International Journal of Transport Development and Integration
Vol. 9, No. 2, June, 2025, pp. 423-440
Journal homepage: http://iieta.org/journals/ijtdi

Enhancing Container Vessel Safety: Insights from Industry Professionals

Manindra Pratap Singh[1*], Bangar Raju Totakura[2]

[1] School of Business, University of Petroleum & Energy Studies, Dehradun 248007, India
[2] School of Maritime Management, Indian Maritime University, Chennai 600119, India

Corresponding Author Email: 500073473@upesalumni.upes.ac.in

https://doi.org/10.18280/ijtdi.090218

Received: 18 March 2025
Revised: 21 April 2025
Accepted: 28 April 2025
Available online: 30 June 2025

Keywords:
shipping accidents, container vessels, NASAFACS, maritime safety analysis, expert view, organizational influences

ABSTRACT

This research paper presents an in-depth exploration of container vessel accidents and preventive measures through semi-structured interviews with industry professionals and subject matter experts. Building on a previous study, utilizing the NASAFACS methodology to analyze container vessel accidents, this paper aims to deepen understanding of the underlying challenges and emerging trends in container vessel safety. The interviews focused on key aspects, such as industry insights, causal factors, environmental risks, crew competency, the regulatory landscape, collaboration with authorities, industry partnership, and crisis management. Participants shared valuable perspectives on major challenges affecting container vessels and the wider industry. Interview data were analyzed using MAXQDA Software, allowing a comprehensive thematic analysis. The findings inform recommendations to improve safety, including the development of comprehensive standards for emerging risks. Specific suggestions include the upgrade of firefighting systems for ultra-large container ships, stricter enforcement of cargo declaration and lashing practices, mandatory IMDG training for shippers and freight forwarders, higher manning levels, and structured inspection regimes akin to those in the tanker industry. While the NASAFACS analysis of accident reports identified preconditions as primary contributory factors, the interview findings highlight systemic organizational issues and external influences. This research contributes to the ongoing maritime safety discourse by integrating expert insights with NASAFACS analysis, offering a holistic perspective on container vessel accidents and proactive measures for their prevention.

1. INTRODUCTION

Container vessels are vital to the global economy, facilitating the efficient movement of goods across continents. However, the increasing size, complexity, and operational demands of these vessels have also led to a rise in accidents, highlighting persistent safety challenges within the maritime industry. Between 2010 and 2021, container vessel accidents—including groundings, fires, collisions, and cargo losses—have drawn growing concern. According to the World Shipping Council, an average of 1,382 containers were lost at sea each year between 2008 and 2019, but this surged to over 3,000 containers in 2020, and nearly 6,000 in 2021, largely due to high-profile incidents involving ultra-large vessels such as *ONE Apus* and *Maersk Essen* [1]. In parallel, shipboard fires have become a critical safety issue, often linked to misdeclared hazardous cargo. As per Allianz Global Corporate & Specialty, there were seventy fire incidents reported onboard container vessels between the years 2017–2022 [2].

Addressing these issues requires a deep understanding of their causes, which often stem from a combination of technical, operational, human, and environmental factors. The need for a comprehensive, multi-perspective analysis is therefore critical in enhancing safety standards and mitigating future risks.

Building on previous research published on the National Aeronautics and Space Administration's Framework for Accident Causation (NASAFACS) analysis in the study [3], which extends the discussion by incorporating insights gained through semi-structured interviews with subject matter experts (SMEs) across various domains of the container vessel industry. These experts bring a wealth of knowledge from diverse fields, including ship design, operations, maintenance, regulatory compliance, and accident investigation, providing a holistic view of the challenges faced by the sector.

This paper aims to investigate the underlying causes of container vessel accidents through the lens of the NASAFACS framework, enriched by expert perspectives. By synthesizing qualitative data from interviews with existing theoretical frameworks, the research seeks to uncover systemic issues, emerging trends, and practical solutions for improving maritime safety. The study not only identifies key risk factors but also offers actionable recommendations to stakeholders in the shipping industry, including shipowners, operators, and regulatory bodies.

By integrating structured methodologies with experiential insights, this research aspires to contribute to the ongoing discourse on maritime safety and establish a robust foundation for reducing the frequency and severity of container vessel accidents.

2. LITERATURE REVIEW

Analyzing maritime accidents and incidents is essential for comprehending their origins, identifying safety shortcomings, and implementing preventative measures to mitigate future occurrences. A variety of methodologies and approaches have been utilized or suggested for conducting such analyses. This section aims to explore these methodologies and gain insights into the process.

The maritime industry has faced incidents and accidents often tied to human error. Some gained worldwide attention, like the Exxon Valdez, while others, such as the Sea Empress, went relatively unnoticed. However, these events consistently raised awareness regarding mariner fatigue, human error, and human performance in maritime safety. International bodies like the International Maritime Organization (IMO) have initiated new regulations in line with international treaties to tackle human error. Flag State safety agencies and port authorities have enacted their own measures, and Classification Societies have issued updated rules. The work by Mccafferty and Baker [4] delves into human error in the marine sector, with a specific focus on crew fatigue as a pivotal factor. It also explores recent initiatives by maritime safety organizations aimed at addressing these issues and reducing human error incidents, concluding with the potential implications of these efforts for maritime safety.

Sánchez-Beaskoetxea et al. [5] analyzed marine incident reports from the U.S. National Transportation Safety Board (NTSB) spanning June 1975 to September 2017. Their study examined the role of ship crews and other stakeholders, such as pilots and shipping companies, in incident causation, while also assessing the impact of international regulations on seafarers. Findings revealed that crew errors on cargo and passenger vessels were rare, underscoring the effectiveness of conventions like STCW. However, high human error rates in pilot waters emphasized the need for better coordination between bridge teams. Additionally, increased crew errors in fishing vessels and tugboats highlighted the necessity for targeted training to reduce navigation mistakes.

Historically, incident investigations focused primarily on hardware problems, such as equipment faults and component failures. However, it has become increasingly evident that human factors, rather than hardware issues, are responsible for most incident precursors. Rothblum et al. [6] aimed to aid offshore and marine organizations in incorporating human elements into their investigation programs to identify the causes of incidents involving human factors and establish practical safety solutions to prevent similar incidents.

Studies on maritime accidents consistently highlight human error as a key contributing factor, despite advances in vessel technology. Singh and Raju [7] carried out a systematic literature review examining the role of risk perception, the impact of the ISM Code on safety standardization, and the use of investigation methodologies to identify both direct and systemic causes. The application of accident causation theories offers a structured understanding of the interaction between human, organizational, and external factors, supporting a move toward more integrated safety management in shipping.

To improve the investigations of shipping accidents, a risk-based model was proposed by Celik et al. [8]. Their approach integrates a new risk framework with Fuzzy Extended Fault Tree Analysis (FFTA) to address both organizational constraints and technical failures. By examining factors such as operational errors and technical malfunctions, the study provides valuable insights into the root causes of maritime accidents. It emphasizes the importance of utilizing SAI reports to develop effective risk mitigation strategies for safer marine operations. Additionally, the research explores the integration of Fault Tree Analysis (FTA) with SAI to standardize data collection and improve the overall effectiveness of maritime accident investigation and prevention.

Schröder-Hinrichs et al. [9] analyzed around 41 maritime accidents caused due to explosions and fires in machinery spaces by deploying HFACS framework. Their findings revealed that these investigations primarily focused on technical failures while often overlooking organizational factors, highlighting a gap in current investigative approaches.

In a study by Caridis [10], the Casualty Analysis Methodology for Maritime Operations (CASMET) Project was introduced. This project concentrated on coding and analyzing maritime accidents and incidents that transpire on seagoing vessels. The impetus behind this project stemmed from a lack of emphasis on organizational and human errors in European nations' investigative practices. CASMET amalgamated the best elements of existing investigative procedures, yielding positive outcomes after being applied to numerous incidents.

Grech et al. [11] investigated mariners' lack of Situation Awareness (SA) by analyzing accident reports within merchant shipping operations. They employ the Leximancer tool, recognized for its rapid textual data processing, to assess its accuracy in comparison to manual analysis conducted by two raters. The results underscore SA's pivotal role in maritime decision-making, with numerous accidents linked to SA deficiencies. Additionally, the Leximancer tool's outcomes align with manual analysis, indicating its potential for analyzing accident reports in various transportation domains.

Salmon et al. [12] used STAMP, HFACS and Accimap methods for comparison in various case studies. While Accimap and STAMP provided a broader perspective on contributing factors, HFACS was noted for its structured taxonomy and reliability. However, as HFACS was originally developed for aviation, it faced challenges in classifying failures in other industries due to the lack of sector-specific taxonomies. The study suggests enhancing Accimap by incorporating more adaptable taxonomies across different investigation levels to improve future accident analyses.

Fu et al. [13] conducted a comparative analysis of HFACS and the 24Model, evaluating their theoretical foundations, classification criteria, and analytical processes. The study found that while both models are valuable, the 24Model demonstrates strong scientific validity and practical applicability, aiding investigators in selecting suitable methodologies for accident analysis.

Wu et al. [14] introduced an improved version of the Cognitive Reliability and Error Analysis Method (CREAM) by incorporating an evidence-based reasoning approach. This enhanced model provides a more precise evaluation of language-related factors in maritime accidents while addressing data uncertainties that affected previous CREAM models.

Kim and Na [15] proposed a human factor methodology to systematically identify and categorize key contributors to human error, establish accident sequences, and develop preventive safety measures.

Kececi and Arslan [16] introduced the Ship Accident Root Cause Evaluation (SHARE) method, specifically designed for maritime incidents. Built on the Fuzzy SWOT AHP framework, SHARE standardizes terminology, quantifies data, assigns accountability, and aids in risk mitigation, with its effectiveness validated through real-world applications.

Total-loss marine accidents result in severe human, economic, and environmental consequences. Chen et al. [17] analyzed global total-loss incidents from 2001 to 2015 using the fuzzy matter element method, identifying critical factors and trends to support policymakers in accident prevention strategies.

Zhang et al. [18] conducted a quantitative analysis of ship accident reports to assess the relationship between accident severity and contributing factors. Their two-phase approach involved standardizing contributory factors from reports and statistically analyzing them using the Kruskal-Wallis test, Cramer's V analysis, and Kendall's tau coefficient, effectively identifying the primary determinants of ship accident outcomes.

Cao et al. [19] conducted a comprehensive review of 491 studies from the Web of Science (2000–2022) to explore trends in marine accident research. Using CiteSpace and VOSviewer for knowledge mapping and cluster analysis, the study highlighted key research areas, including the integration of emerging technologies and the impact of human factors on remote-controlled ships and Arctic operations. Advanced techniques like deep data mining and machine learning were identified as crucial for uncovering new risk factors. The study provides a strong theoretical foundation for improving maritime safety, assessing research trends, and visualizing collaboration networks among institutions and researchers.

Accurate maritime risk assessment often requires extensive data. To bridge this gap, Li et al. [20] integrated recent accident data (2017–2021) from the GISIS and LRF databases into a Bayesian network (BN) model. Their analysis identified 23 key risk-influencing factors (RIFs) across static and dynamic risk categories. The BN model enhances risk prediction and scenario analysis while supporting the development of effective accident prevention strategies.

Despite all the technological developments and enhanced legislation, shipping accidents present a major challenge and cause of global concern. This highlights the importance of producing clear and consistent accident investigation reports that help identify the key factors contributing to such incidents. To improve the assessment of human errors in maritime accidents, Fuzzy analytical hierarchy process was integrated with the Human Factors Analysis and Classification System (HFACS) in the study by Celik and Cebi [21]. This combination strengthens decision-making processes and provides a solid analytical framework for quantitatively evaluating maritime incidents.

Focusing on safety in the maritime, Wu et al. [14] and Akyuz [22] introduced a hybrid model integrating HFACS with the Analytical Network Process (ANP) to analyze shipboard accidents. This combination provides a structured framework for assessing human errors while examining intercomponent relationships, offering a reliable tool for identifying accident causes.

Chen et al. [23] developed a novel Human Factors Analysis and Classification System for Maritime Accidents (HFACS-MA) to analyse human and organizational factors in marine events. This five-tiered structure integrates critical concepts from the Reason's Swiss Cheese Model, HFACS, and the Hawkins' SHEL model and aligns them with IMO regulations. The HFACS-MA is further enriched by combining it with a Why-Because Graph, thereby allowing an additional approach to incentivize the benefits of the HFACS framework.

Ensuring safe and accident-free shipping is a key priority for the maritime industry, with human error accounting for approximately 80–85% of accidents. Hasanspahić et al. [24] investigated 135 accident reports from the UK Marine Accident Investigation Branch (2010–2019) using the HFACS-MA framework. Their study identified frequently occurring causal factors and applied multiple linear regression to analyze their correlation with accident frequency. The findings suggest that addressing two critical human factors identified in the study could significantly reduce accident rates and improve overall maritime safety.

Akyuz and Celik [25] proposed a marine accident analysis and prevention model called HFACS-CM. The model combines the HFACS with the Cognitive Map (CM) technique to analyze the contribution of the human factor in marine accidents. The model gives an effective solution for users to find the pertinent causes of marine accidents. Hence, the latent or active reasons of an accident can be identified and prioritized by this model. Using a life boat situation drill, the aptness of the model could be checked for serious marine accident involving a man.

Batalden and Sydnes [26] applied a customized HFACS framework to marine accident investigations, analyzing 22 serious incidents reported by the UK's Marine Accident Investigation Branch from 2002 to 2010. Their findings highlighted that "Very Serious" accidents were strongly linked to organizational shortcomings, particularly in onboard planning and monitoring.

The oil and gas industry has experienced severe accidents due to operational and organizational failures. Since HFACS was originally developed for aviation, its limitations became evident when applied to this sector, particularly in areas such as regulatory oversight and sabotage. To bridge these gaps, Theophilus et al. [27] developed HFACS-OGI, a tailored version of HFACS for the oil and gas industry, enhancing its effectiveness in accident investigations.

Uğurlu et al. [28] brought forward a modified HFACS for passenger vessels for better classification of the respective vessel accidents. The grounding of 51 passenger vessels which occurred between 1991 and 2017 were analysed using the modified HFACS-PV model. The integration of the framework was found to be more effective for quantitative and qualitative study of passenger vessels.

Yildiz et al. [29] examined 70 passenger ship collisions and contact incidents from 1991 to 2015 using an adapted HFACS-PV model, which incorporated additional operational conditions. Their analysis identified key concerns, including authority misuse, procedural breaches, and rule violations.

Singh and Totakura [3] examined container vessel accidents using the HFACS-derived NASAFACS framework to analyze latent factors and active errors from 2010 to 2021. Findings reveal that 'Preconditions' are the primary contributors, with vessel damage, container loss, and environmental pollution as major consequences. Collisions involve both latent and active errors, while fires are mainly latent-driven. Heavy weather damage incidents show a higher risk of pollution. The study highlights the need for better securing practices, accurate cargo declaration, and stricter stowage compliance to enhance safety and reduce environmental impact.

Despite much work that has been done to analyse marine accidents, gaps still persist, which are:

• Most models underrepresent external commercial and regulatory influences, which are particularly relevant in container shipping.

• There is limited integration of expert experiential knowledge, which can reveal systemic risks not captured in reports.

3. METHODOLOGY

To bring out a holistic perspective towards the prevention of accidents in container vessels, a qualitative research approach is deployed through focus group interviews of various stakeholders.

3.1 Data

Nine industry professionals dealing with varied aspects of container vessels were interviewed semi-structured, and the transcript of the interview response was coded using the NASAFACS framework on the MAXQDA application to generate meaningful insights.

The interview questions were developed in alignment with the research objectives and were structured across key thematic domains, including causal factors, operational risks, regulatory issues, crisis management, and future trends. To ensure validity and clarity, the questions were:

• Based on the initial NASAFACS analysis of accident reports, ensuring alignment with previously identified causal pathways.

• Piloted with two experienced maritime professionals (not part of the final sample) to test clarity, relevance, and scope.

• Revised based on pilot feedback, particularly to avoid leading questions and to ensure open-ended, exploratory dialogue.

The nine professionals interviewed, as detailed in Table 1, represent an exceptional cross-section of the container vessel industry, each with decades of specialized experience. The selection of these individuals covered a wide range of perspectives, from claims handling, loss prevention, shore management, casualty investigations, salvage handling, container logistics and port operations, pilotage, vessel command & onboard operations and maritime training. Their varied roles ensured that the interviews encapsulate a comprehensive understanding of the sector, and the data is drawn from a well-rounded and experienced group, covering all critical aspects of container vessel operations and management. This rich diversity of insights ensured that theoretical saturation was reached after nine interviews, as no new significant themes emerged beyond this point. Saturation was confirmed through the use of the NASAFACS framework in MAXQDA, which allowed for a systematic coding process. The varied yet focused expertise of the interviewees aligns with the literature on qualitative research, which suggests that saturation can be achieved with fewer interviews when participants are highly knowledgeable [30].

3.2 Method

The study and analysis were conducted using the NASAFACS framework. The NASA Human Factors Analysis and Classification System (NASAFACS) is an advanced analytical framework developed by NASA to systematically investigate and classify human errors contributing to accidents, particularly within aerospace contexts. It is an adaptation and extension of the well-established HFACS, originally developed for aviation by Shappell and Wiegmann in 2000 [31]. NASAFACS retains the core HFACS structure but incorporates additional granularity and domain-specific nuances relevant to NASA’s operational requirements.

NASAFACS categorizes human errors into four hierarchical levels:

Organizational Influences – Encompasses factors related to management decisions, organizational processes, resource management, and workplace culture.

Unsafe Supervision – Includes inadequate leadership, insufficient oversight, failure to correct problems, and supervisory violations.

Preconditions for Unsafe Acts – Captures environmental, situational, and individual conditions that set the stage for unsafe practices.

Unsafe Acts – Addresses direct operator errors or deliberate violations that immediately precede an accident or incident.

Table 1. Professional experience of the respondents engaged in the semi-structured interview

Respondent	Experience
Respondent 1	P&I Club representative with more than 15 years of exclusive experience in claims handling and settlement in P&I Club, dealing with various shipping accidents, including container vessels.
Respondent 2	Master mariner with more than 15 years of sailing experience, followed by close to 15 years of experience with P&I Club in loss prevention department.
Respondent 3	Master mariner with more than 30 years of marine industry, including sailing and various shore roles in container vessel management companies.
Respondent 4	Master mariner with more than 25 years in marine industry, which involves about 14 years of sailing and balance dealing with marine casualty investigation, especially with container vessel incident investigations.
Respondent 5	Master mariner with more than 45 years of marine experience spanning across sailing, shore roles and salvage handling.
Respondent 6	Master mariner with more than 25 years active sailing experience and exclusively commanding container vessels.
Respondent 7	Master mariner with around 25 years of experience in shipping industry, which includes sailing on and commanding container vessels, and role as Pilot in container terminal.
Respondent 8	Master mariner with more than 35 years in shipping industry spanning across sailing and varied experience across container vessel industry involving handling container lines, container terminal and container logistics.
Respondent 9	Master mariner with more than 45 years in shipping industry, including sailing and commanding vessels, shore roles and extended period in marine academia and training.

Source: Author’s own analysis

This structured hierarchical approach enables analysts to systematically identify not only immediate operational errors but also latent organizational and environmental conditions contributing to adverse events.

The MAXQDA programme (MAXQDA 24 Analytics Pro) served as the platform for the coding and analysis of the semi-structured interview. MAXQDA is a software program designed for computer-assisted qualitative and mixed methods data, text and multimedia analysis in academic, scientific, and business institutions. It is being developed and distributed by VERBI Software, based in Berlin, Germany. MAXQDA has the advantage of being used for mixed methods, i.e., both quantitative and qualitative analysis.

4. ANALYSIS AND DISCUSSION

4.1 Hierarchical code–subcode model

Figure 1 shows the Hierarchical code–subcode model for the NASAFCS framework used for coding the interview responses from various respondents.

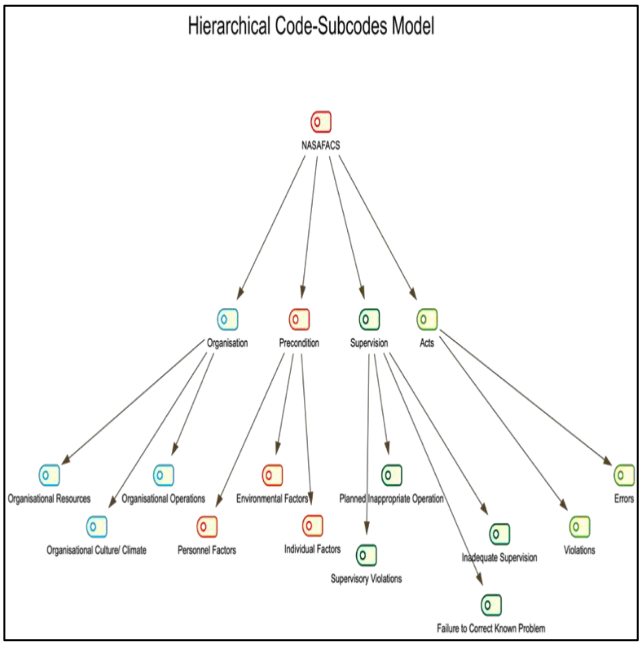

Figure 1. Hierarchical code–subcodes model

Figure 2. MAXQDA word cloud

4.2 Word cloud for high frequency words in the interview transcripts

The word cloud, generated from the coding and analysis of various interview transcripts on MAXQDA application, highlights the most frequently used words by the respondents during the interview, as shown in Figure 2.

4.3 Single case models for various respondents

Looking at the single case model in Figure 3, Respondent 1 gives maximum weightage to Organizational Resources, followed by Organizational Culture/ Climate (L1 – Organization). Equal weightage is given to Communication (L3 – Precondition), Supervisory Violations (L2 – Supervision) and Skills (L4 – Acts).

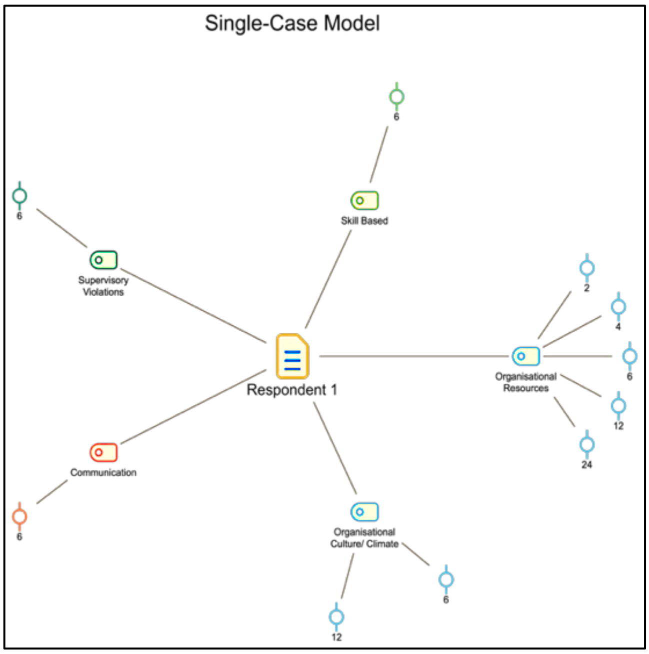

Figure 3. Single case model Respondent 1

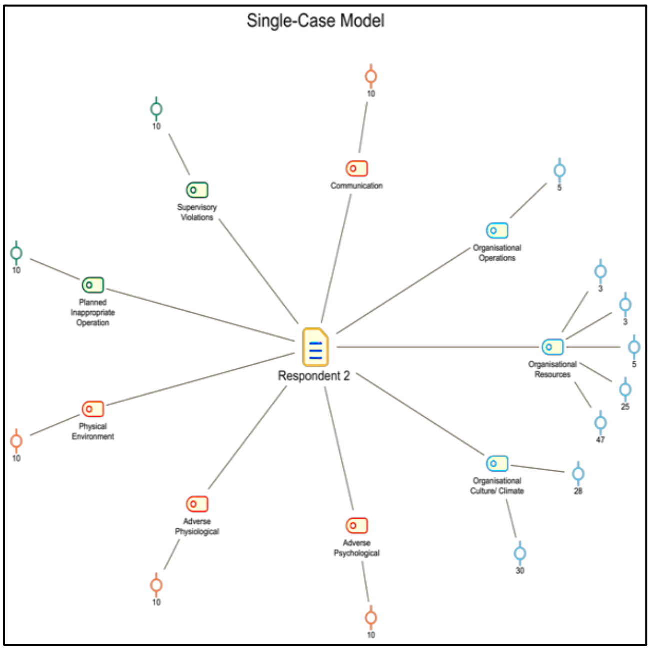

Figure 4. Single case model Respondent 2

Looking at the above single case model in Figure 4, Respondent 2 gives maximum weightage to Organizational Resources, followed by Organizational Culture/ Climate and then Organizational Operations (L1 – Organization). Equal weightage is given to Supervisory Violations and Planned Inappropriate Operations (L2 – Supervision), Communication, Physical Environment, Adverse Physiological and Adverse Psychological (L3 – Precondition).

Looking at the single case model in Figure 5, Respondent 3 gives maximum weightage to Organizational Resources and Organizational Operations, followed by Organizational Culture/ Climate (L1 – Organization). This is followed by Communication, then Technological Environment and Physical Environment (L3 – Precondition). Supervisory Violations & Planned Inappropriate Operations also find place with lesser weightage (L2 – Supervision).

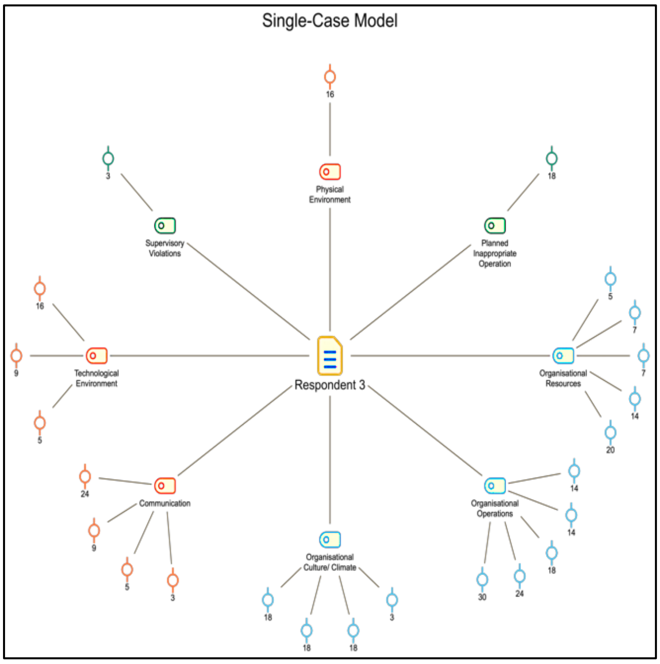

Figure 5. Single case model Respondent 3

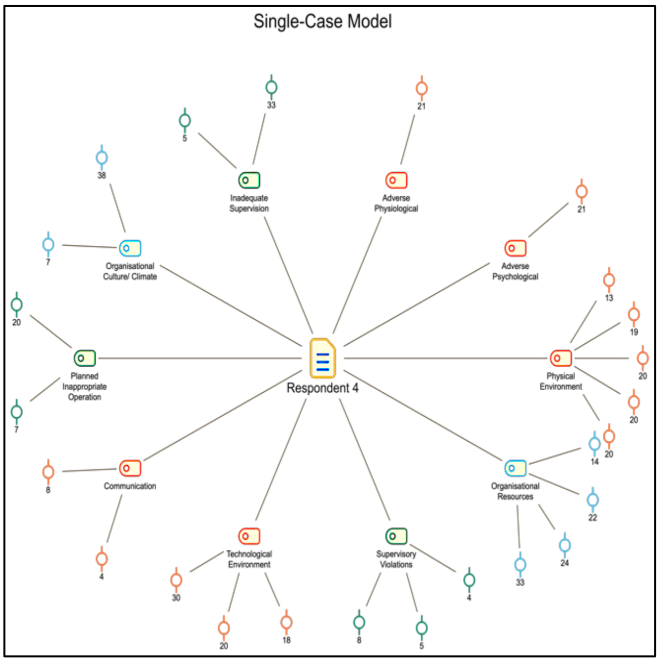

Figure 6. Single case model Respondent 4

Looking at the above single case model in Figure 6, Respondent 4 gives maximum weightage to Physical Environment (L3 – Precondition), followed by Organizational Resources (L1 – Organization), followed by Supervisory Violations (L2 – Supervision) and Technological Environment (L3 – Precondition). These are followed by Communication (L3 – recondition), Planned Inappropriate Operations & Inadequate Supervision (L2 – Supervision) and Organizational Culture/ Climate (L1 – Organization). Weightage though least has also been given to Adverse Physiological and Adverse Psychological (L3 – Precondition).

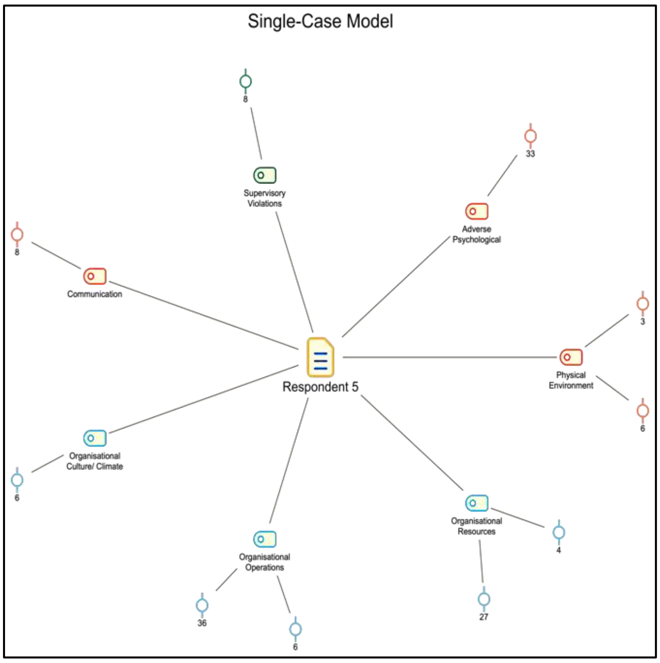

Figure 7. Single case model Respondent 5

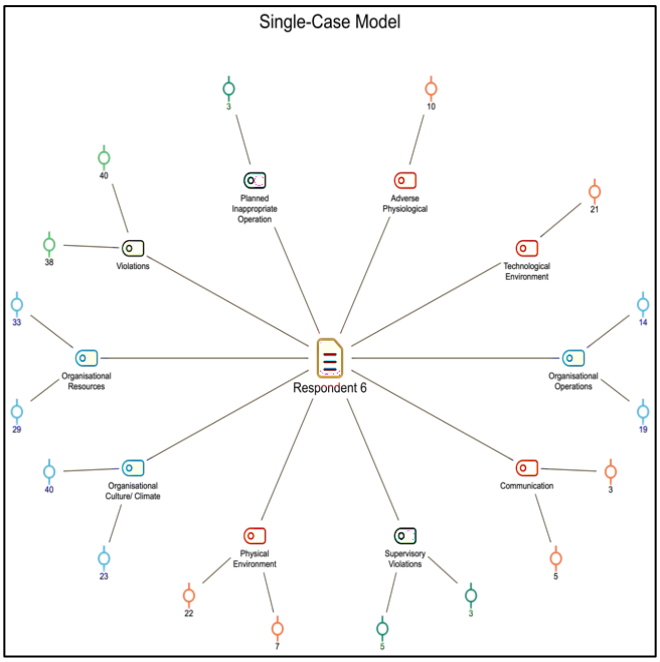

Figure 8. Single case model Respondent 6

Looking at the above single case model in Figure 7, Respondent 5 gives maximum weightage to Organizational Resources, Organizational Operations (L1 – Organization) and Physical Environment (L3 – Precondition) followed by equal weightage to Organizational Culture/ Climate (L1 – Organization), Supervisory Violations (L2 – Supervision), Adverse Psychological and Communication (L3 – Precondition).

Looking at the above single case model in Figure 8, Respondent 6 gives maximum weightage to Organizational Resources, Organizational Operations, Organizational Culture/ Climate (L1 – Organization), Supervisory Violations (L2 – Supervision), Physical Environment, Communication (L3 – Precondition) and Violations (L4 – Acts). The above are followed by lesser and equal weightage to Planned Inappropriate Operations (L2 – Supervision), Adverse Psychological and Technological Environment (L3 – Precondition).

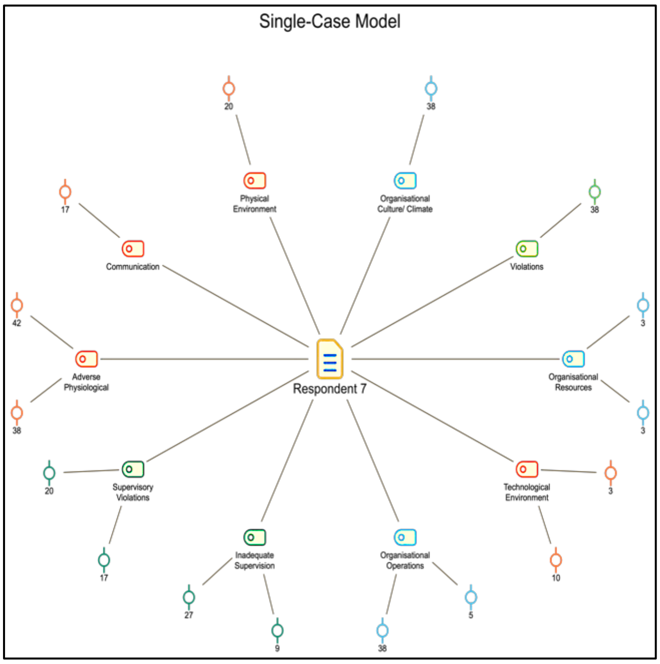

Figure 9. Single case model Respondent 7

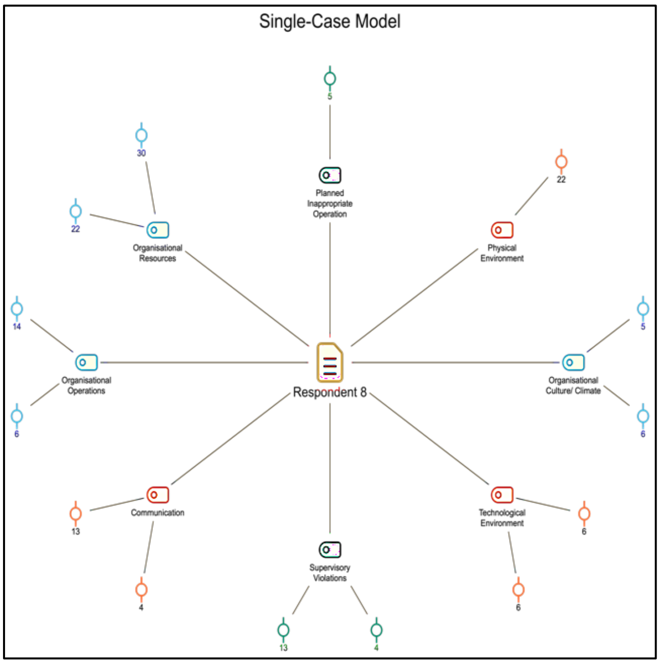

Figure 10. Single case model Respondent 8

Looking at the above single case model in Figure 9, Respondent 7 gives maximum weightage to Organizational Resources, Organizational Operations (L1 – Organization), Supervisory Violations, Inadequate Supervision (L2 – Supervision), Technological Environment and Adverse Psychological (L3 – Precondition). The above are followed by lesser and equal weightage to Organizational Culture/ Climate (L1 – Organization), Physical Environment, Communication (L3 – Precondition) and Violations (L4 – Acts).

Looking at the above single case model in Figure 10, Respondent 8 gives maximum weightage to Organizational Resources, Organizational Operations, Organizational Culture/ Climate (L1 – Organization), Supervisory Violations (L2 – Supervision), Technological Environment and Communication (L3 – Precondition). The above are followed by lesser and equal weightage to Planned Inappropriate Operation (L2 – Supervision) and Physical Environment (L3 – Precondition).

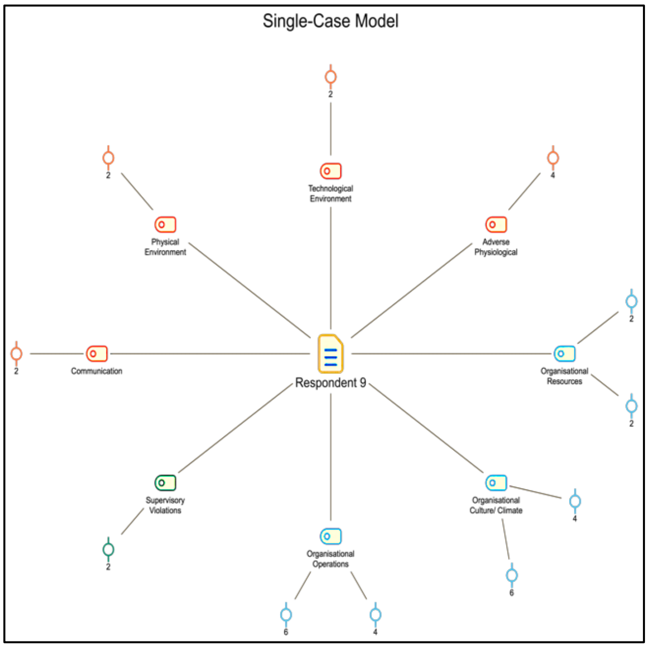

Figure 11. Single case model Respondent 9

Looking at the above single case model in Figure 11, Respondent 9 gives maximum weightage to Organizational Resources, Organizational Operations, Organizational Culture/ Climate (L1 – Organization). The above are followed by lesser and equal weightage to Supervisory Violations (L2 – Supervision), Technological Environment, Physical Environment, Communication and Adverse Psychological (L3 – Precondition).

Summary of max weightage given to factors by various respondents:

Respondent 1: Organizational Resources followed by Organizational Culture/ Climate (L1).

Respondent 2: Organizational Resources followed by Organizational Culture/ Climate (L1).

Respondent 3: Organizational Resources and Organizational Operations (L1).

Respondent 4: Physical Environment (L3) followed by Organizational Resources (L1).

Respondent 5: Organizational Resources, Organizational Operations (L1) and Physical Environment (L3).

Respondent 6: Organizational Resources, Organizational

Operations, Organizational Culture/ Climate (L1), Supervisory Violations (L2), Physical Environment, Communication (L3) and Violations (L4 – Acts).

Respondent 7: Organizational Resources, Organizational Operations (L1), Supervisory Violations, Inadequate Supervision (L2), Technological Environment and Adverse Psychological (L3).

Respondent 8: Organizational Resources, Organizational Operations, Organizational Culture/ Climate (L1), Supervisory Violations (L2), Technological Environment and Communication (L3).

Respondent 9: Organizational Resources, Organizational Operations, Organizational Culture/ Climate (L1).

From above, it's evident that respondents consider Organization playing the maximum role in the causation of the incidents onboard the container, in terms of the availability of resources, culture or operations.

4.4 MAXQDA code matrix browser output–Overview of the response codes

The analysis of the distribution of latent factors and active events as depicted in Table 2 provides a detailed view of the underlying causes and contributing factors to container vessel accidents, based on the NASAFACS framework. The analysis is further detailed through the chart in Figure 12, which visually represents the distribution of these response codes. This pictorial representation helps illustrate the relative weight of different factors and allows for easy comparison.

The distribution of response codes underscores the dominance of 'L1 – Organization' as the most significant causative factor in container vessel accidents, which is in contrast to the NASAFCS analysis of container vessel accidents, which highlights.

Following this, 'L3 – Precondition' factors are recognized as the next most significant contributors.

'L2 – Supervision' ranks third, highlighting the importance of supervisory practices, but indicating that their impact is seen as somewhat less direct compared to Organization and Precondition factors.

Finally, 'L4 – Acts' is seen as the least significant, emphasizing that individual actions or errors by ship staff are not considered major contributors to accidents by the respondents. This reinforces the perception that external parties and systemic issues have a more substantial impact on container vessel operations, often placing many operational aspects beyond the direct control of the ship's crew.

The distribution of NASAFACS subcodes is further detailed in Table 3, based on the feedback received from the various respondents.

Table 2. Overview of the codes assigned based on feedback from the respondents

	NASAFACS L1 Organization	NASAFACS L2 Supervision	NASAFACS L3 Precondition	NASAFACS L4 Acts	SUM
Respondent 1	7	1	1	1	10
Respondent 2	9	2	4	0	15
Respondent 3	15	2	8	0	25
Respondent 4	6	7	13	1	27
Respondent 5	5	1	4	0	10
Respondent 6	7	4	6	3	20
Respondent 7	7	5	8	1	21
Respondent 8	7	3	6	0	16
Respondent 9	10	1	4	0	15
SUM	73	26	54	6	159

Source: Author's own analysis

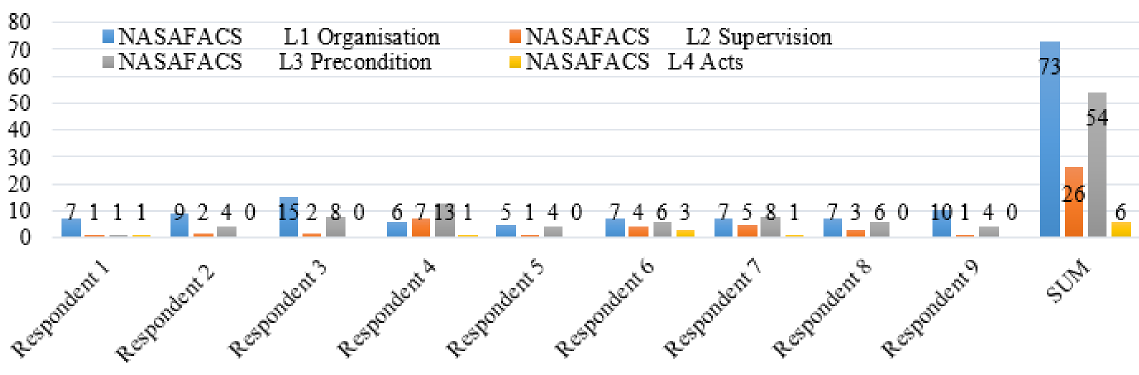

Figure 12. Chart showing the distribution of the response codes under NASAFACS framework

Table 3. Distribution of NASAFACS subcodes

	R-1	R-2	R-3	R-4	R-5	R-6	R-7	R-8	R-9	SUM
NASAFACS	0	0	0	0	0	0	0	0	0	0
NASAFACS > L1 Organization	0	0	0	0	0	0	0	0	0	0
NASAFACS > L1 Organization > Organizational Culture/ Climate	2	2	4	2	1	2	1	3	3	20
NASAFACS > L1 Organization > Organizational Operations	0	1	5	0	2	3	2	2	2	17
NASAFACS > L1 Organization > Organizational Resources	5	6	6	4	2	2	4	2	5	36
NASAFACS > L2 Supervision	0	0	0	0	0	0	0	0	0	0
NASAFACS > L2 Supervision > Failure to Correct Known Problem	0	0	0	0	0	0	1	0	0	1

NASAFACS > L2 Supervision > Inadequate Supervision	0	0	0	2	0	1	2	0	0	5
NASAFACS > L2 Supervision > Planned Inappropriate Operation	0	1	1	2	0	1	0	1	0	6
NASAFACS > L2 Supervision > Supervisory Violations	1	1	1	3	1	2	2	2	1	14
NASAFACS > L3 Precondition	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Environmental Factors	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Environmental Factors > Physical Environment	0	1	1	6	2	2	1	1	1	15
NASAFACS > L3 Precondition > Environmental Factors > Technological Environment	0	0	3	3	0	1	4	3	1	15
NASAFACS > L3 Precondition > Personnel Factors	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Personnel Factors > Communication	1	1	4	2	1	2	1	2	1	15
NASAFACS > L3 Precondition > Personnel Factors > Self Imposed Stress	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Individual Factors	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Individual Factors > Adverse Cognitive Factors	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Individual Factors > Adverse Physiological	0	1	0	1	0	1	2	0	1	6
NASAFACS > L3 Precondition > Individual Factors > Adverse Psychological	0	1	0	1	1	0	0	0	0	3
NASAFACS > L3 Precondition > Individual Factors > Mental/ Medical	0	0	0	0	0	0	0	0	0	0
NASAFACS > L3 Precondition > Individual Factors > Perceptual Factors	0	0	0	0	0	0	0	0	0	0
NASAFACS > L4 Acts	0	0	0	0	0	0	0	0	0	0
NASAFACS > L4 Acts > Errors	0	0	0	0	0	0	0	0	0	0
NASAFACS > L4 Acts > Errors > Decision Making	0	0	0	0	0	1	0	0	0	1
NASAFACS > L4 Acts > Errors > Skill Based	1	0	0	1	0	0	0	0	0	2
NASAFACS > L4 Acts > Errors > Perception	0	0	0	0	0	0	0	0	0	0
NASAFACS > L4 Acts > Violations	0	0	0	0	0	2	1	0	0	3
SUM	10	15	25	27	10	20	21	16	15	159

Source: Author's own analysis

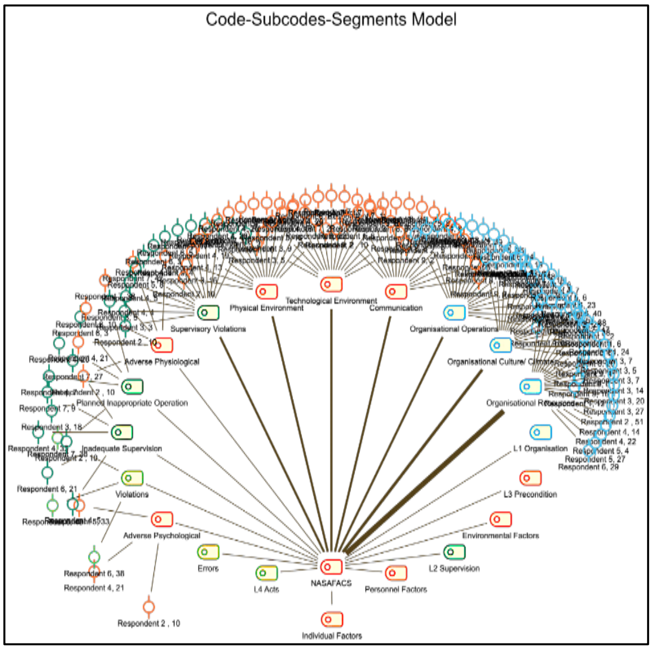

Figure 13. Codes-subcodes segment model

The analysis of the distribution of NASAFACS subcodes table (Table 3) and the codes-subcodes segment model (Figure 13) provides further insight into the hierarchy of causative factors in container vessel accidents as perceived by the respondents.

L1 Organization: Organizational Resources are seen as the most significant causative factor, with Organizational Culture and Organizational Operations following behind. This suggests that respondents view effective resource availability and management as critical to preventing accidents, with the culture and operational practices of the organization and industry playing supportive roles.

L3 Preconditions: This category holds the second most weight in terms of causative factors, with Environmental Factors (both Physical and Technological) and Personnel Factors (specifically Communication) being equally significant contributors. Individual Factors, such as Adverse Physiological and Adverse Psychological conditions, are noted but are seen as less prominent.

L2 Supervision: Within this category, Supervisory Violations are viewed as the primary causative factor, followed by Planned Inappropriate Operation and Inadequate Supervision. This indicates that lapses in supervisory practices and planning are key contributors to accidents.

L4 Acts: According to the respondents, this category plays a limited role in container vessel accidents, suggesting that individual actions or mistakes are seen as less impactful compared to organizational and environmental factors.

This breakdown highlights the emphasis placed on systemic issues or 'Latent Factors' of 'L1 – Organization', 'L3 – Preconditions' & 'L2 – Supervision' and being more prevalent over individual actions or 'Active Events' of 'L4 – Acts' in the context of container vessel accidents.

4.5 MAXQDA maps

4.5.1 MAXQDA code map

The MAXQDA code map in Figure 14 is a visual tool used to display the relationships between different codes based on how frequently they are applied together in a dataset. It allows one to see patterns and connections between themes, concepts, or categories that emerge during qualitative data analysis. The code map shows the association between the codes. The more frequently two codes have been assigned together, the closer they are on the map.

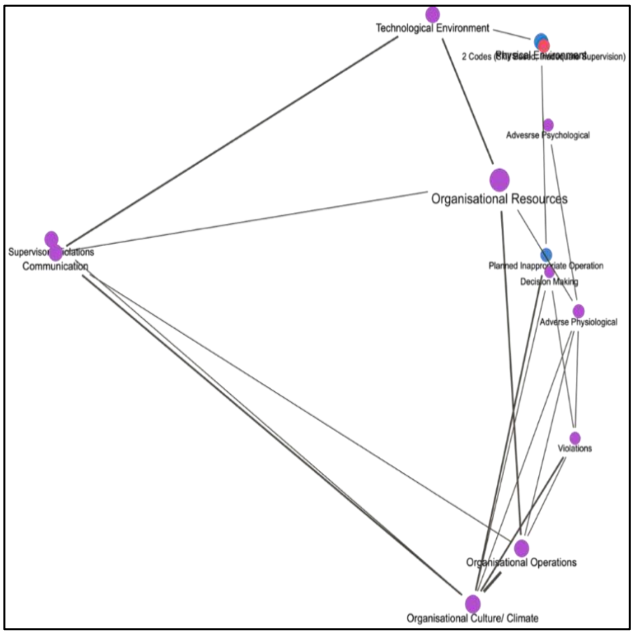

Figure 14. MAXQDA code map

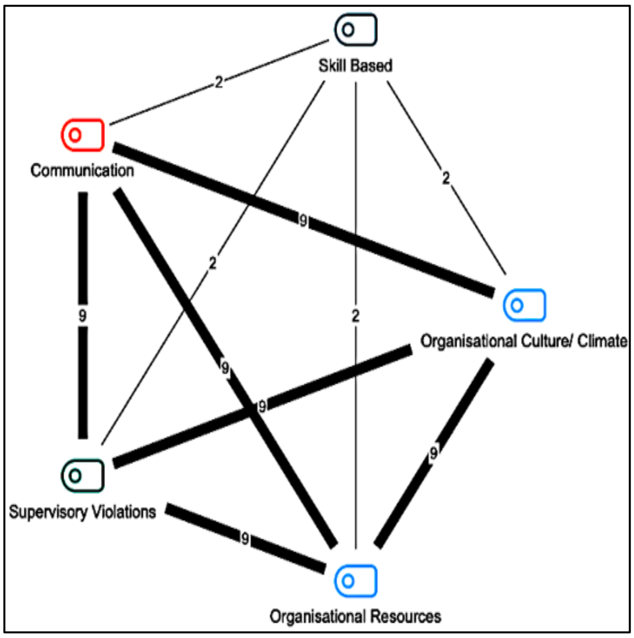

Figure 15. Code co-occurrence model (code intersection)
Source: Author's own analysis

4.5.2 MAXQDA code co-occurrence model (Code Intersection)

The Code Co-occurrence Model (Code Intersection) from MAXQDA in Figure 15, visually represents the relationships between key codes, showing how often specific themes (codes) appear together in the dataset. The lines connecting the nodes represent the 'frequency of co-occurrence' between these codes in the data. Thicker lines indicate stronger relationships, i.e., higher co-occurrence. The 'numbers on the lines' show the exact frequency of intersection. The codes Communication, Supervisory Violations, Organizational Culture/Climate, and Organizational Resources all have thick lines connecting them, and the frequency of 9 co-occurrences indicates a significant overlap between these issues. This suggests that in the dataset, communication failures are frequently linked to supervisory violations, which could be influenced by both organizational culture and resource allocation.

Skill-Based has weaker links with Communication (2), Organizational Resources (2), and Organizational Culture/Climate (2), suggesting that skill-based issues are less frequently tied to these themes in the data. This could mean that while skills-based issues do contribute to problems, they are not as central as organizational factors like resources, culture, or supervision. It could also indicate that skill-based problems tend to appear in more isolated or specific contexts rather than being systemic across the organization.

4.6 Key insights from the container vessel accident analysis and respondent interview

Below are the key insights gathered during the research process.

4.6.1 Challenges with the increased size of vessel

The trend toward Ultra-Large Container Vessels (ULCVs), with capacities exceeding 20,000 TEUs, has brought notable challenges despite the economic benefits. Their substantial windage area and limited engine power create handling difficulties, particularly during adverse weather or emergency scenarios. Operationally, managing stowage and lashing with a minimal crew presents significant concerns. A prominent example is the grounding of a ULCV in the Suez Canal, which disrupted global trade, emphasizing the risks associated with these large vessels.

4.6.2 Inadequacies of port infrastructure

Port infrastructure has struggled to keep pace with the growing dimensions of container vessels. Although ports have upgraded berths and handling equipment, these changes are often reactive. Larger ships with lower engine power require more space and precise manoeuvring, particularly in constrained environments. This mismatch between ship design and port readiness increases the likelihood of incidents, especially in ports lacking advanced tugs or navigational aids.

4.6.3 Firefighting capability

Firefighting systems on modern container ships have not evolved in line with vessel size and cargo complexity. Crews of 16–18 are expected to control fires on vessels over 20,000 TEUs using methods suitable for much smaller ships. Limited accessibility to the fire origin, particularly deep within cargo stacks, further exacerbates the issue. While new technologies are being explored, the current gap in fire response capability remains a critical safety concern on ULCVs.

4.6.4 External factors in container vessel operations

Container shipping operations are significantly influenced by external factors, many of which are beyond the control of the vessel's crew. Cargo-related incidents—such as fires or container losses—are often linked to misdeclared or improperly stowed cargo. Planning is conducted ashore due to the complexities of liner trades, which involve frequent loading and unloading at multiple ports. The crew's role is limited to verifying vessel stability, stress parameters, and IMDG segregation compliance, relying heavily on the accuracy of shore-side cargo information. Consequently, they act more as final checkers than planners, with minimal authority to intervene in broader cargo-related decisions, despite bearing operational responsibility.

4.6.5 Misdeclaration of cargo

The container shipping industry is fraught with cargo misdeclaration challenges, both in terms of its nature and its weight, which are discussed here.

Misdeclaration of dangerous cargo (IMDG). Containerized cargo poses distinct challenges compared to bulk, oil, or general cargo, primarily due to limited transparency regarding container contents. Ship crews and operators rely heavily on the shipper's declaration, making them vulnerable to misdeclarations. Unfortunately, such misdeclarations—especially of dangerous goods (DG)—are not uncommon and have serious safety implications. Shippers may mis-declare hazardous cargo to avoid higher freight costs, which can be three to five times greater than for non-dangerous goods, or to bypass carrier-imposed restrictions on specific DG types. When facing transport limitations, shippers may falsely label hazardous materials as harmless, concealing the actual risks. This practice endangers the vessel, crew, and environment, as misdeclared DG can trigger fires, explosions, or toxic leaks. In addition to false declarations, improper packaging of dangerous cargo further compounds the risk.

Misdeclaration of cargo weight. Another critical concern in container shipping is the misdeclaration of cargo weight. Accurate weight declaration is vital for assessing a vessel's stability, particularly its metacentric height (GM), a key determinant of safe operations at sea. Unlike bulk carriers or oil tankers, which naturally have a high GM, container vessels operate within tighter GM margins, making them more sensitive to weight inaccuracies. Misdeclared cargo, especially when heavier containers are stowed higher than intended, can distort GM calculations. While stability assessments may appear compliant on paper, the actual GM may be lower, compromising safety.

Beyond stability, accurate weight verification is essential for structural integrity, including ensuring stack weight limits on hatch covers are not exceeded. To address these risks, the Verified Gross Mass (VGM) regulation mandates that containers be weighed before loading. While this measure aims to enhance compliance, full industry adherence remains a persistent challenge.

4.6.6 Limited action possibility against faltering shippers and freight forwarders

A major challenge for shipping companies is the persistent issue of misdeclared cargo and improper packaging by freight forwarders, particularly in China, a key hub in global trade. Many Chinese freight forwarding businesses are small-scale or individually operated, making regulatory enforcement and legal action difficult. This decentralized structure hampers accountability for cargo misdeclarations.

The financial motivation to mis-declare hazardous cargo as general cargo is considerable, with DG incurring freight costs up to five times higher. This cost gap incentivizes deliberate misclassification despite safety risks. Attempts by shipping companies to enforce compliance or seek legal remedies are often hindered by complexities in the Chinese legal system.

To mitigate this risk, the industry must adopt stricter penalties and improve awareness among freight forwarders about the legal and safety consequences of misdeclaration. Strengthening enforcement and education can significantly reduce unsafe practices and enhance overall container shipping safety.

4.6.7 Role of commercial pressure

Commercial pressure presents a persistent challenge for shipmasters, especially in the container shipping sector, where schedules are set months in advance. Delays due to traffic, adverse weather, or route adjustments can disrupt tightly coordinated logistics. In such cases, masters often face strong pressure to maintain timetables, sometimes at the expense of safety.

A common consequence is high-speed navigation through congested waters, despite COLREGS requiring a safe speed based on prevailing conditions. Although weather routing services provide guidance, commercial imperatives frequently override safety considerations. Masters increasingly find their authority diminished, as decisions are influenced by shore-based commercial priorities. This imbalance can lead to risky manoeuvres in dense traffic or poor weather, raising the likelihood of incidents or cargo loss.

The same pressures are evident at ports, where rapid turnaround, reduced idle times, and high berth utilization are prioritized. Such demands may prompt pilots to approach berths at unsafe speeds, raising the risk of collisions and damage to ships or infrastructure. To foster safer operations, shipmasters must be empowered to make safety-based decisions without fear of commercial repercussions.

4.6.8 Dilution of risk assessment exercise

In practice, maritime risk assessments have become procedural formalities rather than meaningful safety evaluations. While risk management frameworks exist, commercial imperatives often override them, leading to routine approval of operations, even when significant hazards are identified.

Risk assessment outcomes are shaped by subjective factors such as the assessor's experience, judgment, and risk tolerance. More critically, shipmasters rarely have the autonomy to halt operations based solely on their assessments. The prevailing mindset across the container industry tends to minimize operational disruption, even when residual risk is high.

As a result, risk assessments often reduce to paperwork exercises, assuming that identified hazards can be mitigated without operational delay. However, not all risks are manageable without cost. In some cases, safety may demand postponing a voyage or altering a route. Unless the industry is willing to absorb these commercial implications, genuine risk-based decision-making will remain elusive.

4.6.9 Impact of container loss on economic viability

Despite growing awareness of safety risks, container loss continues to be tolerated within the industry's economic model. Technological improvements—such as enhanced weather forecasting and vessel design to counteract phenomena like parametric rolling—have not been matched by economic incentives for operational change.

For instance, a vessel carrying 25,000 containers may remain profitable despite losing several hundred containers annually. This economic resilience discourages shipowners from investing in structural or procedural upgrades. Container loss, although undesirable, often lacks the financial consequence needed to prompt systemic change.

To shift this paradigm, economic models must place greater emphasis on safety and sustainability. Only when safety lapses result in financial or regulatory consequences will the industry move toward meaningful operational reforms.

4.6.10 Lashing issues encountered in container shipping

Lashing and securing challenges are prevalent in container vessel operations. Non-compliance with cargo securing manuals, improper weight declarations, wrong stowage, and inconsistent or degraded lashing gear contribute significantly to safety risks. Terminals sometimes deviate from the lashing plans specified by the vessel, increasing the likelihood of stack collapse, particularly in rough weather. Moreover, limited onboard manpower and maintenance opportunities cause deterioration in lashing equipment, which is often only addressed during dry dock repairs.

0 weight stress lashing beyond permissible limits (MSL), especially in multi-tier stacks. Incorrect stowage, placing heavier containers above lighter ones, can similarly cause excessive lashing loads. Furthermore, changes to GM caused by mis-stowage or incorrect container weights can either amplify rolling motions or make the ship overly tender, both of which strain lashing systems.

Block stowage, while efficient, can result in isolated "tower" stacks vulnerable in heavy weather. Errors such as mixing incompatible twist locks (left-handed vs. right-handed) pose serious hazards, as some containers may appear secured but are not. Unloading is also risky if one twist lock remains engaged.

Inadequate segregation of defective lashing gear, declining inventory levels over time, and poor lashing inventory management further aggravate safety concerns. The current regulatory requirements may be insufficient for ultra-large vessels where rolling-induced forces exceed the design limits of traditional lashing systems, necessitating a revision of standards tailored for modern container ships.

4.6.11 Impact of schedule intensity and manning levels on safety in container ship operations

Container vessels operate on some of the most demanding schedules in shipping. Rapid port turnarounds leave little room for comprehensive checks, increasing operational risk. Manning levels are often limited to the minimum required, typically 14–16 crew members, with the deck team responsible for watchkeeping, cargo supervision, lashing oversight, and regulatory compliance.

The Chief Officer, despite reliance on shore-based planners, must verify the stowage plan onboard. However, short port stays and excessive responsibilities limit the ability to inspect stowage and lashing properly. Compromised rest hours and fatigue affect crew performance, leading to elevated safety risks during complex cargo operations.

4.6.12 Quality and competency of crew in modern shipping operations

The quality of crew on container vessels is increasingly inconsistent. Rapid global fleet expansion and cost pressures have led to hiring from regions with less robust maritime training systems. While STCW certification is mandated, it does not always reflect practical readiness for modern ship operations.

Theoretical training often falls short in preparing the crew for real-world tasks. Some officers may hold valid CoCs but lack the practical competence to manage operations effectively. Recognizing this, many shipping companies invest in supplemental training programs to bridge the gap between theoretical knowledge and practical application. However, without uniform standards, competency disparities persist across the industry.

4.6.13 Execution of stowage plans and challenges during loading operations

Even well-planned stowage arrangements can falter during execution. Terminals may misplace containers or fail to follow the vessel-approved plan. In some cases, serious GM imbalances are only discovered post-loading, necessitating re-stowage or, worse, becoming apparent after departure.

Communication gaps, time constraints, and emphasis on efficiency at terminals often prevent accurate implementation. When final stowage plans are delayed or received post-sailing, vessels may be left operating with compromised stability, posing severe safety threats.

4.6.14 Crisis response and salvage capabilities in mega-sized container ships

Salvage operations for mega-container ships are increasingly complex. As ship sizes have outpaced available response equipment, salvors often face delays while designing and mobilizing suitable tools. Although casualty frequency has declined, reducing commercial incentives for equipment investment, the scale and difficulty of incidents have risen.

Crisis response protocols remain largely unchanged, but managing emergencies on ultra-large ships, whether fires, groundings, or structural failures, requires specialized gear and strategies. Without investment in scalable salvage capabilities, the maritime industry will struggle to respond effectively to such incidents.

4.6.15 Port of refuge issues

Though international conventions obligate ports to offer refuge to distressed vessels, many ports refuse entry, especially if hazardous cargo is involved. This reluctance stems not from policy gaps but from unpreparedness and risk aversion.

Refused refuge during critical emergencies may force ships to remain at sea, escalating danger. Ports need improved infrastructure, dedicated emergency handling protocols, and trained personnel to fulfil their responsibilities as safe havens.

4.6.16 Industry collaborations in the container shipping sector

Collaborative safety initiatives like Cargo Incident Notification System (CINS) have helped major shipping lines address cargo misdeclaration. By sharing data and identifying high-risk goods, CINS promotes best practices. However, its voluntary nature and lack of enforcement limit its broader impact.

The container sector contrasts with the tightly regulated tanker industry governed by OCIMF. Fragmentation in container shipping, with millions of shippers and a vast range of cargo types, makes regulatory alignment difficult. Projects like the World Shipping Council's Top Tier, involving P&I clubs and container lines, offer promise but remain under development. More structured frameworks with broader participation and accountability are needed.

4.6.17 Environmental concerns: Emerging pollution from container ship accidents

Recent accidents, such as the MV X-Press Pearl, underscore a new class of environmental threats: microplastics. These pollutants are difficult to remove and pose long-term risks to marine ecosystems. Unlike oil spills, microplastics persist in the environment and are often underreported or underestimated.

As public and regulatory scrutiny increases, the industry must proactively develop containment and response strategies to prevent microplastic release and minimize its environmental footprint.

4.6.18 Emerging risks in shipping: Electric vehicles

The transport of electric vehicles (EVs), particularly second-hand units, introduces fire hazards due to degraded lithium-ion batteries. While new EVs often come with certification ensuring battery safety, there is no standardized process for second-hand units.

This lack of assurance creates uncertainty and risk during shipment. Even new EVs can catch fire due to thermal runaway. As EV volumes increase, establishing robust certification standards and safety protocols for battery health will be crucial to ensure safe maritime transport.

4.7 Contribution to theory

The Human Factor Analysis and Classification System (HFACS) formulated by Shappell and Wiegmann and based on the "Reason's Swiss Cheese Model" of human error, looks at four levels of human failure, which include Unsafe Acts, Preconditions for unsafe acts, Unsafe Supervision, and Organizational Influences and classifies them into active failures and latent conditions. The Organizational Influences factored in HFACS are internal to any organization as evident in Figure 16.

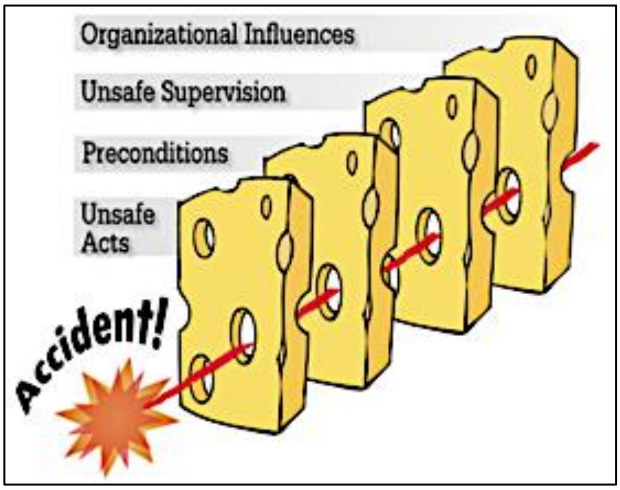

Figure 16. An accident in making (based on Reason, 1990), as adapted by Shappell and Wiegmann [31]

As observed during the study of the container shipping and associated accidents, container shipping relies heavily on the external parties like Shippers, Freight Forwarders, Ports, Terminals etc. and the actions of these external parties and external organizations have a profound impact on the safety outcomes of any container vessel. It is proposed that an additional layer of 'External Organizational Influences' be included in the HFACS, to account for the impact of the actions of these external parties in the container vessel accidents. The structural comparison of the existing model of the HFACS and the proposed model of HFACS for use in analysis of the container vessel accidents is as shown below in Figure 17.

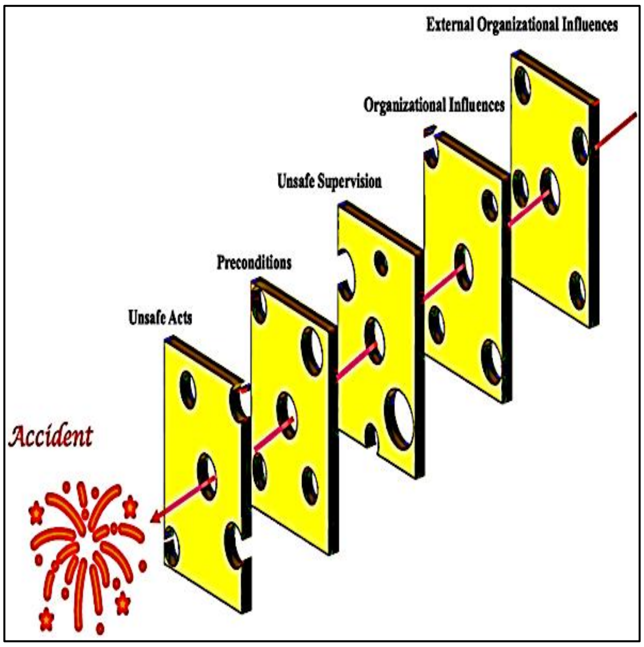

Figure 17. An accident in making (based on Reason, 1990), as adapted for container shipping HFACS-CV

This additional layer of 'External Organizational Influences' can also be included in the HFACS/ NASAFACS and introduced as a category to allow for categorization of factors like cargo planning discrepancies, wrong stowage, cargo misdeclaration, lashing non-compliance, etc., which are outcomes of the actions of the external parties. This maritime-specific adaptation could serve as a new theoretical model for analyzing human factors in maritime safety, especially in container shipping. Basis this additional layer, the NASAFACS structure was modified to include the impact of external organizations in the container shipping and can be used to better evaluate any accident and analyse the role of external agencies in the container vessel accidents. The 'Space Environment', not applying to the Maritime Accidents, has been replaced with 'Operational Environment' in the 'Precondition.' The modified structure has been named as HFACS-CV and will serve better to analyse container vessel accidents and is shown in Figure 18.

This study advances maritime safety research by integrating the established NASAFACS framework—rooted in the HFACS—with insights derived from semi-structured interviews of experienced industry professionals. While HFACS has been extensively applied in aviation, and has been tailored for usage in general marine accident investigations (HFACS-MA), offshore installations (HFACS-OGI), passenger vessels (HFACS-PV), its application to container vessels remains limited. Moreover, previous adaptations often rely solely on historical accident data, overlooking the nuanced, evolving operational realities that practitioners face. The HFACS-CV (Container Vessel) model proposed in this research addresses this gap by combining empirical accident classification with contextual, experience-based perspectives. This dual-input methodology ensures that latent organizational and operational factors—often obscured in retrospective reports—are brought to the forefront through expert testimony. this hybrid approach facilitates a more grounded, domain-specific understanding of error pathways in the container shipping sector.

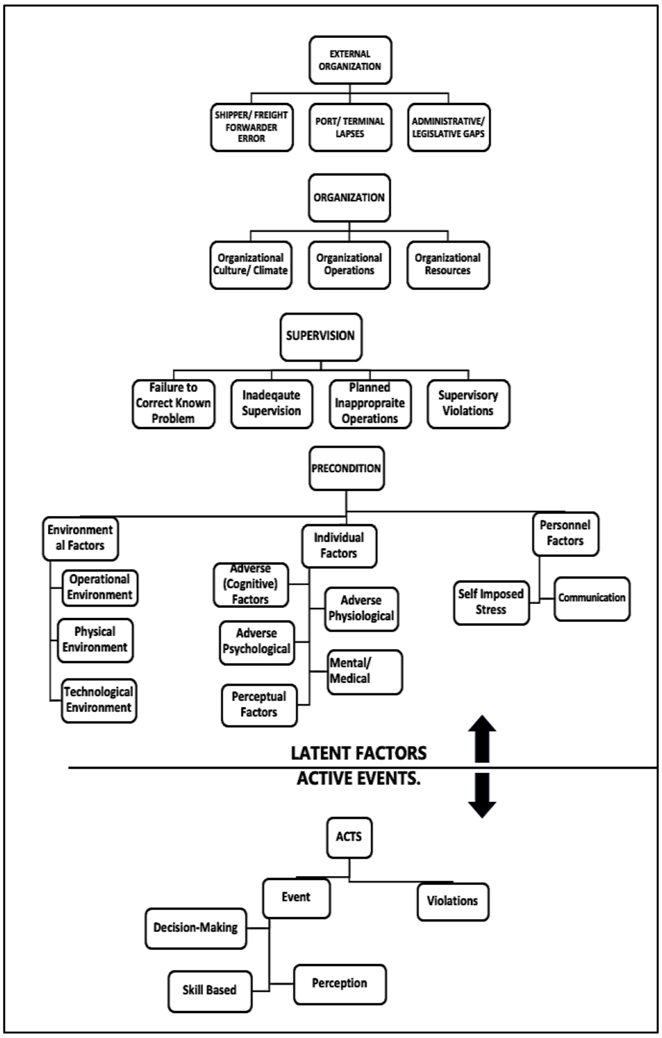

Figure 18. Modified NASAFACS, as adapted for a container vessel (HFACS-CV)

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Key findings

The analysis of the responses from the semi-structured interviews highlights a different outcome as compared to the incident investigation analysis exercise, which emphasised on L3 Preconditions being the highest causative of the container vessel accidents, followed by L4 Acts.

In contrast, the distribution of response codes underscores the dominance of ‘L1 – Organization’ as the most significant causative factor in container vessel accidents. Within L1 Organization, Organizational Resources are seen as the most significant causative factor, with Organizational Culture and Organizational Operations following behind. L3 Preconditions category holds the second most weight in terms of causative factors, with Environmental Factors (both Physical and Technological) and Personnel Factors (specifically Communication) being equally significant contributors. Individual Factors, such as Adverse Physiological and Adverse Psychological conditions, are noted but are seen as less prominent. ‘L2 – Supervision’ ranks third, highlighting the importance of supervisory practices. Within this category, Supervisory Violations are viewed as the primary causative factor, followed by Planned Inappropriate Operation and Inadequate Supervision. This indicates that lapses in supervisory practices and planning are key contributors to accidents. Finally, ‘L4 – Acts’ is seen as the least significant, emphasizing that individual actions or errors by ship staff are not considered major contributors to accidents by the respondents. This reinforces the perception that external parties and systemic issues have a more substantial impact on container vessel operations, often placing many operational aspects beyond the direct control of the ship's crew.

The predominance of organizational-level issues as identified through interviews contrasts with earlier NASAFACS-based container vessel accident analysis conclusions, which emphasized preconditions and unsafe acts. This divergence may stem from the nature of qualitative data, which exposes systemic and recurring latent conditions not easily captured in structured accident reports. For instance, fatigue (L3) may be noted in reports, but its root cause—under-crewing driven by cost-cutting—is more accurately classified as an organizational influence (L1). Likewise, the pressure to maintain schedules, often implicit in company culture or charter agreements, is a persistent theme among interviewees and rarely addressed in formal post-incident documentation.

The research also highlights the complex challenges associated with the rapid evolution of container shipping, particularly in light of the increasing size of vessels and the pressures imposed by economic and operational constraints. ULCVs, while economically advantageous, present significant challenges in terms of manoeuvrability, crew management, and operational safety. These challenges are exacerbated by the inadequacies of port infrastructure, which has struggled to keep pace with the growth in vessel size, leading to heightened safety risks during port operations.

Additionally, the mismatch between the growing scale of vessels and the firefighting capabilities on board underscores the urgent need for enhanced safety measures. The research also sheds light on the critical issue of misdeclared cargo, both in terms of hazardous materials and weight, which pose substantial risks to vessel stability and safety at sea. Furthermore, the commercial pressures faced by vessel masters and port operators significantly influence decision-making, often at the expense of safety. The risk assessment process, while crucial, has become a formality in many instances, driven by commercial imperatives rather than genuine hazard mitigation. Finally, the economic model of container shipping, which allows for a certain tolerance of container loss, limits the industry's motivation to implement meaningful safety improvements. Container shipping is a complex and dynamic sector that faces numerous challenges, particularly regarding lashing and securing of cargo. The safety and stability of containers during maritime transit are critical, and any lapses in compliance with lashing protocols, maintenance of equipment, and accurate weight declaration can lead to serious incidents, including container loss and damage to vessels. Furthermore, the operational schedules, manning levels, and competency of crew members contribute significantly to the overall safety and efficiency of container shipping operations. The sector also faces emerging risks, such as environmental concerns related to container ship accidents and the safe transport of EVs. Industry collaborations, like the CINS, have shown potential in addressing some of these challenges, though the absence of a unified regulatory framework continues to limit their effectiveness.

5.2 Practical implications

Based on the findings of this study, several key recommendations have been formulated that can be considered for implementation by the industry to enhance safety in container vessel operations. These recommendations aim to address the critical factors identified in the research and provide actionable steps to mitigate risks and are prioritized based on their impact on vessel safety and the feasibility of industry-wide implementation, as derived from expert input and comparative case analysis. High-impact, high-feasibility actions are listed first, while longer-term or system-wide reforms are positioned later.

Priority 1: High impact – High feasibility

5.2.1 Strengthening firefighting capabilities

There is a critical need for research and innovation in firefighting techniques and equipment for ULCVs. This should involve the development of new systems tailored to the scale of these vessels, as well as the integration of advanced fire detection and suppression technologies.

5.2.2 Strict enforcement of cargo declaration regulations

Regulatory bodies must enforce stricter penalties for misdeclared cargo, particularly hazardous materials. This includes improving the monitoring and verification processes at both the shipper and terminal levels to ensure compliance with safety regulations.

5.2.3 Improving risk assessment processes

Risk assessments should be conducted with greater rigor, focusing on genuine hazard evaluation rather than merely fulfilling a regulatory requirement. This process should empower crew members to make safety-focused decisions without the pressure of commercial interests.

5.2.4 Strengthening compliance with lashing protocols

Shipping companies and terminal operators must prioritize strict adherence to the cargo securing manual, to ensure that all containers are properly lashed before departure. Regular audits and training programs should be implemented to maintain high standards in cargo securing practices.

5.2.5 Enhanced crew training and resources

Given the operational challenges posed by ULCVs, it is essential to invest in advanced crew training and resources, particularly in areas such as ship handling, stowage management, cargo securing and firefighting. This should include the development of specialized training programs that address the unique demands of operating these mega vessels. Shipping companies should invest in continuous professional development programs for their crew, focusing on both theoretical knowledge and practical skills. Special attention should be given to ensuring that crew members from newer maritime regions receive adequate training that meets international standards.

Priority 2: High impact – Medium feasibility

5.2.6 Addressing weight misdeclaration and stowage issues

Enhanced auditing of shippers and the use of advanced software to detect potential misdeclarations of container weight should be expanded. Additionally, stringent oversight during stowage operations should be enforced to ensure that load inversion and incorrect container placement are avoided.

5.2.7 Enhancing manning requirements

Shipping companies need to realize that meeting minimum safe manning requirements, though it meets regulatory compliance, however, does not suffice to provide manpower required to carry out the container vessel operations, coupled with the frequent and hectic port call schedules. The extra expense on the additional manning is a trade-off to ensure safe and compliant vessel operations. The onus also lies on the flag states, to revisit the safe manning requirements, to ensure sufficient manpower is available onboard at all times, to ensure safe management of operations.

5.2.8 Improved maintenance regimes

Vessel operators should allocate more resources towards the regular maintenance of lashing equipment, even during voyages, to prevent degradation that can lead to lashing failure. This may require increased crew capacity and better scheduling of maintenance tasks to fit within the vessel's operational constraints.

5.2.9 Certification for shippers and freight forwarders

To deal with the issue of misdeclaration of dangerous cargo, it is recommended that shippers and freight forwarders handling DG be mandated to undergo training in the International Maritime Dangerous Goods (IMDG) Code and obtain the necessary certification. This requirement would ensure that all involved parties are thoroughly familiar with the specific regulations and safety protocols associated with the transportation of DG, thereby enhancing compliance and reducing risks related to the handling and shipment of hazardous cargo.

Priority 3: Medium impact – High feasibility

5.2.10 Organizational culture

Fostering a safety-centric organizational culture is essential. Leadership commitment to safety and continuous improvement initiatives can instil a heightened safety culture among crew members. The decision-making authority of vessel master's must be reinforced to prioritize safety over commercial interests. This includes creating a regulatory framework that protects master's from repercussions when making decisions that prioritize the safety of the vessel, crew, and cargo. Fostering a safety-centric organizational culture is essential.

5.2.11 Mental health and support programs

Psychological factors were found to be one of the critical issues contributing towards the accidents. Adequate mental health programs through on-board supportive work environment can help in mitigating the same. Overall safety could also be improved through teamwork and open communications.

Priority 4: System wide reforms – Medium to long-term

5.2.12 Upgraded port infrastructure

Ports must accelerate their infrastructure development to accommodate the increasing size and complexity of container vessels. This includes expanding berths, upgrading cargo handling equipment, trained manpower, including Pilots, Tugs of adequate power and improving navigational aids to enhance safety during port operations.

5.2.13 Advancing industry collaborations

Initiatives like CINS should evolve into more formalized systems with broader industry participation and stronger enforcement mechanisms. The container shipping industry could benefit from adopting some of the regulatory frameworks and best practices seen in the tanker industry, despite the inherent differences in scale and complexity. It would be prudent to establish an inspection regime for container vessels similar to the SIRE (Ship Inspection Report Programme) inspections conducted on tankers and Right-Ship inspections on bulk carriers. This inspection framework should integrate human factors, aligning with the approach of SIRE 2.0, to ensure a more comprehensive evaluation of safety, operational standards, and crew performance. Incorporating human factors into the inspection process would help address not only technical and procedural aspects but also the critical human elements that influence safe and efficient operations on board container vessels.

5.2.14 Revisiting economic models

The industry must re-evaluate its economic models to incentivize safety and sustainability. This could involve creating financial penalties for container loss and offering incentives for vessels that demonstrate exceptional safety performance. The Just-In-Time concept though a path breaking one, to bring efficiency and optimization in any industry, cannot be applied literally to the shipping industry exposed to so many variables and unknowns.

5.2.15 Responding to emerging environmental and safety risks

The shipping industry should develop more effective strategies for managing environmental risks, particularly those related to microplastics and other pollutants from container ship accidents. Additionally, as the transport of second-hand EVs becomes more common, it is crucial to establish a standardized certification process to assess the safety of their batteries during sea carriage.

5.2.16 Enhancing port and salvage capabilities

Ports designated as ports of refuge should be better equipped to handle distressed vessels, especially those carrying hazardous cargo. Investment in specialized salvage equipment and training exercises is also necessary to tackle the unique challenges presented by mega-sized container ships.

This ranked approach provides a roadmap for stakeholders, shipping companies, flag states, port authorities, and regulators, to align safety investments with the areas of greatest immediate and strategic need.

The research provides new insights and fills a significant gap in the existing literature on container vessel accidents by shifting the focus from individual human errors (active failures) to the role of latent factors like organizational practices, supervision, and environmental conditions. While previous studies have largely focused on operational and technical factors contributing to accidents, this study introduces a systemic approach that emphasizes the influence of organizational culture, resource management, supervision and external organizational influences on accident causality.

5.3 Research limitations and future directions

While this study offers valuable insights into the safety of container vessel operations, is subject to its own limitations. The qualitative analysis employed may introduce subjectivity and biases, as the interpretation of data can be influenced by the researcher's perspectives or assumptions. Experts, while offering valuable insights, may bring their own biases, based on personal experiences or specialized knowledge, which could affect the interpretation and generalization of the findings.

Despite these limitations, the following gaps present significant opportunities for further study.

5.3.1 Limited sample size and geographic scope

The current study is based on a small sample of industry professionals and is geographically restricted. Future research should aim to gather a larger and more diverse pool of respondents, covering a broader range of regions and industry stakeholders, to generalize findings more effectively.

5.3.2 Technological advancements and automation

This study does not deeply explore the impact of technological advancements, such as automation and artificial intelligence, on container vessel safety. Research into how these technologies can enhance or challenge safety protocols, particularly in stowage planning, operational monitoring, and human-machine interaction, would be valuable.

5.3.3 Behavioural and psychological factors

Although human factors are considered, there is limited exploration of the psychological and behavioral aspects influencing safety on container vessels. Future research could investigate the cognitive, emotional, and stress-related factors that impact decision-making and safety performance among vessel crew and port operators.

5.3.4 Environmental and climate considerations

The study touches on environmental factors but does not deeply investigate the influence of climate change and extreme weather conditions on container vessel operations. With climate-related risks increasing, future research should focus on how changing environmental conditions affect safety protocols and operational practices.

5.3.5 Geopolitical disruptions

An emerging area of concern not covered in this study is the impact of geopolitical developments on container vessel safety. Trade disputes, sanctions, port access restrictions or conflict zones can have profound implications for routeing and risk exposure. Future research should examine how such macro-level political dynamics influence operational safety and crisis preparedness in the container shipping sector.

By addressing these gaps and expanding the scope of research, the maritime industry can develop a more holistic approach to safety in container vessel operations, ensuring that both current and future challenges are effectively managed.

REFERENCES

[1] World Shipping Council (2023). Analysis of the sixteen-year trends summary of containers lost at sea total loss 3 year moving average. https://mb.cision.com/Public/20134/3772700/9f81b7bcd3582277.pdf.

[2] Allianz Global Corporate & Specialty (AGCS). (2023). Safety and shipping review 2023: An annual review of trends and developments in shipping losses and safety.

https://commercial.allianz.com/content/dam/onemarketing/commercial/commercial/reports/AGCS-Safety-Shipping-Review-2023.pdf.

[3] Singh, M.P., Totakura, B.R. (2024). Container vessel accidents analysis: A nasahfacs framework study. International Journal of Transport Development and Integration, 8(2): 341-357. https://doi.org/10.18280/ijtdi.080211

[4] Mccafferty, D.B., Baker, C.C. (2002). Human error and marine systems: Current trends. In Proceedings of IBC's 2nd Annual Conference on Human Error, London, pp. 175-182.

[5] Sánchez-Beaskoetxea, J., Basterretxea-Iribar, I., Sotés, I., Machado, M.D.L.M.M. (2021). Human error in marine accidents: Is the crew normally to blame? Maritime Transport Research, 2: 100016. https://doi.org/10.1016/j.martra.2021.100016

[6] Rothblum, A.M., Wheal, D., Withington, S., Shappell, S., Wiegmann, D.A., Boehm, W., Chaderjian, M. (2002). Human factors in incident investigation and analysis. In International Workshop on Human Factors in Offshore Operations (HFW2002).

[7] Singh, M.P., Raju, T.B. (2024). Unveiling the shadows of the maritime industry: A comprehensive review of shipping accidents and preventative measures. Journal of Maritime Research, 21(3): 91-100. https://www.jmr.unican.es/jmr/article/view/916.

[8] Celik, M., Lavasani, S.M., Wang, J. (2010). A risk-based modelling approach to enhance shipping accident investigation. Safety Science, 48(1): 18-27. https://doi.org/10.1016/j.ssci.2009.04.007

[9] Schröder-Hinrichs, J.U., Baldauf, M., Ghirxi, K.T. (2011). Accident investigation reporting deficiencies related to organizational factors in machinery space fires and explosions. Accident Analysis & Prevention, 43(3): 1187-1196. https://doi.org/10.1016/j.aap.2010.12.033

[10] Caridis, P. (1999). Casualty analysis methodology for maritime operations [CASMET]. Greece: National Technical University of Athens.

[11] Grech, M.R., Horberry, T., Smith, A. (2002). Human error in maritime operations: Analyses of accident reports using the Leximancer tool. In Proceedings of the human factors and ergonomics society annual meeting, 46(19): 1718-1721. https://doi.org/10.1177/154193120204601906

[12] Salmon, P.M., Cornelissen, M., Trotter, M.J. (2012). Systems-based accident analysis methods: A comparison of Accimap, HFACS, and STAMP. Safety Science, 50(4): 1158-1170. https://doi.org/10.1016/j.ssci.2011.11.009

[13] Fu, G., Cao, J.L., Zhou, L., Xiang, Y.C. (2017). Comparative study of HFACS and the 24Model accident causation models. Petroleum Science, 14: 570-578. https://doi.org/10.1007/s12182-017-0171-4

[14] Wu, B., Yan, X.P., Wang, Y., Soares, C.G. (2017). An evidential reasoning-based CREAM to human reliability analysis in maritime accident process. Risk Analysis, 37(10): 1936-1957. https://doi.org/10.1111/risa.12757

[15] Kim, H.T., Na, S. (2017). Development of a human factors investigation and analysis model for use in maritime accidents: A case study of collision accident investigation. Journal of Navigation and Port Research, 41(5): 303-318. https://doi.org/10.5394/KINPR.2017.41.5.303

[16] Kececi, T., Arslan, O. (2017). SHARE technique: A novel approach to root cause analysis of ship accidents. Safety Science, 96: 1-21. https://doi.org/10.1016/j.ssci.2017.03.002

[17] Chen, J., Zhang, F., Yang, C., Zhang, C., Luo, L. (2017). Factor and trend analysis of total-loss marine casualty using a fuzzy matter element method. International Journal of Disaster Risk Reduction, 24: 383-390. https://doi.org/10.1016/j.ijdrr.2017.07.001

[18] Zhang, L., Wang, H., Meng, Q., Xie, H. (2019). Ship accident consequences and contributing factors analyses using ship accident investigation reports. Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 233(1): 35-47. https://doi.org/10.1177/1748006X18768917

[19] Cao, Y., Wang, X., Yang, Z., Wang, J., Wang, H., Liu, Z. (2023). Research in marine accidents: A bibliometric analysis, systematic review and future directions. Ocean Engineering, 284: 115048. https://doi.org/10.1016/j.oceaneng.2023.115048

[20] Li, H., Ren, X., Yang, Z. (2023). Data-driven Bayesian network for risk analysis of global maritime accidents. Reliability Engineering & System Safety, 230: 108938. https://doi.org/10.1016/j.ress.2022.108938

[21] Celik, M., Cebi, S. (2009). Analytical HFACS for investigating human errors in shipping accidents. Accident Analysis & Prevention, 41(1): 66-75. https://doi.org/10.1016/j.aap.2008.09.004

[22] Akyuz, E. (2017). A marine accident analysing model to evaluate potential operational causes in cargo ships. Safety Science, 92: 17-25. https://doi.org/10.1016/j.ssci.2016.09.010

[23] Chen, S.T., Wall, A., Davies, P., Yang, Z., Wang, J., Chou, Y.H. (2013). A Human and Organisational Factors (HOFs) analysis method for marine casualties using HFACS-Maritime Accidents (HFACS-MA). Safety Science, 60: 105-114. https://doi.org/10.1016/j.ssci.2013.06.009

[24] Hasanspahić, N., Vujičić, S., Frančić, V., Čampara, L. (2021). The role of the human factor in marine accidents. Journal of Marine Science and Engineering, 9(3): 261. https://doi.org/10.3390/jmse9030261

[25] Akyuz, E., Celik, M. (2014). Utilisation of cognitive map in modelling human error in marine accident analysis and prevention. Safety Science, 70, 19-28. https://doi.org/10.1016/j.ssci.2014.05.004

[26] Batalden, B.M., Sydnes, A.K. (2017). What causes 'very serious' maritime accidents? In Safety and Reliability—Theory and Applications. Taylor & Francis Group, London, pp. 3067-3074. https://doi.org/10.1201/9781315210469-389

[27] Theophilus, S.C., Esenowo, V.N., Arewa, A.O., Ifelebuegu, A.O., Nnadi, E.O., Mbanaso, F.U. (2017). Human factors analysis and classification system for the oil and gas industry (HFACS-OGI). Reliability Engineering & System Safety, 167: 168-176. https://doi.org/10.1016/j.ress.2017.05.036

[28] Uğurlu, Ö., Yıldız, S., Loughney, S., Wang, J. (2018). Modified human factor analysis and classification system for passenger vessel accidents (HFACS-PV). Ocean Engineering, 161: 47-61. https://doi.org/10.1016/j.oceaneng.2018.04.086

[29] Yildiz, S., Uğurlu, Ö., Wang, J., Loughney, S. (2021). Application of the HFACS-PV approach for

identification of human and organizational factors (HOFs) influencing marine accidents. Reliability Engineering & System Safety, 208: 107395. https://doi.org/10.1016/j.ress.2020.107395
[30] Guest, G., Bunce, A., Johnson, L. (2006). How many interviews are enough?: An experiment with data saturation and variability. Field Methods, 18(1): 59-82. https://doi.org/10.1177/1525822X05279903
[31] Shappell, S.A., Wiegmann, D.A. (2000). The human factors analysis and classification system--HFACS. Report No. DOT/FAA/AM-00/7. Civil Aeromedical Institute, Oklahoma City, USA.

APPENDIX

Interview Questions

General industry insights:

What are the major challenges and trends in container vessel safety and safe operations that you have observed in recent years?

Would you request to provide an overview of the current state of safety and accident prevention measures in the container vessel industry?

Causal factors and prevention:

Based on your experience, what are the causal factors (latent factors and active errors) contributing to various types of container vessel accidents?

What prevention and mitigation strategies have been most effective in addressing these causal factors?

Operational practices:

Can you discuss the impact of operational practices, such as cargo stowage and securing, on accident rates and severity with a perspective to the recent rise in container loss incidents in heavy weather?

How do vessel crews typically prepare for and respond to heavy weather conditions, and what are the key challenges they face?

How serious is the issue of wrong stowage (especially with the dangerous cargo) and cargo misdeclaration in the industry and its impacts.

What challenges does fixed schedule/ itinerary in various ports bring up, in terms of managing traffic situations, heavy weather conditions, etc.

What are the challenges faced in safe terminal operations?

What are the challenges faced with ever-increasing size of container vessels how are terminals able to cope up with this?

Environmental concerns:

Given your expertise, what are the environmental risks associated with container vessel accidents, particularly those involving cargo spills?

What measures do you recommend for minimizing environmental damage in the event of accidents?

Training and crew competency:

What role does crew training and competency play in accident prevention, and what improvements can be made in this area?

Are there specific training programs or practices that you consider particularly effective?

Regulatory landscape:

How have national and international regulations evolved in response to safety and environmental concerns in the container vessel industry?

Are there regulatory gaps or areas where further improvements are needed?

Technology and innovation:

How has technology, such as advanced navigation systems and predictive analytics, influenced safety and accident prevention in the industry?

Are there emerging technologies or innovations that hold promise for enhancing safety?

Collaboration and best practices:

Are there industry collaborations, partnerships, or best practices that have had a significant impact on safety and accident prevention?

What can the industry learn from successful case studies or experiences in other regions?

Crisis management and response:

In the event of a major incident, what are the best practices for crisis management and response within the industry?

How can preparedness and response strategies be improved?

Collaboration with regulatory bodies:

How can the industry collaborate effectively with regulatory bodies to enhance safety and environmental protection?

What role do industry associations and organizations play in this collaboration?

Future research and analysis:

Based on your insights, are there specific areas within the container vessel safety domain that you believe require further research or analysis?

Are there emerging risks or trends that merit closer examination?