The Seybold Report

ISSN 1533-9211

DOI: 10.5281/zenodo.13363846

GLOBAL PERSPECTIVE OF SHIP COLLISION DETERMINANT RESEARCH BASED ON A SYSTEMATIC LITERATURE REVIEW

ALBERTHA LOLO TANDUNG

Program Studi Doktor Ilmu Teknik Mesin, Departemen Teknik Mesin, Fakultas Teknik, Universitas Hasanuddin.

RAHIMUDDIN

Department of Marine Engineering, Faculty of Engineering, Universitas Hasanuddin.

DARMAWAN NAPITUPULU

Research Center for Domestic Government, National Research and Innovation Agency.
Email: darwan.na70@gmail.com

Abstract

This systematic review investigates the determinants of ship collisions, a critical issue in maritime safety with substantial implications for human lives, the environment, and economic stability. The study analyses data from 627 documents retrieved from the Scopus database, of which 80 documents were selected for detailed analysis after a rigorous screening process. The findings identify seven primary factors influencing ship collisions: human factors, environmental conditions, technical and maintenance errors, safety management and risk assessment errors, regulation violations, traffic density, and technological development and prediction. Human factors, such as navigational errors and crew fatigue, are major contributors to collisions. Environmental conditions, including adverse weather and complex geographical settings, significantly heighten collision risks. Technical failures and poor maintenance compromise navigational safety, while inadequate safety management and risk assessment exacerbate these dangers. Violations of navigation regulations increase collision likelihood, particularly in high-traffic areas where the complexity of navigation is intensified. Finally, the use of advanced technologies like AIS and predictive risk models offers promising solutions for collision prevention. Understanding these factors is important for developing more effective preventative measures, improving maritime safety, and reducing the economic and environmental impact of ship collisions.

Keywords: Ship Collision, Maritime, Determinant, Systematic Literature Review.

1. INTRODUCTION

Ship collisions represent a significant concern in maritime operations, often leading to severe consequences such as loss of life, environmental pollution, and economic disruptions (Pedersen, 2010). These incidents can occur due to a multitude of factors, including human error, adverse weather conditions, technical failures, and navigational challenges in busy maritime routes. The complexity and unpredictability of these factors make ship collisions a persistent threat to maritime safety. Over the years, research on ship collisions has evolved significantly, reflecting advancements in technology and changes in maritime practices (Luo & Shin, 2019). Early studies primarily focused on human factors, recognizing that errors in navigation and decision-making were major contributors to collision (Malone et al., 2000). As technology advanced, researchers began to explore the role of technical failures and the importance of regular maintenance in preventing accidents. With the advent of sophisticated navigation systems like GPS and radar, studies highlighted the impact of technical

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

malfunctions on ship safety. Environmental factors have also been a critical area of research, with studies examining how adverse weather conditions, such as fog, storms, and rough seas, increase the risk of collisions. Geographical challenges, such as narrow straits and congested shipping lanes, have been identified as significant risk factors requiring careful navigation and management.

Recent research has increasingly focused on the interplay between various factors, emphasizing the need for a holistic approach to understanding ship collisions (Ozturk & Cicek, 2019). For example, studies have shown that while advanced technology can enhance navigation, it also requires well-trained personnel to operate effectively, underscoring the interconnectedness of human and technical factors (Soner & Kandemir, 2024). Furthermore, the rise in maritime traffic has led to more complex navigational environments, prompting research into traffic management and collision avoidance systems. The maritime industry, characterized by its global nature and critical role in international trade, necessitates a comprehensive understanding of the underlying causes of ship collisions to mitigate these risks effectively (Kulkarni et al, 2020). By synthesizing findings from various studies, this research aims to provide a detailed analysis of the key determinants of ship collisions, contributing to the development of robust safety measures and policies to enhance maritime safety.

Researching the determinants of ship collisions is crucial for several reasons. Firstly, it provides insights into the multifaceted nature of maritime accidents, enabling stakeholders to develop targeted strategies to prevent collisions. Understanding the contributing factors helps in formulating effective safety regulations, enhancing ship design, and improving crew training programs. For instance, research by (Chauvin et al., 2013) highlights the significant role of human error in maritime accidents, emphasizing the need for comprehensive training and strict adherence to safety protocols to mitigate such risks. Secondly, this research aids in reducing the economic losses associated with maritime accidents. By preventing collisions, shipping companies can avoid the costs of repairs, insurance claims, and legal liabilities. According to a study by Allianz Global Corporate & Specialty (AGCS), the cost of shipping accidents, including collisions, can run into billions of dollars annually, encompassing repairs, cargo loss, and compensation claims. Preventive measures derived from understanding collision determinants can thus result in substantial economic savings for the industry. Additionally, safeguarding the marine environment from the adverse effects of oil spills and other pollutants resulting from ship collisions is of paramount importance for environmental conservation. Ship collisions often lead to significant ecological damage, as seen in the aftermath of incidents like the Exxon Valdez oil spill, which had long-lasting effects on marine life and coastal ecosystems (Paine et al., 1996). Research focusing on collision prevention can help mitigate such environmental disasters, protecting marine biodiversity and coastal habitats.

While there is substantial literature on maritime safety and accident prevention, existing studies often focus on isolated factors contributing to ship collisions. Most research tends to be segmented, examining either human factors, technical aspects, or environmental conditions independently, without considering their interrelated impacts. There is a lack of comprehensive reviews that integrate multiple determinants to provide a holistic understanding of the issue.

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

For example, Li et al (2023) conducted the analysis of the accident cause, especially the human factors that often lacks the corresponding data support. The results show that there are correlations between external factors, organizational influences, unsafe supervision, preconditions for unsafe acts, and unsafe acts. External factors are the potential cause of ship collision accidents and the potential inducement of organizational influences. Furthermore, research of (Q. Zhu et al., 2024) provides a bibliometric and systematic overview of the literature on ship collision avoidance (SCA) to assist researchers in understanding the frontiers and recent trends of intelligent SCA in maritime transportation. Furthermore, there is a need for a systematic review that synthesizes findings from various studies to identify the most critical determinants of ship collisions. Addressing this gap can lead to more effective and integrated strategies for collision prevention.

The primary objective of this study is to systematically review and identify the key determinants of ship collisions. By analyzing data from 627 documents retrieved from the Scopus database and narrowing it down to 80 documents after a thorough screening process, this research aims to highlight the seven main factors influencing ship collisions: human factors, environmental conditions, technical and maintenance errors, safety management and risk assessment errors, regulation violations, traffic density, and technological development and risk prediction. The study seeks to provide a comprehensive understanding of these determinants, facilitating the development of robust measures to enhance maritime safety and prevent ship collisions.

2. METHODS

This systematic literature review was conducted March until May 2024 using PRISMA reporting guidelines. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is an evidence-based minimum set of items aimed at helping scientific authors to report a wide array of systematic reviews and meta-analyses, primarily used to assess the benefits and harms of a health care intervention. PRISMA focuses on ways in which authors can ensure a transparent and complete reporting of this type of research. The PRISMA standard superseded the earlier QUOROM standard. It offers the replicability of a systematic literature review. Researchers have to figure out research objectives that answer the research question, states the keywords, a set of exclusion and inclusion criteria. In the review stage, relevant articles were searched, irrelevant ones are removed. Articles are analyzed according to some pre-defined categories.

According to PRISMA reporting guidelines, there are several steps in this study: 1) defining inclusion criteria; 2) defining information sources; 3) study selection; 4) data collection process. Figure 1 explains the steps of our work in conducting systematic review based on PRISMA flow diagram. Before we conducted the first step which defining the criteria, we should clearly formulate the research question of this study. The research question was derived from the research problems that have been explained in the previous chapter. Thus, we could define the research question as follows as:

Research Question (RQ): What are the determinants of ship collision?

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

2.1. Defining Eligibility Criteria

The following inclusion criteria (IC) were defined for the review guidelines:

IC1: Article written in English;

IC2: Original and peer-reviewed Journal Articles; and

IC3: Studies aimed at investigating determinants (factors/variables/parameters) of ship collision.

Only articles written in English (IC1) were selected, since English is a common language used by researchers in the scientific community. Original and peer-reviewed journal articles was chosen because this is achieved to obtain broad and excellent scientific contribution. Thus, other sources like conference papers, book chapters, books, newspapers, letters, editorials are not included in the dataset. IC3 was used to answer the research questions, that should discuss the determinants (factors/variables/parameters) of Ship Collision.

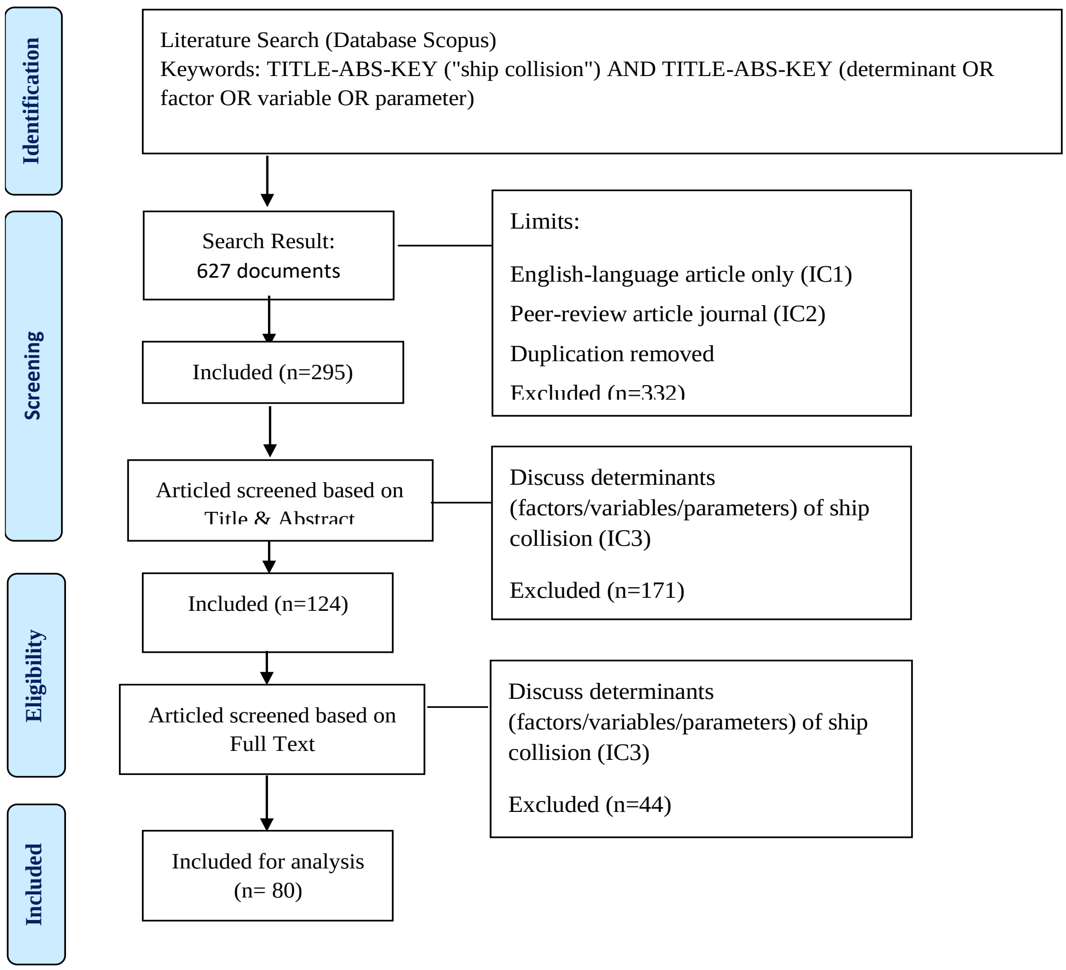

Figure 1: PRISMA Flow diagram of the search strategy (Zakaria et al., 2021)

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

2.2. Defining Information Source

The search for information was carried out on an online database, Scopus, which is the largest indexer of global research content, with over 24,600 active titles, including 23,500+ peer-reviewed journals, 740+ books, and 300+ trade publications. Worldwide, Scopus is used by more than 5,000 academic, government and corporate institutions. Thus, Scopus is one of the largest scientific databases and most widely used indexes. In this study, not fully accessible articles were also excluded for further analysis.

2.3. Study Selection

Study selection was conducted in three stages as follows:

1. Using search keywords following the research objectives, namely, the determinants of legal certainty or other keywords of similar reports (TITLE-ABS-KEY ("ship collision") AND TITLE-ABS-KEY (determinant OR factor OR variable OR parameter)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")).
2. Exploring and selecting the article titles and abstracts on the basis of the inclusion criteria.
3. Exploring and selecting all articles not eliminated in the previous selection by fully reading all articles while adhering to the eligibility criteria)

2.4. Data Collection Process

The data were collected manually by content analysis-based data extraction, including the author, year of publication, title, journal name, research methodology, country of research location and the research objectives. Data extracted was conducted in order to answer the research question has been formulated before. Thus, only data which is needed to be extracted. The process of filtration can be explained as follows as: There are four stages of filtration based on PRISMA flow diagram: identification, screening, eligibility and included. The first stage identification, we initially collected about 627 articles initially from the largest and well-known database, namely Scopus. Then 295 non-full text articles were excluded since they did not fulfil the criteria such as English language (IC1) and journal articles (IC2). If any duplicate articles were also removed in this stage. Thus only 295 non-full text articles were included in next screening stage, that is screening phase as presented in Figure 1. In this screening stage, total 295 non-full text articles were read and filtered based on their title and abstract, resulted 124 non-full text articles that relevant to the research topic. Thus, about 171 non-full text articles were excluded because they are not related to the determinants (factors/variables/parameters) of ship collision (IC3). Every article should discuss determinants (factors/variables/parameters) of ship collision. Furthermore, in the eligibility phase, there are only 124 articles were retained because their full text articles are available. Then, all 124 full text articles were read and filtered again or assessed for their eligibility. Thus, there are only 44 full text articles were removed because the article is irrelevant or do not discuss determinants (factors/variables/parameters) of ship collision (IC3). Those articles are inappropriate and not relevant to our research questions, so they were excluded from the review. From the full text and non-duplicate articles,

ISSN 1533-9211

DOI: 10.5281/zenodo.13363846

80 studies meet the inclusion criteria for analysis on determinants (factors/variables/parameters) of ship collision. Thus, total 80 studies will be analysed and synthesized to obtain the determinants (factors/variables/parameters) of ship collision.

3. RESULTS AND DISCUSSION

3.1. Population and Sampling

In this section, we conducted descriptive analysis to examine the trend of ship collision research. The descriptive analysis was performed by representing the demography of articles and also research method that consisting about 80 studies already filtered through PRISMA flow diagram in Figure 2 and Table 1.

Based on Figure 1, out of total 80 studies there are 56 articles used quantitative methods, 14 articles used qualitative methods and only 10 articles conducted with using mix-methods. In other words, most of the research in the ship collision subject established more quantitative methods rather than other methods. Therefore, there is lack of qualitative and mix-methods used in this subject matter. The methodological gap is need to be fulfilled in the future study.

Based on Table 1, most of ship collision research were conducted in China with 21 studies. Thus, China has become one of the main research loci regarding the factors causing ship accidents. This is because China has heavy ship traffic and a lot of shipping activity. Meanwhile Europe, Norway and Brazil are still significant research loci with each 3 studies. Norway, for example, is known for its advanced shipping industry and involvement in global shipping activities, so there is quite high interest in research on ship accidents and their causal factors. Other countries or continents spread that have less than 2 studies are included. However, there are no studies yet related to ship collision factors conducted in Indonesia. By looking at this distribution, researchers can identify areas that may require more research or focus in understanding the factors that contribute to ship accidents worldwide).

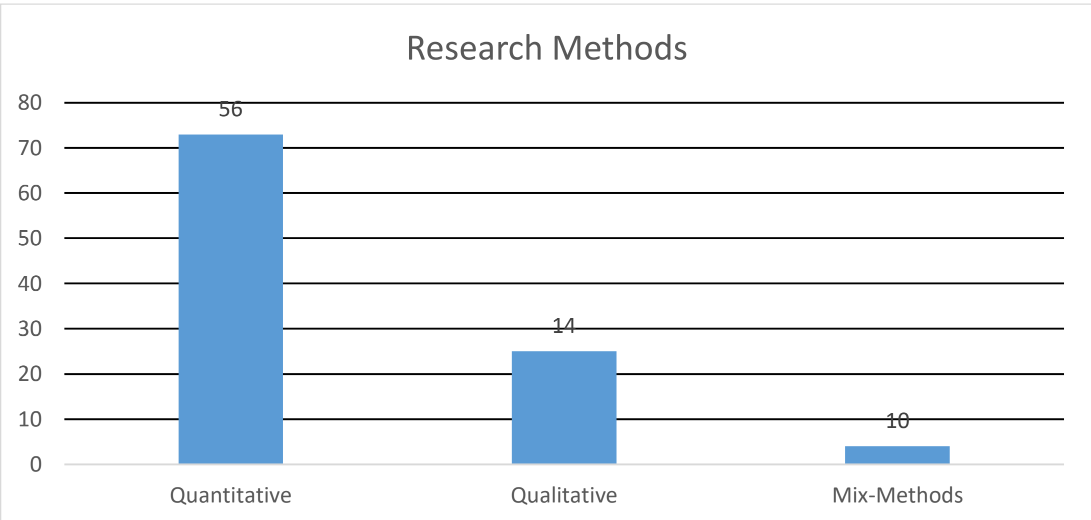

Figure 2: Research Method

ISSN 1533-9211

DOI: 10.5281/zenodo.13363846

Table 1: A Summary of the Study Contexts (Geographical Location)

	Country	Frequency
Geographical locations (Country or Continent) of the included studies by descending order (based on the number of studies identified)	China	21
	Eropa	3
	Norwegia	3
	Brazil	3
	Hongkong	2
	Korea	2
	Canada	2
	America	2
	Spain	2
	Australia	2
	Italia	2
	Singapura	2
	Taiwan	2
	Turkey	2
	Other Countries or Continent	30
Total		**80**

3.2. Content Analysis

In this section, we conducted content analysis by using systematic literature review to answer the research question based on the extracted dataset. The content analysis was performed by synthesizing the dataset especially the determinants (factors/variables/parameters) of ship collision. Research on the determinants of ship collisions is critically important due to the multifaceted impacts such incidents have on safety, the environment, and the economy. Understanding the factors contributing to ship collisions can lead to the development of more effective safety regulations, improved ship design, and better training programs for crew members, thereby enhancing maritime safety. This research helps identify and mitigate risks associated with human error, technical failures, environmental conditions, and operational practices. For governments, the insights gained from such studies can inform policy-making, leading to stricter enforcement of maritime laws and the establishment of safer shipping lanes. For the shipping industry, it can lead to reduced insurance costs and liabilities by decreasing the likelihood of accidents. Moreover, environmental benefits include the prevention of oil spills and other pollutants, protecting marine ecosystems and coastal communities. Overall, the research has broad implications for public safety, economic stability, and environmental conservation, making it a crucial area of study in maritime management.

The following are several factors that have been identified through a systematic review related to ship collision. We have synthesized and categorized all determinant of ship collision into 7 (seven) main factors as follows:

3.2.1. Human Factors

Human factors play a crucial role in ship collisions. Navigational errors are often caused by inadequate knowledge or skills of the crew. Inexperienced or poorly trained crew members may not be able to correctly read and interpret navigational instruments, leading to errors in

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

determining the ship's position or direction. For example, incorrect navigation in adverse weather conditions such as thick fog or storms, or in areas with dense traffic such as ports or narrow straits, can easily cause collisions. In such situations, the crew's ability to make precise and quick decisions is vital, but this is often hindered by fatigue.

Fatigue is a major issue that affects the crew's ability to make quick and accurate decisions. Fatigue can be caused by long working hours without adequate rest, resulting in decreased alertness and slower reflexes. Fatigued crew members may struggle to maintain concentration and alertness, making them more prone to errors in navigation or responding to emergencies. The lack of crew readiness also plays a significant role in collision incidents. This includes insufficient training in handling emergency situations or the absence of strict supervision of operational activities. Unprepared crew members may not know how to respond correctly in critical situations, such as equipment failures or sudden changes in weather conditions.

Decision-making errors, such as misinterpreting navigational charts or receiving incorrect instructions from the captain, can lead to the wrong direction and ultimately cause collisions. These incorrect decisions often stem from a lack of experience or inadequate training. Additionally, in some cases, pressure to meet tight schedules or reduce operational costs can result in hasty and unsafe decision-making. Therefore, improving training and stricter supervision of the crew is essential to reduce the risk of human error. Continuous training and effective supervision can help ensure that the crew has the knowledge and skills needed to operate the ship safely and efficiently, as well as the ability to respond correctly in emergency situations.

3.2.2. Environmental Condition

Extreme environmental conditions significantly increase the risk of ship collisions. Poor weather, such as thick fog, can reduce visibility, making navigation very difficult even with advanced technologies like radar. Thick fog can obscure other ships or obstacles ahead, making it hard for the crew to anticipate and avoid potential collisions.

Additionally, storms with strong winds and heavy rain can destabilize the ship, causing it to sway violently and become difficult to control. In such conditions, the crew's ability to maintain control of the ship is severely compromised, increasing the likelihood of collisions. Geographical factors also play a crucial role in collision risk. In areas with narrow or winding navigation routes, such as straits or rivers, incorrect maneuvers can easily lead to collisions. Large ships require more space to maneuver, and if that space is limited, the risk of collisions becomes higher.

Strong currents and high waves add further challenges to navigation. Strong currents can push the ship off its intended course, requiring the crew to constantly correct the ship's direction. High waves can cause the ship to rock and lose control, especially if the waves come from unexpected directions. In such situations, the crew's ability to react quickly and take appropriate action is crucial. The use of weather and ocean current prediction technology can help plan safer routes, providing accurate information about the weather and currents that may be encountered during the journey.

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

However, the skills and readiness of the crew remain key factors in facing challenging environmental conditions. Technology can provide tools, but ultimately, human decisions and actions will determine the ship's safety. Therefore, continuous training and sufficient field experience for the crew are essential to tackle navigational challenges in extreme environmental conditions.

3.2.3. Technical and Maintenance Errors

Failures in navigation systems, such as radar and GPS, are among the primary technical factors contributing to ship collisions. These systems are crucial for accurately determining a ship's position and direction, as well as for avoiding hazards such as other vessels or obstacles at sea. When these systems malfunction, the captain and crew are forced to rely on manual navigation methods, which are often less precise and more prone to errors. Additionally, poor technical conditions of the ship, such as poorly maintained engines or unresponsive steering systems, can disrupt the vessel's operations and significantly increase the risk of collision.

The lack of maintenance on ship equipment presents another serious issue. Equipment that is not well-maintained is more likely to fail, especially during critical moments. For instance, an uncalibrated radar or a malfunctioning communication radio can severely impede the ship's ability to detect hazards and communicate effectively with other vessels or port authorities.

This can lead to delayed reactions and poor decision-making, further heightening the risk of accidents. Therefore, a rigorous and routine maintenance program is essential to ensure that all equipment functions correctly, thereby reducing the likelihood of accidents caused by technical failures. Regular maintenance checks can identify and address potential issues before they escalate, ensuring the reliability and safety of the ship's operations.

3.2.4. Safety Management and Risk Assessment

Ineffective safety management and inadequate risk assessment often constitute the root causes of ship collisions. The failure to implement established safety standards, whether international or local, can significantly increase the risk of accidents. For example, the lack of adequate training for crew members on safety procedures or negligence in conducting routine inspections of safety equipment can lead to dangerous situations. Additionally, ineffective risk management, such as the absence of thorough risk analysis before commencing a voyage or the lack of contingency plans for emergency situations, also contributes to the occurrence of collisions.

Unauthorized changes to travel plans can further heighten the risk of accidents. Modifying routes without proper knowledge or approval can direct a ship into more dangerous or congested areas. Ineffective communication between ships or with port authorities is another critical factor. Misunderstandings or miscommunications regarding the position or intentions of other vessels can result in incorrect maneuvers, ultimately leading to collisions. Poor coordination in navigation, especially in crowded waters, also amplifies the likelihood of accidents. It is essential that all parties involved in maritime navigation maintain clear and effective communication to ensure the safety of all vessels in the vicinity.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

3.2.5. Regulatory Violations

Violations of international and local navigation rules, such as the COLREGs (Convention on the International Regulations for Preventing Collisions at Sea), significantly increase the risk of ship collisions. These regulations are designed to ensure that all vessels at sea follow a common set of guidelines regarding right of way, safe speeds, and procedures to avoid collisions. When these rules are not adhered to, the likelihood of conflicts between vessels rises sharply. For instance, failure to yield the right of way to a ship navigating through narrow channels or harbors can result in direct collisions, posing severe risks to both vessels involved.

Moreover, compliance with regulations goes beyond merely knowing the rules; it requires consistent and effective implementation in practice. Ships that are not equipped with the necessary safety equipment or that fail to execute recommended maneuvers in specific situations endanger themselves and other vessels. Regulatory violations also include unethical behaviors, such as attempting to cut ahead in busy waterways or sailing too close to other ships to save time. Such actions disrupt the orderly flow of maritime traffic and elevate the chances of accidents. Therefore, strict enforcement of rules and vigilant oversight by port authorities are crucial in mitigating the risk of collisions. Effective regulation enforcement ensures that all vessels operate within safe parameters, contributing to overall maritime safety and preventing avoidable incidents.

3.2.6. Traffic Density

The density of maritime traffic in certain waters creates complex and challenging navigation situations, significantly increasing the likelihood of collisions. High-traffic areas such as narrow straits, busy ports, and crowded shipping lanes demand extra vigilance and precise navigational skills from ship crews. In these conditions, the closer proximity of vessels elevates the risk that even minor errors can have catastrophic consequences. Miscalculations in timing or speed, or untimely maneuvers, can swiftly lead to uncontrollable situations and ultimately result in collisions. Furthermore, the high traffic density impacts the crew's ability to respond to emerging threats effectively. Reduced reaction times and limited maneuvering space make navigation more difficult and heighten the pressure on the crew to make quick and accurate decisions. This situation is exacerbated by the possibility of vessels not adhering to navigational rules correctly, adding to the complexity and risks faced by other ships. The crowded conditions mean that any miscommunication or error can rapidly escalate, emphasizing the need for constant vigilance and expert handling of the ship.

Effective traffic management is crucial in such high-density areas, requiring the deployment of advanced surveillance and communication technologies to ensure safety. Utilizing systems like Automatic Identification System (AIS) and Vessel Traffic Services (VTS) can provide real-time data and enhance situational awareness, enabling better coordination among ships and with port authorities. These technologies help in monitoring traffic patterns, predicting potential collision points, and advising on safer navigational practices. Thus, the integration of such technologies, alongside skilled crew operations, is essential to mitigate collision risks in congested maritime zones.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

3.2.7. Technology Development and Risk Prediction

The development of advanced technology and risk prediction capabilities has had a significant impact on efforts to prevent ship collisions. Technologies such as the Automatic Identification System (AIS) enable ships to automatically transmit and receive information about their position, direction, and speed. This facilitates the detection and avoidance of potential collisions by providing real-time data that can be used to monitor and manage ship movements. When combined with radar and GPS, AIS offers a comprehensive view of the navigational environment, allowing crew members to make more accurate and timely decisions to avoid hazards. Moreover, risk prediction models supported by artificial intelligence and big data analytics play a crucial role in enhancing maritime safety. By leveraging historical and real-time data, these models can predict the likelihood of collisions based on various factors such as weather conditions, traffic density, and ship performance. These predictive capabilities allow ships to adjust their routes and speeds well in advance of entering high-risk areas, thereby reducing the chances of accidents. The integration of these technologies into ship navigation management not only enhances safety but also improves operational efficiency and sustainability within the maritime industry. The benefits of incorporating advanced technology and predictive models extend beyond immediate safety improvements. They also contribute to long-term strategic planning and resource optimization. Enhanced navigational accuracy reduces fuel consumption and emissions, aligning with environmental sustainability goals. Additionally, the ability to foresee and mitigate risks leads to lower insurance premiums and liability costs, providing economic advantages for shipping companies. Overall, the adoption of these technological advancements fosters a safer, more efficient, and environmentally responsible maritime sector.

3.2.8. Gap Analysis

Based on al 80 studies, we analysed the 7 (seven) main factors based on their occurrence especially how frequently they were cited in the studies. This is important to underline what factors are those that have been widely studied and rarely researched by scholars so far, so they require further study in the context of maritime safety, especially in the field of ship collisions. Table 2 shows the factor analysis based on the number of studies obtained. In analysing the main factors influencing ship collisions, there is a variation in the frequency of studies addressing each factor. This frequency provides an overview of the level of research attention given to each factor and indicates gaps in the literature that need further exploration.

Table 2: Factor Analysis Based on Number of Studies

No	Determinant (Factors)	Number of Studies	Sources
1	Human Factors	50	(Martins & Maturana, 2013), (Maturana & Martins,2019), (Montewka et al., 2012), (J. M. Mou et al., 2010), (Moulas et al., 2017), (Park & Jeong, 2021), (Quy et al., 2020), (Rawson & Brito, 2021), (Sahin & Kum, 2015), (Shuai et al., 2020), (Szlapczynski & Szlapczynska, 2017), (Tan et al., 2019), (Tort Castro et al., 2022), (Uğurlu et al., 2015), (Martins & Maturana, 2010), (Ung, 2019), (N. Wang et al., 2020), (T. Wang et al., 2020), (Weng et al., 2018), (Xu

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

			& Kim, 2023), (Yahya et al., 2021),(J. Zhang et al., 2018), (M. Zhang et al., 2019), (W. Zhang et al., 2017), (Y. Zhang et al., 2022), (Zhao et al., 2021), (Zhen et al., 2023), (Ayyub et al., 2002), (Islam & Yazdani, 2008), (Baksh et al., 2018), (Bulian et al., 2019), (Cai et al., 2021), (P. Chen et al., 2019), (S. Chen et al., 2014), (Danczyk et al., 2015), (Endrina et al., 2019), (Fang et al., 2019), (Fiskin et al., 2021), (Gil, 2021), (Guan et al., 2020), (Han et al., 2021), (Hänninen et al., 2014), (Hassel et al., 2021), (Heij & Knapp, 2019), (Hosack et al., 2017), (Kaptan et al., 2021), (R. U. Khan et al., 2020), (G. Li et al., 2021), (W. Li et al., 2020), (Lu et al., 2020).
2	Environmental conditions	45	(Montewka et al., 2017), (Montewka et al., 2012), (J. M. Mou et al., 2010), (J. Mou et al., 2021), (Moulas et al., 2017), (Park & Jeong, 2021), (Quy et al., 2020), (Rawson & Brito, 2021), (Sahin & Kum, 2015), (Shang & Tseng, 2010), (Shuai et al., 2020), (Szlapczynski & Szlapczynska, 2017), (Tan et al., 2019), (Tort Castro et al., 2022), (T. Wang et al., 2020), (Weng et al., 2018), (Weng & Yang, 2015), (Xu & Kim, 2023), (Xu et al., 2022), (Yip, 2008), (J. Zhang et al., 2021), (M. Zhang et al., 2019), (L. Zhang et al., 2019), (W. Zhang et al., 2015), (W. Zhang et al., 2017), (Y. Zhang et al., 2022), (Zhao et al., 2021), (Zhu et al., 2023), (Afenyo et al., 2017), (Ayyub et al., 2002), (Islam & Yazdani, 2008), (Ju & Jang, 2019), (Bulian et al., 2020), (Cai et al., 2021), (P. Chen et al., 2019), (S. Chen et al., 2014), (Danczyk et al., 2015), (Gil, 2021), (Guan et al., 2020),(Hänninen et al., 2014), (Hassel et al., 2021), (Heij & Knapp, 2019), (B. Khan et al., 2020), (R. U. Khan et al., 2020), (G. Li et al., 2021), (Lu et al., 2020).
3	Technical and maintenance errors	33	(Martins & Maturana, 2010), (Maturana & Martins, 2019), (Montewka et al., 2017), (Montewka et al., 2012), (J. Mou et al., 2021), (Park & Jeong, 2021), (Rawson & Brito, 2021), (Sahin & Kum, 2015), (Shang & Tseng, 2010), (Shuai et al., 2020), (Szlapczynski & Szlapczynska, 2017), (Tan et al., 2019), (T. Wang et al., 2020), (Weng & Yang, 2015), (Xu & Kim, 2023), (Xu et al., 2022), (W. Zhang et al., 2017), (Y. Zhang et al., 2022), (Zhen et al., 2023), (Afenyo et al., 2017), (Ayyub et al., 2002), (Argüelles et al., 2021), (Bulian et al., 2019), (Cai et al., 2021), (Charter Jr, 1979), (H. Chen et al., 2004), (Debnath et al., 2011), (Gil, 2021), (Han et al., 2021), (Hassel et al., 2021), (Heij & Knapp, 2019), (R. U. Khan et al., 2020), (Lu et al., 2020).
4	Safety management and risk assessment	23	(Martins & Maturana, 2010), (Martins & Maturana, 2013), (Mayer, 1974), (J. M. Mou et al., 2010), (Rawson & Brito, 2021), (Sahin & Kum, 2015), (Tan et al., 2019), (Ung, 2019), (Yang & Han, 2023), (L. Zhang et al., 2019), (Y. Zhang et al., 2022), (Zhao et al., 2021), (Ahn et al., 2012), (Islam & Yazdani, 2008), (Argüelles et al., 2021), (Baksh et al., 2018), (Cai et al., 2021), (Charter, 1979), (Chauvin et al., 2013), (Fang et al., 2019), (Heij & Knapp, 2019), (Hu et al., 2020), (R. U. Khan et al., 2020).
5	Regulatory violations	15	(Martins & Maturana, 2010), (Montewka et al., 2012), (J. M. Mou et al., 2010), (Park & Jeong, 2021), (Quy et al., 2020), (Shuai et al., 2020), (Szlapczynski & Szlapczynska, 2017), (Uğurlu et al., 2015), (Martins & Maturana, 2010), (M. Zhang et al., 2019), (W. Zhang et al., 2017), (Zhen et al., 2023), (Argüelles et al., 2021), (Fiskin et al.,

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

			2021), (W. Li et al., 2020).
6	Traffic density	13	(Mayer, 1974), (Montewka et al., 2017), (Montewka et al., 2012), (J. M. Mou et al., 2010), (Quy et al., 2020), (Rawson & Brito, 2021), (Sahin & Kum, 2015), (Shuai et al., 2020), (Szlapczynski & Szlapczynska, 2017), (Tan et al., 2019), (Tort Castro et al., 2022), (Y. Zhang et al., 2022), (Zhu et al., 2023).
7	Technology development and risk prediction	18	(Martins & Maturana, 2010), (N. Wang et al., 2020), (T. Wang et al., 2020), (Wu et al., 2019), (Xu & Kim, 2023), (W. Zhang et al., 2015), (D. Zhou & Zheng, 2019), (W. Zhou et al., 2022), (Ahn et al., 2012), (Baksh et al., 2018), (P. Chen et al., 2019), (S. Chen et al., 2014), (Fang et al., 2019), (Fiskin et al., 2021), (Hu et al., 2020), (Kaptan et al., 2021), (Y. Li et al., 2018), (Liu et al., 2020).

Human factors are the most discussed in the literature with a frequency of 50 studies, indicating that this aspect is considered a major contributor in ship collision incidents. It indicates that human factors were mainly studied in the field of ship collision. This suggests that navigation errors, fatigue, lack of crew preparedness, and inadequate surveillance are major concerns in research on ship collisions. This extensive research reflects an awareness of the importance of understanding human error, fatigue, and decision making in maritime operations. This factor is closely related to efforts to improve crew training and supervision to reduce navigation errors and increase safety at sea. Environmental conditions are in second place with 45 studies, also indicating significant attention to the impact of bad weather, geographical conditions, and other natural factors. Studies on environmental conditions emphasize the importance of technology and mitigation strategies to reduce the risks posed by these factors. However, although this factor is very important, the number of studies is still slightly lower compared to human factors, indicating potential for further research on the specific impacts of environmental conditions on various types of ships and shipping routes. Technical and maintenance errors have 33 studies, placing them in third position. This number reflects considerable attention to technical failures and the importance of proper maintenance to ensure the operational safety of ships. This factor involves an in-depth analysis of navigation technology and the technical condition of ships. However, compared to human factors and environmental conditions, there is a significant gap that indicates the need for further research to develop more reliable technology and effective maintenance systems. Errors in safety management and risk assessment are discussed in 23 studies. Although this number is significant, it indicates a larger gap compared to the three main factors above. Further research is needed to develop and implement more effective safety standards and better risk assessment methods. Focusing on comprehensive safety management and better coordination between ships and with port authorities can help reduce the risk of collisions. Regulation violations are only discussed in 15 studies, indicating that this factor receives less attention in the literature compared to other factors. However, compliance with international and local navigation rules is crucial to reducing collision risks. This gap indicates the need for further research to understand why regulation violations occur and how to improve compliance through education, training, and more effective law enforcement. Traffic density is the least discussed factor with only 13 studies. Given that vessel traffic density increases the complexity of navigation and the risk of collisions, especially in busy port areas and shipping routes, this low frequency indicates an urgent need for further research on how to effectively

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

manage traffic density and the development of technologies that can aid navigation in congested waters it is very necessary. Finally, the development of technology and risk prediction is discussed in 18 studies, indicating growing interest in using advanced technology to reduce collision risks. However, the number of studies is still relatively low, suggesting significant potential for further research in developing and implementing new technologies and more advanced risk prediction models. Additional research can help utilize technology more effectively to improve maritime safety and operational efficiency

4. CONCLUSION

This systematic review aims to understand the main factors that influence ship collisions through a systematic review of existing literature. Based on the analysis that has been carried out, there are seven main factors that influence the risk of ship collisions: human factors, environmental conditions, technical and maintenance errors, safety management and risk assessment, regulatory violations, traffic density, as well as technology development and risk prediction. This research makes a significant contribution to the understanding of the main factors influencing the risk of ship collisions. By identifying and elaborating on seven key factors—human factors, environmental conditions, technical and maintenance errors, safety management and risk assessment, regulatory violations, traffic density, and technology development and risk prediction—this research provides a comprehensive foundation for policy makers, ship managers, and researchers to develop more effective risk mitigation strategies. This research also highlights the importance of integrating advanced technology in navigation management and risk management, which can improve safety and operational efficiency in the maritime industry.

Moreover, from gap analysis we obtained that traffic density was the least discussed factor among the studies. Given that vessel traffic density increases the complexity of navigation and the risk of collisions, especially in busy port areas and shipping routes, this low frequency indicates an urgent need for further research on how to effectively manage traffic density and the development of technologies and algorithm that can aid navigation in congested waters it is very necessary. Thus, further research should be conducted in this area such as 1) Developing multi-agent simulations to analyze traffic density in maritime environments. This approach can replicate the complex interactions between various ships in busy traffic conditions. The research could involve creating models to represent different types of vessels with distinct behaviors and goals, helping to understand how individual navigation decisions impact overall traffic dynamics. Additionally, applying algorithms in simulations to test various risk reduction strategies, such as route optimization, speed regulation, and more efficient maneuvering strategies, could be beneficial. Lastly, simulations can evaluate the effectiveness of existing maritime traffic regulations and explore new policies to reduce congestion and enhance safety; 2) Future research should utilize Automatic Identification System (AIS) data for traffic prediction and management. This data provides real-time information on ship positions, courses, and speeds. Further studies can focus on developing predictive models using historical AIS data to anticipate traffic density and high-risk situations, applying techniques like machine learning and deep learning to forecast traffic patterns. Integrating these predictive models with

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

ship navigation systems could offer real-time route recommendations to avoid high-density areas or other risky situations. Additionally, AIS data can be employed in multi-agent simulations for real-time exercises and drills, enhancing crew training in managing busy traffic conditions.

References

1) Afenyo, M., Khan, F., Veitch, B., & Yang, M. (2017). Arctic shipping accident scenario analysis using Bayesian Network approach. *Ocean Engineering*, *133*, 224–230.

2) Ahn, J. H., Rhee, K. P., & You, Y. J. (2012). A study on the collision avoidance of a ship using neural networks and fuzzy logic. *Applied Ocean Research*, *37*, 162–173. https://doi.org/10.1016/j.apor.2012.05.008

3) Argüelles, R. P., Maza, J. A. G., Martín, F. M., & Bartolomé, M. (2021). Ship-to-ship dialogues and agreements for collision risk reduction. *The Journal of Navigation*, *74*(5), 1039–1056.

4) Ayyub, B. M., Beach, J. E., Sarkani, S., & Assakkaf, I. A. (2002). Risk analysis and management for marine systems. *Naval Engineers Journal*, *114*(2), 181–206.

5) Baksh, A.-A., Abbassi, R., Garaniya, V., & Khan, F. (2018). Marine transportation risk assessment using Bayesian Network: Application to Arctic waters. *Ocean Engineering*, *159*, 422–436.

6) Bulian, G., Cardinale, M., Dafermos, G., Lindroth, D., Ruponen, P., & Zaraphonitis, G. (2020). Probabilistic assessment of damaged survivability of passenger ships in case of grounding or contact. *Ocean Engineering*, *218*, 107396.

7) Bulian, G., Cardinale, M., Francescutto, A., & Zaraphonitis, G. (2019). Complementing SOLAS damage ship stability framework with a probabilistic description for the extent of collision damage below the waterline. *Ocean Engineering*, *186*, 106073.

8) Cai, M., Zhang, J., Zhang, D., Yuan, X., & Soares, C. G. (2021). Collision risk analysis on ferry ships in Jiangsu Section of the Yangtze River based on AIS data. *Reliability Engineering & System Safety*, *215*, 107901.

9) Charter Jr, D. B. (1979). Determination of risk of collision using twentieth century techniques. *Navigation*, *26*(3), 237–243.

10) Chauvin, C., Lardjane, S., Morel, G., Clostermann, J.-P., & Langard, B. (2013). Human and organisational factors in maritime accidents: Analysis of collisions at sea using the HFACS. *Accident Analysis & Prevention*, *59*, 26–37.

11) Chen, H., Moan, T., Haver, S., & Larsen, K. (2004). Prediction of relative motion and probability of contact between FPSO and shuttle tanker in tandem offloading operation. *J. Offshore Mech. Arct. Eng.*, *126*(3), 235–242.

12) Chen, P., Mou, J., & Van Gelder, P. (2019). Integration of individual encounter information into causation probability modelling of ship collision accidents. *Safety Science*, *120*, 636–651.

13) Chen, S., Ahmad, R., Lee, B. G., & Kim, D. H. (2014). Composition ship collision risk based on fuzzy theory. *Journal of Central South University*, *21*(11), 4296–4302. https://doi.org/10.1007/s11771-014-2428-z

14) Danczyk, J., Jacobs, P., Thornton, C. W., Kane, S., & Farry, M. (2015). Visualizing Constraints and Awareness of Submarine Maneuverability and Detectability. *Procedia Manufacturing*, *3*, 5155–5160.

15) Debnath, A. K., Chin, H. C., & Haque, M. M. (2011). Modelling port water collision risk using traffic conflicts. *The Journal of Navigation*, *64*(4), 645–655.

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

16) Endrina, N., Konovessis, D., Sourina, O., & Krishnan, G. (2019). Influence of ship design and operational factors on human performance and evaluation of effects and sensitivity using risk models. *Ocean Engineering*, *184*, 143–158.

17) Fang, Z., Yu, H., Ke, R., Shaw, S. L., & Peng, G. (2019). Automatic Identification System-Based Approach for Assessing the Near-Miss Collision Risk Dynamics of Ships in Ports. *IEEE Transactions on Intelligent Transportation Systems*, *20*(2), 534–543. https://doi.org/10.1109/TITS.2018.2816122

18) Fiskin, R., Atik, O., Kisi, H., Nasibov, E., & Johansen, T. A. (2021). Fuzzy domain and meta-heuristic algorithm-based collision avoidance control for ships: Experimental validation in virtual and real environment. *Ocean Engineering*, *220*, 108502.

19) Gil, M. (2021). A concept of critical safety area applicable for an obstacle-avoidance process for manned and autonomous ships. *Reliability Engineering & System Safety*, *214*, 107806.

20) Guan, Z., Wang, Y., Zhou, Z., & Wang, H. (2020). Research on early warning of ship danger based on composition fuzzy inference. *Journal of Marine Science and Engineering*, *8*(12), 1002.

21) Han, S., Wang, T., Chen, J., Wang, Y., Zhu, B., & Zhou, Y. (2021). Towards the Human–Machine Interaction: Strategies, Design, and Human Reliability Assessment of Crews' Response to Daily Cargo Ship Navigation Tasks. *Sustainability*, *13*(15), 8173.

22) Hänninen, M., Mazaheri, A., Kujala, P., Montewka, J., Laaksonen, P., Salmiovirta, M., & Klang, M. (2014). Expert elicitation of a navigation service implementation effects on ship groundings and collisions in the Gulf of Finland. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *228*(1), 19–28.

23) Hassel, M., Utne, I. B., & Vinnem, J. E. (2021). An allision risk model for passing vessels and offshore oil and gas installations on the Norwegian Continental Shelf. *Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability*, *235*(1), 17–32.

24) Heij, C., & Knapp, S. (2019). Shipping inspections, detentions, and incidents: an empirical analysis of risk dimensions. *Maritime Policy & Management*, *46*(7), 866–883.

25) Hosack, G. R., Hayes, K. R., & Barry, S. C. (2017). Prior elicitation for Bayesian generalised linear models with application to risk control option assessment. *Reliability Engineering & System Safety*, *167*, 351–361.

26) Hu, Y., Zhang, A., Tian, W., Zhang, J., & Hou, Z. (2020). Multi-ship collision avoidance decision-making based on collision risk index. *Journal of Marine Science and Engineering*, *8*(9), 640.

27) Islam, A. K. M. A., & Yazdani, N. (2008). Performance of AASHTO girder bridges under blast loading. *Engineering Structures*, *30*(7), 1922–1937.

28) Ju, H. B., & Jang, B. S. (2019). A simplified method for assessing safety of ship collision event. In *Trends in the Analysis and Design of Marine Structures - Proceedings of the 7th International Conference on Marine Structures, MARSTRUCT 2019* (pp. 218–224). https://doi.org/10.1201/9780429298875-25

29) Kaptan, M., Uğurlu, Ö., & Wang, J. (2021). The effect of nonconformities encountered in the use of technology on the occurrence of collision, contact and grounding accidents. *Reliability Engineering & System Safety*, *215*, 107886.

30) Khan, B., Khan, F., & Veitch, B. (2020). A Dynamic Bayesian Network model for ship-ice collision risk in the Arctic waters. *Safety Science*, *130*, 104858.

31) Khan, R. U., Yin, J., Mustafa, F. S., & Liu, H. (2020). Risk assessment and decision support for sustainable traffic safety in Hong Kong waters. *IEEE Access*, *8*, 72893–72909.

32) Li, G., Weng, J., & Hou, Z. (2021). Impact analysis of external factors on human errors using the ARBN method based on small-sample ship collision records. *Ocean Engineering*, *236*, 109533.

ISSN 1533-9211

DOI: 10.5281/zenodo.13363846

33) Li, W., Yang, J., Gao, X., & Yu, J. (2020). Modelling and simulation of intelligent collision avoidance based on ship domain. *International Journal of Simulation and Process Modelling*, *15*(1–2), 64–75.

34) Li, Y., Guo, Z., Yang, J., Fang, H., & Hu, Y. (2018). Prediction of ship collision risk based on CART. *IET Intelligent Transport Systems*, *12*(10), 1345–1350.

35) Liu, H., Zhang, L., & Liu, S. (2020). Modeling of ship collision risk based on cloud model. *IEEE Access*, *8*, 221162–221175.

36) Lu, L., Goerlandt, F., Tabri, K., Höglund, A., Banda, O. A. V., & Kujala, P. (2020). Critical aspects for collision induced oil spill response and recovery system in ice conditions: A model-based analysis. *Journal of Loss Prevention in the Process Industries*, *66*, 104198.

37) Martins, M. R., & Maturana, M. C. (2010). Human error contribution in collision and grounding of oil tankers. *Risk Analysis: An International Journal*, *30*(4), 674–698.

38) Martins, M. R., & Maturana, M. C. (2013). Application of Bayesian Belief networks to the human reliability analysis of an oil tanker operation focusing on collision accidents. *Reliability Engineering & System Safety*, *110*, 89–109.

39) Maturana, M. C., & Martins, M. R. (2019). Technique for early consideration of human reliability: applying a generic model in an oil tanker operation to study scenarios of collision. *Journal of Offshore Mechanics and Arctic Engineering*, *141*(5), 51607.

40) Mayer, H. E. (1974). Hazards at sea. *Accident Analysis and Prevention*, *6*(1), 83–84. https://doi.org/10.1016/0001-4575(74)90017-7

41) Montewka, J., Goerlandt, F., Innes-Jones, G., Owen, D., Hifi, Y., & Puisa, R. (2017). Enhancing human performance in ship operations by modifying global design factors at the design stage. *Reliability Engineering & System Safety*, *159*, 283–300.

42) Montewka, J., Goerlandt, F., & Kujala, P. (2012). Determination of collision criteria and causation factors appropriate to a model for estimating the probability of maritime accidents. *Ocean Engineering*, *40*, 50–61.

43) Mou, J., Jia, X., Chen, P., & Chen, L. (2021). Research on operation safety of offshore wind farms. *Journal of Marine Science and Engineering*, *9*(8), 881.

44) Mou, J. M., Van der Tak, C., & Ligteringen, H. (2010). Study on collision avoidance in busy waterways by using AIS data. *Ocean Engineering*, *37*(5–6), 483–490.

45) Moulas, D., Shafiee, M., & Mehmanparast, A. (2017). Damage analysis of ship collisions with offshore wind turbine foundations. *Ocean Engineering*, *143*, 149–162.

46) Park, J., & Jeong, J. S. (2021). An estimation of ship collision risk based on relevance vector machine. *Journal of Marine Science and Engineering*, *9*(5). https://doi.org/10.3390/jmse9050538

47) Quy, N. M., Łazuga, K., Gucma, L., Vrijling, J. K., & van Gelder, P. (2020). Towards generalized ship's manoeuvre models based on real time simulation results in port approach areas. *Ocean Engineering*, *209*, 107476.

48) Rawson, A., & Brito, M. (2021). Developing contextually aware ship domains using machine learning. *The Journal of Navigation*, *74*(3), 515–532.

49) Sahin, B., & Kum, S. (2015). Risk assessment of Arctic navigation by using improved fuzzy-AHP approach. *International Journal of Maritime Engineering*, *157*(A4).

50) Shang, K. C., & Tseng, W. J. (2010). A risk analysis of stevedoring operations in seaport container terminals. *Journal of Marine Science and Technology*, *18*(2), 201–210. https://doi.org/10.51400/2709-6998.2319

The Seybold Report
ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

51) Shuai, Y., Li, G., Xu, J., & Zhang, H. (2020). An effective ship control strategy for collision-free maneuver toward a dock. *IEEE Access*, *8*, 110140–110152.

52) Szlapczynski, R., & Szlapczynska, J. (2017). Review of ship safety domains: Models and applications. *Ocean Engineering*, *145*, 277–289.

53) Tan, X., Tao, J., & Konovessis, D. (2019). Preliminary design of a tanker ship in the context of collision-induced environmental-risk-based ship design. *Ocean Engineering*, *181*, 185–197.

54) Tort Castro, B., Prieto González, R., O'Callaghan, S. A., Dominguez Rein-Loring, P., & Degollada Bastos, E. (2022). Ship strike risk for fin whales (Balaenoptera physalus) Off the Garraf coast, Northwest Mediterranean Sea. *Frontiers in Marine Science*, *9*, 867287.

55) Uğurlu, Ö., Köse, E., Yıldırım, U., & Yüksekyıldız, E. (2015). Marine accident analysis for collision and grounding in oil tanker using FTA method. *Maritime Policy & Management*, *42*(2), 163–185.

56) Ung, S. T. (2019). Evaluation of human error contribution to oil tanker collision using fault tree analysis and modified fuzzy Bayesian Network based CREAM. *Ocean Engineering*, *179*, 159–172. https://doi.org/10.1016/j.oceaneng.2019.03.031

57) Wang, N., Chang, D., Yuan, J., Shi, X., & Bai, X. (2020). How to maintain the safety level with the increasing capacity of the fairway: A case study of the Yangtze Estuary Deepwater Channel. *Ocean Engineering*, *216*, 108122.

58) Wang, T., Wu, Q., A. Diaconeasa, M., Yan, X., & Mosleh, A. (2020). On the use of the hybrid causal logic methodology in ship collision risk assessment. *Journal of Marine Science and Engineering*, *8*(7), 485.

59) Weng, J., Li, G., Chai, T., & Yang, D. (2018). Evaluation of two-ship collision severity using ordered probit approaches. *The Journal of Navigation*, *71*(4), 822–836.

60) Weng, J., & Yang, D. (2015). Investigation of shipping accident injury severity and mortality. *Accident Analysis & Prevention*, *76*, 92–101.

61) Wu, B., Yip, T. L., Yan, X., & Soares, C. G. (2019). Fuzzy logic based approach for ship-bridge collision alert system. *Ocean Engineering*, *187*, 106152.

62) Xu, S., & Kim, E. (2023). Hybrid causal logic model for estimating the probability of an icebreaker–ship collision in an ice channel during an escort operation along the Northeast Passage. *Ocean Engineering*, *284*, 115264.

63) Xu, S., Kim, E., Haugen, S., & Zhang, M. (2022). A Bayesian network risk model for predicting ship besetting in ice during convoy operations along the Northern Sea Route. *Reliability Engineering & System Safety*, *223*, 108475.

64) Yahya, S., Supomo, H., & Nugroho, S. (2021). Risk Analysis of Ship Collision in Indonesian Water Using House of Risk. *J. Eng. Sci. Technol.*, *16*(6), 5044–5059.

65) Yang, X., & Han, Q. (2023). Improved DQN for Dynamic Obstacle Avoidance and Ship Path Planning. *Algorithms*, *16*(5), 220.

66) Yip, T. L. (2008). Port traffic risks - A study of accidents in Hong Kong waters. *Transportation Research Part E: Logistics and Transportation Review*, *44*(5), 921–931. https://doi.org/10.1016/j.tre.2006.09.002

67) Zhang, J., He, A., Fan, C., Yan, X., & Soares, C. G. (2021). Quantitative analysis on risk influencing factors in the Jiangsu segment of the Yangtze River. *Risk Analysis*, *41*(9), 1560–1578.

68) Zhang, J., Teixeira, Â. P., Soares, C. G., & Yan, X. (2018). Quantitative assessment of collision risk influence factors in the Tianjin port. *Safety Science*, *110*, 363–371.

ISSN 1533-9211
DOI: 10.5281/zenodo.13363846

69) 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.

70) Zhang, M., Zhang, D., Goerlandt, F., Yan, X., & Kujala, P. (2019). Use of HFACS and fault tree model for collision risk factors analysis of icebreaker assistance in ice-covered waters. *Safety Science*, *111*, 128–143. https://doi.org/10.1016/j.ssci.2018.07.002

71) Zhang, W., Goerlandt, F., Montewka, J., & Kujala, P. (2015). A method for detecting possible near miss ship collisions from AIS data. *Ocean Engineering*, *107*, 60–69.

72) Zhang, W., Kopca, C., Tang, J., Ma, D., & Wang, Y. (2017). A systematic approach for collision risk analysis based on AIS data. *The Journal of Navigation*, *70*(5), 1117–1132.

73) Zhang, Y., Zhai, Y., Chen, J., Xu, Q., Fu, S., & Wang, H. (2022). Factors contributing to fatality and injury outcomes of maritime accidents: a comparative study of two accident-prone areas. *Journal of Marine Science and Engineering*, *10*(12), 1945.

74) Zhao, C., Wu, B., Yip, T. L., & Lv, J. (2021). Use of fuzzy fault tree analysis and noisy-or gate bayesian network for navigational risk assessment in qingzhou port. *TransNav*, *15*(4), 765–771. https://doi.org/10.12716/1001.15.04.07

75) Zhen, R., Gu, Q., Shi, Z., & Suo, Y. (2023). An improved A-star ship path-planning algorithm considering current, water depth, and traffic separation rules. *Journal of Marine Science and Engineering*, *11*(7), 1439.

76) Zhou, D., & Zheng, Z. (2019). Dynamic fuzzy ship domain considering the factors of own ship and other ships. *The Journal of Navigation*, *72*(2), 467–482.

77) Zhou, W., Li, Y., Xiao, Y., & Zheng, J. (2022). The Application of Automatic Identification System Information and PSO-LSTM Neural Network in CRI Prediction. *Computational Intelligence and Neuroscience*, *2022*(1), 8699322.

78) Zhu, W., Wang, S., Liu, S., Yang, L., Zheng, X., Li, B., & Zhang, L. (2023). Dynamic Multi-Period Maritime Accident Susceptibility Assessment Based on AIS Data and Random Forest Model. *Journal of Marine Science and Engineering*, *11*(10), 1935.