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Unveiling the Shadows of the Maritime Industry: A Comprehensive Review of Shipping Accidents and Preventative Measures

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ABSTRACT

This review article delves into the complexities of shipping accidents, unraveling the multifaceted factors contributing to these catastrophic events that pose significant risks to human life, the environment, and the global economy. This underscores the persistent role of human error in maritime incidents despite advancements in technology and vessel design. This study explores the critical role of risk perception in shipping operations and discusses the effectiveness of the International Safety Management Code (ISM) in standardizing safety practices. The article also examines the methodologies employed in shipping accident investigations, highlighting their significance in identifying immediate causes and systemic deficiencies to prevent future occurrences. Finally, it highlights the contribution of accident theories in providing comprehensive frameworks to understand the interplay between human actions, organizational structures, and external factors, thereby guiding the development of holistic safety strategies. This review aims to shed light on the intricacies of maritime accidents and the concerted efforts required to enhance safety in the shipping industry.

1. Introduction.

The shipping sector is pivotal for international trade, facilitating the movement of nearly 90% of the world's commodities. It's essential role in the global economic landscape is underscored by the expansive fleet navigating the oceans. However, this marvel is not without hazards. Maritime mishaps, spanning collisions, groundings, oil spills, fires etc. wreak havoc on human life and the environment.

It is crucial to discern the underpinnings of these maritime tragedies. Beyond profound economic setbacks, these incidents imperil marine ecosystems and jeopardize seafarer safety. Delving into their root causes, gauging their implications, and pinpointing preventive protocols are vital for sculpting a safer and sustainable maritime domain.

Human error is a prominent catalyst for these mishaps and consistently serves as a linchpin in maritime incidents. Although technological strides and enhanced safety protocols have been developed, human vulnerability remains a central issue. Understanding the nuances and origins of these errors is a cornerstone in formulating robust preventive and mitigation approaches. The International Maritime Organization (IMO) too underscores the significance of human dynamics in marine casualties.

This review explores prior studies done on maritime accidents, focusing on causative elements, such as human error, risk perception ramifications, and in-depth safety evaluations. It further delves into the influence of the ISM code, tailored explicitly for human error management in maritime operations. Moreover, this research reviews the frameworks and techniques advanced for maritime accident inquiries, probing the foundational theories that shape them.

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2. Methodology.

This study encompasses a systematic literature review, exploring the subject thematically, with a focus on the following areas:

- Accidents and Incidents in Shipping Industry
- Analysis of Human Error Component in Maritime Accidents & Incidents
- Risk Perception & Safety Analysis in Maritime Industry
- Impact of ISM Code on Ship Operations
- Analysis of Methodologies Used/ Proposed for Analysing Maritime Accidents/ Incidents.
- Accident Theories and Models/Applications to Maritime Accident

2.1. Accidents and Incidents in Shipping Industry.

The shipping industry constitutes a vast and intricate sector responsible for transporting goods and passengers via sea routes. As is common in all domains of transportation and logistics, the shipping industry is susceptible to accidents and incidents. These events can range from minor mishaps to major catastrophes, occasionally resulting in the loss of life, environmental harm, and financial ramifications. Given the expansive global scope of the shipping industry, it faces various types of accidents including collisions, capsizing, foundering, groundings, strandings, fires, and explosions. This section examines and comprehends the efforts made to analyze and mitigate accidents and incidents within the shipping industry.

(Anderson 1983) studied maritime accidents by focusing on boarding and access, leading to industry-wide ergonomic recommendations. (Srivastava 1989) highlighted the role of the International Maritime Organization's (IMO) role in enhancing maritime safety and minimizing marine pollution through conventions and recommendations.

(Li 1998) emphasized the role of sea conditions in shipping safety, showing that complex sea states significantly increased risks. (Phillips 2000) linked sleep imbalances to an increased accident risk, noting that 'being asleep' and 'sleep deprivation" contribute significantly to incidents.

(Hansen et al. 2002) studied the associated risk factors for workplace accidents aboard merchant ships, suggesting preventive measures, and highlighting the under-reporting of incidents as an issue. (Barnett et al. 2002) analyzed behavioral indicators to evaluate the crisis management skills of merchant marine officers, highlighting the need for rigorous training. (Giziakis and Bardi-Giziaki 2002) examined the probability of shipping accidents leading to environmental pollution, and found a higher risk in ports and large tankers. (Darbra and Casal 2004) reported an increase in seaport accidents, mostly during the transfer operations. (Jensen et al. 2005) outlined the risks of slip, trip, and fall (STF) accidents in merchant shipping, suggesting a need for better prevention. (Toffoli et al. 2005) advocated for a standardized warning system based on marine forecasts to reduce weather-related accidents. (Nielsen and Panayides 2005) expanded maritime safety to include occupational hazards, calling for more research on fatalities from work-related accidents. (Akten 2006) examined the impact of shipping accidents on marine environments, emphasizing continuous improvements despite the inherent risks. (Antão and Guedes Soares 2008) compared ocean-going vessels and high-speed crafts (HSCs) accidents and found distinct patterns and human factors to be predominant in HSCs.

(Antão and Soares 2010) included wave height data in accident models to reveal the impact of weather patterns on accidents. (Ellis 2011) investigated the causes of dangerous cargo releases on container ships and identified errors during packaging and loading as leading causes. Shipping incidents, many of which led to oil spills, have played a pivotal role in driving environmental protection regulations. (Butt et al. 2015) analyzed shipping accidents affecting life, the environment, and industry reputation with the aim of identifying improvement areas. (Bužančić Primorac and Parunov 2016) reviewed ship accident statistics and noted that design changes and regulations significantly influenced accident rates. (Baalisampang et al. 2018) reviewed fire and explosion accidents and identified human errors as the primary cause. (Chen et al. 2019a) examined total-loss maritime incidents using the entropy weight-TOPSIS model to identify the key influencing elements. (Zhang et al. 2019) analyzed 477 ship accident reports to discern the relationship between accident effects and contributing factors. Key findings include:

- Vessel speed greatly affected collision fatalities and injuries.
- Crew number impacted collision injuries and fatalities.
- Oil spills were mainly linked to specific collision positions.

2.2. Analysis of Human Error Component Maritime Accidents & Incidents.

Human error is a prominent factor in shipping industry accidents. Accidents often result from the complex interplay of various factors, with human error representing a significant contributor. Consequently, addressing human error has become a focal point in accident prevention.

Studies have revealed the substantial involvement of human error in various maritime accidents.

- Tanker accidents: Human error contributes to 84-88% of incidents (Transportation Safety Board of Canada, 1994).
- Towing vessel groundings:79% of cases involve human error (Cormier, 1994).
- Collisions:89-96% of collisions result from human error (Bryant, 1991; U.K. P&I Club, 1992).
- Allisions:75% of allisions are attributed to human error (Bryant, 1991).

- Fires and explosions: Human error is responsible for 75% of such incidents (Bryant, 1991).

This emphasizes the need to focus on understanding and addressing the specific types of human errors that lead to casualties to make significant strides in reducing marine accidents.

(Wagenaar and Groeneweg 1987) highlighted that increasing safety awareness was insufficient. Instead, addressing specific types of human errors, such as poor habits, incorrect diagnoses, inattentiveness, and lack of training, is crucial.

(Hetherington et al. 2006) conducted a comprehensive review of marine safety concerns, including human factors. Their review covered 20 studies on exhaustion, stress, health, situational awareness, teamwork, decision-making, communication, automation, and safety culture. This study emphasizes the importance of monitoring and addressing human factors to enhance maritime safety. (Er et al. 2007) investigated the role of design flaws in shipboard systems, which contribute to operational errors. The researchers recommended adopting the Human Factors Analysis and Classification System (HFACS) to study how design flaws affect human error. (Pennie et al. 2007) explored the importance of Human Factors (HF) in maritime maintenance and inspection. This study discussed adapting HF principles to ship design to enable more efficient maintenance procedures. (Barnett et al. 2007) delved into concerns regarding automation in maritime systems, identifying and discussing issues related to automation, and providing guidance for mitigating human errors in automated shipboard systems. (Song 2009) focused on the application of ergonomic principles in ship machinery design to prevent accidents, emphasizing that these principles can prevent accidents at minimal or no extra cost.

(Mokhtari and Khodadadi Didani 2013) analyzed maritime accidents in Iranian shipping companies, pinpointing factors contributing to human error, including negligence, inadequate training, and a lack of suitable tools. (Akyuz 2016) addressed the gap in the Human Error Assessment and Reduction Technique (HEART) by producing marine-specific error-producing condition (m-EPC) values, enabling more accurate maritime safety analysis. (Ung 2018) suggested conducting a risk analysis using expert advice and developing a fuzzy Cognitive Reliability Error Analysis Method (CREAM) to determine the contribution of human error to oil tanker groundings. (Islam et al. 2018) focused on factors affecting performance in marine maintenance and identified workload, stress, and ship motion as critical factors for Human Error Probability (HEP) estimation. (Youn et al. 2018) aimed at developing an objective classification system for navigator behaviors using a Kinect sensor, this study successfully classified standard lookout activities, providing insights into navigator behavior for accident prevention. (Antão and Soares 2019) employed a Bayesian Belief Network model, to evaluate the role of human error in ship accidents under various weather conditions, offering insights into the patterns of human error causes relative to factors such as sea and weather conditions.

Overall, these studies highlight that human error remains a major challenge in maritime safety. Addressing this issue through targeted strategies, advanced analytical methods, and specialized EPC values can contribute significantly to accident prevention and overall safety improvement in the shipping industry.

2.3. Risk Perception & Safety Analysis in Maritime Industry.

Ensuring safety in the maritime industry requires a comprehensive understanding and management of potential risks. Risk perception, the way individuals and organizations interpret and evaluate the risks associated with their activities, plays a pivotal role in decision-making and safety protocols within the maritime sector. Numerous factors influence risk perception, including past experience, cultural influences, cognitive biases, awareness, and training. Safety analysis, on the other hand, involves the identification of potential hazards, risk assessment, and implementation of measures to prevent accidents and mitigate their impacts.

(Garrick 1999) highlighted the maritime sector's lag in adopting formal risk assessment techniques, emphasizing the need for improved risk assessment guidelines inspired by other industries such as chemical, nuclear, and defense.

(Soares and Teixeira 2001) presented the "systems approach" in "Shipboard Emergency Preparedness" and showcased its potential to revolutionize the legislative frameworks safeguarding shipping safety and pollution prevention. (Bailey et al. 2006) and (Bailey et al. 2007) dived deeply into risk perception, revealing that factors such as nationality, rank, and ship-type experience play significant roles in shaping perceptions of safety and risks within the maritime industry. (Grabowski et al. 2007) highlighted the importance of leading safety indicators in global maritime operations, emphasizing the role of continuous monitoring and organizational culture. (Lu and Tsai 2008) explored the relationship between safety climate and various outcomes in container shipping, including seafarer behavior and vessel accidents. Their findings emphasize the importance of cultivating a positive safety climate onboard.

(Bailey et al. 2010) conducted a study to compare the risk perceptions of maritime industry workers using recorded accident data. The research underscored the impact of rank and nationality on risk perception, whereas age and experience appeared to have less influence. (Lu and Tsai 2010) evaluated the impact of the safety climate on vessel accidents, specifically in the context of container shipping. This study identified dimensions of safety climate and their impacts on crew fatalities and vessel failure, highlighting the significance of job safety, management safety practices, and safety training. (Bailey, N., Ellis, N., Sampson 2012) showed disparities in risk perception among different roles in maritime companies, emphasizing the importance of a unified safety strategy across organizations. (Bhattacharya and Tang 2013) delved into the role of Oil Majors, revealing the intricacies of the supply chain's influence on ship safety and seafarer well-being. (Wang et al. 2013) examined risk perception and communication in the wake of the Fukushima Daiichi Nuclear Disaster. Their findings underscore the profound impact of such events on global maritime operations. (Karahalios 2014) bridged the gap between commercial imperatives and safety, advocating an integrated risk management system that also considers business outcomes. (Hystad et al., 2015) focused on the critical relationships between sleep quality, fatigue, and risk perception. Their study is a clarion call for organizations to prioritize seafarer well-being and recognize its implications on safety. (Chai et al. 2017) introduced an innovative risk-assessment model specifically for ship collisions. Their study emphasized the unique challenges posed by different ship types in high-traffic areas, such as the Singapore Strait. (Cem Kuzu et al. 2019) illuminated the intricacies and potential hazards of ship mooring operations and provided a blueprint for effectively mitigating these risks. (Chen et al. 2019b) offered a comprehensive review of ship-ship collision risk analyses, urging the industry to consistently upgrade its efforts to enhance navigational safety. Collectively, these studies emphasize the multifaceted nature of risk perception and safety analysis within the maritime industry, shedding light on the factors influencing risk perception and ongoing efforts to improve safety protocols and risk mitigation strategies.

2.4. *Impact of ISM Code on Ship Operations.*

In 1993, the International Maritime Organization (IMO) introduced the ISM Code as a reaction to significant maritime accidents in the 1980s, often attributed to human errors and subpar management practices. By 1998, this Code was integrated into SOLAS, Chapter IX, making compliance obligatory for maritime operations. Central to the Code is a set of guidelines that strive to ensure ship safety and mitigate maritime pollution, delineating the responsibilities of both shipping entities and ship personnel, particularly through the implementation of a Safety Management System (SMS).

After formal induction in 1998, certified shipping organizations faced the dual challenge of maintaining new safety standards while seeking avenues for further enhancement. (Thomas 1998) offered one such avenue, suggesting that elements of ISO 14001 should be incorporated to augment environmental compliance. (Golapalli 2003) explored the relationship between the effective implementation of the ISM Code and its impact on maritime claims and found evidence of a positive shift in behavior towards safety due to the experience gained through the adoption of the Code.

(Moore and Roberts 2005) accentuated the IMO's commitment to considering the human dimension of maritime safety. Their exploration delved into the multifaceted safety management system, as it exists within the ISM Code, evaluating its ramifications for a broad spectrum of stakeholders. On a parallel note, research by (Celik 2009) and further studies by (Tzannatos and Kokotos 2009)have shed light on the efficacy of the Code in curbing accidents stemming from human errors and in reinforcing safety protocols on ships.

(Tunidau and Thai 2010) highlighted the need for senior management commitment, employee involvement, effective enforcement by flag state administrations, rationalization of documentation, and the application of quality management principles in SMS, for effective implementation of the ISM code. A contrasting perspective was presented by(Bhattacharya 2012), who pinpointed a perceptual schism between maritime managers and seafarers in terms of how the Code was being applied and interpreted, leading to a lack of trust between the two parties. (Kokotos 2012)indicated a decline in shipping incidents caused by human error, thereby demonstrating the positive impact of the ISM Code. Subsequent academic endeavors continued to expand the implications and applications of the ISM Code. (Lappalainen et al. 2012) offers insights into its operational challenges, especially in the Finnish shipping sector. (Asyali and Bastug 2014) found parallels between the principles of scientific management and the ISM Code, emphasizing their structured and systematic approaches to achieving their objectives. (González et al. 2016) voiced concerns about inconsistent standards in their implementation onboard passenger vessels. (Lee and Lee 2016) pursued an empirical approach, gauging the relationship between ISM audits and PSC inspection outcomes, to find a favorable long-term effect. (Pantouvakis and Karakasnaki 2016) examined the efficacy of the ISM Code by comparing it with ISO 9001, highlighting its contribution to continuous improvement and emphasis on customer satisfaction. (Jung and Jung 2017) evaluated the impact of the ISM Code on safety culture and found significant differences in perceptions between seafarers of oceangoing vessels adhering to the Code and those of domestic ships. (Lappalainen 2017) analyzed the challenges of SMS deployment and emphasized the role of cultural traits in either supporting or obstructing the adoption of safety management systems. (Karakasnaki et al. 2018) investigated the connection between accident reduction and the ISM Code, revealing that effective safety management systems contribute to a higher likelihood of accident reduction. (Laverick 2018) critically examined the ISM Code and its impact on safety, emphasizing the need to address complacency and ensure a continued commitment to safety culture. (Pantouvakis and Karakasnaki 2018) empirically analyzed the role of human talent in ISM Code effectiveness, highlighting the mediating role of the ISM Code in top management commitment and shipping business competitiveness. (Mišković et al. 2019) explored seafarers' attitudes towards safety performance indicators and their perceptions of ISM Code implementation, emphasizing the influence of well-structured procedures, positive work environment, and effective communication. (Xue and Tang 2019) investigated ship managers' approaches to shipboard safety management and highlighted the need for a more supportive framework to reduce risks in the maritime sector.

The ISM Code ensures global ship safety and pollution prevention. Although it initially improved safety, recent data show a decline in compliance, leading to more accidents and pollution. (Baştuğ et al. 2021) proposed combining the ISM and Idea Management System (IMS) using the Seven C approach, aiming to enhance knowledge, awareness, and efficiency.

These studies collectively underscore the significance of the ISM Code in promoting safety, mitigating risks, and fostering a culture of maritime safety while also addressing challenges and areas for improvement in its implementation and enforcement.

2.5. Analysis of Methodologies Used / Proposed for Analysing Maritime Accidents / Incidents.

Analyzing maritime accidents and incidents is crucial for understanding their origins, identifying safety gaps, and implementing preventive measures. This section explores the various methodologies used and proposed for such analyses.

(Caridis 1999) introduced the Casualty Analysis Methodology for Maritime Operations (CASMET) Project, focusing on coding and analyzing maritime incidents. It aimed to address the lack of emphasis on organizational and human errors in European investigative practices.

(Mccafferty and Baker 2002) focused on human error in the marine sector, particularly crew fatigue, and explored initiatives by maritime safety organizations to address these issues. (Rothblum et al. 2002) proposed the incorporation of human elements into investigation programs to identify the causes of incidents involving human factors. (Grech et al. 2002) investigated mariners' lack of situational awareness (SA) by analyzing accident reports using the Leximancer tool for textual data processing. To address shipping accident persistence despite technological advancements and safety-related legislation, (Celik and Cebi 2009) developed human factor analysis and classification system (HFACS) using a Fuzzy Analytical Hierarchy Process (FAHP) to quantify human error contributions to shipping accidents.

(Celik et al. 2010) introduced a risk-based modeling approach using Fuzzy Extended Fault Tree Analysis (FFTA) for shipping accident investigations. (Schröder-Hinrichs et al. 2011) used HFACS analysis to review 41 accident investigation reports concerning fires and explosions in machinery spaces, highlighting a gap in investigative methodology that focuses excessively on technical components. (Salmon et al. 2012)carried out a comparative study of three modern accident analysis techniques–Accimap, HFACS, and STAMP–through case studies. (Chen et al. 2013) proposed a human factor analysis and classification system for maritime accidents (HFACS-MA), a five-layer framework. (Akyuz and Celik 2014) introduced the HFACS-CM model, combining Cognitive Maps (CM) and HFACS for marine accident analysis. (Wu et al. 2017) proposed an improved Cognitive Reliability and Error Analysis Method (CREAM) using an evidential reasoning approach for maritime accidents. (Theophilus et al. 2017) developed a human factors analysis and classification system for the oil and gas industry (HFACS-OGI). (Akyuz 2017) introduced a hybrid model combining an HFACS and Analytical Network Process (ANP) for shipboard accident analysis. (Fu et al. 2017) compared two accident causation models, the HFACS and the 2-4 model (24Model). The study found 24Model to be scientifically valid and more widely applicable in practice. (Kim and Na 2017) proposed a human-factor-investigation process for marine accidents. (Kececi and Arslan 2017) introduced the SHip Accident Root Cause Evaluation (SHARE) technique using the Fuzzy SWOT AHP Method. (Chen et al. 2017) developed a fuzzy matter element method to identify the primary causes of the total loss of marine casualties. (Batalden and Sydnes 2017) analyzed marine accidents using a modified HFACS framework. (Uğurlu et al. 2018) examined ship collisions and contact accidents involving passenger ships, using a custom HFACS framework. (Zhang et al. 2019) quantitatively analyzed ship accidents and contributing factors using statistical analysis techniques.

(Yildiz et al. 2021) studied the adaptability of the human factor analysis and classification system for passenger vessel collisions (HFACS-PV) for different types of marine accidents.

Analyzing maritime accidents has progressed from focusing on human errors to integrating technological and organizational factors. A variety of approaches have highlighted the industry's dedication to enhancing maritime safety through rigorous accident analysis.

2.6. Accident Theories and Models / Application to Maritime Accidents.

Maritime accident analysis aids in discerning the root causes and enhancing safety protocols. Various theories and models inform this domain, offering insights into contributing factors, human oversight, and institutional lapses. The following is an exploration of these perspectives:

(Newbold 1927) introduced statistical methods, the "statistics of repeated trends," focusing on personal factors beyond machinery failures.

(Suchman 1970) posited the social deviance hypothesis, emphasizing the protective role of social controls against accidents.

(Reason 1990) outlined the distinction between active and latent human failures across sectors, thus underscoring the multifaceted nature of major accidents. (Rasmussen 1997) promoted a system-oriented risk management approach, acknowledging the evolving technological and regulatory landscape. (Ericson 1999)accentuated the Fault Tree Analysis for system failure representation. (Allan F. Williams 1999) presented a Haddon Matrix, which is a comprehensive framework for injury control.

(Shappell and Wiegmann 2000) formulated an HFACS framework to pinpoint human factors in aviation mishaps with potential maritime applications. (Leveson 2004) advocated the system-theoretic accident model and processes (STAMP) to ensure holistic accident analysis.

(Rossing et al. 2010) proposed a "functional HAZOP assistant" to supplement the traditional hazard analysis. (Mullai and Paulsson 2011) proposed a model utilizing structural equation modeling (SEM) for maritime accident analysis. (Medina Oliva et al. 2012) integrated multiple root cause analysis techniques for industrial system evaluation. (Awal and Hasegawa 2017) presented a Logic Programming Technique (LPT) to view maritime accidents through an engineering perspective.

These theories and models offer diverse perspectives on accident causation and analysis, contribute to our understanding of maritime accidents, and provide valuable tools for accident prevention and safety improvement.

3. Discussion and Analysis.

Shipping accidents, multifaceted in nature, hold significant implications for the global commerce and transport sectors.

While the maritime industry propels international trade, its associated risks, ranging from collisions and fires to structural breakdowns, can trigger monumental repercussions, notably, human casualties, ecological harm, and economic downturns.

A prominent factor, human error continues to emerge despite the sector's technological progress and vessel advancements. As maritime functions predominantly hinge on human actions, aspects such as decision making, operational conduct, and intercommunication become pivotal. Challenges such as fatigue, insufficient training, miscommunication, and overconfidence amplify the error probabilities. Addressing these human - centric discrepancies calls for augmented training regimens, heightened emphasis on safety, and an organizational reorientation towards crew welfare.

Furthermore, the lens through which the risks are perceived substantially affects maritime accidents. Individual risk interpretations can guide decisions, where downplaying or overstating risks can skew actions. Achieving equilibrium between risk abatement and operational efficiency underscores the criticality of precise risk discernment and adept management.

The advent of the International Safety Management Code (ISM) heralded a new era of standardized safety protocols. Nonetheless, its efficacy is contingent on deep-rooted adoption across maritime echelons. Commitment to the ISM Code predicts sound managerial systems that promote proactive hazard detection, risk evaluation and perpetual enhancement. The fusion of safety-first culture, precise risk perception, and the ISM Code's directives is paramount.

Accident investigation techniques serve as instrumental apparatus, illuminating the intricate causative nexus behind maritime mishaps. Utilizing methods such as root cause diagnosis, human-centric factor scrutiny, and avant-garde simulations offers a panoramic view of accident genesis. Such techniques not only spotlight immediate causal agents, but also expose latent systemic lapses, facilitating the inception of bespoke safety protocols to thwart reoccurrences.

Finally, accident theoretical models offer scaffolding to dissect accidents in their entirety, elucidating the nuanced interplay of human behaviors, institutional architectures, and external dynamics. These guiding frameworks pave the way for all-encompassing safety blueprints that cater to organizational, procedural, and personal dimensions.

Conclusions.

Shipping accidents pose significant challenges to crew safety, vessels, and the marine environment. Although technological advancements have significantly improved maritime safety, human factors are critical to accidents. Addressing these challenges necessitates a comprehensive understanding of the human element, accurate risk perception, and rigorous application of the established safety codes. In conjunction with accident theories, the methodologies utilized for accident investigation offer valuable insights for designing effective preventive strategies. As the maritime industry evolves, embracing a culture of safety that integrates heightened awareness and adherence to safety management principles is crucial for averting future accidents and ensuring the safety of seafarers and the marine environment.

Gaps Identified/ Scope for Further Study.

Container vessels play a pivotal role in the intricate web of global trade, serving as the backbone of the modern international commerce. Their significance lies in their ability to efficiently transport vast quantities of goods across continents, contributing to the global economy interconnectedness and growth. The increasing participation of vessel in global trade is driven by several factors that have reshaped the dynamics of international commerce and supply chains and container trade has adapted and evolved to meet the demands of rapidly changing global economy. Though container vessel play an important role in the global, there is no targeted study on container vessel accidents, to analyse the cause and develop control / mitigating measures.

References.

[1] A. M. Rothblum, "Human Error and Marine Safety," *U.S. Coast Guard Research & Development Center*, pp. 1–9, 2000, [Online]. Available: https://www.google.co.za/webhp?-sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#

[2] D. M. Anderson, "From accident report to design problems - a study of accidents on board sbip," *Ergonomics*, vol. 26, no. 1, pp. 43–50, 1983, doi: 10.1080/00140138308963311.

[3] C. P. Srivastava, "Safer ships and cleaner oceans: Thirty years' work of the international maritime organization: Foreign summaries," *Transp Rev*, vol. 9, no. 1, 1989, doi: 10.1080/01441648908716707.

[4] Z. Z. and X.-M. Li, "Global ship accidents and ocean swell-related sea states," *CEDPA Netw*, p. 5, 1998.

[5] R. Phillips, "Sleep, watchkeeping and accidents: A content analysis of incident at sea reports," *Transp Res Part F Traffic Psychol Behav*, vol. 3, no. 4, pp. 229–240, 2000, doi: 10.1016/S1369-8478(01)00007-9.

[6] H. L. Hansen, D. Nielsen, and M. Frydenberg, "Occupational accidents aboard merchant ships," *Occup Environ Med*, vol. 59, no. 2, pp. 85–91, 2002, doi: 10.1136/oem.59.2.85.

[7] M. Barnett, D. Gatfield, and J. Habberley, "Shipboard crisis management: A Case Study," *RINA, Royal Institution of Naval Architects International Conference - Human Factors in Ship Design, Safety and Operation*, vol. 0, pp. 131–145, 2002.

[8] K. Giziakis and E. Bardi-Giziaki, "Assessing the risk of pollution from ship accidents," *Disaster Prevention and Management: An International Journal*, vol. 11, no. 2, pp. 109–114, 2002, doi: 10.1108/09653560210426786.

[9] R. M. Darbra and J. Casal, "Historical analysis of accidents in seaports," *Saf Sci*, vol. 42, no. 2, pp. 85–98, 2004, doi: 10.1016/S0925-7535(03)00002-X.

[10] O. C. Jensen, J. F. L. Sørensen, M. L. Canals, Y. Hu, N. Nikolic, and A. A. Mozer, "Non-fatal occupational injuries related to slips, trips and falls in seafaring," *Am J Ind Med*, vol. 47, no. 2, pp. 161–171, 2005, doi: 10.1002/ajim.20119.

[11] A. Toffoli, J. M. Lefèvre, E. Bitner-Gregersen, and J. Monbaliu, "Towards the identification of warning criteria: Analysis of a ship accident database," *Applied Ocean Research*, vol. 27, no. 6, pp. 281–291, 2005, doi: 10.1016/j.apor.2006.03-.003.

[12] D. Nielsen and P. M. Panayides, "Causes of casualties and the regulation of occupational health and safety in the shipping industry," *WMU Journal of Maritime Affairs*, vol. 4, no. 2, pp. 147–167, 2005, doi: 10.1007/BF03195071.

[13] N. Akten, "Shipping accidents : a serious threat for marine environment," *Black Sea/Mediterranean Environment*, vol. 12, pp. 269–304, 2006, [Online]. Available: www.blackmedit-journal.org/pdf/2006_vol12_no3-5.pdf

[14] P. Antão and C. Guedes Soares, "Causal factors in accidents of high-speed craft and conventional ocean-going vessels," *Reliab Eng Syst Saf*, vol. 93, no. 9, pp. 1292–1304, 2008, doi: 10.1016/j.ress.2007.07.010.

[15] P. Antão and C. G. Soares, "Analysis of the influence of waves in the occurrence of accidents in the portuguese coast using bayesian belief networks," *Journal of Konbin*, vol. 13, no. 1, pp. 105–116, 2010, doi: 10.2478/v10040-008-0140-5.

[16] J. Ellis, "Analysis of accidents and incidents occurring during transport of packaged dangerous goods by sea," *Saf Sci*, vol. 49, no. 8–9, pp. 1231–1237, 2011, doi: 10.1016/j.ssci.20-11.04.004.

[17] N. Butt, D. Johnson, N. Pryce-roberts, and N. Vigar, "15 Years of Shipping Accidents : A review for WWF Southampton Solent University," vol. 44, no. 0, pp. 37–63, 2015, [Online]. Available: http://awsassets.panda.org/downloads/15_years-_of_shipping_accidents_a_review_for_wwf_.pdf

[18] B. Bužančić Primorac and J. Parunov, "Review of statistical data on ship accidents," *Proceedings of 3rd International Conference on Maritime Technology and Engineering, MARTECH 2016*, vol. 2, no. Figure 1, pp. 809–814, 2016, doi: 10.1201/b21890-106.

[19] T. Baalisampang, R. Abbassi, V. Garaniya, F. Khan, and M. Dadashzadeh, "Review and analysis of fire and explosion accidents in maritime transportation," *Ocean Engineering*, vol. 158, no. April, pp. 350–366, 2018, doi: 10.1016/j.oceaneng-.2018.04.022.

[20] J. Chen, W. Bian, Z. Wan, Z. Yang, H. Zheng, and P. Wang, "Identifying factors influencing total-loss marine accidents in the world: Analysis and evaluation based on ship types and sea regions," *Ocean Engineering*, vol. 191, no. September, p. 106495, 2019, doi: 10.1016/j.oceaneng.2019.106495.

[21] L. Zhang, H. Wang, Q. Meng, and H. Xie, "Ship accident consequences and contributing factors analyses using ship accident investigation reports," *Proc Inst Mech Eng O J Risk Reliab*, vol. 233, no. 1, pp. 35–47, 2019, doi: 10.1177/174800-6X18768917.

[22] W. A. Wagenaar and J. Groeneweg, "Accidents at sea: Multiple causes and impossible consequences," *Int J Man Mach Stud*, vol. 27, no. 5–6, pp. 587–598, 1987, doi: 10.1016/S0020-7373(87)80017-2.

[23] C. Hetherington, R. Flin, and K. Mearns, "Safety in shipping: The human element," *J Safety Res*, vol. 37, no. 4, pp. 401–411, 2006, doi: 10.1016/j.jsr.2006.04.007.

[24] I. D. Er, M. Celik, and I. D. Er, "Identifying the potential roles of design-based failures on human errors in shipboard operations," vol. 1, no. 3, 2007.

[25] D. J. Pennie, N. Brook-Carter, and W. H. Gibson, "Human factors guidance for maintenance," *RINA, Royal Institution of Naval Architects International Conference - Human Factors in Ship Design, Safety and Operation - Papers*, no. March, pp. 145–154, 2007.

[26] M. Barnett, D. Gatfield, C. Pekcan, L. Northcott, D. M. Turner, and I. Rowley, "The mitigation of human error in the use of automated shipboard systems," in *RINA, Royal Institution of Naval Architects International Conference - Human Factors in Ship Design, Safety and Operation - Papers*, 2007.

[27] Y. Song, "Analyzing human error triggered accidents onboard ships against ergonomic design principles," in *RINA, Royal Institution of Naval Architects International Conference - Human Factors in Ship Design, Safety and Operation - Papers*, 2009.

[28] A. H. Mokhtari and H. R. Khodadadi Didani, "An Empirical Survey on the Role of Human Error in Marine Incidents," *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, vol. 7, no. 3, pp. 363–367, 2013, doi: 10.12716/1001.07.03.06.

[29] E. Akyuz, "Quantitative human error assessment during abandon ship procedures in maritime transportation," *Ocean Engineering*, vol. 120, pp. 21–29, 2016, doi: 10.1016/j.oceaneng-.2016.05.017.

[30] S. T. Ung, "Human error assessment of oil tanker grounding," *Saf Sci*, vol. 104, no. December, pp. 16–28, 2018, doi: 10.1016/j.ssci.2017.12.035.

[31] R. Islam, F. Khan, R. Abbassi, and V. Garaniya, "Human error assessment during maintenance operations of marine systems – What are the effective environmental factors?," *Saf Sci*, vol. 107, no. April, pp. 85–98, 2018, doi: 10.1016/j.ssci.20-18.04.011.

[32] I. H. Youn, D. J. Park, and J. Bin Yim, "Analysis of lookout activity in a simulated environment to investigate maritime accidents caused by human error," *Applied Sciences (Switzerland)*, vol. 9, no. 1, 2018, doi: 10.3390/app9010004.

[33] P. Antão and C. G. Soares, "Analysis of the influence of human errors on the occurrence of coastal ship accidents in different wave conditions using Bayesian Belief Networks," *Accid Anal Prev*, vol. 133, no. July, p. 105262, 2019, doi: 10.1016/j.aap.2019.105262.

[34] B. J. Garrick, "Risk Assessment Methodologioes Applicable to Marine Systems." p. 82, 1999.

[35] C. G. Soares and A. P. Teixeira, "Risk assessment in maritime transportation," *Reliab Eng Syst Saf*, vol. 74, no. 3, pp. 299–309, 2001, doi: 10.1016/S0951-8320(01)00104-1.

[36] N. Bailey, N. Ellis, and H. Sampson, *Perceptions of Risk in the Maritime Industry: Ship Casulaty*. 2006. [Online].

Available: http://www.sirc.cf.ac.uk/uploads/publications/Perceptions of risk, personal injury.pdf

[37] N. Bailey *et al.*, *Human Factors in Incident Investigation and Analysis*, vol. 43, no. 3. 2007. doi: 10.1016/S1369-8478(01)00007-9.

[38] M. Grabowski, P. Ayyalasomayajula, J. Merrick, and D. McCafferty, "Accident precursors and safety nets: Leading indicators of tanker operations safety," *Maritime Policy and Management*, vol. 34, no. 5, pp. 405–425, 2007, doi: 10.1080/03088830701585084.

[39] C. S. Lu and C. L. Tsai, "The effects of safety climate on vessel accidents in the container shipping context," *Accid Anal Prev*, vol. 40, no. 2, pp. 594–601, 2008, doi: 10.1016/j.aap.2007.08.015.

[40] N. Bailey, N. Ellis, and H. A. Sampson, *Safety and perceptions of risk: A comparison between respondent perceptions and recorded accident data*. 2010. [Online]. Available: http://orca.cf.ac.uk/27456/

[41] C. S. Lu and C. L. Tsai, "The effect of safety climate on seafarers' safety behaviors in container shipping," *Accid Anal Prev*, vol. 42, no. 6, pp. 1999–2006, 2010, doi: 10.1016/j.aap.2010.06.008.

[42] H. Bailey, N., Ellis, N., Sampson, "Exploring differences in perceptions of risk , and its management , amongst personnel directly associated with the operation of ships," 2012.

[43] S. Bhattacharya and L. Tang, "Fatigued for safety? Supply chain occupational health and safety initiatives in shipping," *Economic and Industrial Democracy*, vol. 34, no. 3, pp. 383–399, 2013, doi: 10.1177/0143831X12439760.

[44] X. Wang, H. Kato, and R. Shibasaki, "Risk perception and communication in international maritime shipping in Japan after the Fukushima Daiichi nuclear power plant disaster," *Transp Res Rec*, no. 2330, pp. 87–94, 2013, doi: 10.3141/2330-12.

[45] H. Karahalios, "The contribution of risk management in ship management: The case of ship collision," *Saf Sci*, vol. 63, pp. 104–114, 2014, doi: 10.1016/j.ssci.2013.11.004.

[46] 2015 B, J. Eida a S.W. Hystada ∗ M.B. NielsenaHystad et al., "The impact of sleep quality, fatigue and safety climate on the perceptions of accident risk among seafarers," *G Model*, vol. 1, no. 1, pp. 1–9, 2015, doi: 10.1016/j.jinf.2020.02.020.

[47] T. Chai, J. Weng, and X. De-qi, "Development of a quantitative risk assessment model for ship collisions in fairways," *Saf Sci*, vol. 91, pp. 71–83, 2017, doi: 10.1016/j.ssci.2016.07.018.

[48] A. Cem Kuzu, E. Akyuz, and O. Arslan, "Application of Fuzzy Fault Tree Analysis (FFTA) to maritime industry: A risk analysing of ship mooring operation," *Ocean Engineering*, vol. 179, no. May 2018, pp. 128–134, 2019, doi: 10.1016/j.oceaneng.2019.03.029.

[49] P. Chen, Y. Huang, J. Mou, and P. H. A. J. M. van Gelder, "Probabilistic risk analysis for ship-ship collision: State-of-the-art," *Saf Sci*, vol. 117, no. September 2018, pp. 108–122, 2019, doi: 10.1016/j.ssci.2019.04.014.

[50] W. L. Thomas, "Achieving and maximizing ISM code compliance with ISO 14001," *Environmental Quality Management*, vol. 7, no. 4, pp. 9–17, 1998, doi: 10.1002/tqem.3310070403.

[51] L. M. Golapalli, "The ISM Code Implementation and its Effect on Maritime Claims," p. 101, 2003.

[52] W. H. Moore and K. H. Roberts, "Safety management for the maritime industry: The international safety management code," *2005 International Oil Spill Conference, IOSC 2005*, pp. 7383–7398, 2005, doi: 10.7901/2169-3358-1995-1-305.

[53] M. Celik, "Designing of integrated quality and safety management system (IQSMS) for shipping operations," *Saf Sci*, vol. 47, no. 5, pp. 569–577, 2009, doi: 10.1016/j.ssci.2008.07.002.

[54] E. Tzannatos and D. Kokotos, "Analysis of accidents in Greek shipping during the pre- and post-ISM period," *Mar Policy*, vol. 33, no. 4, pp. 679–684, 2009, doi: 10.1016/j.marpol.2009.01.006.

[55] J. Tunidau and V. V. Thai, "Critical factors for successful implementation of the ISM Code in some Pacific Islands states," *WMU Journal of Maritime Affairs*, vol. 9, no. 1, pp. 63–80, 2010, doi: 10.1007/BF03195166.

[56] S. Bhattacharya, "The effectiveness of the ISM Code: A qualitative enquiry," *Mar Policy*, vol. 36, no. 2, pp. 528–535, 2012, doi: 10.1016/j.marpol.2011.09.004.

[57] D. X. Kokotos, "a Study of Shipping Accidents Validates the Effectiveness of Ism-Code," *Eur Sci J*, vol. June, no. Edition 1, pp. 387–392, 2012, [Online]. Available: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1005.5764&rep=rep1&type=pdf

[58] F. J. Lappalainen, J. Kuronen, and U. Tapaninen, "Evaluation of the Ism Code in the finnish shipping companies," *Journal of Maritime Research*, vol. 9, no. 1, pp. 23–32, 2012.

[59] E. Asyali and S. Bastug, "Influence of scientific management principles on ISM Code," *Saf Sci*, vol. 68, pp. 121–127, 2014, doi: 10.1016/j.ssci.2014.03.011.

[60] J. González, F. Padrón, A. Dionis, J. Gómez, M. Adrián, and J. Calvilla, "Application of The ISM Code on Passenger Ships and Impact on The Loss of Human Lives At Sea Over The Past 35 Years," *Journal of Maritime Research*, vol. 13, no. 2, pp. 39–44, 2016.

[61] M. Lee and M. Lee, "A study on the effectiveness of the ISM Code through a comparative analysis of ISM and PSC Data By," 2016.

[62] A. Pantouvakis and M. Karakasnaki, "An empirical assessment of ISM Code effectiveness on performance: the role of ISO certification," *Maritime Policy and Management*, vol. 43, no. 7, pp. 874–886, 2016, doi: 10.1080/03088839.2016.1169451.

[63] M. Jung and M. Jung, "The Maritime Commons : Digital Repository of the World Maritime A study on the effectiveness of the ISM Code on the seafarers ' awareness of safety culture A STUDY ON THE EFFECTIVENESS OF THE ISM CODE ON THE SEAFARERS ' AWARENESS OF SAFETY CULTURE By In," 2017.

[64] J. Lappalainen, "Overcoming Obstacles to Implementing SMS," 2017, doi: 10.1787/0564329c-en.

[65] M. Karakasnaki, P. Vlachopoulos, A. Pantouvakis, and N. Bouranta, "ISM Code implementation: an investigation of

safety issues in the shipping industry," *WMU Journal of Maritime Affairs*, vol. 17, no. 3, pp. 461–474, 2018, doi: 10.1007/-s13437-018-0153-4.

[66] C. Laverick, "Enforcing the ISM Code, and Improving Maritime Safety, with an Improved Corporate Manslaughter Act: A Safety Culture Theory Perspective," vol. 1, no. February, 2018, [Online]. Available: http://clok.uclan.ac.uk/23768/

[67] A. Pantouvakis and M. Karakasnaki, "The human talent and its role in ISM Code effectiveness and competitiveness in the shipping industry," *Maritime Policy and Management*, vol. 45, no. 5, pp. 649–664, 2018, doi: 10.1080/03088839.2018-.1454989.

[68] D. Mišković, I. Jelaska, and R. Ivče, "Attitudes of experienced seafarers as predictor of ism code implementation: A Croatian example," *Promet - Traffic - Traffico*, vol. 31, no. 5, pp. 569–579, 2019, doi: 10.7307/ptt.v31i5.3118.

[69] C. Xue and L. Tang, "Organisational support and safety management: A study of shipboard safety supervision," *Economic and Labour Relations Review*, vol. 30, no. 4, 2019, doi: 10.1177/1035304619869575.

[70] S. Baştuğ, E. Asyali, and T. Battal, "Beyond the ISM code: a conceptual proposal for an integrated system within the Seven C's approach," *Maritime Policy and Management*, vol. 48, no. 3, pp. 354–377, 2021, doi: 10.1080/03088839.2020.177-0884.

[71] P. Caridis, *CASUALTY ANALYSIS METHODOLOGY FOR MARITIME OPERATIONS Final Report for Publication*, no. October. 1999.

[72] D. B. Mccafferty and C. C. Baker, "Human Error and Marine Systems : Current Trends," pp. 175–182, 2002.

[73] A. M. Rothblum *et al.*, "Human Factors in Incident Investigation and Analysis," *International workshop on human factors in offshore operations (HFW2002)*, pp. 1–150, 2002.

[74] M. R. Grech, T. Horberry, and A. Smith, "Human Error in Maritime Operations: Analyses of Accident Reports Using the Leximancer Tool," *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, vol. 46, no. 19, pp. 1718–1721, 2002, doi: 10.1177/154193120204601906.

[75] M. Celik and S. Cebi, "Analytical HFACS for investigating human errors in shipping accidents," *Accid Anal Prev*, vol. 41, no. 1, pp. 66–75, 2009, doi: 10.1016/j.aap.2008.09.004.

[76] M. Celik, S. M. Lavasani, and J. Wang, "A risk-based modelling approach to enhance shipping accident investigation," *Saf Sci*, vol. 48, no. 1, pp. 18–27, 2010, doi: 10.1016/j.ssci.20-09.04.007.

[77] J. U. Schröder-Hinrichs, M. Baldauf, and K. T. Ghirxi, "Accident investigation reporting deficiencies related to organizational factors in machinery space fires and explosions," *Accid Anal Prev*, vol. 43, no. 3, pp. 1187–1196, 2011, doi: 10.1016/j.aap.2010.12.033.

[78] P. M. Salmon, M. Cornelissen, and M. J. Trotter, "Systems-based accident analysis methods: A comparison of Accimap, HFACS, and STAMP," *Saf Sci*, vol. 50, no. 4, pp. 1158–1170, 2012, doi: 10.1016/j.ssci.2011.11.009.

[79] S. T. Chen, A. Wall, P. Davies, Z. Yang, J. Wang, and Y. H. Chou, "A Human and Organisational Factors (HOFs) analysis method for marine casualties using HFACS-Maritime Accidents (HFACS-MA)," *Saf Sci*, vol. 60, pp. 105–114, 2013, doi: 10.1016/j.ssci.2013.06.009.

[80] E. Akyuz and M. Celik, "Utilisation of cognitive map in modelling human error in marine accident analysis and prevention," *Saf Sci*, vol. 70, pp. 19–28, 2014, doi: 10.1016/j.ssci-.2014.05.004.

[81] B. Wu, X. Yan, Y. Wang, and C. G. Soares, "An Evidential Reasoning-Based CREAM to Human Reliability Analysis in Maritime Accident Process," *Risk Analysis*, vol. 37, no. 10, pp. 1936–1957, Oct. 2017, doi: 10.1111/risa.12757.

[82] S. C. Theophilus, V. N. Esenowo, A. O. Arewa, A. O. Ifelebuegu, E. O. Nnadi, and F. U. Mbanaso, "Human factors analysis and classification system for the oil and gas industry (HFACS-OGI)," *Reliab Eng Syst Saf*, vol. 167, no. April, pp. 168–176, 2017, doi: 10.1016/j.ress.2017.05.036.

[83] E. Akyuz, "A marine accident analysing model to evaluate potential operational causes in cargo ships," *Saf Sci*, vol. 92, pp. 17–25, 2017, doi: 10.1016/j.ssci.2016.09.010.

[84] G. Fu, J. L. Cao, L. Zhou, and Y. C. Xiang, "Comparative study of HFACS and the 24Model accident causation models," *Pet Sci*, vol. 14, no. 3, pp. 570–578, 2017, doi: 10.1007/s12182-017-0171-4.

[85] H.-T. Kim and S. Na, "Development of a Human Factors Investigation and Analysis Model for Use in Maritime Accidents : A Case Study of Collision Accident Investigation," *Journal of Korean Navigation and Port Reserch*, vol. 41, no. 5, pp. 303–318, 2017.

[86] T. Kececi and O. Arslan, "SHARE technique: A novel approach to root cause analysis of ship accidents," *Saf Sci*, vol. 96, no. 152, pp. 1–21, 2017, doi: 10.1016/j.ssci.2017.03.002.

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

[88] B. M. Batalden and A. K. Sydnes, "What causes 'very serious' maritime accidents?," *Safety and Reliability - Theory and Applications - Proceedings of the 27th European Safety and Reliability Conference, ESREL 2017*, pp. 3067–3074, 2017, doi: 10.1201/9781315210469-389.

[89] Ö. Uğurlu, S. Yıldız, S. Loughney, and J. Wang, "Modified human factor analysis and classification system for passenger vessel accidents (HFACS-PV)," *Ocean Engineering*, vol. 161, no. April, pp. 47–61, 2018, doi: 10.1016/j.oceaneng.2018-.04.086.

[90] S. Yildiz, Ö. Uğurlu, J. Wang, and S. Loughney, "Application of the HFACS-PV approach for identification of human and organizational factors (HOFs) influencing marine accidents," *Reliab Eng Syst Saf*, vol. 208, no. December 2020, 2021, doi: 10.1016/j.ress.2020.107395.

[91] E. M. Newbold, "Practical Applications of the Statistics of Repeated Events ' Particularly to Industrial Accidents," vol. 90, no. 3, pp. 487–547, 1927.

[92] E. A. Suchman, "Accidents and social deviance.," *J Health Soc Behav*, vol. 11, no. 1, pp. 4–15, 1970, doi: 10.2307/-2948283.

[93] J. Reason, "The contribution of latent human failures to the breakdown of complex systems.," *Philos Trans R Soc Lond B Biol Sci*, vol. 327, no. 1241, pp. 475–484, 1990, doi: 10.1098/rstb.1990.0090.

[94] J. Rasmussen, "Risk management in a dynamic society: A modelling problem," *Saf Sci*, vol. 27, no. 2–3, pp. 183–213, 1997, doi: 10.1016/S0925-7535(97)00052-0.

[95] C. Ericson, "Fault Tree Analysis – A History Clifton A. Ericson II The Boeing Company; Seattle, Washington," *System*, pp. 1–9, 1999.

[96] G. Medina Oliva, B. Iung, L. Barberá, P. Viveros, and T. Ruin, "Root cause analysis to identify physical causes," *11th International Probabilistic Safety Assessment and Management Conference and the Annual European Safety and Reliability Conference 2012, PSAM11 ESREL 2012*, vol. 1, pp. 671–680, 2012.

[97] Allan F. Williams, "The Haddon Matrix: Its Contribution to Injury Prevention and Control," *3rd National Conference on Injury Prevention and Control*. pp. 15–16, 1999.

[98] S. A. Shappell and D. A. Wiegmann, "The Human Factors Analysis and Classification System – HFACS," pp. 1–15, 2000.

[99] N. Leveson, "A new accident model for engineering safer systems," *Saf Sci*, vol. 42, no. 4, pp. 237–270, 2004, doi: 10.1016/S0925-7535(03)00047-X.

[100] N. L. Rossing, M. Lind, N. Jensen, and S. B. Jørgensen, "A functional HAZOP methodology," *Comput Chem Eng*, vol. 34, no. 2, pp. 244–253, 2010, doi: 10.1016/j.compchemeng.2009.06.028.

[101] Z. I. Awal and K. Hasegawa, "A study on accident theories and application to maritime accidents," *Procedia Eng*, vol. 194, no. December, pp. 298–306, 2017, doi: 10.1016/j.proeng.2017.08.149.