them merely to assign the liability of the accident to the “bad apple” (Dekker, 2002, 2006) in hindsight. Often, investigators also tend to identify the person who seems to be the most responsible for the accident, but leave the root cause hidden. This phenomenon often takes place in maritime industry (UK P&I Club, 2003), where large numbers of examples can be found in maritime history, such as the *PRESTIGE* pollution incident in 2002 and *HEBEI SPIRIT* disaster in 2007 where both captains were blamed for their so-called negligence even though they had made reasonable efforts to prevent the accidents. However, from the perspective of the preventive measures, a change of human behaviour through selection of better personnel, will be of little avail and no well-controlled study convincingly shows that a decrease of accident rate can be achieved by general safety-training or motivation programs (Wagenaar & Groeneweg, 1987, p.587) .

In fact, the concept of human error in industrial environments and transportation systems appears to be far more sophisticated to interpret than simply blaming the operator (Reinach & Viale, 2006). Recently, however, the increasing research (Brown & Haugene, 1998; Gordon, 1997; Kongsvik, Almklov & Fenstad, 2010; Reason, 1990, 1997; Schröder, Baldauf & Ghirxi, 2009; Wagenaar & Groeneweg, 1987) has intimated that in consideration of human error, organizational factors are in need to be specially taken account of. Time has come to accept these methods that control safety performance other than by simply telling frontline operators not to do stupidly. For instance, the high-value “Swiss cheese” model created by Reason (1990; 1997; 2008) in better comprehending the accident, divides the failures in organizational accidents (in sharp contrast to individual accidents) into two groups: active failures at the sharp end and latent failures at blunt end. Woods, Johannesen, Cook and Sarter (1994) further defined the relative connection between sharp end and blunt end that failures made at the sharp end are determined by those at blunt end. Reason’s model (1990; 1997; 2008) has been highly appreciated by a large number of researchers. One of them is Barnett (2005) who noted that the contributions of such a model make the determination of a single cause for any accident virtually impossible, despite the shortage of practical application (Wiegmann & Shappell, 2001). In maritime industrial practice, the United Kingdom’s Maritime Administration (IMO, 2004) has highlighted a group of findings from a number of accidents associated with the deficiencies of the ISM Code, which primarily deals with standardizing the organizational control in the safety field. We have learned from this research, e.g. Brown & Haugene’s work (1998), that organizational factors are essential for accident analysis in accident investigations, particularly in the maritime industry where the ISM Code needs to be considered.

In our routine practice of maritime accident investigations, a proper accident causation model is needed in order to fully consider all the possible factors which may influence system failures. This causation model will not only help investigators to conceptualize human error in an appropriate manner, but also direct data collection and accident analysis. In addition, the elements of the ISM Code are highly directive to those factors influential on safety performance. What are the roles of the organizational factors in the context of maritime safety? What is a proper accident causation model incorporating the elements of ISM Code? Is such an adapted accident causation framework applicable in specific maritime cases? In response to the above questions, this paper has been developed by combining the proper academic theories and their empirical applications.

1.2 Objectives of the study

This study attempts to achieve the following objectives:

1. Describe the organizational functions of the ISM Code;
2. Discuss the feasibility of establishment of the connection between the selected causation model and ISM Code;
3. Adapt a proper accident causation model incorporating the elements of the ISM Code;
4. Test the applicability of adapted accident causation model into two specific cases;
5. Discuss the role of organizational factors in the context of maritime safety;
6. Discuss the verification of the adapted causation model;
7. Make some recommendations on how to apply the adapted causation model.

1.3 Methodology

In order to achieve the above described tasks in the given time period, the selection of proper methodology is necessary. The commonly used research methodologies can be generally be divided into two groups, namely quantitative methodology and qualitative methodology, each having its pros and cons. In contrast to the qualitative methodology, the quantitative methodology is often preferred by decision makers in practices due to its easy of application and readiness in terms of figures and graphs. Challenging in applying the qualitative methodology into practice, e.g. the lack of sufficient theoretical foundation, increases the difficulties in application of the qualitative methodology.

Despite these difficulties, the qualitative methodology has been decided to be the prior option for this research due to the fact that some sensitive accident reports or details are unlikely to be exposed to public scrutiny. The lack of sufficient accident reports may impair the accuracy of this research or even make this study void. In addition, the construction of mathematical models for the quantitative approach is a demanding and time-consuming job which may not be practically completed within a couple of months.

Given the introduction of the background, human error, as the predominant cause of marine casualties, it should be interpreted as the factors not only related to the operator’s error at the proximal end, but also associated with the organizational factors at the remote end. All the possible factors in relation to the event failure should be taken into account in the causation model below.

In searching the required accident report, two criteria for determination are in need of consideration. Firstly, the investigation should be completed and the accident information should be released as reasonably as it should be. Secondly, one is suggested to be more sophisticated than the other. Hence, two accident reports have been selected randomly under the two criteria aforementioned. The first case locks on to the historic disaster of the foundering of the vessel Estonia, leading to 852 deaths and the sinking of the vessel, mainly relating to human error apart from some technical failures exposed. The application attempts to shun any new source of evidence aside from the facts revealed by the official report. This paper tries to provide the comparison of different approaches on their applications, as well as the same in the second case regarding the QINGFENG 128 flying Chinese flag which collided with a constructing bridge, an accident that led to 4 deaths.

During the period of searching for the literature material to establishing the essential theoretical basis, the author was heavily shocked by two phenomena: firstly, the few sources of maritime studies on theoretical development associated with maritime safety issues in comparison to other industries; in particular most articles on maritime issues have been written decades ago. Even in response to the compulsory report to IMO, the database in GISIS proved conclusively to be insufficient, specifically that inadequate relevant details were released in the submitted reports (IMO, 2010). It seems that the maritime industry lacks motivation to do academic research on this issue. This may be one of the reasons why the theoretical development has often lagged behind other transport sectors, especially the aviation field. Secondly, as for the accident reports, the sensitive/shamefulness makes the authorities unwilling to fully open the information to the public. The Academic researchers often complain about the lack of any complete and structured accident database, which heavily impedes the development speed of a safety theory in the maritime industry. In contrast, most of the aviation reports have been published with more details and less hidden information. This is one reason why more and deeper research is carried out in aviation safety rather than maritime safety.

In spite of these negative issues, the author has still managed to make more endeavours to reach a valuable and workable result for the maritime industry.

1.4 Limitations of the study

Not only the learning from an extensive range of literature reviews, but also the author’s empirical opinion gained from a decade of work and study involved in profession of maritime accident investigation in administration is applied to this study. The accuracy of this study is constrained by the extent of how vast and deep the literature review is and how far the author will conclude experience from practice.

Furthermore, the limited quantity of case studies also reflects the constraints of this study. In order to further validate the findings from this paper, further studies need to be considered.

1.5 Plan of the study

This dissertation is mainly divided into six main chapters. The first chapter begins with a preliminary explanatory background of the topic giving the motivation for and methodology of this research. The prevailing ISM Code dealing with organizational control in terms of safety performance is discussed in Chapter Two, followed ´by the identification of organizational factors in the ISM Code in connection with the causation model. After that, the selection of a proper causation model is determined on the basis of certain given principles. In consideration of the practical situations of maritime accident investigation and organizational factors in the ISM Code, the selected causation model is adapted so as to apply it in practice. Chapter Three contains two case studies, representing a complicated and a simple case. These case studies start with a summary of the official report, facts and analyses, then gives the re-analysis of cases by the new framework perspective. Some findings in short are observed from the applications described at the end of each case study followed by the subsequent discussion. Chapter Four discusses the findings in terms of roles of organizational factors. In Chapter Five, the verification of the new developed framework is discussed. Last but not least, the concluding parts are placed in Chapter Six, followed by some recommendations on how to apply the new model in practice as perceived through the applications.

Chapter 2 ISM Code and HFACS model

In order to verify an accident causation model in specific cases and assess the role of organizational factors in the maritime context by employment of such a model, proper theoretical foundation and an appropriate accident causation model need to be established and determined with reference to the organizational factors. The International Safety Management (ISM) Code (IMO, 2002) which aims at enhancing the safety performance on board by consolidation of organizational functions, is described and reviewed in this chapter, as well as the identification of the organizational factors in the ISM Code. Then, its connection in terms of the organizational factors with the targeted model is established. In addition, a proper accident causation model is selected, adapted and adopted in consideration of its aim to address the significance of the organizational factors in the maritime context.

2.1 The International Safety Management Code

The lessons learned from serious accidents during the 1980s, such as the *HERALD OF FREE ENTERPRISE*, pointed out the importance of organizational factors and that impact on accident casualties. In particular poor management plays a central role in these accidents (Whittingham, 2004, p.120; IMO, 2005). To meet the needs of addressing overall organizational functions, the ISM Code was adopted in 1993 by IMO Resolution A.741(18) (IMO, 2005). In sharp contrast to much other maritime legislation, the ISM Code specifically focuses on the management of people and processed in the maritime industry, perhaps for the first time.

The implementation and enforcement of the ISM Code resulted in a dramatic improvement in safety and environmental performance of the industry (Figure 2), impressively with growth in the volume of the world fleet by almost 50%. (ICS & ISF, 2010). This appealing result was supported by an assessment to the impact of the ISM Code on the safety of ships by IMO three years after implementing on the remaining world fleet (IMO, 2005). As a specific case, the assessment of the effectiveness of the implemented ISM Code in the Greek fleet further justified its positive control on organizational factors in the shipping industry by analyzing the factors related to human error by scrutinizing all accidents over the pre- and post-ISM period (Tzannatos & Kokotos, 2009).

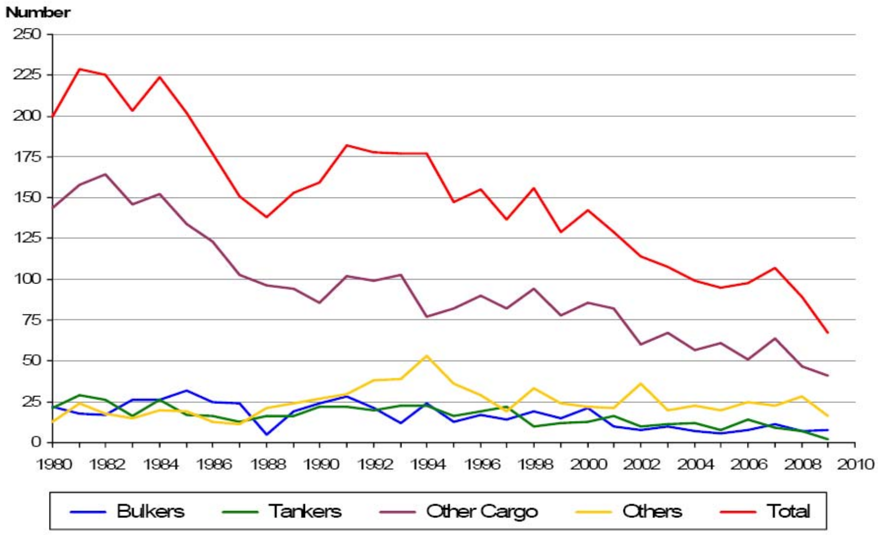

Figure 2 Reduction of Total Ship Losses by Number (Ships over 500 GT)

Source: International Union of Maritime Insurance, 2010

The ISM Code itself is a thin document seeing that it is functional in outcome rather than in process (Trafford, 2009), an indication of the need for flexibility and adaptability in its implementing process (ICS & ISF, 2010). The overall objective of the ISM Code is to encourage the shipping companies to establish the Safety Management System for safety compliance with relevant international regulations. The required Safety Management System shall constitute the company’s safety and environmental protection policies, instructions and procedures for the safe operations of the vessel, procedures for the reporting of reporting accidents and non-conformities, procedures to prepare for emergency situations as well as for internal audits and management review (Pamborides, Holman, Fenwick & Willan, 1996).

The explicit requirement of prevailing risk assessment has been incorporated into the new amendments of the ISM Code which have entered into force by 1 July, 2010 (IMO, 2008b). In compliance with the Code, the Company is obligated to establish proper procedures to assess and manage all identified risk on board in relation to the safety operation in a proper way as thorough and detailed as possible. The requirement of risk assessment should be seen more than only paper document and work to be done by the company.

The ISM Code itself is regarded as a piece of a legal “umbrella” (Herbert-Burns, Bateman & Lehr, 2009) with a coverage of all the requirements on the vessel and further extends the full responsibility to its company for safety compliance. It has been noted that the innovative idea of involving management into shipping at the legal level was inspired by large amounts of findings of a series of disasters from which the authorities observed the absent function of management as the chief factors which led to the accidents. It highlights the organizational controls in contribution to maritime safety. By all means, *inter alia*, the legal requirements and the unwritten or written guidance formulated from the long-run best maritime practice and common sense, the company is obligated to ensure that the ship is in a seaworthy condition at the commencement of its voyage. These elements in the Code provide us with a reliably legal reference for analyzing the organizational factors in the context below. In the case of a response to the contingency plan, for instance, crew members are instructed to follow the procedure described in the contingency plan. If they fail to prevent the occurrence or minimize the consequences by observing the procedure, the management level is responsible for realizing such an incremental need of perfecting such a procedure in terms of effectiveness and quality. On the other hand, if the crew does not follow the procedure or follow the procedure in a proper manner, further improvement should be made to enhance the education or training of the crew for the familiarization of the contingency response by the company. In other words, the company should ensure that its employees follow the proper instructions so as to complete their performance well, and in the case of contingency, appropriate measures are taken to mitigate the potential consequence in which the loss of life or property may occur. The organizational factors at the remote end always go along with their influence on the proximal operation in accordance with the stipulations in the Code. The management at each level of the organization should therefore be aware of the importance of their functions; any tiny mishap of which may lead to a disaster at the sharp end, and take care of the ship with due diligence. Such emphasis of the fundamental function of organization in the ISM Code constitutes the legal framework to assess the role of organizational factors in maritime industry performance. This is further discussed in detail below.

2.2 Identification of the organizational factors in the ISM Code

To justify as to whether the organizational factors are properly functional or not, or whether the responsible company acts in a reasonable or prudent way, in terms of Safety Management System, depends on the following two elements: firstly, whether the company has established an appropriate Safety Management System, and secondly, whether the company takes proper actions to ensure the effective running of the system. To clarify such questions, the identification of the organizational factors involved in the Code becomes more than necessary.

In order to establish the linkage in relation to organizational factors between the ISM Code and the selected model to be used, the general organizational function of the ISM Code can be grouped into two categories: organizational influences which represent the latent failures at the organizational level and further end away from the seafarers end within the hierarchy of organization and supervision, on which the top organization relies to fulfil its overall objective. Moreover, having been inspired by the classification approach in Reason’s model (1990; 1997; 2008), the organizational influences can be further divided into three sub-groups: resource, climate and process, while the supervision factors compose four families: inadequate supervision, planned inappropriate operations, failure to correct a problem and supervisory violations. More details about these factors are discussed in section 2.4 on how to adapt the accident causation model.

In scrutinizing the context of the ISM Code, this has been stated in the form of general principles and objectives as argued above. This leads to the divergent interpretations of the elements in the Code. Thereby, IACS made its unified interpretation available for industrial reference to facilitate the Code's implementation (IMO, 1995). Anyhow, whatever the interpretation is, the involvement of the organizational factors in the context is sure. The real context to stipulate in detail what the outcome shall be made begins with element 2, concerning the company's safety and environmental protection policy, while element 1 refers to the associated definitions and general requirements to its applications. In element 2.1, the company is obligated to set a safety and environmental protection policy addressing how to achieve the overall objective of SMS, while all means shall be taken into account of the effective fulfilling of the company's policy at every level as its general legal obligation.

In the following element, the company shall not reduce its assumed responsibility imposed by the Code to be in control of all associated activities. The level of the authority and lines of communication in relation to the safety operation shall be clearly defined and documented by the company. A designated person shall be appointed and ensured to be acted as a linkage between top management and its ship, in order to ensure the sufficient resource support the board and monitor performance of each ship by element 4. Besides, adequate resources and shore-based support from the company shall be made available to the designated person for his complete performance. Both full responsibilities and authorization of implementation and verification of the requirements shall be authorized to the master by the company on its behalf (element 5). The seafarers manned by the company on board, in particular the master, are required to be qualified, certified and medically fit, with adequate ability of understanding the related rules and effective communication. Effective updated training shall be proceduralized and given to meet the need of seafarers' proficient performance (element 6).

The entire key operations on board shall be identified and assessed in advance and documented with preparation of plans and instructions to standardize its critical shipboard operations. In addition, each operation shall be assigned to the proper personnel (element 7). Element 8 of the ISM Code stipulates the possibility of the company to prepare corresponding measures for capping any possibly potential threat. It has been noted that with its responsibility the company shall identify all possible sources of potential threats and establish proper procedures to reduce the possibility of conveyance of the potential threat into practice, plus programming some appropriate associated exercises and drills.

Element 9 provides the system with an ability to self-learn and improve. Corresponding procedures to report non-conformities and accidents and corresponding correction measures shall be established for the purpose of monitoring its performance and enhancing its ability to self advance. One of the innovations of the ISM Code requires record keeping for routine ship maintenance which shall be in line with the relevant regulations, including ensuring the routine inspections, and reporting and correcting deficiencies. The company shall ensure that the critical equipment and system be recognized and all possible measures ought to be taken to the incremental reliability of the equipment and system.

The last two elements stipulate that the documentation and internal safety audit within both the ship and the company itself shall be carried out in accordance with the requirements of the Code. The company shall ensure all the relevant and updated documents are available on board. The internal safety audit provides an opportunity of review and correction to perfect the SMS.

The above analyzed organizational factors in contributing to maritime safety are introduced in Table 1. In addition, as mentioned above, a structure to define the organizational factors is given in the table as well. The table gives a short description of each element in the context of the Code and a brief organizational function of each element.

Element	The ISM Code Descriptions	Organizational functions
2.1	Statement of company's policy.	Climate.
2.2	Implementation and maintenance of policy.	Climate.
3.1	Report its responsible company to authority.	Climate.
3.2	Responsibility, authority and interrelation of related personnel.	Resources and process
3.3	Adequate resource and shore-based support.	Resources.
4	Designated persons.	Resources, climate and inadequate supervision.
5.1	Responsibility of the master.	Climate and Inadequate supervision.
5.2	Overriding authority of the master.	Climate and Resources.
6.1	Qualification of the master.	Resources and Process.
6.2	Seafarers' qualification.	Resources and Process.
6.3	Procedure of new assignments.	Process, and shipborne and shore supervision.
6.4	Seafarers' ability to understand the rules.	Resource.
6.5	Training requirements.	Resources, process and planned in appropriate operation.
6.6	Linguistic requirements to seafarers.	Resource and planned in appropriate operation.
6.7	Effective communication capability of personnel.	Resources and planned in appropriate operation.

7	Plans for shipboard operations.	Process and planned in appropriate operation.
8.1	Identification of potential threats.	Process and planned in appropriate operation.
8.2	Drill and exercises.	Process and planned in appropriate operation.
8.3	Measures to respond the hazard and accidents.	Process and planned in appropriate operation.
9.1	Non-conformities and accident report.	Process, failed to correct known problems and Supervisory violations
9.2	Implementation of corrective action.	Process and failed to correct known problems
10.1	Statutory maintenance.	Process and planned in appropriate operation.
10.2	Routine inspections.	Process and planned in appropriate operation.
10.3	Specific actions to the system failures.	Process and planned in appropriate operation.
10.4	Routine maintenance and test.	Process and planned in appropriate operation.
11.1	Procedure to control documentation and data.	Process.
11.2	Updated and available documentation.	Resources.
11.3	Effective control of documentation.	Process.
12	Company verification, review and evaluation.	Process, failed to correct know problems and supervisory violations.

Table 1 An overview to the function of the ISM Code in terms of the organizational factors.

Source: Author.

2.3 The selection of the accident causation model

The selection of the accident causation model for this study should be determined on the basis of its capability to meet our requirements and preferences. Both the theoretical and pragmatic concerns should be considered concerning the organizational factors. By and large, in accordance with the discussed norms of a systemic model (Leveson, 2004) that is in parallel with Hollnagel's (2009, p.10) three standards of a 'good' cause as well as ten criteria proposed by Benner (1985, p.113), the causation model being chose should preferably be:

1. Adequately burgeoned theoretic foundation to support the model's adaptation, i.e. with a sound basis from safety management theory (particularly the organizational factors indicated in Chapter 1) and accident analysis theory.
2. Structured and classified, i.e. clearly define the interaction of classified components at the divergent levels.
3. The selected model's applicability enough to cap all maritime accident and incident data. This means, the framework of such a model should be adequate to accommodate all underlying accident factors in its application.

In searching for the desired model, the author found the traditional models often used in practice to analyze accident investigations do not fit the three norms above, as the literature review (Lundberg, Rollenhagen & Hollnagel, 2009, p.1310) on investigatory manuals of eight Swedish organizations which rely on linear models demonstrated the need of more systemic models in practice. Fortunately, a proposed accident causation model, namely Human Factors Analysis and Classification System (HFACS) model (Shappell & Wiegmann, 2000; 2003; Wiegmann & Shappell, 2001), initially developed for the U.S. Military on the basis of Reason's model (1990; 1997) system, meets the demands above.

It has been learned that the HFACS framework bridges the gap between theory - its original model - Reason's model (1990; 1997) and practices by providing investigators with a "comprehensive, user-friendly tool" for identifying and classifying the human causes of accidents (Wiegmann & Shappell, 2001; Shappell & Wiegmann, 2003). Such an incident analysis approach supported by a structured taxonomy captures the range of active failures at the proximal side and latent conditions at the remote side. This is why it prevails in the aviation field (Dambier & Hinkelbein, 2006; Gaur, 2005; Wiegmann & Shappell, 2001) and a variety of other industries such as mining, oil, manufacturing, and medicine. For the maritime industry, Celik and Cebi (2009) have proposed an analytical foundation for such a model quantitatively characterizes the role of latent human errors by extending such a model in a fuzzy environment to investigate shipping accidents. Its findings pinpoint human error as contributing factors at different levels of the organization. The HFACS model, after adaptation, was applied on a group of 41 accident investigation reports concerning machinery space fire and explosion by Ghirxi (2008). Its results have disclosed the need to investigate organizational factors which should be taken care of as important as the technical failures in maritime accident investigation.

Thereby, the HFACS model chiefly aims at solving the organizational factors in line with the ISM Code, but in different ways. The following section focuses on how to adapt the HFACS model in combination with the organizational factors identified in the ISM Code in order to optimize its applicability in specific cases.

2.4 Integrate the ISM Code into Human Factors Analysis and Classification System model

Since the similarities between the Reason’s model adopted by IMO (1997) and the HFACS model and the linkage between the ISM Code and HFACS model have been established previously, the possibility of applying the HFACS model in maritime accident analysis becomes clear. To ensure all maritime factors involving the HFACS model, and merging all the organizational factors defined in the ISM Code into the HFACS model, the need to address the proper adaptation of the HFACS model, which was originally designed for aviation, becomes necessary. The next section describes the revised HFACS model while considering Ghirxi’s (2008) adapted framework and its origin from the US. Department of Defense (2005) in hopes of being faithful to its origin and being practicable. The adapted model includes five levels of failures: unsafe acts, preconditions for unsafe acts, unsafe supervision/workplace factors, organizational influences and social environment influences, as explain below:

Unsafe Acts. The unsafe acts of seafarers can be generally categorized into two groups: *errors* and *violations* (Reason, 1990). Errors, as the nature of the human being, constitute skill-based, decision and perceptual errors, while the violations include routine and exceptional violations. These unsafe acts are directly or indirectly influenced through certain middle parts by the organizational factors which more likely endanger the sharp end.

Skill-based errors refer to the failures without significant conscious thought. Within the context of the maritime field, a lot of actions formed by conventional or long-term practice are very vulnerable considering the fact that they always suffer from the lack of attention or memory failure. During the safety patrol to pipe connection operation before pumping oil to shore side, skill-based errors happen often in ticking the checklist by assuming everything is perfect. Decision errors are occurred when a problem is not well understood, and formal procedures and response options are not available within SMS. In the maritime context, vessels when visiting some ports without any knowledge about the local meteorological conditions often need a pilot to service berthing for the purpose of avoiding decision errors. Perceptual errors take place comparative less often than skill-based and decision errors in the maritime realm. Such factors are in a mishap when failure occurs in the perception of an object, threat or situation, resulting in a sluggish response to the action.

Routine violations appear to be acceptable in a situation where no sanction or action could be taken to prevent their occurrence. A proper lookout is often absent during navigation under low visible condition due to insufficient manning, however, such a violation may not always lead to accidents. Routine violations happen on board with the situation where the SMS does not follow all requirements of ISM Code, an indication of something wrong in its manuals or procedures without coverage of all the compulsory requirements, or their implementations. For instance, the internal interval audit requires the line management to verify, review, analyze and correct deficiencies and non-conformities on board, including such violations. There may be some reasons for such violations, such as time pressure or deficiencies in the procedures. However, for the shipping company, the tolerance of the routine violations is assumed to be zero so that such violations will not be accumulated until the accident occurs. As to exceptional violations, it may be attributed to the speculation that operators assume these violations may not lead to a disaster. For instance, vessel's violation may be made by crossing the prohibited water area for a short voyage against the time pressure.

The identification of unsafe acts has been proven to be fundamental so as to determine who will be liable for the disaster, in particular in the event of involving technical failure or unexpected meteorological circumstances. On board, even well-prepared contingency plans cannot cover all emergency situations. Therefore, seafarers are required to be able to make a proper and timely response with no procedure to refer to. It is notable that currently people tend to off-handly attribute the failure to human error in the end with an ignorance of the fundamental role of technical failure and managerial deficiencies. Given that the crew has exercised due diligence in their responsibilities, in the event of exceptional stormy weather, people at the sharp end are in the realm of possibility to be blamed for their unsafe acts to respond to the emergency, even though this may be due to, at least partly, the technical failure being triggered by an unexpected storm.

Preconditions for unsafe acts. This step provides deeper analysis than the unsafe acts on the internal or external circumstance that makes unsafe acts more likely to happen. Exploring the preconditions for unsafe acts allows us to understand the factors behind the unsafe acts. The preconditions for unsafe acts are divided into three categories: *condition of crew members; environmental factors and personal factors*.

Condition of crew members can be classified into two groups: cognitive factors and physiological state. Theoretically, both the cognitive factors and physiological state play fundamental roles in driving people to commit unsafe acts. These factors vary from diverse people at distinct stages and are not easy to be observed and studied, especially in some cases where no seafarer concerned survives. In most maritime cases, no such *condition of crew members* could be investigated unless such factors stand out from the effect of unsafe acts. In accordance with *the HFACS Quick Users Guide* by U.S. Department of Defense (2005), 8 types of factors, like inattention and distraction, affect the cognitive factors, with a total of more than 47 types of conditions, including but not limited to fatigue and motion sickness, are considered in the realm of possibility to make the personal physiological state dysfunctional.

Internal environmental factors are primarily divided into two groups, the physical and the technological environmental factors. The physical environmental factors contain the internal in which the seafarer works and operates. The technological environment normally looks into the technological condition of ships, including the workspace design and equipment technological condition, depending upon what sort of accident is being investigated.

Personal factors are traditionally divided into two staple categories: crew interaction and personal readiness. Crew interaction among the bridge team is a symbolic factor when investigating a collision case. In particular nowadays, the increasing presence of multiple-national seafarers has emphasized the importance of crew interaction in bridge management. In addition, personal readiness shows the extent to which the seafarers are familiar with the fresh situations. In the ISM Code, the responsible company is required to ensure the adequacy of familiarization with the new position on board. Lack of personal readiness should not be interpreted as violation.

Unsafe supervision/workplace factors. At this level, four categories of unsafe supervision have been tagged, namely *inadequate supervision*, *planned* *inappropriate operations, failure to correct a problem and supervisory violations*. Failure occurring at this level mostly refers to the management level on board which directly affects and is approached by the organizational factors. The top management intensively relies on this level to realize its management objective in the ISM Code on board; the factors at this level are thereby highly related to the organizational factors in the ISM Code at a higher level.

Inadequate supervision principally refers to the shipborne and shore supervision of operations on board. One of the responsibilities required by the ISM Code of the master is verifying that the specified requirements are observed. By the company's documented definition of the master's responsibility, the master on behalf of the company monitors and supervises the ship's performance together with other senior officers' on board. In some cases, it shows the lack of supervision by the master to approve and scrutinize the planned route leading to a grounding accident (Brown & Haugene, 1998).

Planned inappropriate operations mainly address the shipborne operations that are required by the ISM Code to the company which is due to maintain adequate and proper procedures and plans of shipborne operations. Any inadequate or improper procedures or plans of shipborne operations may increase the possibility of the onset of an unsafe act, ultimately resulting in accidents. These operations include the emergency preparedness on board as required in element 8 of the ISM Code for instance.

Failure to correct known problems just reflect one of the most elementary features of the SMS. The system requires the company to establish proper procedures to report non-conformity and mishaps, and also trace such a deficiency until it is corrected or mitigated at a satisfactory level. Within the ship, proper procedures should be established and exercised to report and correct the problems so as to improve the safety of ship operations. Take the chart small correction as an example. Failures to exercise the chart small correction could be in such a category to increase the possibility of a grounding or collision.

Supervisory violations at this level reflect the tolerance to which extent the management level on board can be accepted with the routine violations committed at the sharp end. This is somehow related to the company's safety policy and culture and to the extent the routine violation can be accepted. In similarity to a tiny screw in a machine, under certain conditions routine violations become more likely to result in a tragic disaster when combined with other factors. Nowadays with the shortage of senior seafarers, the acceptance of people with fraudulent certificates in some small size vessels may jeopardize the safety of all crew.

Organizational Influences. Organizational influences as renowned latent failures are at the top level and farthest end from the crew members within the hierarchy of the organization. Four organizational factors have been labeled as follows: *resource management, organizational climate, organizational process and statutory*, all of which affect the supervisory actions, as well as the conditions and unsafe acts of seafarers. The aim of the ISM Code is to require the company to establish and maintain a proper procedure and plan to ensure sufficient resources to support the ship, cultivate a proper climate within the organization and address appropriate organizational processes. In line with the Reason's "cheese" model, the introduction of the ISM Code provides a complete view of how to plug the "holes" in the "cheese" up at the level of organization influence until they are penetrated and developed and an accident comes up.

Resource management includes all the resources the ship needs, i.e. human resources, technological environment and equipment/facility resources. Adequate resource support plays a key role in ensuring the system to maintain at an acceptable and stable safety level. For instance, safety always becomes a loser in the battle of fighting against resource support with productivity. In addressing this conflict and prioritizing safety, the ISM Code specifically sets up a designated person to ensure that there are adequate resources and shore-based support. In the aspect of technological environment and equipment resources support, the company is obligated to make sure that proper measures are taken to ensure the company can respond at any time to resource demand from its ships.

Organizational Climate is to seek to define proper organizational structure, policies and culture within the organization. Element 3.2 in the ISM Code provides the requirements for the company to define and document the responsibility, authority and interrelation of all personnel related to safety management. For the policy, the Code stipulates not only the aims to achieve in terms of safety and environmental protection, but also the requirements to ensure how the aims are fulfilled and maintained. Safety culture is the collective perception and practice on safety issues within the organization (Toft & Reynolds, 1997, p.15). Take the master's overriding authority as an example; an organization's priority of the master's professional decision-making in terms of safety and environmental protection can be viewed as one component of safety culture.

Organizational process refers to the established operation plans and processes, documented procedures and oversight. One of the most outstanding features of the ISM Code is that it requires the company to document and standardize the operations for the purpose of minimizing random and mistake operations. Such operations and procedures include not only the routine operations and maintenance, but also the emergent response; assisting the concerned people to observe the standard operation sooner. Oversight refers to the system audit which provides an opportunity of overall or partial scrutiny of the entire system, and the risk assessment. It is incumbent upon any organization to cordially seek out the weakness of management and address it through risk assessment approach for instance.

Social environment influences. This is an additional component in contrast to the original HFACS framework, inspired by the Safety Control Theory of "Human-Machine-Environment-Management" argued by Chen (1988) in his paper and the systemic view to look into an organization as living with unpredictable environment (Hollnagel, 2009, p.38). The social environment's influences can be subdivided into two categories: *Statutory* and *external environment*. They have strong influence on both the shore management and the ship. In turn, both levels may have the possibility of minimizing the social influence by improving management and technology.

Statutory is to reflect long-term social requirements. The reality that the development of legislation always lags behind the tempo of technological innovation makes it possible to seek the “holes” at this legislative level. It is necessary to address two groups, namely international/national standards and administration implementation/ enforcement in this respect. The administration relies on the implementation of the international/national standards to realize the safety management of its national fleet. Notwithstanding, drastically innovative techniques often disconcert the slow legislative development which may result in an inadequate safety standard. Conventionally, the implementation and enforcement of statutory documentation upon fleet depends upon the flag state administration, plus the port state administration which plays as a supplementary role. In spite of the fact that no requirement is imposed upon the company with regard to the responsibility of statutory legislation in addition to its compliance, it is necessary for the company to work together with the legislative agency by providing it with feedback.

External environment refers to the outside environment of the organization or ship in sharp contrast to the physical environment of the operator. It mainly refers to the meteorological factors, such as weather conditions which are often viewed as the main factors that trigger the onset of an accident. Such factors reflect the vulnerable feature of maritime safety when it encounters extreme meteorological conditions. For instance, heavy fog may reduce the physical visibility of the operator, and then increases the possibility of a collision at sea. Political/economic factors reflect the short term social demand. For instance, the economic recession that started from the end of 2008 may lead to a reduction of resource investment in safety in order to maintain the commercial operations due to a limited budget. These reductions may increase the possibility of maritime risks at sea. The third one is navigation aids or conditions referring to the outside navigation environment, such as the VTS, light buoy or some other items that may influence the safety of navigation as well.

In conclusion, an overview of the adapted HFACS framework (table 2) combined with the functions of the ISM Code, is described and discussed above. The adapted

HFACS framework gives us a new view with reference to how the ISM Code seeks the “holes” within an organization and addresses them at all organizational levels. By integrating the organizational factors into the HFACS framework, the significance of organizational factors identified in the ISM Code is assumed to be fundamental in defense of maritime safety which is applied into practice and further discussed in the following chapters.

HFACS framework			ISM Descriptions	ISM Code
1st Tier	2nd Tier	3rd Tier		
Social Environment influences	Statutory	• International/national standards • Administration Implementation/enforcement	•	•
	External environment	• Meteorological factors • Political/economic factors • Navigation aids/conditions	•	•
Organizational Influences	Resources	• Human Resources • Technological Environment • Equipment/Facility Resources	• Definition of responsibility, authority and interrelation of related personnel • Adequate resource and shore-based support • Designed persons • Authority of the master • Qualification of the master • Seafarers' qualification • Seafarers' ability to understand the rules • Training requirements • Linguistic requirements to seafarers • Effective communication capability of personnel • Statutory maintenance support • Updated and availabe documentation	• 3.2 • 3.3 • 4 • 5.2 • 6.1 • 6.2 • 6.4 • 6.5 • 6.6 • 6.7 • 10.1 • 11.2
	Organizational climate	• Structure • Policies • Culture	• Statement of company's policy • Implementation and maintenance of policy • Report its responsible company to authority • Definition of responsibility, authority and interrelation of related personnel	• 2.1 • 2.2 • 3.1 • 3.2 • 4

			• Designated persons • Responsibility of the master • Authority of the master	• 5.1 • 5.2
	Organizational Process	• Operations • Procedures • Checks and balances	• Qualification of the master • Seafarers’ qualification • Process of the new assignments • Training requirements • Plans for shipboard operations • Identification of potential threats • Drill and exercises • Measures to respond the hazard and accidents • Non-conformities and accident report • Implementation of corrective action • Statutory maintenance • Routine inspections • Procedure to control documentation and data • Effective control of documentation • Company verification, review and evaluation	• 6.1 • 6.2 • 6.3 • 6.4 • 7 • 8.1 • 8.2 • 8.3 • 9.1 • 9.2 • 10.1 • 10.2 • 11.1 • 11.3 • 12
Unsafe supervision/ workplace factors	Inadequate supervision	• Shipborne and shore supervision	• Designated persons • Responsibility of the master • Procedure of new assignments	• 4 • 5.1 • 6.3
	Planned in appropriate operations	• Ship borne operations	• Training requirements • Linguistic requirements to seafarers • Effective communication capability of personnel • Plans for shipboard operations • Identification of potential threats. • Drill and exercise	• 6.5 • 6.6 • 6.7 • 7 • 8.1 • 8.2

			• Measures to respond the hazard and accidents • Statutory maintenance • Routine inspections • Specific actions to the system failures • Routine maintenance and test	• 8.3 • 10.1 • 10.2 • 10.3 • 10.4
	Failed to correct known problems	• Shipborne related shortcomings	• Measures to respond the hazard and accidents • Non-conformities and accident report • Implementation of corrective action	• 8.3 • 9.1 • 9.2
	Supervisory violations	• Shipborne violations	• Non-conformities and accident report • Company verification, review and evaluation	• 9.1
Preconditions for unsafe acts	Internal Environmental factors	• Physical • Technological	•	•
	Condition of crew members	• Cognitive factors • Physiological state	•	•
	Personal factors	• Crew resources managment • Personal readiness	•	•
Unsafe acts	Error	• Skill-based • Decision • Perceptional	•	•
	Violation	• Routine • Exceptional	•	•

Table 2 An overview of the adapted HFACS framework based on the framework developed by the US. Department of Defense.

Source: Author.

Chapter 3 Case Studies

Since proper theoretical foundation has been established and an appropriate causation model has been adapted and adopted, the next step is moving to test its applicability in practice. This chapter focuses on case studies that apply the model in two diverse specific maritime cases with the purpose of seeking the feasibility of application of the adapted HFACS framework into specific maritime cases and acquiring evidence of how the organizational factors are functional in maritime safety. To achieve these aims, the synopsis and official findings and analysis of each accident will be briefly introduced according to their respective official reports (CMSA, 2008; JAIC, 1997) online, subsequently with the corresponding re-analysis of the cases from the perspective of the adapted HFACS framework in accordance with their flow of event developments, then integrating each contributory factor into the framework by its classification. However, in order to fairly treat the official analysis on the basis of the same fact, the re-analysis by the new insight attempts to shun the introduction of the new evidence from other sources, otherwise possibly leading to adverse results. In the end of each case study, short conclusions from comparisons between two differing manners will be made available for further discussion in the next chapters in relation to the objectives stated in Chapter 1.

3.1 Case 1-*ESTONIA* disaster on 28 September, 1994

3.1.1 The accident

The ro-ro passenger ferry *ESTONIA* under the Estonia flag was operating between Tallinn of Estonia, and Stockholm of Sweden. The vessel owned by Estiline Maritime Company Limited, however, was virtually operated by its parental company, Estonia Shipping Company Limited, which is an Estonia state-owned company, and had a maximum carrying capacity of 2000 passengers.

On the evening of 27 September 1994 at 1915 the ferry left Tallinn with 989 people, 803 of whom were passengers, for a routine voyage to Stockholm. At the moment when the vessel left the sheltered waters, sea conditions along the Estonian coast became harsher than before, with a gradually increasing wind to a velocity of 18-20 m/s and a wave height of approximately 4 m; a sufficient height to flood the car deck. The vessel proceeded her route at a full speed of around 15 knots with four engines fully running.

At about 0045 hours the first abnormal metallic sounds were heard by several witnesses indicating something was wrong. Nothing was gained from the position of the bow visor after the seaman of the watch was instructed to find out what the source of the noise was. 15 minutes later, the key part, the bow visor, separated from the bow subsequently opening the ramp completely. A great amount of water entered the car deck with a high rate due to the full speed against the wind and sea waves, rapidly resulting in a heavy starboard list. Due to the unbelievable speed at which the tragedy developed there was little chance to prepare a response, with the result that many people with inadequate time were trapped in their cabins. Those who successfully approached the boat deck jumped overboard or were washed into the sea with or without life jackets. No lifeboats could be launched due to the heavy list. Shortly after the internal alarm a Mayday call was transmitted at around 0120. All four main engines were stopped and the main generators were stopped as well afterwards. Furthermore, with the increased water in the vessel, the list was more than 90 degrees. The vessel sank rapidly, stern first, and disappeared from the radar screens of ships proceeding for assistance in the area at about 0150 hours. As a result, 137 persons survived from the accident following rescue, while 852 people died.

3.1.2 Findings of the disaster released by the Joint Accident Investigation Commission of Estonia, Sweden and Finland

The JAIC believed that the cause to the capsizing of the vessel was the detachment of the visor, of which the locking device failed to withstand the wave-induced load, which lead to a great amount of sea water entering the car deck, following the heavy listing and then sinking of the vessel. It was established that the most wanted part of the investigation was to find out why the failure of the bow visor happened in this case. The maximum withstanding capabilities of the visor against the varied wave-induced and wind-induced force with diverse vessel speeds were thereafter simulated and calculated in authorized laboratories. It was quantitatively concluded that the design load and distribution of the visor on the attachments as installed were insufficient to sustain wave-induced impact loads on the night of this accident.

By observing the recovered visor traced on the seabed some distance from the wreck, and recalculating how much load the visor could virtually withstand, the team found it short of the designed load of the visor, and that this was the main reason why the attachment failed on the night of the disaster. It has been noted that the visor locking device was not produced in the light of the design intent, an indication of a scarcity of affordable load. The load calculation was only done by the shipyard without the involvement of the supervised construction classification, Bureau Veritas, in that no such guideline or regulation was in place at that time.

To make matters worse, the approval of the hull inspection by the Finnish Maritime Administration greatly rested on the Classification Society. Instead of itself, the Administration did not further examine or inspect the water load of the visor as long as it got the certificate from the Classification Society.

Besides the failure of the attachment of the visor, the JAIC has concluded some contributory factors which attributed to the disaster. Factors like encountering prevailing and unacceptable weather conditions, and inadequate attention and alertness from both the administration and company sides in response to the exposure of deficiencies of the bow visor on similar vessels were also firmly identified in the JAIC report. The improper installation of the upper extension of the collision bulkhead which did not comply with the requirements of the SOLAS regulations had been determined as one of the contributory factors to the disaster.

Some actions by the crew were also marked as being relevant to the aftermath. At the moment of the first signal of unconventionality occurred, the bridge was not aware of what happened on board until the heavy list of the vessel was exposed. This information was vital and essential in determining the following remedied measures. No reduction of speed was therefore taken even after receiving more than two reports of abnormal metallic bangs. The efforts to find out information on the source of bangs failed. It seems that the crew members neither watched the TV monitor, nor asked those in the control room from where the ingress was observed. The most effective way to remind crew of the failure of the visor by the position sensors did not work, unfortunately. Subsequently, almost no warning message as early as it should be, was successfully released or broadcasted to the passengers involved in this disaster. Further the Mayday call was transmitted later than supposed. The short time available for response made the evacuation and taking courtermeasures meaningless, resulting in the chaotic situation faced by the crew and passengers. The Commission further asserted that the crew on board were not aware of the visor incident taking place on other similar vessels at that time.

In summary, the JAIC report is a document emphasizing and detailing the technical issues which concluded that the accident resulted from the failure of the bow visor. This report appears to be in favor of technique failure more than management failure in fact, otherwise more people at the blunt end would be blamed for their management failure. Most of the failures were analyzed on a surface level, not able to imply how to prevent such failure reoccurring. All the contributory factors in relation to the occurrence of the accident as analyzed above are screened in Table 3.

Cause	Description	Type of error or other failure	Systemic cause or preventive action
Direct cause	The detachment of the *ESTONIA*'s bow visor leads amounts of water to enter into cardeck, sinking the vessel.	Technical failure	From the analysis, it was concluded that this failure was due to the wave-induced impact loads and lack of designed load.
Contributory causes	The sea condition that the *ESTONIA* experienced at that night was shocking and abnormal to the vessel itself.	Meteorological condition	The accurate and timely obtaining of weather reports could be as a source to refer to and make the right decision and prevent such an accident.
	The visor attachments were not designed in the light of realistic design assumptions.	Design error	There was no industry or regulatory standard at that time as a reference to set the designed load.
	The master on board had a very limited knowledge of the potential danger of the bow visor closure concept.	Training deficiency	No information on bow visor failures was systematically and intentionally collected, warned and disseminated within the company and its ships.
	Failure to indicate the	Equipment	The position sensors of

	opening bow visor in the bridge control panel to inform to crew on bridge prior to the occurrence.	failure	ramp and bow visor were not well designed and maintained in good manner even though they were approved by the administration.
	The installation of the upper extension of the collision bulkhead did not comply with the requirements of the SOLAS regulations.	Design failure	The Commission believes that the non-conformity of the collision bulkhead has a somehow positive effect on the entering a mount of water the cardeck.

Table 3 An overview of accident analysis of the *ESTONIA* according to the JAIC report.
Source: author.

3.1.3 Analysis of the case by application of the HFACS framework

According to what we have learned from the aforementioned discussion of the rationality and principle of the adapted HFACS framework, as well as its established linkage with the elements of the ISM Code, the proper theory is ready for analyzing and recategorizing such complex disaster for the purpose of evaluating the role of organizational factors in maritime safety and diagnosing how the adapted HFACS framework functions in the maritime context. The basic purpose of such an effort here is to search a new insight into mechanisms through which safety is achieved through a fresh analysis of such a case from the human error perspective, rather than attempting to analyze them by citing the additional sources to criticize the old report.

Someone may doubt the feasibility of applying the doctrine of the ISM Code to justify the organizational role in such case in that the implemented ISM Code was not yet in place at the time of *ESTONIA*. However, the origin of the ISM Code - IMO Resolution A.595 (15) called on the need to develop the guidelines on shipboard and shore-based management (UK MCA, 2009) and the discussion in Chapter 2 has already implied that the ISM Code is a legal and operational umbrella in the maritime field, most of which as analyzed previously stem from operations in the course of maritime history, namely common sense or best practices. For instance, in the case of the *HERALD OF FREE ENTERPRISE* disaster on 6 March 1987, when no such ISM Code was in place either, the management factors such as “the absent responsibility extended as high as the Board of Director level” (Whittingham, 2004), were already throwing light on as the equivalent influential factors at the remote end with those factors at the proximal end. In spite of the fact that at the time when the accident occurred, the requirement to the management level on its responsibility to frontline operation had not yet been available legally, at least in written form, so the court still imposed the company’s corresponding responsibility on the management level according to its deficient management. It is thereby justified to analyze such a case based on the doctrine of the ISM Code.

Before going into details on the latent conditions which create an environment for the sharp end operators to more likely commit unsafe acts, there is a need to clarify what an unsafe act is. Equally important is the question which sort of unsafe act is involved, error or violation. Surprisingly, the official report appears to be reluctant to distinctly disclose any unsafe acts. The report use a great number of chapters to focus more on technical details, such as what is the possibility of the bow visor failure and why the bow visor failed, but with few words on what is the human operation in relation to the failure of the bow visor, without a clear clue on what the unsafe act is. Based on recognized details in the official report, there was no unsafe act at the sharp end involved in the initial event. The other latent failures have been analyzed as follows in accordance with the flow of event developments.

Firstly, the technical resource support from the company appeared to be inadequate for the required maintenance and operations on board.

Daily experiences suggest that the lack of technical support may greatly result in various serious negative aftermaths on board, e.g. deteriorated maintenance operational level. The report has been of the opinion that there were some deficiencies found by the trainee PSCOs prior to the accident, nevertheless, no further attention was drawn by either the master or the management level on shore. Unfortunately, no details on how the management or supervision carefully responded to such a fatal deficiency prior to the commencement of this voyage are given. The pronounced and tightened conflict between production and the safety has been proved conclusively in this case when the master decided to sail for the sake of time pressure rather than caring about safety margin despite the absence of rubber packings in the visor. With reference to the requirements in the ISM Code, the shipping company should ensure adequate resource and shore-based support to the ship's operation and maintenance. The dismayed ignorance of missed or damaged rubber packings which assure the watertightness of the external visor gave rise to two developments: losing the watertightness of the visor which would allow water to enter inside and create a resultant force directed at about 45 degrees forward and down, as the official report admitted, and increasing the possibility of vibrating or shaking, which further leads to accelerated wear and induces fatigue to the connections between the bow visor and shell plates as well as the cleats, hinges and bolts. These problems growingly caused the probability of the visor failing to attach under harsh weather conditions where the accident took place. Similar maintenance operation problems containing damage to the locking devices which reduced the strength were observed. In addition, the dysfunction of the signal lamps of the ramp and bow visor position sensors, respectively, failing to indicate the state of the ramp and bow visor reflected the poor management on board and shore-based. No established proper procedure and process supports such maintenance prior to the departure. These problems could be categorized as resource support from the shore side and process failure in accordance with the Table in Chapter 2.

Secondly, the non-compliance with the SOLAS regulations regarding the upper extension of the collision bulkhead reflects the failure occurred at levels of management within the company as well as administrations.

As best safety practice, before flagging into Estonia to start the new operation, the shipowner should have been sufficiently aware of the essential need to ensure the vessel's condition was in compliance with all relevant international Conventions and national law in order to run the vessel on a full international route. In spite of the fact that there was no document showing the evidence of exempting the bulkhead from the administrations during the construction and the short international operation, due to the hesitating attitude of the IMO at that time on whether the requirement should be further extended to passenger ships or not, administrations by and large accepted the fact without proper collision bulkhead by acquiescence, equally with exemption. However, since the 1981 Amendments to SOLAS entered into force in 1984 specifying the requirement of the collision bulkhead on passenger ships, the new flag administration was supposed to follow the requirement. Neither in the course of the first inspection by the administration prior to the new traffic in Estonia, nor the following two inspections, was any proper remark made to non-compliance with the SOLAS regulations regarding the upper extension of the collision bulkhead. As the professional and recognized organization on the classification survey, Bureau Veritas did not observe any deficiency either in their first survey or annual survey due to the scarcity of the bulkhead requirement in the SOLAS Convention.

Thirdly, remote factors failing at the vessel transferring stage resulted in a sequel of the vessel's capsizing with regard to certificate management.

As the report revealed, the original safety navigation certificate, which is sufficient to meet the initial route issued by the Finnish Maritime Administration, was only intended for the short international voyage sailing within 200 nm between two ports. The reasons why the authority issued the short international voyage were not recovered in detail, but surely based on the actual operating voyage in terms of the meteorological conditions and distance. Therefore, including the upper extension of the collision bulkhead, several requirements to such a vessel in the operation of such voyage were exempted by the Finnish Authority. Both the new company management and administration were not aware of the need to fully assess the feasibility of the vessel to run in a tougher meteorological condition and longer voyage than the previous one so that actually the vessel was running over a voyage area out of its reach. Such a symbolic governmental job was utterly authorized to Classification Society - Bureau Veritas - the same one as under the Finnish flag. Based on an agreement between Bureau Veritas and the company it was merely arranged for certain items not covered by the conventions to be taken care of, for instance, the drawing plan was not scrutinized, rather than a full survey. In spite of the fact that there may have been some uncovered truth behind the agreement, one thing is sure here and that is the lack of any effective certificate management from the company management perspective.

Fourthly, the company was not mindful of a potential hazard on board which had been warned by a series of similar serious incidents occurring in maritime industry.

Despite the absence of a legal requirement risk assessment for the time, the frequently occurred incidents associated with the failure of the bow visor should have reminded the management level to notice its seriousness of the hazard. To be an informative and responsible company, onshore management should have collected, analyzed and distributed the intensive occurred accidents related to such analogical passenger ship' safety, and educated their crew on board to enhance safety awareness. The company satisfied itself with the proud reason that the bow visor of the *ESTONIA* was the latest and biggest design at the time of construction. In addition, it has been noted that the master and crew, who were limited to access such information based on the limited resources on board, lacked knowledge and awareness on the hazard of the bow visor; otherwise they could have noticed soon the source of bang sound and take necessary countermeasures. The occurrence of numerous incidents analyzed in the official report had already given the evidence that the timely observation of the failure or part - failure was rather conducive to minimize the consequence of the incidents. As a matter of fact, most vessels involved in the cases occurring successfully recovered from the risk of disaster by reducing the speed or stopping the voyage. In the statistics of the cases it was stated in the official report, that most cases (12 out 14) were triggered by the heavy weather and waves. Likewise, if the management had been sufficiently mindful of the negative effect of the heavy weather to underpin the safety margin by authorizing the master with the freedom of navigation decision-making in terms of time pressure, this case would have had the biggest probability to be eradicated or at least mitigated. However, for the company, it is a failure that the potential hazard of the bow visor finally resulted in such disaster.

On the one hand, no extensive research by the industry was made to find out the common reasons in such incidents and enhance the safety standard in the related regulations with regard to the failure of the bow visor. The affected administrations and classification societies, involving major ones, were satisfied with the fact that the strengthened requirements to the affected vessels were enhanced, and such new requirements were only applied to new constructions. The *ESTONIA* heavily slapped the industry with a disaster for the compromised result between the administrations and industry that the new requirement was not applicable to existing vessels, including the *ESTONIA*. Unfortunately, these unacceptable attitudes are still prevailing nowadays for the reason of the mount of costs arising from the implementation of the new legislation on existing vessels.

Last but not least, looking back to the design stage of construction, there were no legal standards or requirements for the bow visor loads at the national level which made the role of classification and administration in monitoring the bow visor design and production voluntary. The official report claimed that the shortage of the designed load led to the failed resistance against the wave-induced impact. Again, this suggested the industrial legislation or standard development was lagging behind technical innovation.

To sum up, there is no unsafe act, but with the named active failure involved in this case, where a number of latent failures constitutes those causation events in the course of accident development from the blunt ends which were creating the deteriorated surroundings for the sharp end to be more likely to suffer the aftermath of poor management. The whole new picture of the analyzed brief causation graph in the adapted HFACS framework is described in Table 4.

	1st Tier	2nd Tier	3rd Tier	*ESTONIA* Causation	
Latent Conditions	Social Environment influences	Statutory	• International/national standards • Administration Implementation/enforcement	★Absence of national law on standardizing the exemption and scrutinizing the hull survey. ★Vacuum role of administration on hull survey for flag changing. ★ Lagged law reaction to restrict the frequently and similarly occurred accidents. ★Absence of standards and requirements on bow visor design	Remote from the ship
		External environment	• Meteorological factors • Political/economic factors • Navigation aids/conditions	★ Encountering the exceptional meteorological condition.	
	Organizational Influences	Resources	• Definition of responsibility, authority and interrelation of related personnel • Adequate resource and shore-based support • Designed persons • Authority of the master • Qualification of the master • Seafarers' qualification	★Inadequate shore-based resource support to board maintenance and operations.	

			• Seafarers' ability to understand the rules • Training requirements • Linguistic requirements to seafarers • Effective communication capability of personnel • Statutory maintenance support • Updated and available documentation		
		Organizational climate	• Statement of company's policy • Implementation and maintenance of policy • Report its responsible company to authority • Definition of responsibility, authority and interrelation of related personnel • Designated persons • Responsibility of the master • Authority of the master	★Failure to collect, analyze and distribute similar accidents.	
		Organizational Process	• Qualification of the master • Seafarers' qualification • Process of the new assignments • Training requirements • Plans for shipboard operations • Identification of potential threats • Drill and exercises • Measures to respond the hazard and accidents • Non-conformities and accident report • Implementation of corrective action • Statutory maintenance • Routine inspections • Procedure to control documentation and data	★Failure to manage the deficiency in the certificate in terms of short voyage. ★Failure to respond the deficiency found prior to the commencement of the voyage. ★Failure to maintain the bow visor in proper condition. ★Failure to identify the non-compliance with the SOLAS regulations regarding the	

		• Effective control of documentation • Company verification, review and evaluation	upper extension of the collision bulkhead. ★Shortage to identify the potential hazard on board with reference to the bow visor. ★Shortage of training the crew over the bow visor management.
Unsafe supervision/ workplace factors	Inadequate supervision	• Designated persons • Responsibility of the master • Procedure of new assignments	
	Planned in appropriate operations	• Training requirements • Linguistic requirements to seafarers • Effective communication capability of personnel • Plans for shipboard operations • Identification of potential threats. • Drill and exercise • Measures to respond the hazard and accidents • Statutory maintenance • Routine inspections • Specific actions to the system failures • Routine maintenance and test	★Failure to maintain the visor and ramp position indicator in order. ★Failure to maintain the locking device in order. ★Shortage of training the crew over the bow visor management.
	Failed to correct known problems	• Measures to respond the hazard and accidents • Non-conformities and accident report	★Failure to correct the absence of rubble packings.

Active failures			• Implementation of corrective action		Proximity to the ship
		Supervisory violations	• Non-conformities and accident report • Company verification, review and evaluation		
	Preconditions for unsafe acts	Environmental factors	• Physical • Technical	★Running out of its original certificated voyage area. ★Deficiencies in the bow visor regarding the inadequacy of design.	
		Condition of crew members	• Cognitive factors • Physiological state		
		Personal factors	• Crew interaction • Personal readiness		
	Unsafe acts	Error	• Skill-based errors • Decision and judgment errors • Perceptual errors		
		Violation	• Routine • Exceptional		

Table 4 An overview of analyzing *ESTOINA* disaster by the adapted HFACS framework.

Source: Author.

3.1.4 Outcomes of the comparison between the original findings by JAIC and further analysis by HFACS

Since the final JAIC report represents only a summary and therefore does not mean first hand statements or materials, it should be born in mind that this ultimately affects the accuracy of the result of the re-analysis of the accident report. Some information necessary for re-analysis in the framework may not be available or accessible. The interpretations or assumptions made are therefore only based on the refined materials from the official report, and may not be as exact as those stemming from the raw material. Furthermore, without the mandatory ISM Code in place at that time, there was no legal responsibility for the company to be in compliance with it. Anything assumed in the above section is based on the philosophy of the ISM Code. However, those limitations do not impede the purpose of the re-analysis of this case, which is to test as to whether the adapted framework is proper to apply in the specific case, not to refer to evaluate as to whether the result is right or not. Thus, based on the above limited assumptions, some short findings are observed from the comparison between the original report and the re-analysis:

1. More latent or remote factors on the environment to create the possibility of such an accident have come clear from the re-analysis. If we could code a certain value into each factor, according to the approach similarly done by Brown and Haugen (1998), we could then evaluate the influential proportion of each factor in this case.

2. Since the latent or remote factors were clearly presented and structured in the framework, recommendations generated from such a way make more sense and directive.

3. Even though there is no unsafe act at the sharp end, the latent organizational factors are still greatly influential in the safety performance on board.

4. The statutory requirement in place is vital to guarantee the active role of the organization in ensuring maritime safety.

5. The selections of the initial event and stop event from the new insight appear to be better and more reasonable than those from the traditional one.

3.2 Case 2-*QINFENG 128* accident on 27 March, 2008

3.2.1 The accident

The multiple-purpose cargo vessel *QINFENG 128*, under the Chinese flag with 7122 GT, called at Ningbo, China via the southern fairway of Jintang Island from Tianjing, a northern port mainly for exporting coal from the mines in China. During the period of anchorage, when waiting for the berthing order, the exchange of crew, including a new master, took place on board according to the shipowner's crew exchange order.

Two days later at 0025 on 27 March, when the vessel had completely unloaded all coal, it unmoored and sailed to Tianjing again to loading coal via a short cut route; the eastern fairway of the Jintang Island, where a new bridge, namely the Jintang Great Bridge, with a length of approximate 18km over the sea, had been constructed since 2005. At this stage of bridge construction, non-construction-related vessels were not allowed to pass through any bridge spans aside from the central navigational bridge span and western side navigational bridge span next to the central bridge span, which had already been put into use for a few months. Unfortunately, the vessel decided to sail with a velocity of 14 knots against the wind through the western side bridge non-navigation span as it was planned, where the new concrete bridge box girders had just been put across the supporting piers a couple of days earlier, and had not yet been fixed permanently. Even with very good visibility that night, the fore mast, conning bridge and Radar mast of *QINFENG 128* subsequently crashed into two pending concrete bridge box girders between the No.E19-E20 supporting piers.

Finally, two pending concrete bridge box girders over the supporting piers fell down, collapsing the fore mast, the conning bridge and Radar mast of the *QINFENG 128* and then landed on the compass deck of the vessel with the consequence that four crew on the bridge died, including the new master, chief officer, second officer and a wheel man, and the vessel grounded. The fallen bridge box girders broke into several pieces but were still connected by the reinforcing steel bar inside the box girders and some damage was caused to the span bridge supports as well.

3.2.2 Findings of the disaster released by the official investigatory report

It has been learned that in order to ensure the safety of the bridge - the constructed operation, the *Navigation Order* prohibited any non-related vessels to sail within a 700 m area of the bridge operation on each side. 14 pairs of warning light-buoys in good condition were set up on both sides of the operation areas. In addition, 7 pairs of navigation light-buoys were set up on the way to two navigation bridge apertures.

With reference to this *Navigation Order*, the official report has established that the direct cause of the accident was the vessel’s violation, no mater intentionally or unintentionally, to sail through the bridge - constructed operational water area, non-navigational bridge span between No.E19-E20 supporting piers. This conclusion was evidenced by its navigation track of the vessel history prior to the collision with the bridge as recorded by the company’s navigation track system.

The natural question in connection with exploring the cause of this accident is why they decided to choose the short cut fairway rather than the fairway from which the vessel approached to the port. Due to the fact that all the duty crew, including the master and second mate, died, no certain answer can be given in response to such a question-why they violated the *Navigation Order* to go through the prohibited, narrow and shallow water area rather than that allowed, wide and deep water area. However, two possibilities with regard to explanations to such questions were attempted to be established.

Firstly, the crew members, especially the master, had not been informed by the message that the concrete bridge box girders had already been put there, nor did the duty crew notice the concrete bridge box girders, with a negligent lookout, even under good visibility at that night. The master had just joined the ship, and a few days earlier the concrete bridge box girders had just stood there. There was no evidence that the master noticed such information.

Secondly, the estimation of the net height of the bridge span above the water was insufficient for the requirement of actual height, providing that the master knew the fact that two pending concrete bridge box girders were there. According to the local meteorological report on the tide information, a calculation was made of the net height of the bridge span above the water, which was less than 15.1m considering the tide effect. Under the condition of idle load, the top point of the fore mast was more than 22m, while that of the Radar mast was more than 21.8m. As a result, the clear height of the bridge span was insufficient to pass under such a low draft and an over height vessel.

In searching the chart the vessel applied in this voyage, the absence of a chart small correction was believed to be a significant contributory factor to the occurrence of the violation, and the accident. Even though every Notices to Mariners, including that concerning the information of setting up the navigation prohibited zone especially for a bridge construction, from the chart station being timely distributed to the vessels, no mark about the chart small correction was found on the chart in the spot area. On the chart, the planned route had been drawn, as it actually went through, to pass through that prohibited water area, deviating 1 nm far away from the western side of the navigational bridge span. Conclusively, the second mate drew the planned route on the basis of shortage of chart small correction.

In summary, no matter if the master approved the planned route in advance or not, this is a case where the master should be responsible for the negligence of his duty to ensure the safety of this ship. The whole picture of the analyzed causes to this case is drawn in the Table 5 as shown below:

Causes	Description	Type of error or other failure	Systemic cause or preventive action
Direct Cause	Crew's violation to pass through the prohibited navigational water area.	Violation	The crew on duty should always maintain with full due care on the safety information, so that the master can determine informatively the right sailing route without negligent violation.
Contributory Causes	The absence of a small correction on the chart on the information of prohibited navigational water area.	Violation	The master should supervise the responsible mate to make the chart timely informative with small correction.
	Wrongly planned route for navigation to Tianjing port	Planned error	When making the planned route, the responsible mate should refer to all relevant safety information to ensure the safety on route.
	Overestimation of the safety margin of the net height above the water area across the aperture.	Skill-based error	When passing the bridge span and estimating the height of the vessel, the tide and draft should often be taken into account.
	Negligent lookout of the duty crew who did not observe the bridge contributed to the occurrence of the accident.	Violation	The proper lookout is needed to be maintained in all circumstances on board, whenever the master is on board or not.

Table 5 An overview of the cause analysis of *QINFENG 128* according to its official report.

Source: Author.

3.2.3 Analysis of the case by application of the adapted HFACS framework

From the perspective of the human error causation framework as discussed in Chapter 2, the application of the adapted HFACS model is described in the way that highlights the latent failures, based on the unveiled details in the official report.

By its very nature, the feasibility of the application of the adapted HFACS framework with reference to the ISM Code to this case seems to be appropriate. The ship's responsibility to implement the ISM Code since 2005 has been delegated and contracted to the shipping company which is a specialized shipping management company with dozens of non-itself-owned ships from diverse shipowners, which provides the foundation of applying the doctrine of the ISM Code in this case. Referring to its shipping manager independent from the shipowner, the need to introduce some background of the management is necessary to better understand the latent failures.

A couple of months prior to the accident, the shipowner of the *QINFENG 128* signed a sales contract with a view that the new shipowner took over the full responsibility of its management half a month before the accident, however, without notifying its shipping company. In accordance with the supplemented contract signed later, the registration change of the vessel would not be applied until the final payment, half of which had already been transacted successfully, being completed. Thereby, instead of its shipping company, the new shipowner virtually took control of the vessel since the contract had been signed, but with no change of its registration prior to the accident.

In knowing the confused organizational responsibilities, we now could throw light on several developments from latent failures to active failures. Compared to the first case analyzed above, this case would be comparatively simple structured in failure event flows. Undebatably, the duty mate and master should be blamed for their violation of approaching the prohibited navigational water area, which is of course the unsafe act, and the improper lookout before the collision so that the crew had insufficient time to take the proper measures of prevention, in the adapted HFACS framework. The remote failures in this case were analyzed by its developments of event flow as follows.

First of all, as an elementary source of essential navigation information, no document on board is more significant than the chart and its publications in the aspect of ensuring safe navigation. The obtained evidence of the chart used in this voyage suggests that the chart management was in a mess on board. The official *Navigation Order* of setting up the prohibited navigational water area was issued in 2007, and its chart information was subsequently broadcasted via the Coastal Radio System as well as published in the latest *Notice to Mariner*. In the light of its implemented documents of the SMS, the second mate is specifically responsible for the chart management, while the master, at the top management level on board, has the overall responsibility of such management. Until the accident happened, no information, even with the projection of bridge construction which was initiated in 2005, was marked on the concerned chart in terms of chart small correction.

The mentioned mess corporation between the shipowner and shipping company fully reflects the insufficient and inconsistent support of the implementation of ISM Code, by the shipowner, who discouraged the shipping company to exercise its obligations to monitor the vessel’s performance. In the first quarter of 2008 prior to the accident, the vessel was not boarded and inspected by the shipping company. In accordance with its ISM documents, certain inspections by the shipping company should have been exercised on board at a given interval.

More surprisingly, even in the company’s safety operation room, the chart used in this voyage which should have contained the bridge construction information was not maintained at the updated level either. It was equipped with a live voyage tracking system with a non-updated digital chart, but no warning information was being sent to its vessel prior to the collision. It conveys an explicit message that the chart small correction was not a compelling concern from the company’s perspective.

During the flag state inspection on board in November 2007, the competent authority issued a report concerning such deficiencies, but with a disappointed consequence that no one really took care of this issue in their hearts. Thereby, whoever at the proximal or remote side, both sides maintained the safety operation with regard to chart management at an improper level, ultimately leading to the occurrence of the collision.

In addition, the qualification of the master should be doubted in terms of sufficient proficiency to exercise his job. The inquiry record of the shipping company signaled that another master recommended by the shipowner failed to pass the examination by the shipping company a couple of months earlier. Neither the process of employment of the new master involved in this accident, together with two other ordinary crew members, nor its interview and examination according to its SMS documentation, was conducted by or even notified to the shipping company. The non-involvement of the crew employment of the shipping company with regard to the requirement of the ISM Code constitutes the evidence of non-conformity at its organizational level. It has been widely agreed that a competent master should have been aware of the elementary role of the updated chart in safety navigation on board. The new master in question failed to emphasize but succeeded in proving the importance of the role of the updated chart by showing his experience.

Furthermore, by its job description, the master was supposed to scrutinize and approve the planned route that the second mate had made under the direction of his best professional judgement and credible informative sources. Because of his competency was in question and insufficient attention on the validity of the chart, the planned route, as the vessel actually sailed, was believed not to have been scrutinized, at least in an acceptable manner.

With reference to the preconditions for unsafe acts, no information written on the official report intimated that there was something wrong on board concerning the psychologically technical shortage due to the fact that all four of the seafarers involved died during the accident. It was technically and objectively difficult to determine what was wrong in this respect.

Theoretically speaking, an analysis of any collision case should be made by both sides with a view to diagnosing what failures had taken place on each side. To give a simple example, if the regulation have been set up to demand one more barrier to be established, e.g. special navigation monitoring system within the bridge water area, such an accident could have been prevented from occurring by warning and informing the crew prior to its collision. However, the adapted HFACS framework appears to be incapable of dealing with more than one part involved in the same incident, otherwise being in a mess condition so that the incident developments involved would not be recognized in a comfortable way.

In summary, the cause of the collision between the *QINFENG 128* and the bridge span appears to be an exceptional violation, transferring through the prohibited navigational water area, by the scarcity of a valid and updated informative chart due to the improper safety management at both the ship and onshore levels, and the inappropriate lookout on board. The entire view of the causation analysis from the adapted HFACS framework point of view is analyzed and presented in Table 6 as follows.

	1st Tier	2nd Tier	3rd Tier	*QINFENG 128* case causation	
Latent Conditions	Social Environment influences	Statutory	• International/national standards • Administration Implementation/enforcement		Remote from the ship
		External environment	• Meteorological factors • Political/economic factors • Navigation aids/conditions	★Constructing bridge barrier cross on the voyage.	
	Organizational Influences	Resources	• Definition of responsibility, authority and interrelation of related personnel • Adequate resource and shore-based support • Designed persons • Authority of the master • Qualification of the master • Seafarers’ qualification • Seafarers’ ability to understand the rules • Training requirements • Linguistic requirements to seafarers • Effective communication capability of personnel • Statutory maintenance support • Updated and available documentation	★Failure to manage the employment of master in a proper procedure.	
		Organizational climate	• Statement of company’s policy • Implementation and maintenance of policy • Report its responsible company to authority • Definition of responsibility, authority and interrelation of related personnel • Designated persons • Responsibility of the master • Authority of the master	★Insufficient and inconsistent support from the shipowner to the shipping company.	
		Organizational Process	• Qualification of the master • Seafarers’ qualification • Process of the new assignments	★Failure to supervise the ship safety operation in relation to the chart small	

			• Training requirements • Plans for shipboard operations • Identification of potential threats • Drill and exercises • Measures to respond the hazard and accidents • Non-conformities and accident report • Implementation of corrective action • Statutory maintenance • Routine inspections • Procedure to control documentation and data • Effective control of documentation • Company verification, review and evaluation	correction. ★Failure to monitor the ship's voyage on board. Failure to execute its inspection on board.	↓
	Unsafe supervision/ workplace factors	Inadequate supervision	• Designated persons • Responsibility of the master • Procedure of new assignments	★Failure to approve the planned route in proper manner. Failure to supervise the chart small correction from both ship and onshore side.	
		Planned in appropriate operations	• Training requirements • Linguistic requirements to seafarers • Effective communication capability of personnel • Plans for shipboard operations • Identification of potential threats. • Drill and exercise • Measures to respond the hazard and accidents • Statutory maintenance • Routine inspections • Specific actions to the system failures • Routine maintenance and test	★Failure to make a safe planned route. Failure to manage chart in a proper way.	

↓ Active failures		Failed to correct known problems	• Measures to respond the hazard and accidents • Non-conformities and accident report • Implementation of corrective action	★ Failure to correct the defects in connection with the chart small correction reported by the Administration Officer.	↓ Proximity to the ship
		Supervisory violations	• Non-conformities and accident report • Company verification, review and evaluation	★Violation to not maintain the chart in updated level.	
	Preconditions for unsafe acts	Environment	• Physical • Technical		
		Condition of crew members	• Cognitive factors • Physiological state		
		Personal	• Crew interaction • Personal readiness		
	Unsafe acts	Error	• Skill-based errors • Decision and judgment errors • Perceptual errors		
		Violation	• Routine • Exceptional	★ Violation to sail through the prohibited navigational water area-bridge constructed water area. ★ Failure to maintain the proper lookout on board.	

Table 6 An overview of the causation in the case of the QINGFENG 128 by application of the adapted HFACS framework.

Source: Author.

3.2.4 Outcomes of the comparison between the official report and further analysis using the adapted HFACS model

After all, the official accident report is a report with refined material in consideration of its validity and authenticity which may not be verified in a proper way. In this respect, without precise first-hand material from the investigation, the accuracy of the re-analysis result cannot be guaranteed. There may have been a possibility of deviation from the truth. Nevertheless, these negative elements cannot impair our findings from the comparison in terms of its manner of application manner because our focus on the way of how we analyze the accident from the new insight perspective:

1. Effective organizational implementation and support plays a crucial role in the improvement of safety performance on board.
2. Organizational factors were in a dynamic state, meaning that they may trigger the onset of accidents or unexpected incidents under certain conditions.
3. There may have more than one unsafe act involved in one case.
4. If more than one part is involved in the case, oversimplification will appear to be shakier.
5. In contrast to the official analysis manner, the new manner by application of the adapted HFACS framework appears much more guided on how to make the precautions.
6. The new model guided the investigator to lock the reasonable initiating event and stop event in the course of maritime investigations.
7. With the benefits of classified and structured categories in the framework, it is conducive to streamline the data collection from the investigation.

Chapter 4 Verification of the adapted HFACS Framework

As noted in Chapter 1, one of the primary tasks of this study is to aim at verifying the feasibility of the adapted HFACS framework applied in specific maritime cases. The result of this verification during the application in Chapter 3 appears to be positive. The benefits from the usage of an accident model have justified its validity in the maritime field. It is a useful tool in determining what we are going to look for and resolve. This has been concluded in Chapter 3 and will be discussed partly in Chapter 4 that, by means of the adapted HFACS tool, it guides the analysis of accidents into deeper and more fundamental causal levels - in particular the organizational factors, which are the most influential elements in the system and heightened in an outstanding position. In addition, the applied model contributes to make clear how the organizational factors affect the system's safety and how much the organizational factors contribute to system's safety. By tracing its pathway to the failures of those factors, eventually the effective and functional measures to prevent the onset of maritime accidents at certain organizational levels may be developed in a proper way. So as to decide the validity of such a framework in the maritime industry, besides what is generally stated above, we still have to look into the details of two aspects, cf. the three standards stated in Chapter 2, as follows.

4.1 Comprehensiveness of the data collection of the adapted HFACS framework

Leveson (2004) once argued that the most effective causation models we need are supposed to go beyond portioning liability and instead promote investigators to gain learning from the accidents as much as possible about all the possible factors involved, including but not limited to those related to organizational structures and influencing the accident. The need of such effective causation models in the maritime domain is also argued for in this study.

In Chapter 3, it has been learned that using the adapted HFACS framework can accommodate and explore a substantial number of contributory factors by the distinct classification of those factors. 16 sorts of factors in case 1 while 12 factors in case 2, on the basis of two official reports, were analyzed using the new insight. The practical application has proved that none of the possible factors disclosed in the official reports has fallen outside the HFACS classification and framework. Even the dynamic and unpredicted weather condition as the external factor, in case 1, has been integrated in that model. In particular, the functions of the organizational factors in the framework are proved to be apparent due to their origin under the prevailing ISM Code. However, the factors in the adapted HFACS framework, which were not presented in Chapter 3, are still in need of more practice and application in the foreseeable future.

The experience in such applications suggests that the well-sorted and -structured failure categories in the HFACS framework are applicable in the analysis of maritime accidents, at least in the discussed instances. With the well-sorted categories of failures, investigators are capable of placing the pre-analyzed failures in proper positions within the framework according to their nature. Some benefits may be gained from such well sorted categories; including the accident analysis report in more strategically structured form and the more distinct factors explored and classified by such well-sorting. Later on the statistics and analysis of a group of such reports can be well managed because of their uniform structure and factor classifications. Looking back on the application of the adapted HFACS framework in cases, it looks as if the organizational factors were heightened in a certain manner. The around reverse-Pyramid-structure of the adapted HFACS framework *per se* has intimated its propensity in the organizational factors, an indication that the investigators are guided to do something with regard to the organizational factors under the guidance of the model. If investigators ask themselves more questions similar to what rationality is behind the preconditions of unsafe acts, the disappointing situation identified by Schröder, Baldauf and Ghirxi’s work (2009) where 73% of precondition of unsafe acts accounted for the fire accident in machinery space in comparison to 30% of unsafe supervision/workplace factors, could be shunned. Particular similarity of such a model is the argument of Rasmussen (1997) that the investigators have to consider that as a compelling accident causation model, it requires emphasis in explaining the factors that shape human error, rather than focusing on the frontline operator who commits unsafe acts. In addition, by its classification structure, the adapted tool appears to combat its comprehensive data involved by ensuring the “consistency, objectivity and transparency of the data collection and analysis processes” (Reinach & Viale, 2006).

In spite of the fact that more studies and practices are needed to prove its applicability in maritime accident investigation practice, the adapted HFACS framework, at least in this study, has illustrated that its taxonomies were capable of capturing all collected contributory factors available and its propensity of well-sorted category may enhance maritime investigation and analysis.

4.2 Depth and reliability of analysis using the adapted HFACS framework

Despite the origin of the adapted HFACS framework - Reason’s model, which is a sort of epidemiological model argued by Hollnagel (2004), the experience of its application implies that the adapted HFACS framework can be viewed as a kind of system model, as agreed by Reason (2008) in his article. The merits of the framework in its application, *inter alia*, its nature of accommodation of all the factors stated above, the functional interactions between each factor discussed in Chapter 4, its capability of dealing with environmental disturbances, and its applicability to maritime cases, can justify the nature of the systemic model, in comparison to all the features from the example of the systemic model described by Leveson (2004).

The need of the systemic models in the maritime field has also been proved conclusively to be necessary. The systemic nature of such a model shows its depth, credibility and comprehensiveness of analysis in maritime accident investigations. The applied experience has evidenced that, notwithstanding, the depth of its analysis by the framework would be contingent closely to the extent which the investigatory information released by the cited official reports. There are two aspects affecting how much the accident details will disclose: subjectivity and objectivity.

- Subjectivity refers to the willingness of the investigator to release the information in avoidance of publicity challenge on his/her result. Rather than releasing more information which may mislead publicity to doubt its ability of clarifying its explanatory report, he/her prefers to focus on the responsibility of frontline operators, a kind of popularity favored by the authority which may exclude a good deal of trouble.
- Objectivity could be interpreted as the investigators' objective impossibility in obtaining the necessary information, such as the geographic separation between the shipowner and shipping company often makes the investigators incapable of accessing information unless the authority is willing to invest a lot in its investigations. The more information the report discloses, the deeper and more latent factors in the analysis by the new model could be approached.

Moreover, the application of such an adapted HFACS framework makes good the advantage of shunning the answer of what is the root cause, which is the best suitable for analyzing assumed simple linear causation accidents that is not a systemic view and needs intensive time and cost investment to clarify (ABS Consulting, 2005; Hollnagel, 2009, p.105) and has two more limitations in its application as claimed by Ferjencik (2010), but with a pragmatic focus on producing workable and effective corrective measures at all levels of organization to prevent the occurrence. In contrast, it looks like a complete treatment not only resolves the symptoms on the surface but also eliminates the underlying disease that causes it. The motivation to formulate an explanation by using this framework is more pragmatic than the root cause, in a sense that it well addresses the compelling concern of how to prevent the accident from reoccurring.

More importantly, “various weaknesses” (Wreathall, 2006) suffered from several currently used techniques of accident analysis can be addressed by the comprehensive structure of the adapted HFACS framework. Firstly, as discussed in 4.1, the structured data sufficiently captures all the present collected data covering a variety from technical process to social process. Secondly, the developed framework greatly focuses on the role of the organizational factors which is discussed in next chapter, not simply relying on partially recalled knowledge of events by the seafarers concerned. Thirdly, this framework describing the control of safety by intangible safety control flow and tangible well-sorted and -organized structure emphasizes the couplings between each factor, as if there was no connection, which are further demonstrated in 5.2.

On the other hand, the perfect application of the “stop rule” (Rasmussen, 1988; Kinnersley & Roelen, 2007; Hollnagel, 2009, p.11) - “keep investigating until a familiar cause is found to which the cure is known” - in the adapted HFACS framework rightly reflects the selection of the initiating event and end event in the structure of the framework itself. Actually, the structured and classified HFACS framework provides a pragmatic guidance in selection of both an initiating point traditionally at its sharp end and a stopping point normally at its organizational level or social environment level in an effort to trace back the event. In the traditional manner in our cases, the first and final event in the chain of events is often not fixed, varying from case to case and subject to the investigators’ preference. The investigators' subjectivity in the selection of an initiating and stopping point leads to a quite diverse analysis outcome from the accident investigation. In addition, it may be due to the diversified assumptions implied by the causation models that were used, known as *What-You-Look-For-Is-What-You-Find* or *WYLFIWYF* principle (Hollnagel, 2009, p.85). A typical example can be referred to the case of BP's Texas City refinery in Hollnagel's work.

Why is this matter so important for the outcome of the investigation? Two concerns should be referred to in order to answer such a question: to assign liability for the accident and to understand how to prevent the reoccurrence. The former is quite relevant to the administrative investigation, whose main responsibility is perhaps to portion the blame and penalize the responsible persons. Some criticisms arise in response to such an approach for its allocation of blame. A typical one is Dekker (as cited in Ghirxi, 2008) who criticized as the error classification systems which just shift the blame up to the organizational level rather than blaming the frontline operators. In respect of the blame culture, it is a fact that the more failures that are observed at the organizational level, the more corresponding liability will be assigned on them. However, the question is why we have to stick ourselves in the domain of the blame culture. If so, the management level will be motivated by such to invest more resources in building safety; if so, the mere result of investigation is to blame the people in operation, no matter which approach is considered. Rather than the former one, it is more meaningful to see the benefits from the second point of view - to know how to prevent a reoccurrence. The selection of the initiating and stopping point provides us with a better and more thorough way to systemically review the entire organization at enough depth, to cover all the possibilities of workable measures of prevention ranging from the top management to the frontline operators, from social process to technical process. All the factors which may affect the stability of the system are possible to accept the systemic assessment.

By looking into the details of its application, the applicability of the adapted HFACS framework in specific maritime cases is sufficiently reflected in two aspects as discussed above. It has been learned that the adapted HFACS framework provides us with a far more adequate and thorough structure and classifications than actually needed. In theory, by its established connection with the ISM Code and the generality of elements in the ISM Code in terms of the organizational factors, its applicability will be extended positively to other sorts of accidents in maritime accident investigation practice. On the other hand, its kindred with the Reason’s model provides the credibility of the adapted HFACS framework while its depth of analysis by the new framework tightly relies on the thorough review of contributory factors in the framework, which has been proved to be positive previously. The conclusion is made, therefore, that the adapted HFACS framework is effective in maritime accident investigations.

Chapter 5 Findings and discussions

Since the verification of the adapted HFACS framework has been established in the previous chapter, the discussion in this chapter on the organizational factors becomes more convincing and comfortable in terms of its validity. In contrast to the traditional manner used by the authorities, the obvious issue we can see is that the adapted HFACS framework provides investigators with a comprehensive view for remarkably exploring and classifying not only the human factors, but also some other factors identified in the course of the analysis of accidents, as discussed in Chapter 2. In analyzing human error in the cases, the organizational factors have been highlighted by pinpointing the fundamental positions of the organizational factors in the system and providing insight about why accidents occur. The following section focuses on discussing some findings in Chapter 3 in relation to the outcomes compared between the traditional manner and the new insight.

5.1 More functional barriers towards the organizational levels become available

The new insight, from the HFACS point of view, into the analysis of the causation provides a brand new view into the causation of an accident, which constitutes how the accident develops, as demonstrated in Chapter 3. In contrast to the traditional manner previously applied in the official analysis of the accident, the most fundamental benefits of the application of the adapted HFACS model are comprehensive explanations in response to what caused the unsafe acts. The difference to other views is that the focus is not on the unsafe acts alone, but on a variety of factors from the precondition of unsafe acts to the social environment influence, far away from the sharp end. This positively guides the investigators to look beyond the actions taken by the frontline operators and into the latent conditions that provide the opportunity of expression of those actions. Those latent conditions at the blunt end, in particular the organizational factors, albeit far from the sharp end, once identified are relevant to prevent the accident occurrence and protect the system in the form of setting up functional barriers at those levels. As a consequence, it has been noted that the new insight is conducive to generate lessons learned from the accidents and strategies for safety management.

By analyzing the two instances in the adapted HFACS model, an increasing quantity of remote factors other than proximal factors were presented and analyzed in Chapter 3, in spite of the fact that these factors are not direct causes in nature. In the first case, eight sorts of organizational factors out of nineteen contributory factors were presented in comparison to one out of six contributory factors by the traditional manner, while in the second instance, five sorts of organizational factors out of fourteen in total were illustrated in contrast to nil out of five in the traditional picture, with a systemic approach to view and understand accidents. A number of contributory factors explored from its ground make people understand more deeply on what, how and why accidents happened in a more systemic, distinct and detailed way. More remote contributory factors, including organizational factors, are unveiled and analyzed according to the model structure, specifically conducive to research into human error, based on the extent of how the latent factors affect the actions or decision-makings of the frontline operators.

In fact, Hollnagel (2004) pointed out that the process of analysis and explanation of the accident causation could be appreciated as to an approach to understand how one or more supposed barriers fail in protection of the system or mitigation of consequence severity. In this respect, the emerging numbers of underlying cause factors means more choices of functional barriers could be set up so as to protect the system next time if those companies in the instances are aware of the importance of the safety barriers highlighted by the model, similar accidents will perhaps occur again in the present settings otherwise. In other words, by using this model, the investment to implement the ISM Code will maximise its financial benefits and cost savings in the form of a reduced possibility that an accident will take place again. More importantly, from the safety management point of view, these safety barriers could be regarded as the safety functions more than barriers themselves, which constitute the “safety web” (Harms-Ringdahl, 2009, p.362) in the system it protects. By analysing the safety function in the organization, people are capable of evaluating how far the safety functions still effectively work.

On the other hand, those failures at the remote end often persist for a long while, but not being detected until their expressions in the form of accidents come true, perhaps triggered by the unfortunate frontline operators. They have an incubation period prior to the outbreak, in comparison to the virus in the animal body posing potential dangers. In this respect, an accident is not a totally bad issue to an organization, but generating an opportunity of detecting the remote and potential deficiencies which may not be detected and identified in the routine course of risk assessment. However, this opportunity carries with the possibility of property or even life loss. Examples can be easily found in the above instances in Chapter 3. A typical example is the failure of correcting the absence of the rubber packings around the edge of the bow visor although it was denied as the decisive factor of the causal story. As one of the contributory factors, it could have been corrected if the organizational climates, e.g. if the priority of safety margin despite time pressure, had worked effectively prior to departure. It is true that in the company instead of safety awareness, the awareness of voyage time pressure was emphatic and often recognized at all operational levels prior to that accident. The correction of the absence of the rubber packings proved conclusively to be impossible when the solutions to prevent this occurring seemed to be out of the captain’s reach due to this reason. The pressing concern on barriers to be set up at the management levels was dysfunctional in terms of the repeatedly noted time pressure on voyage, with the speculation that the disaster may not take place by such a deficiency. Moreover, given the risk assessment perspective, the identification of a potential threat at the first stage had been already noted and reported prior to the evolution of the defects in the accident, but failed to evaluate its severity and stop its further evolution, still in an alive state. Due to the safety climate, the management level discounted the “ambiguous threat” (Edmondson, Roberto, Bohmer, Ferlins & Feldman, 2005) rather than making an explicit decision to assume the presence of such a real threat, and then eradicate the potential threat in its cradle. The level of management where safety was not deeply engaged in accordance with the adapted HFACS model application and analysis should be required to be reviewed overall at intervals in order to build proper barriers at those levels within the system accordingly.

In brief, it is suggested that more preventive measures in both quantity and quality at all levels of an organization will be produced when employing this new form of analysis. In addition, a better understanding over the pathology of an accident, particularly factors at organizational level, is significant for ensuring the future preventive work be successful. These results with organizational barriers can be used in both safety improvements and learning accordingly.

5.2 The significant role of the organizational factors in the maritime context

As discussed in the first part, the agreement we have reached is that the new insight, provided by the adapted HFACS model, authorizes us to have a free hand to diagnose how the accident took place with a deeper and more comprehensive view, and explores more fundamental contributory factors - in particular organizational factors, although these factors were seldom revealed by formal investigations (Schröder, Baldauf & Ghirxi, 2009). This section establishes an overview of how these factors influence a ship’s safety, namely by recognizing the contribution of organizational factors associated with the ISM Code to a ship’s safety, by discussing the final outcomes observed in Chapter 3.

In fact, a considerable amount of recent research (including Schröder, Baldauf & Ghirxi, 2009) revealed some reasons why investigators were reluctant to trace the origin of an accident back to the organizational level. A scarcity of familiarization with a proper causation model in coping with non-linear development events becomes one of the identified reasons. Additionally, in the absence of a comprehensive approach over the analysis of accidents, it is hard to assess the role of organizational factors in safety performance in the maritime context. Fortunately, thanks to the creation of the adapted HFACS framework, a comprehensive review on the contribution of the organizational factors, directive to the effectiveness of the ISM Code in the organization, can be conducted. From the adapted HFACS framework point of view, within the spectrum of the model, the relations among each factor are mostly interdependent. Among them are diverse degree and direction interactions, an indication of the "safety control flow" (Swedish Rescue Service Agency, 2000, p57) from a closed loop control perspective, including those factors at the low and high levels. As to the original Reason's model, aside from the sequent influential flow between higher and lower levels and its influence from top to bottom, Reason (1997, see Figure 3) himself did not specify any clear clues of interactions at the same level.

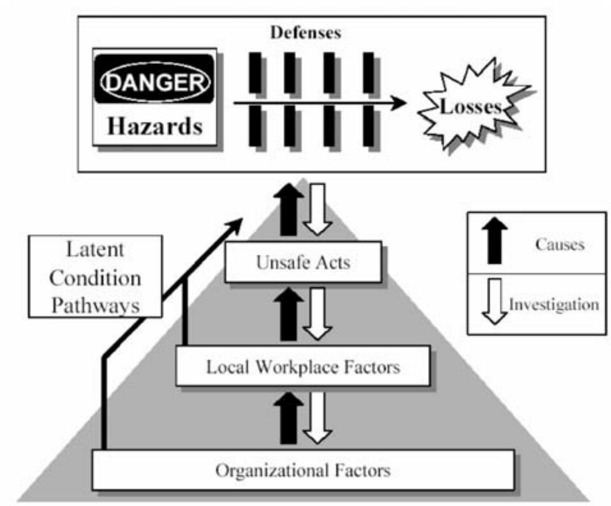

Figure 3 Reason's Model.
Source: Reason (1997).

Actually, the experience to apply such a framework suggests the interactions be far more complicated than those described by Reason. The epidemiological property of the Reason's model argued by Hollnagel (2004), discussed in Chapter 4, also supports such evidence of the sophisticated interactions inside Reason's model. So is the adapted HFACS framework by its origin. In the adapted HFACS framework, the failures of organizational factors' interactions often end up with the unsafe acts (except some cases where there is no unsafe act involved, such as the first case), subsequently inducing the accident. In this respect, human error was no longer regarded as being the symptom of trouble inside the system. If so, the blame should be placed on the account of the system as well. If not, it is the failure of the system that creates human error, such as the failure of interaction. To simplify, the interactions that affect the organizational manner in terms of maritime safety are generally categorized as two groups: internal interactions and external interactions.

(1) Within the categories of the organizational influences, the sub-factors at the level of 2nd Tier or even the 3rd Tier directly or indirectly interact with each other concerning maritime safety. Whether the induced effects are positive or negative depends on the extent to how one factor is compatible with another. For instance, organizational climate, which is defined as the collective perception of organization safety practice at the individual level, affects greatly the process of decision-making of allocation of resource. In the second case, the lack of an ideal safety climate within the shipping company led to the inadequacy of implementing the safety regulation on equipping it with updated charts on board, as well as the proper procedure of crew employment. In some cases, job designs with critical functions will be allocated to several positions at the same level, and are based on these principles so that diverse and independent interactions serve to monitor or verify the safety performance in a particular function. These factors are in parallel in the system, often overlapping with diverse interactions. If these interactions are proved to be incompatible and dysfunctional, it will be a risk ending up with a negative consequence, with an increasing possibility of an unsafe act at the sharp end accordingly.

(2) When it comes to the interactions between organizational factors with other levels of contributory factors, it becomes far more complicated than the internal interactions as discussed above. From the top to bottom, the interaction is naturally transmitted through the levels one by one from the latent failure to the active failure. However, sometimes, the interaction could be directly transmitted to the unsafe act at the sharp end rather than through the supervision or workplace level. In spite of the fact that, e.g. in the first case, when there was no unsafe act, the accident still takes place, the combination or accumulation of organizational factors directly or indirectly contributes to the onset of accidents. In other words, the organizational factors are able to induce the accident in the situation even without initial event triggering by the unsafe acts. On the other hand, no organization is living outside the social environments. In determining the contributory factors, those factors at the environmental level should be taken into account in this regard. This provides us with an opportunity to review the effectiveness of the legislative systems in the event of it lagging behind the technological innovation or malfunctioning presently. Yet the organizational factors still play a decisive role in determining the level of system safety performance because of their proactive requirements and social responsibility to the public. In consideration of the new amended requirement of risk assessment in the ISM Code, the organization is obligatory to be proactive to protect their system or specifically its ships, no matter there is a proper legislative requirement or standard or not. In return for the wealth gained socially, the organization shall be in collaboration to well create a safe society. The unique feature of the ISM Code fully reflects that the legislative system exhibits a tendency of setting more functional requirements than descriptive requirements. Another example is Chapter Ⅱ-2 of the SOLAS Convention concerning fire safety on board.

By judging the model itself, the accident itself, whether triggered unsafe acts or not, often begins with the negative organizational influence – from the top position in the model. On the other hand, by its diverse interactions with the dynamic environment and preventive influences on the human variability, the organization in the framework functions as a buffer between the human variability and system and between the social environment and system, as something that offsets the excessive variability when there is too much of it or compensates the variability when there is a scarcity of it (Hollnagel, 2009, p.57). The failures in terms of being functioned as a buffer at the organizational level become clear, with its negative effect transferring down through various organizational and departmental pathways to, no matter via supervision or the workplace or not, where there is no offsetting or compensation of variability to cope with human variability and its dynamic environment (which is discussed in the next part). A huge number of such unsafe acts often take place, however, whereas only a very few of unsafe acts can really trigger the accident unless they penetrate into the last barrier in the "Swiss Cheese". Considering the fact that, on the other hand, the established barriers, which should have been effective, are impaired by the organizational factors.

In addition, Reason (1997) argues "the higher an individual's position within the organization is, the harder it is to proceduralize the job operation", it will end up with a wider and more tragic consequence if such an individual fails to achieve his/her role. In this respect, human variability at the higher management level with fewer standard barriers or restrictions often brings about more risks to the whole system than that at the sharp end. On the other hand, will it become debatable to define whether decision-making at that level is right or not, until the tragic consequences become visible? The need to analyze organizational factors thereby becomes straightforwardly urgent in hope that the system with effective barriers at all levels can be established.

The main contribution of this model helps people to understand and appreciate that the frontline operators-the seafarers-will possibly be remitted from the instigators of an accident, subsequently to be as the inheritors, as asserted by Reason (2008). Those people who should have been protected by the organizational barriers are expected to be regarded as the victims of failures of organizational factors, but not perpetrators from the traditional perspective. The meaning of this model, if being applied in maritime accident investigations practice, will lie in directing the accident analysis into a deeper and more symbolic level at which the factors contribute more substantially than the frontline operator to the accident (Mohaghegh, Kazemi & Mosleh, 2009). What is more significant is that it may give birth to an innovative reform to shift the emphasis of investigation from the sharp end to the remote end by a function of multiple organizational factors in practice. But we are more willing to see a phenomenon that the organizational managers will be motivated to take more effective measures to create an ideal workplace where unsafe acts can be least likely to be committed, in avoidance of being blamed for their absent role.

In short, diversified organizational factors involved in the system directly or indirectly affect the possibility of occurrence of unsafe acts, eventually leading to disasters. Therefore, proper consideration should be taken into account at the organizational level for effectively preventing the similar accident recurrence. The significant exploration of organizational factors in such a way helps us not only to better understand how the accident occurred, but also learn more lessons from the accidents on how to prevent their occurrence.

5.3 The dynamic and uncertain system in nature

Thousands of years ago, the ancient Chinese philosophical text the *I Ching* (or *Book of Changes*) described a philosophical proverb that in brief in Chinese is “Shangbian, Guizhong, and Qushi”, meaning that the world where we live in always remains in a state of varying; in order to survive, we therefore need to be in well-preparedness and respond correspondingly to the proper extent in a justified manner at a appropriate time. In essence, “Shangbian” rightly unveils one of important properties of the system safety - dynamics and uncertainty. This is not only due to “the human variability in the form of timely adjustments, tweakings and adaptations” (Reason, 2008), but also the dynamic and unpredictable environment surrounding the system.

The human variability in the safety system could be evidenced by the unbelievably malfunctioned action of exchanging a crew in the second instance. The system with regard to the safe navigation had transiently been maintained at a comparably stable level before the new master boarded the vessel, despite some deficiencies or turbulences residing. Since the former master was familiar with, and often called at this port by another route, even without updated information on the bridge construction available on board, the vessel was still able to leave and arrive safely and as stable as required. For the time, the significant role of updated information on the bridge construction in terms of past routes was not so prominent due to the fact that the master's voyage passage did not come across the water area of constructed bridge, something like the role of the positive "performance variability" (Hollnagel, 2009, p.96), i.e. "heroic recovery" (Reason, 2008) under the circumstance without proper charts. Since the arrival of the new master in question brought about a change of climate on board, such "stochastic resonance" (Hollnagel, 2004) by the human variability beyond the acceptable limit - the occurrence of the unexpected - the collision between the vessel and the bridge span. From the systemic point of view, the human variability regarded as the internal source of uncertainty leads to the instability of the system. Given that the vessel was manned with a group of qualified crew, using standard procedures and equipped with updated charts with proper small corrections, the "stochastic resonance" may be maintained at a certain acceptable level, without running over the threshold, even in the case of route changing.

Another reason why the system is dynamic is seeing that the varied and unpredictable circumstances. In the second example described in Chapter 3, when the vessel's voyage moved to the current line between Tallinn and Stockholm, the unexceptional wind and wave condition resulted in an over wave-induced impact load, the inadequacy of load on the bow visor appearing to be prominent enough to bring about the failure of the bow visor's attachment. Such a given situation that the ESTONIA encountered was unpredictable and out of all human capability in spite of the weather report that was issued in advance. However, in accordance with the survey in the official report, the weather conditions in the open area of the Baltic Sea are apparently rougher than that along the previous line between Turku and Stockholm. Apparently, the outside environment surrounding the vessel's operation varied after the vessel's transferring. Notwithstanding, the following disaster proves that insufficient countermeasures had been taken in response to the rougher and longer route condition. In contrast to the second case, there was no unsafe act triggering the ESTONIA disaster, in the sense that nothing relating to human wrongdoing apparently occurred. However, this does not matter with the occurrence of the accident. Instead, the concurrence of an amount of events at diverse levels within the organization, in particularly under a dynamic and uncertain environment, induced such a disaster.

Living in such a kind of dynamic and uncertain world, the *Book of Changes* properly requires us to respond proactively in order to drag the system with potential risk back to the stable state at the appropriate time with a proper and sufficient approach. The requirement of the *Book of Changes* is what is to be discussed a little further here - organizational resilience, a kind of solution for the organization in response to the dynamic and uncertain system. The eminent safety engineering author Hollnagel (2006) defines it as “the essence of resilience is the intrinsic ability of an organization (system) to maintain or regain a dynamically stable state, which allows it to continue operations after a major mishap and/or in the presence of a continue stress.” Such a definition is in line with the motto of the *Book of Changes*, with an illustration of the necessity of corresponding change and appropriateness of both the extent and opportunity of that change.

In response to the system’s disturbance caused by human variability and interaction under uncertain surroundings, correspondingly changing a part of, or the entire system, is necessary to improve the reliability and quality of the system. From the perspective of Hollnagel (2009, pp.41-44), the human variability refers to the *satisficing* which is explained as a consequence of limited cognitive capacity, while the dynamic and uncertain environment relates to the *sacrificing* which is construed as a consequence of the intractability of the work environment. The key issues here in response to the *satisficing* and *sacrificing* are the extent to how much changes are needed, what the opportunity of change is, and what the changes should react, so that, for instance, the legislation can keep pace with the innovation of the techniques. In the first cases if the industry can work together with the companies or administrations involved in response to the numbers of similar incidents properly and timely, the accident may not end up with such a dramatically tragic outcome. The degree of the organizational resilience relies on the capacity at each organizational level in dealing with the "flexible and informal way of working" (McDonald, 2006) system dynamics. Even in the context of the shuttle program in the USA where there are enough budgets, well-programmed procedures and well-educated personnel, for instance, the lack of informal communication channel flow of information was blamed as one of the organizational deficiencies in the case of the *Columbia* (Milliken, Lant & Bridwell-Mitcheel, 2005).

On the other hand, the system itself, when in a safe situation, is not stable in nature at all - still in dynamic and uncertain property. Seeing that the human "heroic role" in adjustment of the deviation functions back to normative performance, the system appears to run peacefully and smoothly, in comparison with the calm sea surface that an amount of water in dynamic movement is moving inside it. In the second case, the former master acted as "heroic role" in maintaining the operation of the ship at a safety level despite the absence of chart small correction and bridge construction information.

The dynamic and uncertain property of the system makes the importance of the organizational resilience symbolic in striving to offset the negative effect through human variability and a dynamic environment. Therefore, being ready to encounter the unexpected at any time as a "high reliable organization" (Weick & Sutchliffe, 2007) is an obligatory way to pave the road to safety heaven. The legal style of elements in the ISM Code to be functional rather than descriptive, rightly addresses such a need for the organizational factors - dynamics.

To sum up, the role of the organizational factors appears to be indispensable in ensuring the safety performance in the maritime context. In this regard, more functional barriers for the purpose of minimizing the possibility of unsafe-acts-induced accidents and the consequences are recommended to be set up at each level of organization under the direction of the fundamental lessons and strategies learned from the maritime accident investigations. Furthermore, the dynamic property of a system requires organizational resilience in terms of safety performance, to be ready to respond with the appropriate action in an acceptable manner at the proper opportunity.

Chapter 6 Conclusions and Recommendations

As noted previously, in comparison to only blaming the frontline operators, it is more symbolic for us to learn lessons from the accident investigation on how to prevent similar accidents recurrence. For this purpose, this paper is motivated to seek a proper accident causation model to identify the roles of the organizational factors in maritime casualties. A substantial amount of effort was made to adapt the Human Factors Analysis and Classification System (HFACS) framework with proper consideration of the specific situation in the maritime industry and elements of the ISM Code, which predominantly deals with organizational control in safety performance on board. Then along with two case studies using such a model, the applicability was verified positively and the roles of the organizational factors in maritime context are highlighted and discussed. Some observations regarding the framework applications into maritime cases and recommendations concerning how to use the framework in the future are made below:

6.1 Conclusions

For the adapted model:

1. The adapted HFACS framework proved to be effective in maritime accident investigation. By successfully analyzing two case studies, it was observed that it is positive to collect comprehensive data with the help of the adapted HFACS framework and provide deep and reliable analysis of the accident. Its special contribution to the maritime accident investigation is to guide investigators how

to collect data and proceduralize investigations and the analysis of an accident with the focus on human and organizational factors.

2. Aside from specialized investigatory authorities, same principles of the adapted HFACS framework can be applied as well by the shipping industry for the purpose of reviewing and benchmarking safety performance both on board and for shore management. In addition to look into maritime accidents retrospectively for the purpose of diagnose what is wrong inside the organization, successful experience can also be concluded and exampled by the means of the adapted HFACS framework from the majority of successful cases which are more valuable and pervasive than failures to learn.
3. Due to its full integration of the elements of the ISM Code, the adapted HFACS framework can be specifically utilized as a manual of measuring the safety performance of the ISM Code on board and for shore-based management. By providing the whole-view picture on how the elements the ISM Code interact with safety performance, safety managers are aware of the importance of implementing the ISM Code with higher possibility. In this regard, the implementing organizational decision can be well managed by clearly evaluating possible interactions with those factors in the adapted HFACS framework.

For the organizational factors in maritime casualties:

1. By the means of such an adapted HFACS, it will be positive to learn lessons from maritime accidents with a focus on the organizational levels. This is important because of their significant influence on maintaining maritime safety.
2. Organizational factors by their interactions with those factors mostly at the lower level, such as the sharp end, are substantially influential on safety performance on board, even in the situation where there is no unsafe act involved. The magnification of the influence by the organizational factors is possible to be made on the sharp end.

3. Organizational resilience is required to be maintained in response to the human variability and environmental dynamics in order to sustain stable safety performance on board. The adapted HFACS framework is, however, not fully capable of focusing on resilience aspects.

6.2 Recommendations

Based on the considerations above, the following recommendations should be given:

1. Time and resources are suggested to be intensively invested in investigation and analysis. According to the categories in the framework discussed previously, a thorough review of the organizational performance requires relevant information at all levels of organization. In this respect, thoroughness should not be compromised with efficiency to quickly and off-handily finalize accident investigations without producing high-value and workable results, cf. ETTO (Hollnagel, 2009), at least in major accidents. In accordance with the ISM Code, however, contemporary shipowners are allowed to set aside the responsibility of management to the shipping companies. This may bring about difficulties to the flag state administration concerning the geographical separation of the shipping companies diverse from the flag state. At least, a complete review of a major accident requires a considerable amount of time and resources.
2. A major consideration should be made to develop and document proper procedures or guidance on how to apply the adapted HFACS framework. Each framework has its limitations. As Svenson (as cited in Katsakiori, Sakellaropoulos & Manatakis, 2009) noted “an accident can be explained in different ways depending on the accident analysis model that is used” due to its diverse theoretical hypotheses on which the model is based. The WYLFIWYE principle stated by Hollnagel also implicated that the conclusions of accident investigations may be guided explicitly or implicitly by the assumptions or methods that are used in investigations. It is not surprising that a number of

investigations with differing premises or instructions may lead to diverse conclusions in practical maritime accident investigations. This means a certain accident causation model, such as the adapted HFACS framework, has always limitations, and therefore accident investigators have to be aware of this.

3. Sufficient training of familiarization of the adapted HFACS framework should be given to investigators. The quality of utilizing such a framework greatly would be contingent on the degree of the investigators’ comprehension of the framework. A typical example is the external environmental factors in the framework. In some cases, the meteorological conditions have a decisive effect in determining safety performance on board. These cases should not be off-handly attributed failures to the organizational factors if such organizations have completed all reasonable measures to prevent those accidents.

Last but not least, the extent of effectiveness of applying the adapted model into specific accidents relies on the recognized degree of the investigatory agency concerning the comprehension of human error and profile of the investigatory agency. The acceptance of the adapted HFACS framework might not positively change the way in which the maritime industry, commerce and regulatory authorities view the causation of the accident derived from such a framework unless they properly apply it. If such a framework is widely applied in the maritime industry, corresponding accident databases will be in a well-organized and unique format so statistical and analytical job from these databases by administrations to conclude certain safety tendencies, or shipping companies to generate certain safety patterns, will make more practical sense.

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