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Determination of Shipping Safety by Maintenance, Ship Construction, Weather, and Human Resource Competence: In a Literature Review

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Abstract: This article aims to provide a more holistic and in-depth insight into the factors that determine shipping safety and provide a basis for developing more effective strategies and policies in the maritime sector. A qualitative method by exploring and understanding how factors such as maintenance, ship construction, weather, and human resource competence affect shipping safety. Relevant literature sources come from reputable journals that analyze the literature's findings by providing researchers' perspectives. In addition to adding insight from the results of this article, it can be concluded that the effective implementation of human resource competence, monitoring and management of weather and technological risks, as well as in-depth analysis of the factors that cause accidents, are the keys to improving shipping safety. An emphasis on continuous training, adaptation to new technologies, and thorough risk evaluation will help in creating a safer and more efficient shipping environment.

Keywords: Shipping Safety, Maintenance, Ship Construction, Weather, Human Resource Competencies

INTRODUCTION

Shipping safety is a very crucial aspect in the maritime industry, given the high risks faced in daily operations. In recent years, various shipping incidents around the world have highlighted how important it is to maintain high safety standards. Accidents involving ships, whether caused by human error, extreme weather, or technical failures, often lead to large losses, both in terms of materials, the environment, and human lives (Kim, 2022). With global maritime traffic increasing as international trade grows, attention to shipping safety standards is increasing. Shipping safety cannot be thought of as the result of a single variable, but rather as the result of a complex interaction between various interrelated factors (Wróbel, Gil and Chae, 2021).

In the midst of globalization and technological developments, the maritime industry is currently facing increasingly complex challenges. The operation of ships in a variety of marine environmental conditions, as well as the increase in ship size and capacity, requires special attention to efforts to improve safety (Wu *et al.*, 2021). Empirical phenomena show that despite

the improvement in international safety regulations and standards, ship incidents and accidents are still frequent (Yıldız *et al.*, 2022). Some of these incidents resulted in significant losses, both financially and ecologically, indicating a gap in the shipping safety system currently in place (Hopcraft *et al.*, 2022).

One of the main problems that is often identified in shipping incidents is the lack of adequate maintenance (Tsaimou, Chelioti and Tsoukala, 2024). Poor or untimely maintenance can lead to undetected mechanical or technical failures, which can then trigger operational failures in the middle of the sea. For example, machinery that is not properly maintained may not function optimally when needed, or electrical systems that are not routinely inspected can cause fires (Anwar, Latief and Wardahni, 2024). Therefore, planned and structured maintenance is one of the main pillars in ensuring shipping safety (Shukla, Nefti-Meziani and Davis, 2022). The quality of ship construction is also a critical factor in the context of shipping safety. Ships built with low-quality materials or whose The design does not meet international safety standards and has the potential to experience structural failure when facing severe sea conditions (Rosa, 2018). Poor ship construction can increase the risk of hull damage, leakage, or even sinking when facing extreme conditions such as storms or collisions (Pawara *et al.*, 2023). Therefore, ensuring that the ship is built in accordance with strict safety standards and uses the latest construction technology is essential in an effort to reduce the risk of accidents.

Weather is a factor that is often beyond human control but has a significant impact on shipping safety (Kolowrocki and Kuligowska, 2018). Volatile global climate change has resulted in an increase in the frequency and intensity of extreme weather, such as large storms, high waves, and strong winds, which can threaten the safety of ships at sea. Although weather prediction technology has advanced rapidly, uncertainty in weather changes is still a major challenge for ship operators (Bajad, 2024). An inability to predict and respond to suddenly changing weather conditions can lead to ships being in dangerous situations without adequate preparedness. Another factor that plays a big role in shipping safety is the competence of human resources (HR) who operate ships. Crew members who do not have sufficient knowledge, necessary skills, or adequate experience in handling emergency situations can be a great source of risk (Chaudhary and Rizwan, 2018).

Maritime Safety

Shipping safety refers to all efforts, actions, and procedures carried out to ensure the safety of ships, passengers, crew, cargo, and the maritime environment during the shipping process. This includes accident prevention, risk mitigation, and handling of incidents that can occur at sea, including aspects such as safe navigation, ship maintenance, response to severe weather, and compliance with international maritime regulations (Fei, 2018). Shipping safety can also be defined as a set of preventive and procedural measures implemented to protect ships and individuals on board from potential hazards at sea. It covers all aspects related to ship operations, from design and construction, navigation equipment, maintenance, crew training, to risk management and emergency response. Shipping safety aims to ensure that ships can operate safely in a variety of marine conditions, as well as minimize negative impacts on the environment and society.

In addition, shipping safety includes the management of risks related to natural conditions such as storms or high waves, as well as operational risks such as fires, collisions, or engine failures. Effective implementation of shipping safety requires good coordination between various parties, including the government, shipping companies, and port authorities (Yokota and Frangopol, 2021). The results of this new application study in the domain of Bayesian network-based expert systems show that, although some subareas are functioning well, the status of safety management on ships sailing in Finland waters still needs to be improved; the probability of the absence of poor safety management is only 0.13 (Hänninen, Banda and Kujala, 2014).

Another study states it provides a descriptive analysis process for designing a maritime safety management system. This process includes two additional concrete elements that support the implementation of the planned safety management system. First, the adjustment of the identification process to establish key performance indicators for planning, monitoring, and evaluating the performance of the safety management system. Second, the development of performance monitoring tools that can monitor, measure, and update the main performance indicators that have been set as well as the overall function of the designed safety management system (Banda and Goerlandt, 2018). Another study stated substantially improving maritime safety and preventing major accidents that could threaten the seas and coasts (Fan *et al.*, 2023).

Maintenance

Maintenance is a series of activities that are carried out regularly and periodically to maintain, repair, and ensure that assets, equipment, or systems function properly in accordance with operational standards. In the industrial context, maintenance includes actions such as inspections, repairs, replacement of parts, lubrication, and adjustment of components to prevent damage or failure that can disrupt operations and pose a safety risk (Cachada *et al.*, 2018). In the context of shipping, maintenance refers to a series of maintenance activities carried out on ships and related equipment to ensure safe, efficient, and compliant operations with maritime regulatory standards. Maintenance in the shipping sector involves inspection, repair, replacement of spare parts, and adjustment of ship components and their supporting systems such as engines, navigation systems, hulls, and safety facilities.

Maintenance that is carried out regularly and scheduled aims to prevent damage that can cause accidents at sea, maintain the structural integrity of the ship, and extend the service life of the ship. In addition, maintenance activities also comply with international regulations as set by the International Maritime Organization (IMO) and the SOLAS (Safety of Life at Sea) convention, which regulates ship safety standards and shipping equipment (Zareei and Iranmanesh, 2018). The results of related research state that optimal *maintenance* planning for ship structures can be achieved by formulating and solving multi-objective optimization problems. In recent years, the use of risk as an indicator of structural performance has become increasingly common. The goal of this optimization problem is to reduce *maintenance costs* throughout the life cycle of the structure, including inspection and repair costs, and minimize the risk of structural failure during the operational life of the vessel. In In addition, to get more good results, the reliability index is also added as the third goal in this optimization (Zareei and Iranmanesh, 2018).

Another study in its findings states that policymakers regarding the benefits of following maintenance optimization strategies, life cycle assessments can provide shipyards and shipowners with information to facilitate reliable long-term maintenance decision-making (Wang *et al.*, 2018). Other studies have also stated that helping policymakers understand these differences can be a major obstacle to the efficient and smooth implementation of ballast water management (Čampara *et al.*, 2019).

Ship Construction

Ship construction is the process of designing, building, and assembling ship parts into a complete structure that functions in accordance with applicable technical specifications and safety regulations. This process includes various stages, including the initial design, the manufacture of the hull, the installation of support systems such as propulsion, electrical, and safety systems, and final testing to ensure that the ship can operate safely and efficiently. Ship construction requires in-depth knowledge of marine engineering, the materials used, as well as international regulations as set by the International Maritime Organization (IMO). In addition, aspects such as fuel efficiency, durability, and navigationability are also considered during the construction process (Mallam, Lundh and MacKinnon, 2017).

Another definition also states that ship construction is a discipline in marine engineering that focuses on the process of designing and building ships, starting from the initial concept to the ship being ready to operate at sea. Ship construction involves a series of technical and practical activities, including the creation of blueprints, material selection, fabrication, and assembly of ship parts such as the hull, deck, and engine systems. The process also considers factors such as stability, durability, maneuverability, and compliance with international maritime safety standards. In practice, ship construction requires the collaboration of various experts, such as marine engineers, ship architects, and technicians, and involves the use of advanced technology to ensure that the resulting ship meets the specifications and standards required for safe and efficient operation (Papanikolaou, 2014).

The results of the related study state that this framework will be a valuable area in the life cycle of ships, offshore structures, and industrial plants (Han *et al.*, 2019). Another study also states that the three main feedbacks (condition evaluation, response plan, response implementation) in a cognitive model can be viewed as a series of cognitive cycles, where each cycle provides the necessary information for the next stage (Fang *et al.*, 2020).

Weather

Weather refers to the atmospheric conditions in a place at any given time, including temperature, humidity, air pressure, wind, and sky conditions such as clouds or rain. The weather can change over a short period of time, ranging from a few hours to a few days, and affect various aspects of daily life, such as outdoor activities, transportation, and health. Weather is distinguished from climate, which is a long-term weather pattern in an area. Weather studies involve the observation and analysis of meteorological data to understand current atmospheric conditions and predict future changes (Spiridonov and Ćurić, 2021). Another definition states that weather is an atmospheric state that describes the physical and meteorological conditions in a location on at a certain time. This includes variables such as temperature, relative humidity, air pressure, wind speed and direction, as well as atmospheric events such as rain, snow, or fog. Weather fluctuates over time and can affect various aspects of daily life as well as human activities. Weather studies focus on observing and predicting atmospheric conditions to understand and anticipate changes that can affect the environment and activities (Davis, Fu and Godish, 2021).

The results of the related study stated that a prediction model using phase space reconstruction has revealed that seasonal intramuscular oscillations can be predicted more accurately over longer periods of time (Krishnamurthy, 2019). Another study stated that the type of algorithm, measurement environment, modeling tools, as well as the advantages and disadvantages of each paper were extracted. In addition, open issues and future trends are also discussed (Fathi *et al.*, 2022).

HR Competencies

Human resource competencies refer to the skills, knowledge, abilities, and attributes required by HR professionals to effectively manage and support an organization's workforce. It covers a wide range of competencies, including strategic HR management, employee relations, recruitment and selection, performance management, training and development, compensation and benefits, and compliance with employment laws and regulations. Competence in human resources also involves understanding organizational dynamics and contributing to the overall strategic goals of the organization (Armstrong and Taylor, 2023). Another definition states that the competence of human resources in the field of shipping refers to the skills, knowledge, and abilities required by professionals working in the shipping industry to carry out their duties effectively (Li *et al.*, 2023).

The study of related results states that The complexity of their tasks, along with the need to provide high-quality services in global shipping, necessitates the existence of high-

standard accredited training as well as harmonization in maritime health practices. Policy analysis conducted using two policy models shows that there is an opportunity to support policies that recognize maritime medicine as a medical specialty. International stakeholders, along with the International Maritime Health Association, need to actively support this perspective, which will benefit seafarers by providing better health and well-being, higher incomes, as well as avoiding health problems. On the other hand, the shipping industry will also benefit by having satisfied and loyal employees and improving their reputation (Bygvraa *et al.*, 2020).

Another study also stated that five competency requirements, in order of importance, showed a significant positive influence on teaching performance: Pedagogy, Maritime, Interpersonal, Business, and Digital. Academically, this study strengthens the existing literature and identifies new core competencies expected of MBEs in the digital age (Yuen, Tan and Loh, 2022). Another study also stated in the results that various digital technologies, including e-learning platforms (ELPs), learning management systems (LMS), virtual reality (VR), augmented reality (AR), gamification, as well as artificial intelligence (AI) and machine learning (ML), have been present. However, the maritime sector is likely to face a number of challenges, such as security issues, skills shortages, strategic planning, change management, budget constraints, and regulatory compliance (Autsadee *et al.*, 2023).

METHOD

A qualitative method by exploring and understanding how factors such as maintenance, ship construction, weather, and human resource competence affect shipping safety. Relevant literature sources come from reputable journals that analyze the literature's findings by providing researchers' perspectives.

RESULTS AND DISCUSSION

Implementation of Maintenance with Shipping Safety

Studies state that optimizing the virtual reality training environment of this engine room and affecting ship and maritime safety (Markopoulos *et al.*, 2020). A study of guidelines on asset monitoring, ongoing maintenance, and safety practices for offshore structures is presented in this paper, a discussion of the management of offshore structures, including the use of sensors for damage monitoring. In addition, this paper proposes a sustainable asset management approach as a suggested guide, as well as discusses its policy implications (Amaechi *et al.*, 2022). Another study also states that Determining the right maintenance strategy to improve the operational efficiency of marine and offshore machinery in uncertain environments is a challenge due to the many criteria that must be considered and modeled. In addition, the design of complex engines on board involves a variety of subjective and inaccurate parameters that appear in both quantitative and qualitative forms (Asuquo *et al.*, 2019).

Similar outcome studies also state that a risk assessment model was developed to assess the risk level of crane components and recommend solutions by utilizing all existing diagnostic capabilities for effective monitoring of gearbox and bearing conditions on ship cranes (Asuquo *et al.*, 2020). Other findings also stated that the relationship between health maintenance and safety policies for maritime transport workers at Port Harcourt Port found a significant positive correlation between health maintenance and safety policies. The study recommends the implementation of policies to monitor and regulate healthcare providers to prevent poor performance and increase risks in the workplace (Asikia *et al.*, 2023).

Another study aims to improve existing maritime incident databases by creating a relational database model. This approach supports the efficient maintenance and use of data, which is essential for improving maritime safety (Xu and Hu, 2019).

Implementation of Ship Construction with Shipping Safety

The study states that Goal Based Standards are high-level standards that provide a framework for ship construction, with a focus on safety and environmental protection. These standards have had a significant impact on the maritime industry by changing the way standards are developed and creating new business opportunities (Asuquo *et al.*, 2020). Another study stated in its findings that the IMO establishes and enforces global standards for maritime safety, including the International Safety Management Code (ISM), which requires ships with a gross tonnage (GT) of more than 500 to have an International Safety Management System (Lymperopoulos and Karagiannis, 2023). Other research results state IMO also implement a Safety Level Approach (SLA), which involves setting safety objectives and measuring tolerance levels from current safety levels to ensure continuous improvement (Sun, Zheng and Gang, 2018).

Another study states that Knowledge graphs have been built on ship collision accident reports to improve maritime traffic safety. These graphs help in analyzing the causes of accidents and identifying contributing factors (Gan *et al.*, 2023). Event graphs, such as the Ship Collision Accident Event Graph (SCAEG), have been developed to analyze the degree of contribution of the various causes and paths of occurrence of accidents. This method provides a more objective and accurate analysis of ship collision accidents (Ma *et al.*, 2024).

Implementation of Weather with Shipping Safety

The results of the study stated that thick fog and ice accumulation were very critical risk factors, followed by thunderstorms, hail and/or tornadoes, extreme temperatures, and blizzards (Panahi *et al.*, 2020). Another study also states that applying a model that has been developed through the case study of Hurricane Matthew (October 2016). This method contributes to improved maritime safety by allowing risk-taking vessel routing and vessel transit monitoring by Coast Guard agents (Rawson *et al.*, 2021). Other outcome studies state that government efforts to reduce weather-induced fishing incidents are typically focused on two things: improving risk communication (such as public ocean weather forecasts) or increasing the meteorological capacity of fishermen through training. While the initiative aims to increase awareness and decision-making ability, weather is just one of the many factors that influence fishermen's decisions. Other important safety factors, such as access to fishing sites and competition between fishers, are influenced by other institutions and policies that are more explicit in regulating fisherman behavior (e.g., when and where fishing is allowed), and do not traditionally consider weather or safety factors (Finnis and Reid-Musson, 2022).

Another study states that Optimizing evacuation procedures is a crucial element in maritime safety. The use of smart devices and changes to procedures can significantly improve the existing evacuation process, especially when facing adverse weather conditions (Stefanou *et al.*, 2024). Another study states that climate change and weather are impacting safety functions in port systems and maritime transportation. Evaluation of these impacts facilitates the determination of average values and variations in system life and other safety indicators (Torbicki, 2018). The results stated that deck cargo transport faces special challenges, especially in adverse weather conditions. Improper placement and securing of deck cargo is a common cause of accidents at sea and during Port operations (Melnyk, 2024).

Another outcome study states that weather routing services are essential for cruise ships to ensure safe operations and prevent accidents caused by unforeseen weather conditions. The system helps improve fuel efficiency and is integrated in maritime education and training programs (Dimitrakieva, Milev and Atanasova, 2023).

Implementation of Human Resource Competencies with Shipping Safety

The results of the study of related states that the grouping of causative factors appropriately into one of nineteen categories, known as the coding process (Galieriková, 2019).

Another study states that the future skills needs are analyzed in depth by taking into account new technologies that emerge in the maritime industry (Cicek, Akyuz and Celik, 2019). Other studies state The main risk factors for different types of accidents include the age of the ship, the operation of the ship, the shipping segment, information, and the condition of the ship. In addition, it also identifies differences in human factors that affect different types of accidents. The Most Probable Explanation (MPE) method is applied to present specific scenarios in which beliefs are maintained, by examining the most likely configurations (Fan, Shiqi, et al, 2020).

The study states a comprehensive training program is essential to ensure that crew members have the necessary skills to handle emergency situations. This includes training in areas such as firefighting, first aid, and emergency response (Ventura, Torre and Reina, 2019; Helal, 2022). Specialized training in accident reconstruction and advanced technology is essential for maritime accident investigators to improve their competencies (Taer, 2024). Another study states that with the increasing use of digital technology on ships, cyber risk management has become very important. The implementation of appropriate security measures against cyber incidents ensures the integrity of the safety system and prevents potential threats (Aboul-Dahab, 2020).

This resulting study states that human resource management (HRM) involves planning and coordinating various activities related to crew management, including recruitment, placement, and retention. This ensures that the right personnel are in the right place at the right time (Vuji\vcić *et al.*, 2020). The results study states that the HFACS-PV structure designed for passenger ship accidents is suitable for accidents due to impacts, groundings, sinkings, and collisions. This allows for a consistent analysis of maritime accidents. In addition, due to the flexibility of HFACS, this structure can be combined with other analytical methods for qualitative as well as quantitative analysis (Yildiz, Serdar, et al, 2021).

The study of results stated that although previous studies generally agreed that human error played a significant role in the occurrence of maritime accidents, the widely accepted figure of 80% was actually not supported by sufficient evidence (Wróbel, Krzysztof, 2021).

Discussion

From the results of the above description, the discussion here conveys the perspective of the researcher in this article where the first perspective is that the implementation of maintenance in the context of shipping safety involves the integration of advanced technology, effective risk management, attention to worker welfare, and proper data management. This holistic approach not only improves operational efficiency but also minimizes risks that threaten ship and maritime safety, both the importance of implementing high safety standards, strict international regulations, a sustainable approach to safety improvement, and the use of technology and data analysis to prevent accidents in ship construction and operations. The implementation of safety-focused ship construction involves not only technical and regulatory aspects, but also innovations in risk analysis and continuous improvement.

Furthermore, the researcher in his perspective said that there is a need for a comprehensive approach in dealing with the impact of weather on shipping safety. This includes understanding extreme weather risks, developing weather-based routing models, increasing meteorological capacity, optimizing evacuation procedures, as well as integrating weather routing services in maritime training. In addition, it is important to consider the impact of climate change and cargo security in shipping safety. And The last perspective of the researcher is to highlight the importance of human resource competence in improving shipping safety. It includes analysis of the causative factors of accidents, training for new skills and advanced technologies, cyber risk management, as well as effective HRM management. In addition, the application of consistent analytical methods and a more in-depth evaluation of the role of human error are key to the development of better safety strategies.

CONCLUSION

In addition to adding insight from the results of this article, it can be concluded that the effective implementation of human resource competence, monitoring and management of weather and technological risks, as well as in-depth analysis of the factors that cause accidents, are the keys to improving shipping safety. An emphasis on continuous training, adaptation to new technologies, and thorough risk evaluation will help in creating a safer and more efficient shipping environment.

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