Project Report
“A CRITICAL ANALYSIS OF MARITIME ACCIDENTS WITH REFERENCE TO GLOBAL PERSPECTIVE”

Project report submitted to the School of Maritime Management, Indian Maritime University,
in partial fulfilment of the requirements for the award of a degree of

MASTER OF BUSINESS ADMINISTRATION

(INTERNATIONAL TRANSPORTATION AND LOGISTICS MANAGEMENT)

Submitted by
Paitode Abhishek Nandkishor
(Reg. No. 2303305030)

Under the guidance of,

Dr. Totakura Bangar Raju

Professor, Dean SMM

INDIAN MARITIME UNIVERSITY

(A Central University, Government of India)

SCHOOL OF MARITIME MANAGEMENT

CHENNAI CAMPUS

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DECLARATION

I, Paitode Abhishek Nandkishor, hereby declare the project report entitled "**A CRITICAL ANALYSIS OF MARITIME ACCIDENTS WITH REFERENCE TO GLOBAL PERSPECTIVE**" is an independent work carried and submitted by me towards the partial fulfilment of the Master of Business Administration in International Transportation and Logistics Management under the supervision of **Dr. Totakura Bangar Raju** Professor Dean SMM, Indian Maritime University, Chennai Campus. Additionally, I affirm that my project report is entirely original with no copies from prior reports that I have submitted for consideration for a degree, fellowship, or other equivalent designation.

27-5-25

Paitode Abhishek Nandkishor

MBA (ITLM)
School of Maritime Management
Indian Maritime University, Chennai
(A Central University, Govt. of India)
East Coast Road, Uthandi
Chennai - 600119

CERTIFICATE

This is to certify that the project report entitled "**A CRITICAL ANALYSIS OF MARITIME ACCIDENTS WITH REFERENCE TO GLOBAL PERSPECTIVE**" submitted to partial fulfillment of the requirement for awarding the degree, MBA in International Transportation and Logistics Management is genuine work of Paitode Abhishek Nandkishor (Reg no.2303305030).

Dr. Totakura Bangar Raju

Professor, Dean SMM

Dr. B Swaminathan

Associate Professor & Head SMM

27-5-25

External Examiner

Place: Chennai

Date: 27-5-25

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ABSTRACT

Marine accidents still pose grave threats to life, property, and the environment, despite continuing developments in maritime safety and technology. This thesis is a systematic examination of ten chosen marine accidents that were on fire, collision, grounding, experienced onboard accidents, and sinking. The general aim of this study is to identify the human and systemic causes underlying these incidents. For this purpose, the Human Factors Analysis and Classification System (HFACS) and SHEL (Software, Hardware, Environment, and Liveware) model have been utilized as the analytical frameworks. The HFACS model allowed a systematic examination of human errors on various levels, whereas the SHEL model supported the detection of interaction mismatches between human operators and system components.

The HFACS system offers a multi-layered method of deconstructing human error, and it considers organizational factors, unsafe supervision, preconditions for hazardous acts, and the hazardous acts themselves. The SHEL model is concurrently utilized to analyze how human operators and system elements interact, and what mismatches or weaknesses may occur in the work environment, equipment design, procedures, and man-machine interface.

Findings from the analysis identify persistent patterns of organizational failure, poor communication, decision-making, and failures in safety management systems. The research emphasizes the importance of holistic human factor considerations in maritime safety procedures and provides pragmatic recommendations to prevent future marine accidents. This thesis adds to the increasing literature focusing on a systems approach to maritime accident analysis and prevention.

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Acronyms

IMO - International Maritime Organization

HFACS - Human Factors Analysis and Classification System

SHEL - Software, Hardware, Environment, and Liveware

ISM Code - International Safety Management code

STCW - Standards of Training, Certification, and Watchkeeping for Seafarers

SOLAS - Safety of Life at Sea

HELCOM - Helsinki Commission

IMDG code - International Maritime Dangerous Goods Code

VDR - Voyage Data Recorder

SMS - Safety Management System

MRM - Maritime Resource Management

VTS - Vessel Traffic Service

OOW - Officer on watch

MSA - Maritime Situational Awareness

CPA - Closest Point of Approach

COLREGs - The International Regulations for Preventing Collisions at Sea

CTU code - Cargo Transport Units “Code of Practice for Packing”

ECIDS - Electronic Chart Display and Information System

BNWAS - Bridge Navigational Watch Alarm System

TSS - Traffic Separation Scheme

BAC - Blood Alcohol Content

1.0 Introduction

Global trade and transportation will inevitably involve maritime mishaps, which frequently have disastrous effects on human life, the environment, and economic stability. From small operational errors to major catastrophes involving ship collisions, oil spills, cargo loss, and fire, these incidents can take many different forms. The risk of accidents has increased due to the growing volume of maritime traffic and the complicated navigational conditions, which calls for thorough investigation and preventative safety measures.

One notable maritime mishap is the fall of the Baltimore Key Bridge in 2024, which seriously damaged infrastructure and interrupted supply routes. For six days, the Ever-Given Suez Canal blockage in 2021 disrupted international trade, causing billions of dollars in costs and highlighting how susceptible important shipping routes are to unanticipated delays. Furthermore, the 2018 Maersk Honam disaster in the Arabian Sea brought to light the perils of fire threats on contemporary ships transporting hazardous chemicals, since it tragically claimed the lives of five crew members and destroyed a significant amount of cargo. To prevent similar incidents in the future, these incidents highlight the weaknesses in maritime operations, the shortcomings of current safety protocols, and the urgent need for better risk management techniques, emergency preparedness, and technological advancements in ship design and firefighting techniques.

Approximately 90% of the world's commodities are moved via maritime means, making it the foundation of international trade. The shipping sector is essential to global logistics due to its effectiveness and financial sustainability. However, there are several risks associated with this vital industry, such as marine mishaps that have serious negative effects on people, the environment, and the economy. Human error, organizational shortcomings, and environmental risks are only a few of the contributing variables that keep marine disasters common despite improvements in ship design, navigation technology, and regulatory frameworks. (Singh & Raju, 2024).

Collisions, groundings, fires, oil spills, and equipment malfunctions are all included in the wide category of maritime accidents. These occurrences have long-term effects on global supply chains and economic activity in addition to posing immediate risks to seafarers and the marine environment. To create effective prevention measures, it is essential to analyse these accidents and determine their underlying causes. Despite strict rules and sophisticated safety management systems, studies show that human and organizational errors rank among the primary causes of maritime disasters. (Chen et al., 2013).

1.1 Rationale of the Study

What inspired the choice of this thesis topic is the necessity to thoroughly examine 10 significant maritime incidents, pinpointing their underlying causes and evaluating their effects. Maritime mishaps have detrimental effects on the environment and people in addition to interfering with global trade. It is feasible to identify trends, comprehend operational and human error, and suggest improved safety procedures to reduce risks in the future by examining these accidents.

A comprehensive study into these incidents will educate regulatory policy and offer insightful information about industry-wide safety issues. Additionally, this study attempts to close the gap between theoretical safety standards and their actual execution by concentrating on the direct and indirect repercussions of these events. By ensuring that lessons learned from previous disasters are translated into more effective preventive measures, the goal is to support a stronger safety culture in maritime operations.

Analysing these incidents also makes it possible to determine whether more legislative changes are required and how effective the current maritime safety laws are. To give a comprehensive picture of accident prevention, the study will consider elements like ship design, crew training, emergency response plans, and international maritime regulations. The economic impact of these accidents is another goal of this research, along with suggesting affordable ways to reduce risks. This study aims to persuade industry players, regulatory agencies, and legislators to implement significant changes that improve overall marine security by highlighting serious flaws in maritime safety.

1.2 Objectives of the Study

This study's main goal is to use the HFACS and SHEL models to objectively analyse marine incidents in order to find systemic failures and underlying causes.

1. Using the HFACS (Human Factors Analysis and Classification System) framework, the specific objectives are to classify human errors in maritime accidents.

2. To use the SHEL paradigm to analyze system interactions (hardware, software, environment, and liveware).

1.3 Business problem

There are several levels of the business issue related to maritime accidents:

Financial Losses: Ship damage, cargo loss, legal responsibilities, and compensation claims all result in large financial losses in maritime accidents. Businesses that experience recurring occurrences see an increase in insurance costs, which has an impact on profitability.

Supply Chain Disruptions: Mishaps cause delays in shipments, bottlenecks, and higher freight costs, which affect international trade. Production stops in industries that rely on just-in-time supply chains.

Costs associated with compliance and the environment. Vessel groundings, oil spills, and hazardous material leaks cause significant environmental harm that entails high fines and cleaning expenses. Shipping businesses incur higher operating costs result of stricter regulations.
Reputation Damage: Maritime businesses with a bad safety record are subject to more regulatory scrutiny and fewer business possibilities. Contract loss results from recurring instances that damage their brand image.
Inefficiency in operations Human mistakes, insufficient risk assessments, and a lack of a safety culture all lead to more accidents, which raise downtime, repair expenses, and fleet utilization inefficiencies.
These incidents have far-reaching financial repercussions, from immediate repair and salvage expenses to drawn-out court cases and insurance claims. Shipping businesses bear significant financial costs in the event of incidents like collisions, oil spills, or structural collapses. These costs include vessel repair costs, compensation for impacted parties, and regulatory body penalties. Major marine incidents, like the Ever-Given blockade, also cause delays that disrupt global supply systems, costing businesses that depend on on-time delivery billions of dollars in lost revenue.

Another significant problem with maritime safety is operational inefficiencies. Inadequate risk assessment, poor safety regulations, and a lack of training all lead to frequent occurrences that interrupt corporate operations. To reduce risks and guarantee more efficient operations, shipping businesses need to make investments in improved safety procedures, crew training courses, and cutting-edge technologies. Furthermore, it takes ongoing investment to comply with international safety rules, such as the International Maritime Organization (IMO) standards, which puts a financial burden on shipping companies that don't satisfy changing safety standards.

Another crucial component of the business issue is reputational harm. Shipping businesses that are involved in accidents are subject to legal liabilities, public scrutiny, and a decline in stakeholder confidence. Financial instability, more regulatory scrutiny, and fewer economic prospects are all consequences of negative media coverage and environmental issues. Therefore, to preserve their reputation and avoid operational delays, businesses need to use proactive risk management techniques and disaster preparedness plans.

Long-term financial risks are also presented by environmental and regulatory issues. Legal ramifications and expensive environmental clean-up activities are the outcomes of accidents that cause oil spills or the release of dangerous materials. Businesses must adopt sustainable and compliant operating processes since governments and environmental organizations impose harsher rules and fines on those who cause such occurrences. Failing to do so affects a company's long-term viability and competitiveness in the market in addition to resulting in monetary fines.

A wide range of events are included in maritime accidents, such as collisions, groundings, fires, oil spills, and equipment malfunctions. In addition to posing immediate risks to marine life and mariners, these occurrences have long-term effects on global supply systems and economic activity. Developing successful prevention strategies requires analyzing these incidents and determining their underlying causes. According to studies, despite strict laws and sophisticated safety management procedures, human and organizational errors rank among the main causes of marine incidents. (Chen et al., 2013)

1.4 The frequency of Maritime Accidents

Accidents have increased as a result of the growing number of marine traffic, especially in crowded waterways like the Baltic Sea, the Turkish Straits, and other important trade channels. The Istanbul and Canakkale Straits, for example, are vital transit routes for international trade, but they also pose navigation difficulties. These areas frequently see accidents due to strong currents, constrained passageways, and heavy vessel traffic (Essiz & Dagkiran, 2017). In the Baltic Sea, which raises the possibility of environmental catastrophes brought on by marine mishaps (Szubrycht, 2020a).

The risk of maritime accidents is still significant despite technical developments because of outside variables like bad weather, low visibility, and mechanical breakdowns. Furthermore, as demonstrated by instances where oil spills from big tankers have resulted in permanent environmental harm, larger vessels and heavier loads worsen the effects of mishaps (Dominguez-Péry et al., 2021). These figures demonstrate how urgent it is to put thorough risk mitigation plans into place and enhance safety procedures in the maritime sector.

In maritime safety, organizational shortcomings are also quite important. Unsafe working conditions are a result of insufficient training programs, poor safety cultures, and ineffective leadership. Although enforcement and compliance continue to be obstacles, the International Maritime Organization (IMO) has underlined the significance of strong safety management systems to address these difficulties (IMO, 1999b). To reduce human error and avoid accidents, shipping businesses must make sure that they take a proactive approach to safety rather than a reactive one.

2.0 Literature Review

Maritime accidents represent a significant challenge because they influence international trade, marine ecosystems, and human lives. Maritime accidents pose a serious threat to the worldwide shipping sector. Accidents continue to occur often despite improvements in technology and safety laws because of several causes, including environmental factors, operational inefficiencies, human mistakes, and systemic shortcomings in safety management (Gokce Cicek Ceyhun, 2014). Through the examination of current scholarly research, statistical results, and accident causation models, this literature review seeks to offer a thorough study of maritime accidents by looking at their causes, trends, and mitigation techniques.

According to several studies, up to 80% of recorded events in the maritime industry are caused by human mistakes (Bowo & Furusho, 2018). Numerous variables contribute to these inaccuracies, such as:

Regulations on fatigue and work hours for maritime crewmen must work long hours, frequently in stressful situations, which wear them out. Research shows that situational awareness, reaction times, and decision-making abilities are all severely hampered by fatigue (Nielsen & Jungnickel, 2003). Shift work-related irregular sleep patterns throw off circadian rhythms, which lowers cognitive function (Bye & Aalberg, 2018). Limiting work hours is the goal of regulatory initiatives like the Maritime Labour Convention (MLC 2006), but compliance varies among flag states, which has an impact on accident rates (Puisa et al., 2018).

Errors in navigation and situational awareness, a primary cause of crashes and groundings, are exacerbated by situational awareness lapses: Failure to monitor radar, poor bridge resource management, and dependence on antiquated navigational charts are the main causes of accidents (Gokce Cicek Ceyhun, 2014). According to data analysis from the Automatic Identification System (AIS), accidents frequently occur when ships fail to abide by safety zones and suggested speed restrictions in busy locations (Bye & Aalberg, 2018).

Crew competency and training deficiencies increase accident risk is to inadequate training and inexperience in complex navigation environments (Bowo & Furusho, 2018). Inadequate ice navigation training increases the likelihood of mishaps in the Arctic and in severe weather conditions. The idea that marine accidents are entirely random occurrences is called into question by the significant influence of economic considerations on accident frequency.

Due to inadequate Safety Rules and Flag of Convenience (FOC) safety regulations and unfavorable working conditions, ships registered in FOC states, such as Panama, Liberia, and the Marshall Islands, generally have higher accident rates (Puisa et al., 2018) The International Safety Management Code (ISM Code) has increased safety compliance yet there are inconsistencies in enforcement, which raises the likelihood of accidents in vessels registered to FOC (Bye & Aalberg, 2018).

A large percentage of marine accidents are caused by severe storms, choppy seas, and poor visibility (Bye & Aalberg, 2018). As Arctic shipping routes become more popular, there has been an increase in ice navigation mishaps in polar regions, putting boats at risk for hull integrity damage from ice collision (Bowo & Furusho, 2018). Limitations of port and coastal infrastructure increase accident rates are greater in ports with antiquated navigational aids and inadequate depth for large ships (Gokce Cicek Ceyhun, 2014)High vessel density and intricate traffic separation techniques increase the risk of collisions on congested waterways (such as the English Channel, Singapore, and the Turkish Straits) (Rømer et al., 1995).

A key element of marine safety is risk analysis, which enables participants to evaluate possible risks and put preventative measures in place. To assess accident risks, a variety of approaches are used, such as statistical modelling, simulation techniques, and historical data analysis. An organized framework for recognizing hazards and improving safety procedures in the maritime sector is offered by the IMO's International Safety Management (ISM) Code (IMO, 2008).

Additionally, programs that increase seafarers' capacity and provide ongoing training are essential for reducing human error. Frequent exercises, safety awareness programs, and competency evaluations guarantee that crew members are equipped to manage crises successfully. Establishing a safety culture in marine enterprises promotes proactive risk management techniques and strengthens adherence to safety laws (Hetherington et al., 2006).

2.1 Regulatory Frameworks and Safety Initiatives

In order to improve safety standards and lower accident rates, international marine rules are essential. To guarantee uniform safety procedures throughout the sector, the IMO has created several conventions, including the International Convention on Standards of Training,

Certification, and Watchkeeping for Seafarers (STCW) and the Safety of Life at Sea (SOLAS) Convention (IMO, 1999b).
Additionally, regional programs like the Baltic Marine Environment Protection Commission (HELCOM) concentrate on keeping an eye on and reducing maritime hazards unique to regions with heavy traffic, like the Baltic Sea. In order to enforce safety rules and handle new issues in maritime transportation, cooperation between maritime authorities, shipping firms, and port operators is crucial (Szubrycht, 2020).

2.2 Human Errors Induced by Technology

Human mistake brought on by technology is still a major worry in the maritime sector, even with automation and digitization. (Uğurlu et al., 2015) used the Fault Tree Analysis (FTA) method to evaluate collision and grounding accidents. According to the research, accidents may be caused by an over-reliance on automation and improper crew-technology interaction.

Montewka et al. (2017) draw attention to the dangers posed by autonomous ships and how they might affect maritime safety. Strong regulatory structures are needed to handle the issues raised by autonomous ships, according to the report. Furthermore, accurate risk assessments are necessary when integrating Artificial Intelligence (AI) into decision-making processes to avoid mishaps brought on by system malfunctions and human-machine interactions.

Organizational inefficiencies and human mistakes are responsible for a substantial percentage of maritime accidents. According to studies, human-related issues such as weariness, poor decision-making, misunderstanding, and insufficient training account for between 75 and 85 percent of marine accidents (Kaptan et al., n.d.). A popular tool for examining the part that organizational and human error play in marine mishaps is the Human Factors Analysis and Classification System (HFACS). This concept divides faults into many levels, such as dangerous acts, unsafe supervision, organizational influences, and preconditions for hazardous acts. Organizational inefficiencies and human mistakes are responsible for a substantial percentage of maritime accidents. According to studies, human-related issues such as weariness, poor decision-making, misunderstanding, and insufficient training account for between 75 and 85 percent of marine accidents (Kaptan et al., n.d.).

A popular tool for examining the part that organizational and human error play in marine mishaps is the Human Factors Analysis and Classification System (HFACS). According to (Chen et al., 2013), this method divides mistakes into many layers, such as unsafe acts, unsafe supervision, unsafe acts' preconditions, and organizational influences. Among sailors, fatigue is a common problem that frequently results in poor decision-making and diminished situational awareness.

Errors are far more likely to occur in marine labour due to its demanding nature, lengthy shifts, and little downtime. Language limitations among international crew members also make communication much more difficult and can result in miscommunications in urgent situations.

The flaws of the safety systems in place are further supported by empirical data. According to (Goulielmos et al., 2008) who examined 47 maritime mishaps that took place between September 2006 and January 2007, 41% of them involved collisions and frequently happened in inclement weather. The idea that only older ships are at risk was refuted by the fact that 40% of the events involved relatively recent vessels. Furthermore, operational errors and inadequate safety procedures were responsible for 80% of the fatalities in these accidents, proving that merely adhering to regulations does not guarantee accident prevention (Goulielmos et al., 2008).

2.3 Adaptation of Marine technology

A methodological development in marine risk analysis is the combination of network science and machine learning. It provides a scalable, comprehensible framework for safety management and accident prevention, bridging the gap between statistical pattern recognition and systemic understanding. It is suggested that future studies improve this paradigm by employing deep learning methods and causal inference algorithms to glean more insightful information from unstructured accident data (Feng et al., 2024).

The use of cutting-edge technology in ship operations is one practical strategy for preventing accidents. Digital navigation technologies, automation, and artificial intelligence (AI) have greatly enhanced situational awareness and decision-making on board ships. Over-reliance on technology, however, can also result in new hazards, like system malfunctions or a decline in crew members' physical navigation abilities (Celik & Cebi, 2009).Therefore, to maximize maritime safety, a balanced blend of technical breakthroughs and human knowledge is required.

3.0 Methodology

3.1 Statement of the Problem

Marine accidents pose a significant risk to maritime operations and can lead to fatalities, environmental damage, and financial losses. Although a lot of study has been done on the causes of these accidents, no thorough analysis that combines system interaction analysis with the classification of human mistakes has been done. In favour of focusing on the immediate causes, current accident investigations usually overlook underlying systemic issues that contribute to incidents.

This study aims to investigate various human factors in maritime accidents by using HFACS and SHEL model analysis.

1. What are the primary human factors responsible for marine mishaps?

2. How do interactions between humans, the environment, software, and hardware affect the reasons for accidents?

3. How might the HFACS and SHEL models be used to establish a comprehensive framework for investigating marine accidents?

3.2 About the HFACS framework

A thorough analysis technique called HFACS was created to examine the root causes of human mistake (Shappell & Wiegmann, n.d.); Shappell et al., 2007). The initial HFACS framework was based on the Swiss Cheese Model (Reason, 1990), which separated the elements that lead to an accident into two categories: active failures and latent factors. Four sub-levels comprise these two categories (Reason, 2016). While the final level (hazardous acts) shows active failures, the preceding three levels (preconditions for unsafe acts, unsafe supervision, and organizational impacts) represent latent variables. According to this framework, latent factors have a significant role in the development of active failures.

Shappell and Wiegmann (2000) were the first to employ HFACS for aviation accident analysis. A tried-and-true technique for detecting human error, HFACS allows accident incidents to be examined in a hierarchical manner. The ability of HFACS to describe the role of organizational and administrative aspects in complex systems such as accident occurrences, is the key characteristic that sets it apart from other accident causality approaches (Wiegmann and Shappell, 2003; Ergai et al., 2016;(Uğurlu et al., n.d.).

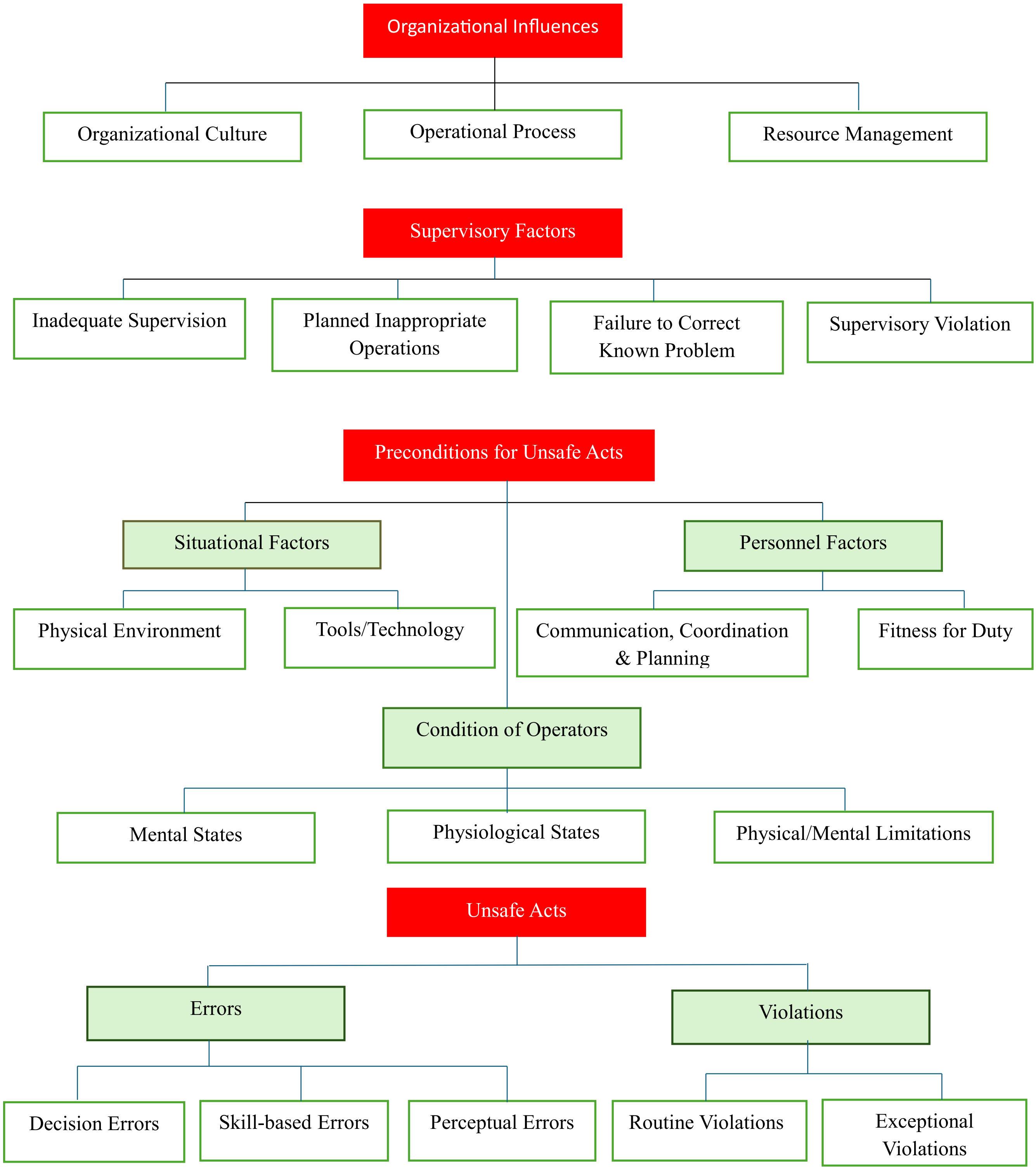

Figure No. 3.1: HFACS Framework

Four categories of classification for human-related causes of marine accidents are used in this study by using HFACS:

Organizational Influences: -

investigates the effects of corporate policies, managerial choices, and financial strains on marine safety. This comprises:

- Training guidelines and safety culture
- Gaps in regulatory compliance and enforcement
- Financial limitations on investments in safety
- Policies for crew scheduling and fatigue management

Dangerous Supervision: -

Examines how regulators, ship managers, and supervisors contribute to accidents. Important elements consist of:

- Poor supervision and leadership.
- a failure to address hazardous situations.
- a lack of effective risk assessments and insufficient crew performance monitoring

Preconditions for Unsafe Acts: -

Focuses on elements that impact crew performance, including:

- Environmental elements (weather, traffic, port design)
- Conditions of the crew (weariness, tension, workload, and communication obstacles)
- Deficits in procedures and technology (faulty machinery, insufficient training)

Unsafe Acts: -

The last level looks at the mistakes or infractions that caused accidents right away. They fall into the following categories:

- Errors include perception errors, choice errors (like wrong scenario assessment), and skill-based errors (like navigation errors).
- Violations include both routine (like avoiding safety protocols) and extraordinary (like purposeful risk-taking) infractions.

3.3 About SHEL Model

Edwards first introduced the SHEL model in 1972, and Hawkins made modifications to it (Hawkins, 1987). The International Maritime Organization, or IMO, has now publicly adopted it as a human factor framework. The SHEL model is a conceptual model that aims to show how the operator and the different system components interact. It is made up of four parts: - Liveware is L, Environment (physical aspects) is E, Hardware (equipment) is H, and Software (rules, manuals, and regulations) is S. "m- (management)" was added to the SHEL model in the m-SHEL model.

Any elements that specify how the various parts of the system interact with one another and with the outside world, such as policies, rules, computational codes, and practices, are represented by software.

Any tangible, non-human element of the system, including tools, vehicles, equipment, manuals, and signage, is referred to as hardware.

The socio-political and economic context in which the various components interact is referred to as the environment.

In the centre, Liveware stands in for the actual operating staff. The primary focus is on role and communication components.

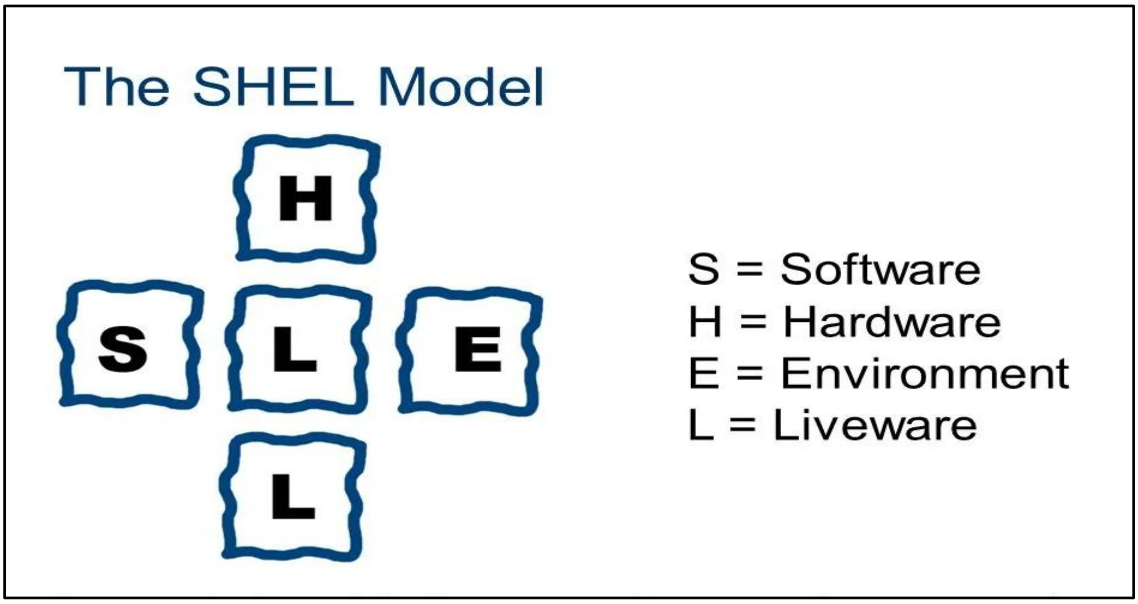

Figure No. 3.2: The SHEL Model of human factors

Software (S) – Rules, Procedures, and Training: -

The non-physical components of a maritime system, like rules, procedures, and training courses, are represented by the software component. Inadequate performance in these areas may result in risky behaviours and an elevated likelihood of accidents. The following are some of the main aspects examined:

- Regulatory compliance and company operating procedures: evaluating whether safety measures comply with national and international requirements.

- Adequacy of crew training programs: Assessing how well seafarers are trained in risk management, emergency response, and navigation.

- Effectiveness of emergency response procedures: Examining crew readiness for crashes, fires, and ship abandonment scenarios.

- Standard operating procedures (SOPs) and accident prevention: An examination of SOPs' lucidity, relevance, and implementation.

Hardware (H) – Equipment and Vessel Design: -

The actual tools, machinery, and ship design that affect safety are referred to as the hardware component. Accidents might result from malfunctions, bad design, or inadequate maintenance. The following are the topics of this study:

- Shipboard equipment failures: An analysis of issues with fire suppression, engine control, navigation, and communication systems.

- Safety inspections and maintenance records: Examining adherence to safety audit reports and maintenance schedules.

- Design-related elements influencing operations: evaluating the layout of the ship's bridge, the positioning of its machinery, and ergonomic issues that affect the productivity and security of the crew.

Environment (E) – Outside Factors Impacting Operations: -

The operational and physical environments that affect ship safety are included in the Environment component. Accidents frequently worsen as a result of environmental conditions, especially when human error is involved. The following are the main factors examined:

- Weather, sea conditions, and visibility: assessing the impact of severe weather (storms, fog, and large waves) on navigating safety.

- Traffic density and navigational hazards: Evaluating the likelihood of accidents in locations with heavy vessel movement and crowded shipping routes.

- Linguistic and cultural obstacles in multinational crews: Recognizing communication issues that could result in miscommunications or misinterpretations in situations where safety is at stake.

Liveware (L) – Human Factors and Crew Interactions: -

The Liveware component focuses on the human element in marine operations by examining crew interactions, decision-making, and individual performance. Important topics looked at include:

- Psychological and physiological aspects of decision-making: Assessing the effects of stress, strain, and mental exhaustion on judgment and critical thinking.
- Effectiveness of team coordination and communication: Examining how successfully crew members work together, particularly in high-risk circumstances.
- Analysing the effects of extended workdays, shift patterns, and operational demands on crew alertness is known as fatigue, workload, and stress analysis.
- Effective leadership in emergency scenarios: Evaluating the part that ship captains and officers play in handling crises and making decisions under strain.

3.4 Data Collection

This study also uses previous research studies, journal articles, and literature reviews about human variables in marine accidents, as well as secondary data sources from respected maritime organizations.

1. Gathering Secondary Data

The secondary sources for accident data:

- Marine Accident Reports: Gathered from national and international maritime safety agencies, including the

European Maritime Safety Agency (EMSA),

The National Transportation Safety Board (NTSB, USA),

The International Maritime Organization (IMO),

and the Marine Accident Investigation Branch (MAIB, UK).

- Marine incident databases, including the

Global Integrated Shipping Information System (GISIS) and Lloyd's List intelligence

To give a comprehensive analysis, data from ten maritime accidents were collected for this research. The incidents were selected because they were relevant to the study objectives and there were comprehensive investigation reports. Three fire incidents, one grounding incident, four collisions, one onboard hatch cover crushing tragedy and one case of structural failure are all in the data set. Official reports of maritime accidents published by both foreign and domestic maritime agencies were the source for these cases. The range of types of accidents provides a broad foundation upon which to use the HFACS and SHEL models to study numerous contributing factors and paths of human error.

The cases analysed are as follows:

Fire Accidents: - 1. Maersk Honam fire Incident (2018)

2. Athlos tankers fire explosion (2018)

3. X-Press Pearl Container ship onboard fire (2021)

Grounding: - 1. Ever given Suez Canal incident (2021)

Collisions: - 1. Kattegat Incident (Ro-Ro collided with pilot boat) (2023)

2. Polar Spirit v Zhe Xiang Yu 41020 (2018)

3. Gulnak and Cape Mathilde collision Incident (2019)

4. Scot Carrier & Karin Hoj Collision (2021)

Onboard hatch crushing: - 1. Solymar hatch Incident (2021)

Structural failure: - 1. Mol comfort structural failure (2013)

4.0 Data Analysis and Interpretation

4.1 Maersk Honam fire Incident by the HFACS model

Around 900 nautical miles west of India, in the Arabian Sea, the Singapore-registered container ship Maersk Honam suffered a serious fire in its No. 3 cargo hold on March 6, 2018. After failing to contain the fire, the crew left the ship, and 23 of the 27 were saved.

Table no. 4.1: HFACS model of Maersk Honam

HFACS Level	Findings from the Incident	Code
Organizational Influences	- Ineffective cargo booking and classification process: a hazardous chemical classified under IMDG Class 9 instead of the stricter Class 5.1. -Some of the crew are waiting to be given instructions. -The emergency response plan did not ensure that all the ventilator flaps/ dampers on board were closed	OI1: Inadequate Hazard Classification OI2: Unclear Instructions OI3: Unreliable emergency response
Unsafe Supervision	Some of the crew had not been assigned duties in the muster list. - Supervisors did not ensure strict adherence to fire control procedures resulting in smoke spreading into the accommodation area.	US1: Work not assigned US2: Failure to Enforce Emergency Procedures
Preconditions for Unsafe Acts	-The crew waited for instructions, unclear radio communication -Wind direction worsened fire spread, high temperatures -Recognition of chlorine smell with laundry by the crew, late recognition of fire.	PUA1: Communication Breakdown PUA2: Environmental Challenges PUA3: Misinterpretation of chlorine smell
Unsafe Acts (Human Errors & Violations)	-Instead of raising the fire alarm, the crew raised the general alarm. -The crew was not able to close the natural ventilator flaps in the no.3 cargo hold,	UA1: Wrong decision UA2: Non closure of ventilator flaps

Table no. 4.2: HFACS Summary Table of Maersk Honam

Failure Type	Frequency of errors	Percentage (%)
Organizational Failures	4	33.3%
Technical Failures	3	25.0%
Human Errors	3	25.0%
Environmental Factors	2	16.7%

(Frequency of Failure Type(errors)/ Total Failures(errors) × 100

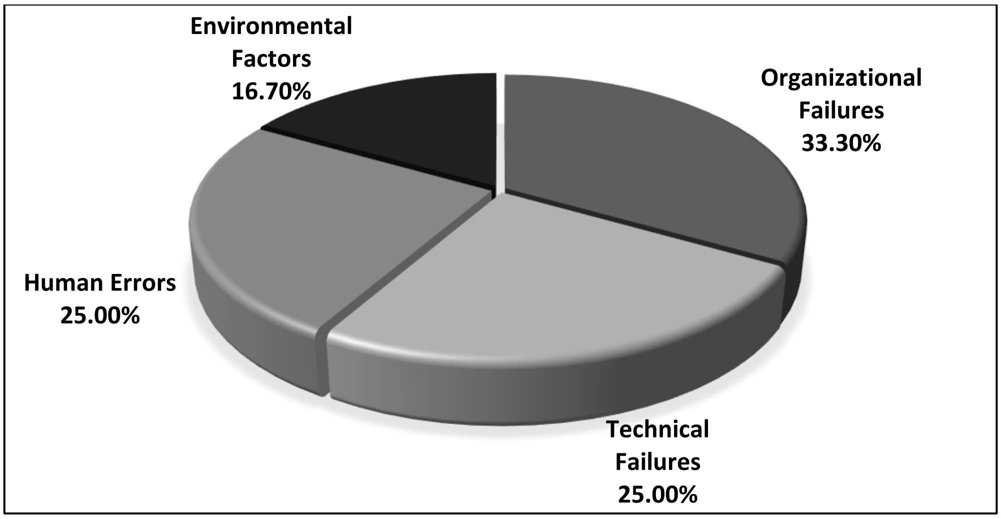

Figure No. 4.1: Percentage Distribution of Contributing Failures in Maersk Honam Incident

The disaster was mostly caused by organizational failures, which accounted for 33.3% of all failures.

4.2 Ever given Suez Canal incident analysis by SHEL Model

In March 2021, the enormous cargo ship Ever Given became horizontally stranded in the Suez Canal, one of the busiest commerce routes in the world. Over 400 ships experienced a severe traffic bottleneck during the six-day stoppage, which disrupted international trade.

Table no. 4.3: SHEL model of Ever given Suez Canal

SHEL Level	Findings from the Incident	Code
Software	-The non-use of tugboats in a restricted area to better control the manoeuvrability of the ship contributed to the occurrence of the grounding.	SO1:Unclear Instructions
	-The permissible speed for ships is 8.64 knots; on average, the MV Ever Given sailed at a speed higher than the permissible.	SO2: Crossing Speed Limit
	-The ship did not have the latest edition of the Rules of Navigation for the Suez Canal on board.	SO3: Old Regulations
Hardware	-Such ships are significantly longer than the navigable width of the canal waterway.	HA1: Exceeds Navigable
	-Canal tugs did not have sufficient HP to push and release M/V EVER GIVEN.	HA2: Insufficient power of tug boats
Environment	-Wind Speed: 25-27 knots with wind gusts to 40 knots. The South wind is pushing the vessel towards the portside bank of the canal.	EN1: Heavy wind speed
	-The loss of steering control likely started at this moment due to the Bank Effect.	EN2: Bank Effect
Liveware	-Pilots did not realise the hazard of steering the ship off the planned track and did not cooperate with the bridge team.	LI1: Communication Error
	-Pilots conducted the pilotage without requesting assistance from the Master, giving direct orders to the helmsman.	LI2:Decision making under Constraint conditions
	-Pilots did not take into consideration the bad weather conditions, and consequently, they did not request assistance from tugs.	LI3: Being negligent
	-Moreover, from the analysis of VDR data, it was noticed that there was an argument between the two pilots also had language barrier.	LI4: Communication between pilots

Table No. 4.4: SHEL Summary Table of Ever given Suez Canal

Failure Type	Sub Type	Frequency of errors	Percentage
Software	1. Old Regulations	3	27.27%
	2. Unclear Instructions		
	3. Crossing Speed Limit		
Hardware	1. Exceeds Navigable Length	2	18.18%
	2. Insufficient power of tug boats		
Environment	1. Heavy wind speed	2	18.18%
	2. Bank Effect		
Liveware	1. Communication Error	4	36.36%
	2. Decision making under Constraint conditions		
	3. Being negligent		
	4. Communication between pilots		

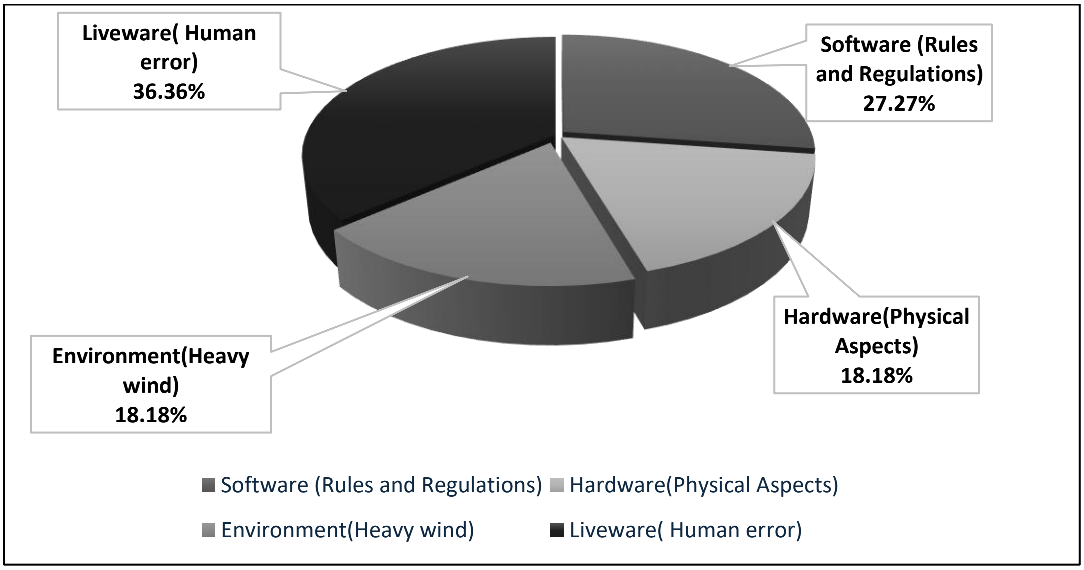

Figure No. 4.2: Distribution of Failure Types in the Ever-Given Incident

-Human factors (Liveware) played the most critical role (36.36%), indicating a need for better training, coordination, and communication.

4.3 Kattegat Incident (Ro-Ro collided with pilot boat)

In Koge Bugt, Denmark, on February 15, 2023, the Swedish pilot boat PILOT 111 SE and the Danish-flagged ro-ro passenger ship KATTEGAT collided. A close-quarters situation evolved, and the ships collided despite initial visual contact and attempts to change course. No pollution or injuries were recorded; however, the pilot boat was damaged.

Table No. 4.5: HFACS model with qualitative analysis codes of Kattegat Incident

HFACS Level	Findings from the Incident	Code
Organizational Influences	- Safety Management System (SMS) in place, but improper lookout identified as a safety issue.	OI1: Inadequate Safety Culture
	- Need for improved Bridge Simulator Training & Maritime Resource Management (MRM) Training.	OI2: Insufficient Training
	- Crew fatigue was not a factor, as rest hours complied with STCW.	OI3: Fatigue Not a Factor
Unsafe Supervision	- No dedicated lookout on "KATTEGAT" during nighttime navigation.	US1: Inadequate Supervision
	- Captain and Chief Officer were occupied with navigation and decision-making.	US2: Task Overload on Crew
	- Lack of proactive communication with VTS about small vessel movements.	US3: Ineffective Communication with VTS
Preconditions for Unsafe Acts	- Environmental factors: Strong winds, moderate sea, and sea spray, possibly reducing the pilot boat crew's visibility.	PUA1: Environmental Constraints
	- Erratic course alterations by the pilot boat caused confusion for the "KATTEGAT" bridge team.	PUA2: Poor Situational Awareness
	- VTS did not warn "KATTEGAT" about the pilot boat's presence or course changes.	PUA3: Lack of External Warnings
Unsafe Acts of Operators	- Misjudgment by the "KATTEGAT" crew in assuming the pilot boat would pass astern.	UA1: Decision Error (Misjudgement)
	- Delayed response to the pilot boat's erratic course changes.	UA2: Delayed Reaction
	- The pilot boat violated Tanger Med Port Operating Rules, which give priority to large vessels.	UA3: Violation of Port Operating Rules
	- The pilot boat failed to react to "KATTEGAT's" sound signals before the collision.	UA4: Failure to Respond to Sound Signals

Table No. 4.6: HFACS summary table for Kattegat Incident

Failure Type	Frequency	Percentage%
Organizational Influences	3	23.08%
Unsafe Supervision	3	23.08%
Preconditions for Unsafe Acts	3	23.08%
Unsafe Acts	4	30.77%

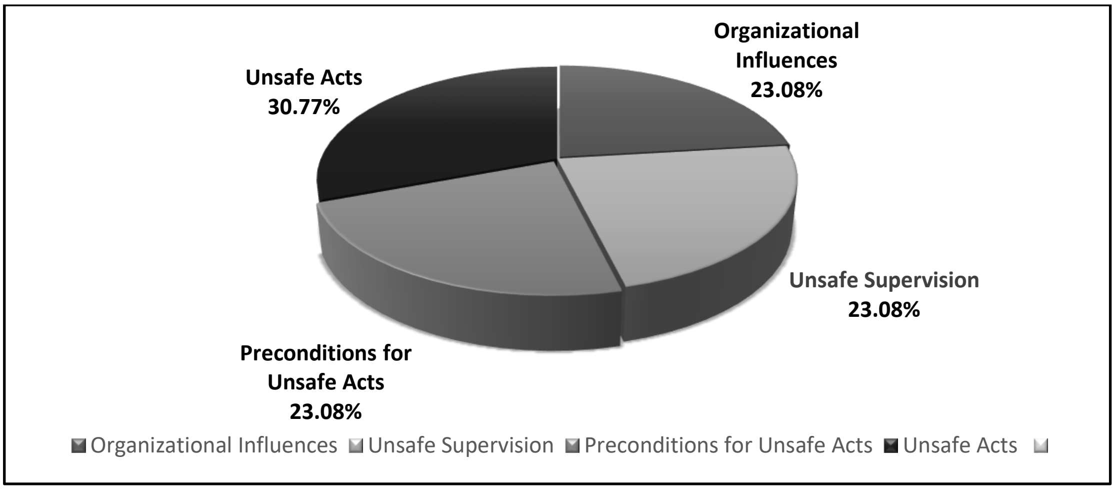

Figure No. 4.3: Pie chart for the HFACS Summary Table of Kattegat Incident

4.4 Solymar hatch Incident

A tragic accident happened on board the general cargo ship "SOLYMAR" in Vejle Port, Denmark, on March 16, 2021. The Chief Officer used the ship's gantry crane to raise the hatch cover during routine maintenance to repair the rubber bars on Hatch Cover No. 8. Two crew workers below were setting up wooden stanchions as supports when the hatch cover detached from the crane and crashed on them. One crew member survived uninjured, but the other was crushed to death.

Table no. 4.7: HFACS model with qualitative analysis codes of SOLYMAR hatch Incident

HFACS Level	Findings from the Incident	Code
Organizational Influences	- Lack of proactive risk management: The crew was aware of the gantry cranes hydraulic issues but did not report them as required by ISM Code Section 9. - Training gaps: Crew received familiarization training, but it was insufficient in addressing specific risks of hatch cover operations.	OI1: Inadequate Risk Management OI2: Insufficient Training
Unsafe Supervision	- Chief Officer operated the gantry crane without visual contact with the crew placing the wooden stanchions. - No specific risk assessment was conducted for the crane's hydraulic malfunction. - Crew was permitted to work beneath the hatch cover despite the risks.	US1: Lack of Direct Supervision US2: Failure to Enforce Risk Assessments US3: Violation of Safety Procedures
Preconditions for Unsafe Acts	- Poor Equipment Maintenance: The gantry crane had a known hydraulic malfunction, but it was not properly addressed. - Ineffective Communication: The Chief Officer and crew used walkie-talkies, but lack of direct visibility led to misjudgement.	PUA1: Poor Situational Awareness PUA2: Inadequate Communication
Unsafe Acts of Operators	- The Chief Officer misjudged whether the hatch cover was properly supported. - The crew incorrectly relied on wooden stanchions, which were untested and uncertified. - Crew members worked directly under a suspended load, against manufacturer's safety instructions. - The Chief Officer attempted to lift the hatch cover after the accident, causing the gantry crane to derail.	UA1: Decision Error (Misjudgement of Load Stability) UA2: Procedural Violation (Working Under Suspended Load) UA3: Improper Use of Support Materials

Table No. 4.8: HFACS Summary Table Based on Given Data of Solymar Incident

Failure Type	Frequency	Percentage%
Organizational Influences	2	20%
Unsafe Supervision	3	30%
Preconditions for Unsafe Acts	2	20%
Unsafe Acts	3	30%

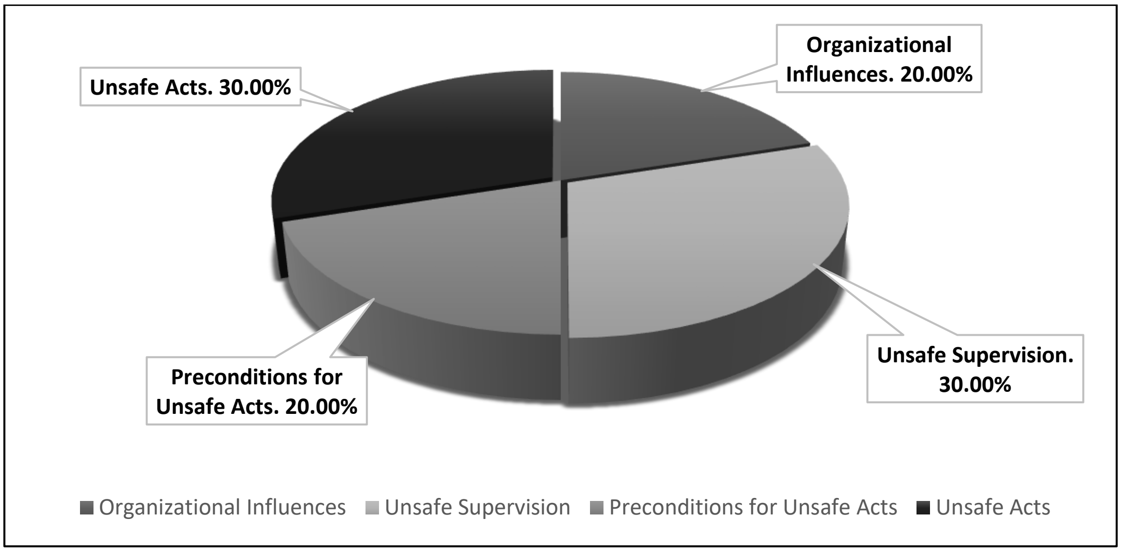

Figure no. 4.4: Pie Chart for HFACS Failure Type Distribution – Solymar Accident

Unsafe Supervision and Unsafe Acts had the highest contribution (30% each), indicating significant issues in risk assessment, procedural violations, and unsafe decisions by crew members.

4.5 Polar Spirit v Zhe Xiang Yu 41020

On 7th August 2018, the Chinese fishing boat Zhe Xiang Yu 41020 collided with the LNG vessel Polar Spirit in the East China Sea. A person lost their life and another was reported missing when the fishing vessel overturned.

Table No. 4.9: HFACS model with qualitative codes of Polar Spirit v Zhe Xiang Yu 41020

HFACS Level	Findings from the Incident	Code
Organizational Influences	- OOW (officer on watch) did not follow minimum passing distance requirements. -Not intervened when minimum passing distance thresholds were not met -There have been multiple similar incidents in the region -Guidance contained in the MSA Advisory Note was not effectively incorporated	OI1: Violation of passage plan OI2: External guidelines ignored OI3: Failure to learn OI4: Ambigous process
Unsafe Supervision	-After a near miss, no further attempt to verify this conclusion or the condition of Zhe Xiang Yu -the decision to alter course in small increments may have resulted from a lack of awareness -Master/Chief Officer on the bridge but failed to intervene in 29 CPA violations.	US1: Violations were normalized. US2: Unawareness of Officer on watch US3: Passive supervision
Preconditions for Unsafe Acts	-No CPA alarms were set on the radars -OOW (Third Officer) had less than a month of onboard experience -Typhoon aftermath caused a moderate swell but good visibility. - about 5000 fishing boats along the coast of Ningbo every day.	PUA1: Unused tools PUA2: Inexperienced personnel PUA3: Weather conditions PUA4: High density traffic
Unsafe Acts (Human Errors & Violations)	-The bridge team misjudged the collision as a "near-miss." -Neither vessel made any manoeuvring sound signal, which may have alerted the other to the action being taken to avoid collision. - OOW (officer on watch) made small course changes.	UA1: Perceptual error UA2: Improper communication UA3: Violating COLREGs Rules

Table No. 4.10: HFACS summary table of Polar Spirit v Zhe Xiang Yu

Failure Type	Frequency	Percentage (%)
Organizational Influences	4	28.60%
Preconditions for Unsafe Acts	4	28.60%
Unsafe Supervision	3	21.40%
Unsafe Acts	3	21.40%

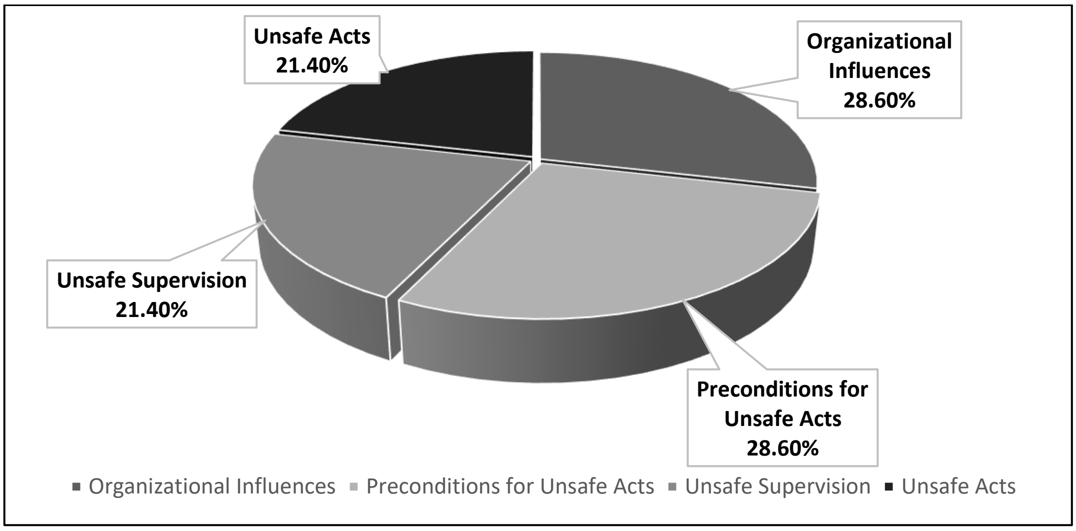

Figure No. 4.5: Pie chart for summary table of Polar Spirit v Zhe Xiang Yu

4.6 Athlos tankers fire explosion

On December 29, 2018, shortly after leaving Larnaca, Cyprus, the oil/chemical tanker ATHLOS (flagged under the Malta flag) experienced a fire and explosion. A plastic bucket used to catch small spills and droplets from a vacuum ejector during cargo tank stripping caught fire, causing the tragedy. Hydrocarbon gases were released onto the deck due to the spread of the fire when the crew attempted to extinguish the fire with water. Tanks Nos 4–6 and adjacent ballast tanks were damaged extensively due to explosions caused by the fire, which entered a non-inerted cargo tank through an open sounding port.

Table no. 4.11: HFACS model with qualitative codes of Athlos tankers fire explosion

HFACS Level	Findings from the Incident	Code
Organizational Influences	-The Bosun who was first time as Bosun, in the absence of Pumpman should have attended if the meeting had been held. -The SMS procedure was violated with the knowledge and acceptance of the Master. -The Management Company did not adhere to safety by failing to use the Inert Gas System during discharging	OI1: Skipping meeting OI2: habitual violation OI3: Failing to use inert gas-system
Unsafe Supervision	-Bosun was unsupervised to make the preparations for tank cleaning and went to rest. -Bosun did not know how to activate the foam system.	US1: left unsupervised US2: unfamiliar with foam system
Preconditions for Unsafe Acts	-The use of the Vacuum Ejector and the plastic bucket in the cargo system was not based on risk assessment -The crew's actions during the emergency response indicate that they were untrained and panicked -The Chief Officer as well as a first time Bosun who also performed the duties of the Pumpman, was a contributing factor to the accident. -The inappropriate practice of using the plastic bucket for the Vacuum Ejector's de-aeration allowed the migration of hydrocarbon vapour in the plastic bucket.	PUA1: No risk assessment PUA2: panic response PUA3: inexperience crew PUA4:Flammable gas hazard
Unsafe Acts (Human Errors & Violations)	-Violated SMS requirement to keep closed tanks that were not gas-free.	UA1: keep closed tanks

	-No detailed plan was prepared for the tank cleaning, including hours of operation and, manpower required. -should have alerted the other crew by pushing an alarm button or calling the Master or Nav Bridge. -The crew sprayed water on a flammable liquid fire, causing it to spread.	UA2: SMS procedure violations UA3: Emergency alarm unraised UA4: Firefighting error

Table No. 4.12: HFACS summary table for Athlos tankers fire explosion

Failure Type	Frequency	Percentage (%)
Organizational Influences	3	23.1%
Preconditions for Unsafe Act	4	30.8%
Unsafe Supervision	2	15.4%
Unsafe Acts	4	30.8%

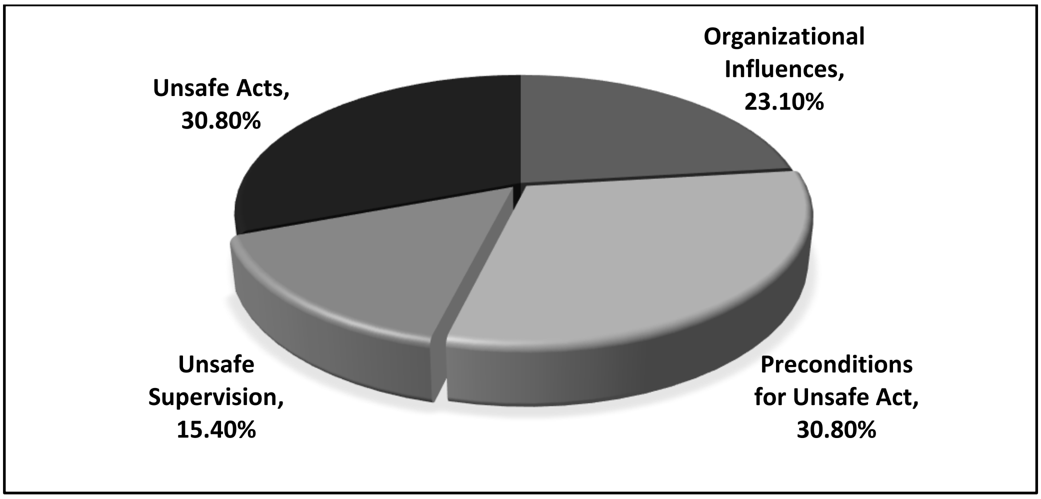

Figure No. 4.6: Pie chart for the Summary Table for Athlos tankers fire explosion

4.7 Onboard X-press Pearl at Colombo Anchorage analysis by SHEL Model

On May 20, 2021, the container ship X-Press Pearl caught fire while anchored off the coast of Colombo, Sri Lanka. Along with other risky commodities, the ship was transporting nitric acid and other hazardous chemicals. Rapid fire growth led to a large conflagration and multiple explosions before the ship partially sank.

Table no. 4.13: SHEL model with qualitative codes for Onboard X-press Pearl Incident

SHEL Level	Findings from the Incident	Code
Software	Sri Lankan authorities did not grant access to a sheltered port despite monsoon risks	SO1: Lack of Place of Refuge (POR) Protocol
	-Since the ship was delivered in February 2021, there was no fire drill scenario involving a cargo hold fire.	SO2: Ineffective sms implementation
	-The firefighting response and boundary cooling were not as per the prescribed muster list.	SO3: Muster list not updated
	-Possible non-compliance with IMDG and CTU code.	SO4: Regulatory non-compliance
	-Used sawdust instead of inert absorbent pads to manage the leak	SO5: Incorrect emergency response
	-Delayed response to the nitric acid leak	SO6: Emergency Response Delay
Hardware	- Penetrating through the container floorboard, the accumulated Nitric Acid found its way onto the hatch covers	HA:1 Hatch cover gaps
	-Some of the natural ventilation flaps in the way of bay 11, starboard side, remained open.	HA2: Ventilation flap Closing Difficulty
	-They had limited tug resources on site and had to prioritise between towing and firefighting.	HA3: Salvage Equipment Limitations
Environment	-Due to the effect of the cyclone causing the ship to roll and pitch, the deck crew was not given any deck work due to the bad weather.	EN:1 Cyclone Cause
	-The mooring ropes broke due to shock loading and wear and tear under the prevailing weather conditions.	EN:2 Adverse Weather
Liveware	- Communication between the Master and the Company indicated that the off-signers were no longer willing to help with the firefighting activities.	LI1: Off-signers Refused Duties
	-The response from Colombo Port Control to assist XP in managing the emergency was deemed limited.	LI2: Shore-side Communication Failure
	- Conversations with the Chinese crew in English required translation as language barriers were evident.	LI3: Language Barrier

Table No. 4.14: SHEL Summary Table for Onboard X-press Pearl Incident

Failure Type	Sub Type	Frequency of errors	Percentage
Software	1. Lack of Place of Refuge (POR) Protocol	6	42.86%
	2. Ineffective SMS implementation		
	3. Muster list not updated		
	4. Regulatory non-compliance		
	5. Incorrect emergency response		
	6. Emergency Response Delay		
Hardware	1. Hatch cover gaps	3	21.43%
	2. Ventilation flap Closing Difficulty		
	3. Salvage Equipment's Limitations		
Environment	1. Cyclone Cause	2	14.28%
	2. Adverse Weather		
Liveware	1. Off-signers Refused Duties	3	21.43%
	2. Shore-side Communication Failure		
	3. Language Barrier		

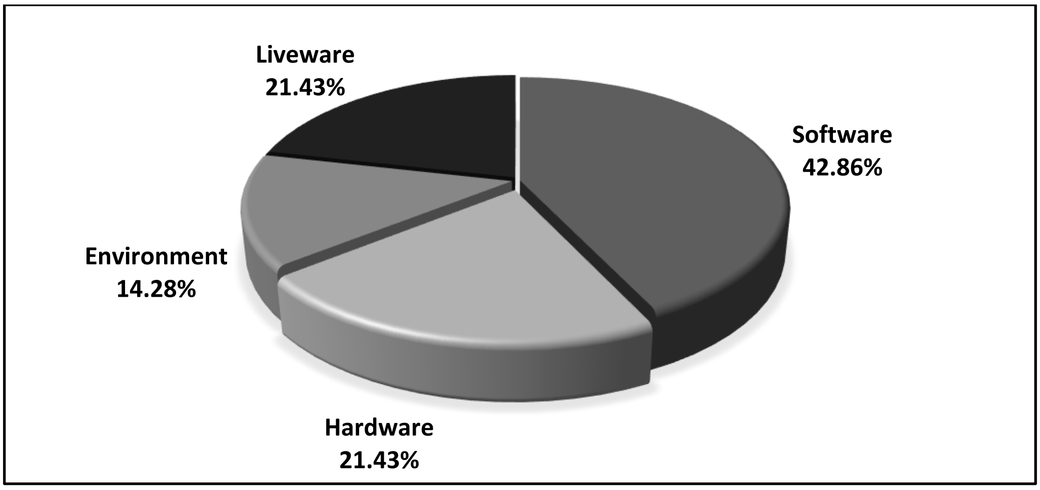

Figure No. 4.7: Pie Chart for the Summary Table of Onboard X-press Pearl

4.8 Mol comfort structural failure

The container ship MOL Comfort experienced a catastrophic structural failure in the Indian Ocean on June 17, 2013, when it was sailing from Singapore to Jeddah. The ship broke into two parts around 200 nautical miles off the coast of Yemen when it splintered amidships.

Approximately 7,000 containers were being transported by MOL Comfort at the time of the incident. Thankfully, all 26 crew members were rescued unharmed and were able to securely exit the ship.

Table No. 4.15: SHEL model with qualitative codes for MOL COMFORT Incident

SHEL Level	Findings from the Incident	Code
Software	-Emergency procedures lacked guidance for a catastrophic hull break.	SO1: Inadequate Emergency Procedures
	-Training didn’t cover total structural loss scenarios	SO2: Training Scope Limitation
	-No structural stress monitoring protocols onboard	SO3: Absence of Maintenance Framework
	-Voyage planning prioritized schedule over weather safety	SO4: Risky voyage
Hardware	-Hull girder failure amidships under heavy load and sea conditions	HA:1 Structural Integrity Failure
	-Aging ship or possible weld fatigue at the midship area and -Possible steel fatigue or micro-fractures not detected	HA:2 Material Defect
Environment	-Severe weather and sea state at the time of the incident Monsoon conditions (6m waves, 38-knot winds)	EN:1 Adverse Environmental Condition
	-Longitudinal bending stress increased by wave action	EN:2 Load Exceedance
Liveware	-Lack of awareness of structural risks before failure	LI: - Situational Awareness Deficiency
	-The crew lacked real-time structural integrity data	LI2: Information Availability Gap
	-Continued sailing despite worsening weather	LI3: Environmental Risk Misjudgement

Table No. 4.16: SHEL Analysis Summary Table for MOL COMFORT

Failure Type	Sub Type	Frequency of errors	Percentage
Software	Inadequate Emergency Procedures	4	36.36%
	Training Scope Limitation		
	Absence of Maintenance Framework		
	Risky voyage		
Hardware	1. Structural Integrity Failure	2	18.18%
	2. Material Defect		
Environment	1. Adverse Environmental Condition	2	18.18%
	2. Load Exceedance		
Liveware	1. Situational Awareness Deficiency	3	27.27%
	2. Information Availability Gap		
	3. Environmental Risk Misjudgement		

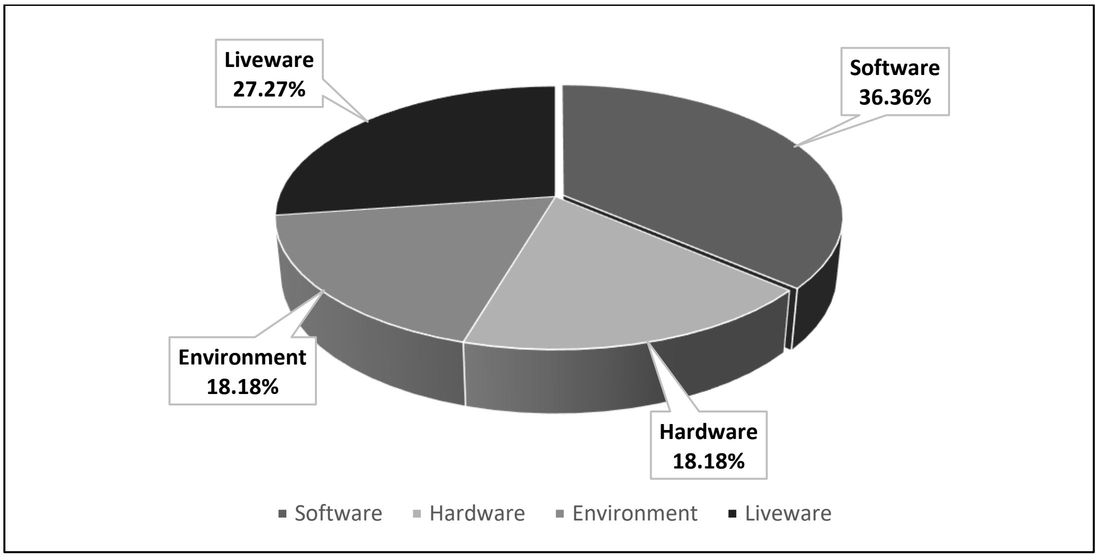

Figure No. 4.8: Pie Chart for the Summary Table of MOL COMFORT

4.9 Gulnak and Cape Mathilde collision Incident

On April 18, 2019, the bulk ships Gulnak and Cape Mathilde collided on the River Tees. During a bend, Gulnak lost control and struck the moored Cape Mathilde. Both vessels suffered significant damage, but there were no injuries or pollutants.

Table No. 4.17: HFACS model with qualitative codes for Gulnak and Cape Mathilde Incident

HFACS Level	Findings from the Incident	Code
Organizational Influences	- Missing VDR rudder/engine data due to weak resource management or maintenance	OI1: Higher Speed
	- Lack of internal processes to cross-check ship manoeuvring and recording systems	OI2: Delay in Reacting
	- The VDR annual test was 6 months old	OI3: Maintenance oversight
	- No prior reports of manoeuvring issues, despite potential risks	OI4: Complacency in safety culture
Unsafe Supervision	- Lack of validation of Gulnak's manoeuvring data and shiphandling behavior	US1: Planned Inappropriate Operation
	- Departure pilot observed that the master seemed uncertain about the engine indicator even after repairs	US2: Inadequate Lookout
Preconditions for Unsafe Acts	-Tugs were nearby but not made fast early enough to assist.	PUA1: Inadequate coordination with Tugboats
	- Minor shallow water effects.	PUA2: Environment factor
	- Incomplete bridge information display.	PUA3: limited data
Unsafe Acts (Human Errors & Violations)	-(10 knots) during turn instead of the preferred 8 knots, reducing reaction time.	UA1: Higher Speed
	-Late use of full astern power, insufficient to avoid collision.	UA2: Delay in Reacting
	- No earlier warning or alternative manoeuvring action when overswing became apparent.	UA3: Being negligent
	-Possible misjudgement of the ship's dynamic behaviour.	UA4: Perceptual Error
	-Master's unfamiliarity with Gulnak's handling (first contract)	UA5: Inadequate familiarity

Table No. 4.18 HFACS Summary Table for Gulnak and Cape Mathilde Incident

Failure Type	Frequency	Percentage (%)
Organizational Influences	4	28.57%
Preconditions for Unsafe Acts	3	21.42%
Unsafe Supervision	2	14.28%
Unsafe Acts	5	35.71%

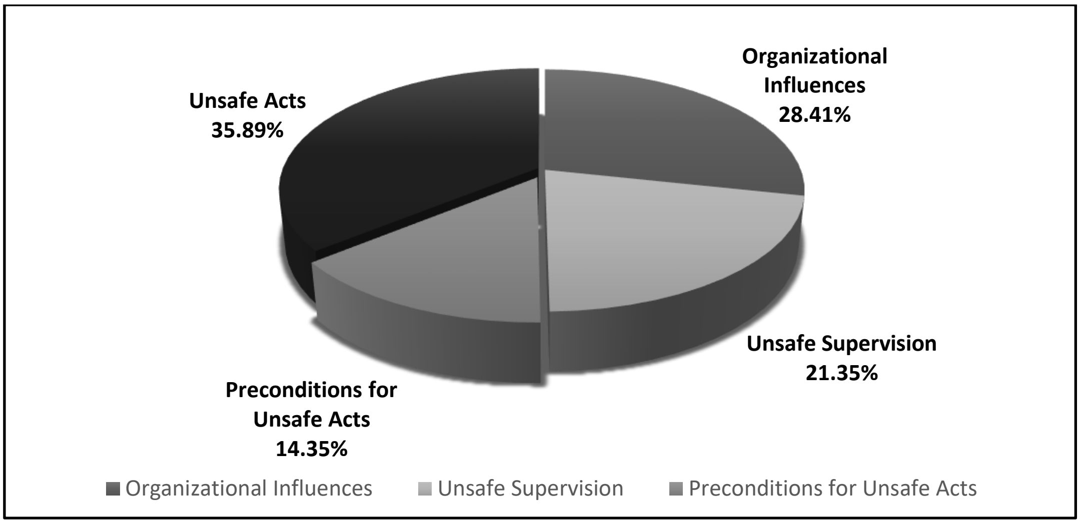

Figure No. 4.9 Percentage Distribution - collision between Gulnak and Cape Mathilde

4.10 Scot Carrier & Karin Hoj Collision

In the Bornholmsgat Traffic Separation Scheme in the Baltic Sea, Sweden, the general cargo ship Scot Carrier, flying the flag of the United Kingdom, and the split hopper barge Karin Hoj, flying the flag of Denmark, collided at 03:27 on December 13, 2021. Karin Hoj, therefore capsized, killing both crew members on board.

Table No. 4.19 SHEL analysis with qualitative codes for Scot Carrier & Karin Hoj Collision

SHEL Level	Findings from the Incident	Code
Software	-No lookout posted during night hours despite standing orders and SMS. -Alcohol policy misunderstood and breached. -Standing orders about ECDIS alarms and BNWAS activation were ignored.	SO1: Watchkeeping Failure SO2: Alcohol Policy Failure SO3: Procedure Violation
Hardware	-BNWAS on Scot Carrier was turned OFF during the critical night watch. -Radar and ECDIS alarms were disabled because they were "too distracting" according to crew practice.	HA1: BNWAS Deactivation HA2: Alarm Management Failure
Environment	-Night-time, no moonlight, partly cloudy, low swell, good visibility (>5nm) before collision, but patchy fog later. -Collision occurred at night in TSS (Traffic Separation Scheme). long dark hours (15+ hours darkness/day).	EN1: Adverse Environmental Condition EN2: Extended Night Operations
Liveware	-2/O was actively using a personal tablet for video chats during the bridge watch. -2/O had a Blood Alcohol Content (BAC) of 0.042% post-accident -Most operators disabled the alarms or ignored alerts. -After the collision, Scot Carrier's 2/O delayed raising the alarm for 17 minutes. - No lookout assigned on Karin HOJ during collision	LI1: Distraction by Electronic Device LI2: Excessive alcohol use LI3: Negligence Act LI4: Delayed Distress Notification LI5: Absent Watch

Table No. 4.20 Summary Table for Shel analysis of Scot Carrier & Karin Hoj Collision

Failure Type	Sub Type	Frequency of errors	Percentage
Software	Watchkeeping Failure	3	25.01%
	Alcohol Policy Failure		
	Procedure Violation		
Hardware	BNWAS Deactivation	2	16.66%
	Alarm Management Failure		
Environment	Adverse Environmental Condition	2	16.66%
	Extended Night Operations		
Liveware	Distraction by Electronic Device	5	41.67%
	Excessive alcohol use		
	Negligence act		
	Delayed Distress Notification		
	Absent Watch		

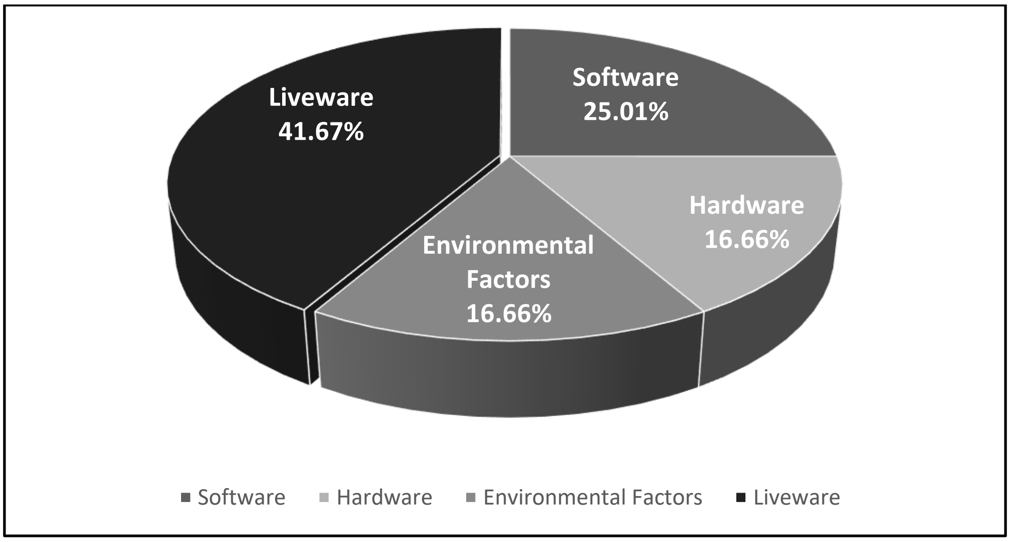

Figure No. 4.10 Pie Chart for the Summary Table of Scot Carrier & Karin Hoj Collision

5.0 Findings and Conclusions

5.1 Findings:

Based on the critical application of the HFACS Model (Human Factor Analysis and Classification) and SHEL Model (Software, Hardware, Environment, Liveware) on the ten Marine accidents, several findings have been emerged.

1. Major contributing factor in most of the cases is Unsafe Acts and Liveware (Human Error) like:

* During the night watch, the incident involving Scot Carrier and Karin Hoj, when the second officer used a personal device during night watch, had alcohol in his system (BAC 0.042%), and neglected to designate a proper lookout.

* In the case of the Ever-Given Suez grounding, Pilots have not requested help from tugs since they failed to account for the poor weather conditions.

* Ineffective emergency response resulted from crew members failing to close ventilation flaps and setting off the general alert rather than the fire alarm during the Maersk Honam fire.

* Supervisory staff frequently did not step in to stop dangerous behaviours or situations (Athlos, Polar Spirit, Kattegat).

2. Organizational or software failures

Poor safety culture, insufficient training, a failure to implement lessons learned, and non-compliance with international standards.

* Delays in responding to nitric acid leaks and the refusal of Sri Lankan authorities to allow access to a port of refuge hindered the X-Press Pearl response, which ultimately led to the issue getting worse.

* Additionally, Potential violation of the CTU and IMDG codes regarding the handling of hazardous goods.

* A procedural error that had disastrous consequences occurred when the X-Press Pearl relied on sawdust rather than authorized absorbents to stop nitric acid leaks.

3. Deficiencies in Training and Procedural Implementation

* Lack of risk assessment training about hatch cover maintenance and hydraulic equipment operating methods led to the Solymar fatality.

* Emergency response drills and equipment knowledge were often missing or poorly executed.

4. Environmental conditions:

At least six incidents (Ever Given, X-Press Pearl, Kattegat, MOL Comfort, Gulnak, Scot Carrier) were exacerbated by poor weather, poor visibility, and sea conditions.

These were rarely the only factor, though; human error under pressure was often more significant.

5.2 Conclusion:

The analysis of these ten significant marine incidents shows that tragedy at sea is rarely caused by a single error or failure. Rather, they are the outcome of structural defects that are exacerbated by human limitations and environmental forces. Organizational culture, inadequate training, and oversight mistakes are often the root causes of these defects.

Although human error is more common, it's usually the final link: Human error - miscalculations, violations, and communication breakdowns—is the most obvious cause, but more significant systemic issues including insufficient training, unclear procedures, and ineffective supervision are typically to blame.

Organizational Factors Are Essential: Organizational failures can be linked to a number of risky activities, such as inadequate risk management (Solymar, Athlos), violation normalization (Polar Spirit), and unsolved procedural gaps (X-Press Pearl, MOL Comfort).

Several accidents and grounding events underscore the critical requirement for the enforcement of watch protocols, ongoing oversight, and immediate risk awareness, particularly in restricted water areas.

Training programmes need to take into consideration the complexity of real-world scenarios: Inexperienced staff, inadequate emergency preparedness, or antiquated SMS protocols that did not account for real-world risk situations have been blamed for numerous incidents (Maersk Honam, MOL Comfort, Athlos). Instead than replacing safety culture, technology should strengthen it. For ease, safety systems and alarms must not be disregarded. It is important to closely monitor and enforce the maintenance of the vital safety systems (ECDIS, VDR, and BNAWS).

In the end, effective accident prevention in the maritime sector requires a comprehensive, systems-based approach. To create a robust safety framework that emphasizes learning rather than placing blame and anticipating problems rather than just reacting to them, this methodology integrates organizational dynamics, environmental factors, and human elements.

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