TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 18 Number 1 March 2024
DOI: 10.12716/1001.18.01.06

Collision and Contact – Analysis of Accidents at Sea

M. Bogalecka
Gdynia Maritime University, Gdynia, Poland

ABSTRACT: The analysis of sea accidents including the collision and contact of ships is the aim of this paper. The analysis of over 4,700 sea accidents that occurred between 2004 and 2021 reveals that the collisions and contacts are the most frequent initiating events for sea accidents. It is found that the collision and contact at the sea (as the primary event) can occur the next-step initiating event as well as the other primary events (e.g. fire, grounding, and damages) can occur the collision and contact (as the next-step initiating event). Moreover, the type and age of ships affected the collisions or contacts and the locations of sea accidents, as well as the consequences of these accidents, are analysed.

1 INTRODUCTION

The maritime transport plays a significant role in global trade and transportation. Approximately 90% of global trade is transported by sea [1]. Thus, it remains the backbone of global trade, facilitating the movement of goods and commodities, including raw materials, manufactured goods, and energy resources, across continents, connecting producers and consumers worldwide. The role of maritime transport is dynamic and subject to ongoing changes influenced by various factors, including global economic conditions, geopolitical developments, technological advancements, and environmental considerations [2-4]. The rapid growth of e-commerce has increased the demand for maritime transport [5]. As consumers increasingly rely on online shopping, maritime shipping plays a crucial role in transporting goods from manufacturing centres to consumer markets worldwide.

The intensity of maritime transport can have an influence on the occurrence of accidents at sea [6-12]. As the intensity of maritime transport rises, with more vessels operating in a given area, the density of traffic increases [13]. High traffic density can lead to a higher risk of accidents, including collisions between vessels. Manoeuvring in congested areas becomes more challenging, and the probability of human error or misjudgement increases. With increased maritime transport intensity, navigational challenges become more prominent. Busy shipping lanes, narrow waterways, and areas with complex navigational routes can increase the likelihood of accidents. Vessels may need to navigate through challenging conditions, such as heavy traffic, adverse weather, or restricted visibility, which can increase the risk of accidents. The intensity of maritime transport can place additional pressure on crew members, leading to fatigue, stress, or reduced attention levels. Increased workload and operational demands may contribute to human errors, which can be a significant factor in accidents at sea. Mistakes in navigation, communication, or judgment can also result in accidents [14,15]. The intensity of maritime transport can impact compliance with safety regulations. In busy shipping areas, some vessels may be tempted to cut corners or take shortcuts to meet tight schedules, potentially compromising safety measures. Adequate enforcement of safety regulations and oversight by maritime authorities are crucial to ensuring that vessels maintain compliance and minimize the risk of accidents. The intensity of maritime transport places demands on port infrastructure and capacity. Inadequate port facilities, such as limited berthing space or insufficient handling equipment, can lead to congestion and delays. These factors can contribute to accidents during port operations, including collisions, contact with port structures, or accidents involving handling equipment.

Efforts to manage and mitigate the risks associated with the intensity of maritime transport include improved navigation technologies, enhanced communication systems, better traffic management, and ongoing training programs for seafarers [16-23]. Regulatory bodies and industry organizations work towards promoting safe practices, enforcing regulations, and raising awareness to minimize accidents and ensure the safe and sustainable operation of maritime transport. The accident investigation also contributes to increased safety at sea. The aim of investigating sea accidents is to determine the causes, contributing factors, and circumstances surrounding the incident. The investigation aims to identify the underlying causes of the accident. This involves examining factors such as human error, equipment failure, environmental conditions, navigational challenges, or other contributing factors. Understanding the cause helps in preventing similar accidents in the future. Investigating sea accidents provides valuable insights into safety deficiencies and shortcomings. By identifying areas where safety measures can be improved, authorities, regulatory bodies, and industry stakeholders can take appropriate actions to enhance safety protocols, standards, and practices. This includes implementing new regulations, improving training programs, or enhancing equipment and infrastructure. One of the primary objectives of investigating sea accidents is to prevent similar incidents from occurring in the future. Lessons learned from investigations can lead to the implementation of measures aimed at preventing accidents, improving vessel design, enhancing crew training, strengthening safety regulations, and developing industry guidelines. The ultimate goal is to reduce the occurrence of accidents and improve the overall safety record of the maritime industry.

2 INVESTIGATION OF ACCIDENTS AT SEA

Investigations of sea accidents are typically conducted by competent authorities, such as maritime administrations, accident investigation boards, or specialized organizations at national and international levels [24-33]. The findings and recommendations from these investigations serve as a basis for implementing safety improvements and preventing similar accidents in the future. There are some key authorities involved in investigating sea accidents, such as: flag, port or coastal state authorities, accident investigation boards and commissions, classification societies, international bodies and cooperation and of course the International Maritime Organization (IMO).

The IMO is a specialized agency of the United Nations responsible for the safety, security, and environmental performance of international shipping. The IMO facilitates the investigation of marine accidents through its Casualty Investigation Code [34], which provides guidelines and standards for conducting investigations. The organization also promotes the exchange of information and lessons learned from accidents among member states. In certain circumstances, international bodies or cooperation may be involved in investigating sea accidents. For example, the IMO's Marine Casualty Investigation Facilitation Program assists member states in coordinating and conducting investigations into major accidents involving multiple countries or significant consequences [35].

The flag state of a vessel is responsible for regulating and overseeing its operations. When an accident involving a vessel flying its flag occurs, the flag state authority usually conducts an investigation [36-38]. They examine factors such as vessel maintenance, crew competence, compliance with regulations, and any potential violations of maritime laws. Port state authorities have the responsibility to ensure the safety and security of vessels visiting their ports [39]. If an accident occurs in port waters or involves a vessel in port, the port state authority may conduct an investigation. They focus on aspects such as port operations, vessel traffic management, pilotage, and compliance with port regulations. Coastal states have jurisdiction over their territorial waters and are responsible for enforcing maritime laws and regulations within those waters. They may investigate accidents occurring in their waters, especially if they involve multiple vessels or pose a significant risk to the marine environment or public safety. Many countries have dedicated accident investigation boards or commissions responsible for investigating major maritime accidents. These independent bodies conduct thorough investigations to determine the causes, contributing factors, and lessons learned from accidents. They often make recommendations to improve safety and prevent similar incidents in the future. Classification societies are organizations responsible for certifying and classifying vessels based on their compliance with safety and technical standards. In some cases, classification societies may participate in accident investigations to assess any potential role of vessel design, construction, or maintenance in the incident.

The specific authority involved in investigating a sea accident depends on factors such as the location of the incident, the type of vessel involved, the severity of the accident, and the national or international regulations in place. The ultimate goal of these investigations is to determine the causes, learn from the incident, and take appropriate measures to prevent similar accidents in the future.

The Maritime Safety Committee (MSC) and the Marine Environment Protection Committee (MEPC) of IMO jointly issued "Reports on marine casualties and incidents" – MSC-MEPC.3/Circ.4/Rev.1 [40]. The role of MSC-MEPC.3/Circ.4/Rev.1 is to establish a framework and provide guidance to member states and authorities involved in the investigation of marine casualties and incidents. The circular outlines the principles and procedures for conducting effective investigations, promoting transparency, and facilitating the exchange of information and lessons learned.

According to the IMO document MSC-MEPC.3/Circ.4/Rev.1 [40], the sea accidents are classified as: very serious casualties, serious casualties, less serious casualties and marine incidents. The classification depends on the kinds of initiating events or consequences of sea accidents. Very serious casualties refer to accidents that encompass the total loss of the ship, loss of life, or severe pollution. Serious casualties refer to accidents that do not qualify as very serious ones and which involve pollution, breakdown necessitating towage or shore assistance or involve a fire, explosion, collision, grounding, contact, heavy weather damage, ice damage, hull cracking, or suspected hull defect, etc., resulting in immobilization of main engines, extensive accommodation damage, severe structural damage, rendering the ship unfit to proceed. Then described in the paper collisions and contacts at the sea are classified at least as the serious casualties.

Moreover, according to the above mentioned IMO document [40], there are some types of initiating events: collision, grounding, contact, fire or explosion, hull failure, loss of control, ship or equipment damage, capsizing or listing, flooding or foundering, ship missing, occupational accident, and others. However, based on the analysis of sea accidents, it is concluded that a casualty was due to more than a single initial event. An initial event (called the primary event) usually causes the next one (called the next-step event), finally creating a chain of events [41,42]. For example, there are the primary initiating event and three next-step initiating events of the collision MV Everise Glory (bulk dry carrier) with MV Uni-Concord (container ship), 4th June 2005. From the report of the accident, it is known that these ships collided, suffered hull failures, and other damages of ship and equipment. The vessels were then separated, and MV Everise Glory sank. One man was missing and five crewmembers were injured as well as the slight oil spill was observed as the result of the accident. This means that the primary initiating event of the accident is the collision. On the other hand, the hull failure, other damages of ship and grounding are the next-step initiating event of the accident (Fig.1), causing dangerous situations and threats in the ship operating surroundings.

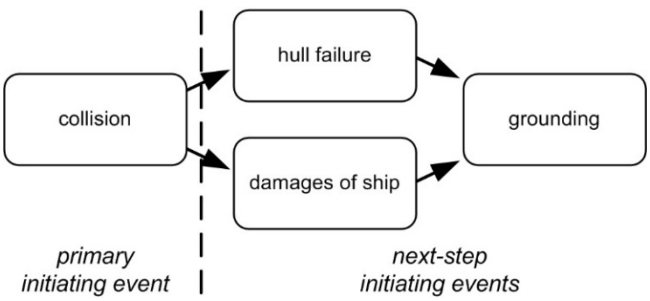

Figure 1. Primary initiating event and next-step initiating events in exemplary accident at sea. Source: own work.

Unfortunately, the reports prepared after an accident and according to the above mentioned document MSC-MEPC.3/Circ.4/Rev.1 [40] allow one point no more than two of initial events of an accident. It means that the determining the initial events of sea accidents according to the IMO document is not comprehensive. Only full-text reports of accidents give a view of all accident reasons.

3 MATERIALS AND METHODS

The research concerns the analysis of sea accidents particularly focused on collisions and contacts that happened in 2004-2021. The data of collision and contact at the sea were taken from the free-accessible Global Integrated Shipping Information System (GISIS) of the International Maritime Organization, section Marine Casualties and Incidents [35]. Then, more than 4,700 accident reports collected were the basis of the data analysis and interpretation. Namely, collisions and contacts were described from the point of view of their initiating event, the type and age of ships affected the accident, location of accident and their consequences for people, ship and environment.

Unfortunately, the GISIS data prior to 2004 lacks completeness, rendering the study results including previous years would be unreliable. Furthermore, the data concerning accidents since 2022 remains incomplete, as reports are still being gathered. Consequently, this research is concentrated on the timeframe spanning from 2004 to 2014.

4 RESULTS AND DISCUSSION

The detailed analysis of more than 4700 sea accidents that happened in years 2004-2021 around the world lets to point the collision and contact (jointly) as the most frequent sea accidents initiating events. The collision at sea occurs when two or more vessels collide with each other while traveling on the water, while the contact means the hitting of a moving ship with the unmoving object, e.g. a pier or a berth.

These kinds of accidents at sea have occurred throughout history, and many have had significant impacts on maritime safety and international relations. One of the most notable collisions at sea in history occurred in 1912 when the Titanic, a passenger liner considered to be unsinkable, collided with an iceberg in the North Atlantic Ocean on its maiden voyage. The collision resulted in the loss of over 1,500 lives and prompted significant changes to international maritime safety regulations. Another significant collision occurred in 1942 during World War II when the HMS Edinburgh, a British cruiser carrying gold bullion, was hit by torpedoes from a German submarine and sank in the Barents Sea. The loss of the gold bullion, worth millions of dollars, had a significant impact on the war effort. In more recent years, there have been several high-profile collisions at sea. In 2017, the USS Fitzgerald, a United States Navy destroyer, collided with a cargo ship off the coast of Japan, resulting in the deaths of seven U.S. Navy sailors. Later that same year, the USS John S.

McCain, another U.S. Navy destroyer, collided with an oil tanker near Singapore, resulting in the deaths of ten U.S. Navy sailors. In 2018, the Iranian oil tanker MV Sanchi collided with the Hong Kong-flagged bulk carrier CF Crystal in the East China Sea, resulting in the deaths of all 32 crew members on board the MV Sanchi. In 2019, the containership MSC Zoe collided with the Liberian-flagged container ship YM Efficiency off the coast of Australia, resulting in the loss of over 280 shipping containers and causing an environmental disaster. In 2020, the Panama-flagged livestock carrier Gulf Livestock 1 sank in the East China Sea after being hit by Typhoon Maysak, resulting in the loss of 41 crew members.

According to data from the IMO [35], the number of reported marine casualties and incidents worldwide has been decreasing over the years, including collisions at sea. However, collisions still occur and can have serious consequences as noted previously. The statistics on collisions at sea from 2004 to 2021 based on GISIS data points out that the total number of reported collisions at sea worldwide decreased from 48 in 2004 to 21 in 2021. The highest number of reported collisions at sea in this period occurred in 2006 and 2007, with 130 and 97 reported incidents, respectively [35].

The analysis of mentioned 4,700 accidents at the sea that happened around the world makes collision and contact the most frequent sea accident initiating events (31.70% jointly). Despite the collision and contact, the grounding and fire are the frequent initiating events – they are the initiating event of every 5th accident, while collision and contact are the initiating events of every 3rd one.

Detailed analysis of sea accident initiating events is presented in Figure 2.

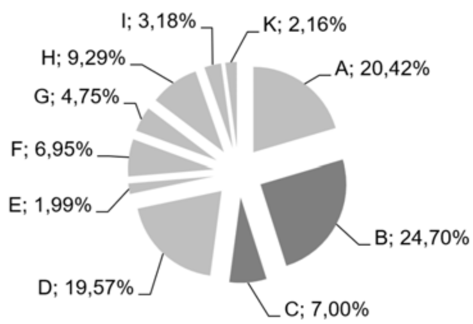

Figure 2. Sea accident initiating events (A – stranding / grounding, B – collision, C – contact, D – fire / explosion, E – hull failure / failure of watertight doors/ports, etc., F – machinery damage, G – damages to ship or equipment, H – capsizing / listing, I – missing: assumed lost, K – accidents with life-saving appliances). Source: own study based on data for years 2004-2021.

4.1 *Collision and contact as primary initiating event*

The collision is more frequent sea initiating events (24.70%) than contact with unmoving infrastructure element (7.00%). On the other hand, the contact more frequent does not occur the next step initiating event (6.40%) than collision; the collision does not occur the next step initiating event of every 34th one.

Collision and contact at sea usually occurs same damages of ship or its equipment (35.77% and 45.60% respectively) as well as the hull failure (17.20% and 20.00% respectively). Moreover, the grounding can be expected as the next-step initiating event of the collision (24.54%) and sporadically of contacts (5.60%).

The analysis of sea accidents allows to identify that the collision seldom occurs ship capsizing or listing (5.05%), fire (2.06%), contact (0.46%) and missing (0.23%) opposite to contact that never occurs these next-step events. Additionally, some collisions and contacts at sea are not very serious and occur only slight damage to the ship that the vessel is able to continue the journey (11.47% for collisions and 12.80% for contacts).

The detailed analysis of collision and contact at sea as the primary initiating events is presented in Figures 3-4.

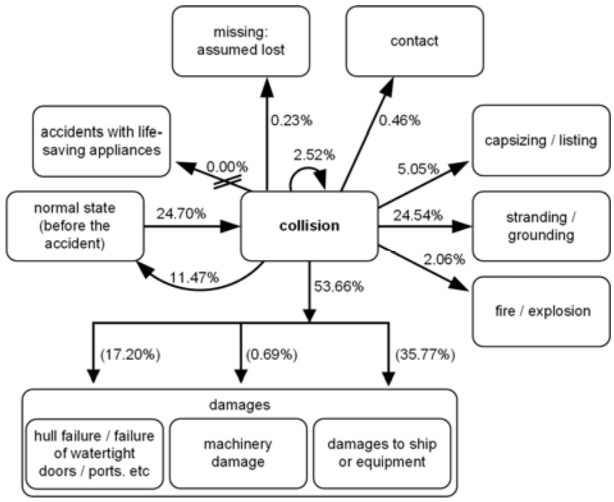

Figure 3. Collision as primary initiating event of accidents at sea. Source: own study based on data for years 2004-2021.

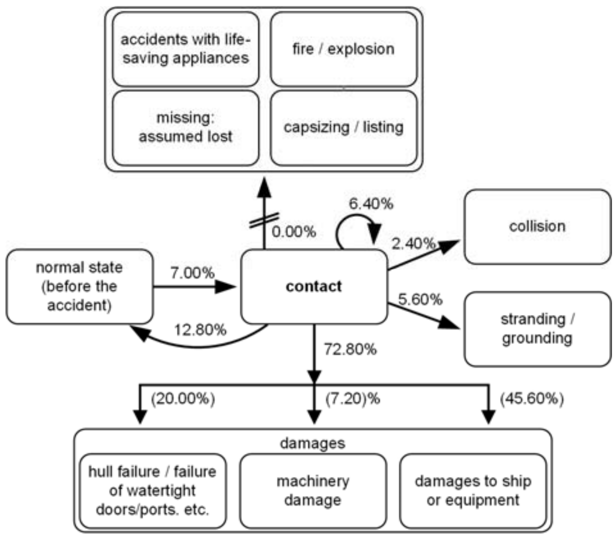

Figure 4. Contact as primary initiating event of accidents at sea. Source: own study based on data for years 2004-2021.

4.2 *Collision and contact as next-step initiating event*

The collision and contact are the primary initiating event of accidents at sea rather than next-step one.

The collision and contact usually may be the result of ship damage (for collision: machinery damage – 20.00%, damage to the ship or equipment – 13.33%, and hull failure or failure of watertight doors – 6.67%; for contact: machinery damage – 50.00%, hull failure or failure of watertight doors – 16.67% and damage to the ship or equipment – 5.56%). Additionally, the collision is occurred as the effect of the fire – 26.67%, the contact – 20.00%, the grounding and listening – each 6.67%. On the other hand, the contact occurs as the effect of the collision – 11.11%, as well as the grounding – 5.56%. Moreover, it was found that missing or accidents with life-saving appliances do not occur collision and contact.

The detailed analysis of collision and contact at sea as the next-step initiating events is presented in Figures 5-6.

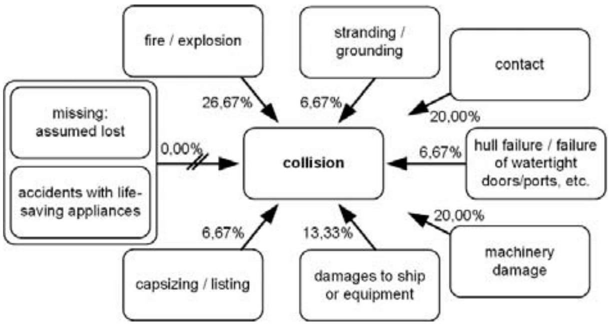

Figure 5. Collision as next-step initiating event of accidents at sea. Source: own study based on data for years 2004-2021.

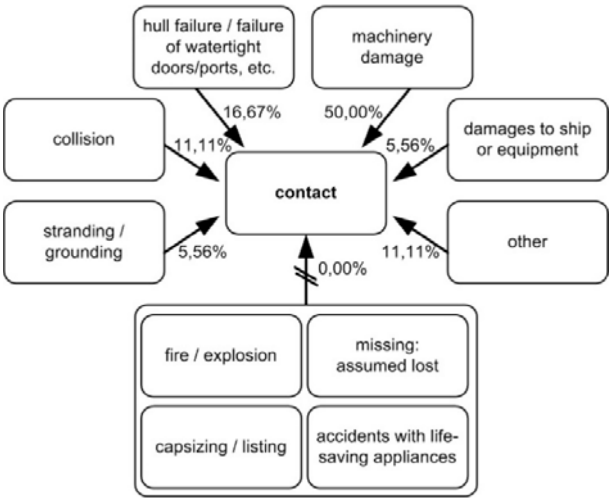

Figure 6. Contact as next-step initiating event of accidents at sea. Source: own study based on data for years 2004-2021.

4.3 *Location of collision and contact at sea*

The place of sea accidents can vary depending on various factors such as shipping routes, traffic density, navigational challenges, and local conditions [43-49]. Some areas are known for higher accident rates due to these factors. Here are a few regions that have experienced a relatively higher frequency of sea accidents. Regions with heavy maritime traffic and busy shipping lanes, such as major trade routes and ports, are more prone to accidents. Examples include the Strait of Malacca, the English Channel, the Mediterranean Sea, and the Gulf of Aden. Similarly, ports with high vessel traffic and congested harbour areas can pose collision risks, especially during periods of heavy traffic or challenging weather conditions. Examples include major ports like Rotterdam, Singapore, Shanghai, and New York. Narrow or congested waterways can present navigational challenges, such as Suez Canal, the Panama Canal, and certain straits and channels like the Singapore Strait and the Turkish Straits (Bosphorus and Dardanelles), increasing the likelihood of accidents. Coastal areas with challenging weather conditions, strong currents, reefs, or shallow waters, with significant maritime activities, including ferry routes, fishing zones, or areas near offshore energy installations can pose risks to vessels, leading to higher accident rates. Areas prone to storms, hurricanes, or typhoons, such as the Gulf of Mexico, the South China Sea, and the Caribbean Sea, may have increased accident occurrences. Certain areas with a higher risk of piracy or armed attacks, or regions experiencing political or security challenges, such as Gulf of Aden, the waters off the coast of Somalia, parts of the South China, and the Black Sea can be more prone to accidents. These incidents can be a result of deliberate acts by criminal groups or hostile actions and pose significant risks to crew members, vessels, and cargo.

Maps showing the location of accidents discussed in this paper are depicted in Figure 7.

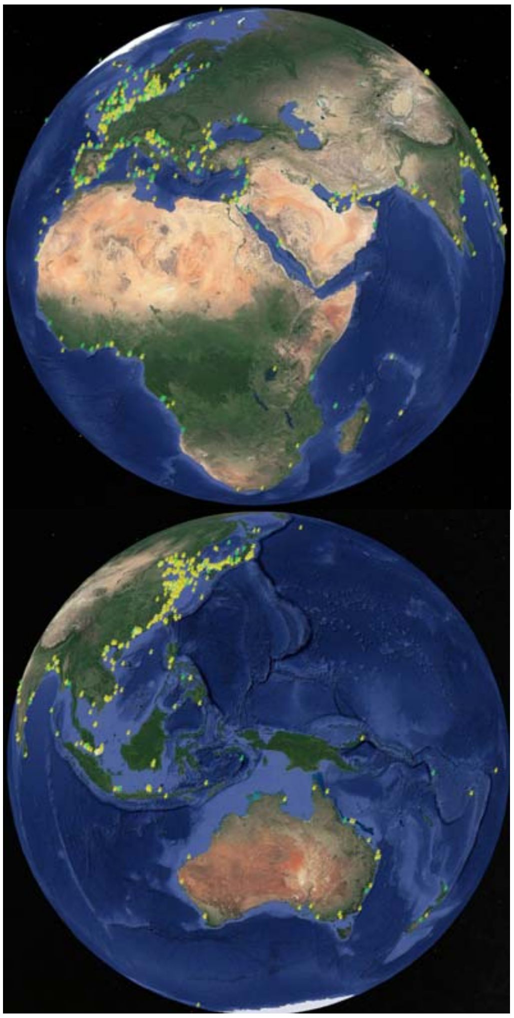

Figure 7. Collisions (yellow points) and contacts (green point) .of years 2004-2021, discussed in this paper. Source: own work at Google Earth.

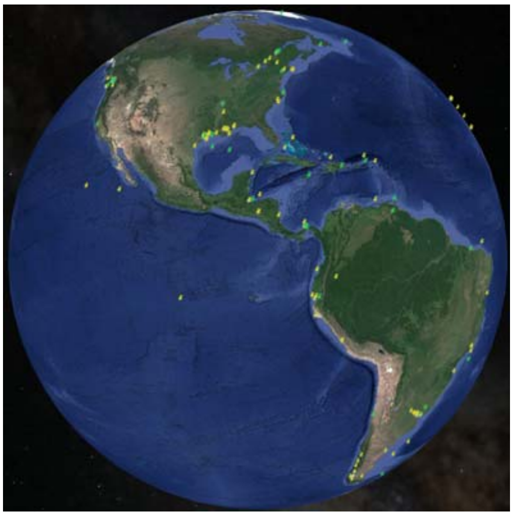

Figure 7 *cont*. Collisions (yellow points) and contacts (green point) .of years 2004-2021, discussed in this paper. Source: own work at Google Earth.

There are 10 types of casualty location described in the IMO document MSC-MEPC.3/Circ.4/Rev.1 [40]: at a berth, an anchorage, a port, a port approach, inland waters, a canal, a river, archipelagos, coastal waters (within 12 miles), and open sea.

Due to the huge traffic around the coastal areas, the most sea accidents occur in these regions, especially collisions in coastal waters (within 12 miles) – 21.64% and contacts in ports – 27.74% and at the berth – 16.79%. Then beaches, ports and costs are the most threatened areas as the result of collisions and contacts at sea.

The detailed analysis of collision and contact location at sea is presented in Figure 8.

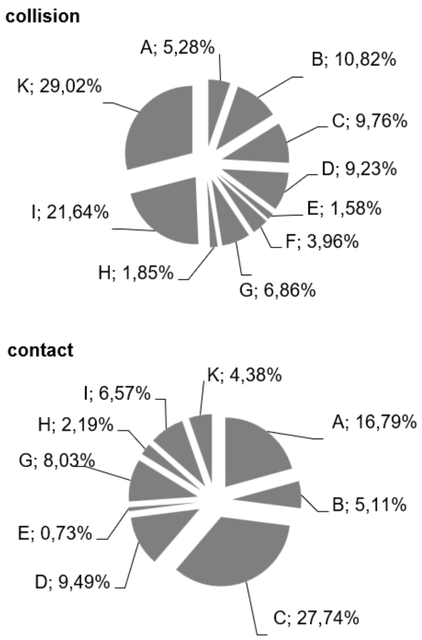

Figure 8. Location of collision and contact at sea (A – at berth, B – anchorage, C – port, D – port approach, E – inland waters, F – canal, G – river, H – archipelagos, I – coastal waters (within 12 miles), K – open sea). Source: own study based on data for years 2004-2021.

4.4 *Type of ships involved in collision and contact at sea*

The size and types of vessels involved in maritime transport can impact the intensity of shipping activities and potential accidents [30,43,50,51]. Larger vessels, such as container ships and bulk carriers, often carry substantial cargo volumes and have a significant presence in global trade. Therefore it is expected that their operations can have a greater impact in terms of intensity and potential risks.

The IMO document MSC-MEPC.3/Circ.4/Rev.1 [40] identifies 27 types of ships. General cargo ships, container ships and bulk dry carriers are frequent involved in collisions (18.35%, 17.32% and 14.23% respectively), as well as the passenger / Ro-Ro cargo ships, general cargo ships and container ships are frequent involved in contacts (26.57%, 13.99% and 12.59% respectively).

The detailed analysis of ships' type that have taken part in collisions and contacts at the sea is presented in Figure 9.

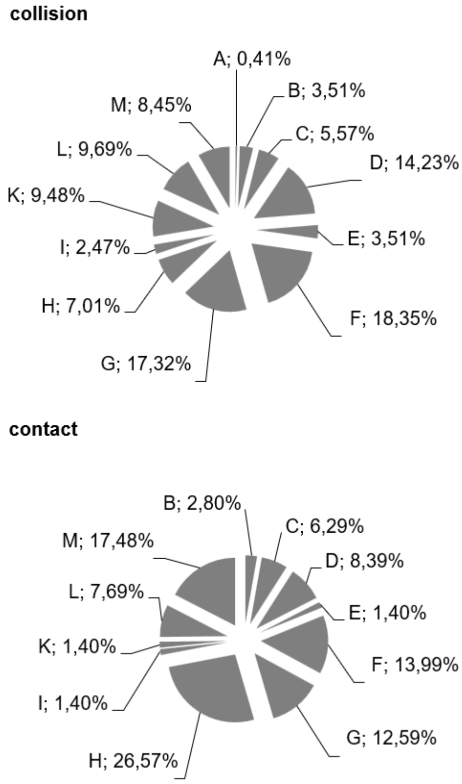

Figure 9. The type of ships that have taken part in collisions and contacts at the sea (A – liquefied gas tanker, B – chemical tanker, C – oil tanker, D – bulk dry (general, ore) carrier, E – bulk dry / oil carrier, F – general cargo ship, G – container ship, H – passenger / Ro-Ro cargo ship, I – tug, K – fish catching vessel, L – unspecified, M – other). Source: own study based on data for years 2004-2021.

4.5 *Age of ship involved in collision and contact at sea*

The average age of the global fleet varies depending on the ship types and regions. Some ship types, such as bulk carriers or tankers, may have a higher average age compared to others. However, the average age of ships involved in accidents does not necessarily imply a direct correlation between vessel age and the likelihood of incidents [52-54]. Therefore the age of ships involved in collisions and contacts at sea can vary widely. Ships of different ages can be involved in such incidents depending on various factors, including maintenance practices, vessel condition, operational procedures, and compliance with safety regulations. Newer ships, including those recently built or relatively young in age, are generally expected to have modern design features, advanced navigation equipment, and improved safety systems. These ships often adhere to the latest international safety standards and regulations. However, even new ships can be involved in accidents due to human error, unforeseen circumstances, or other factors. Older ships, particularly those nearing the end of their operational lives, may be more prone to technical failures, equipment malfunctions, or structural issues if not properly maintained. The age of a ship alone does not necessarily determine its seaworthiness or safety, as older vessels can still be operated safely through diligent maintenance and regular inspections. Ships, regardless of their age, are required to meet safety and maintenance standards set by regulatory bodies such as the IMO and flag state authorities. Compliance with these regulations is crucial to ensure the safe operation of ships and minimize the risk of accidents. Moreover, regular inspections, surveys, and audits are conducted to assess the condition and safety compliance of ships, regardless of their age, in order to prevent accidents and ensure the well-being of crew, passengers, and the marine environment.

A lot of ships involved in collision and contact at the sea are more than ten years old (13-15 years). It is significant for the sea environment condition because older ships are more exploited and their hull can be damaged easier. Then the transported cargo or fuel may sweep overboard and finally causing the marine ecosystem pollution.

The detailed analysis of the age of ships that have participated in the collision and contact at sea is presented in Figure 10.

Figure 10. Age of ship that have taken part in collision and contact at sea. Source: own study based on data for years 2004-2021.

4.6 *Consequences of collision and contact at sea*

Accidents at sea can have serious consequences, including loss of life or serious injurie of crew members and passengers on board the vessels involved [40,55,56], property damage of ship as well as any cargo or other property on board and other infrastructure in the accident area [40,43,57]. Accidents can also result in spills of oil, hazardous materials, or other pollutants into the marine environment, which can have serious ecological and economic consequences [40,58-65]. These spills can harm marine life, damage sensitive ecosystems, and disrupt local fisheries and tourism industries. Moreover, accidents can cause disruptions to shipping lanes and port operations, which can have economic consequences for the global shipping industry [66]. This can lead to delays, rerouting of vessels, and increased costs for shippers and consumers.

The frequent consequence of collision and contact for ship is its damages that make impossible the further journey (28.66% and 52.80%, respectively). In the case of consequences for people it is known that every 6th collision and contact occurs loss of life. The pollution is the result of less collisions and contacts: every 17th collision and every 15th contact occurs the marine ecosystem pollution.

The detailed analysis of consequences of collision and contact for people, ships and sea environment is presented in Figure 11 (one accident can occur several kinds of consequences).

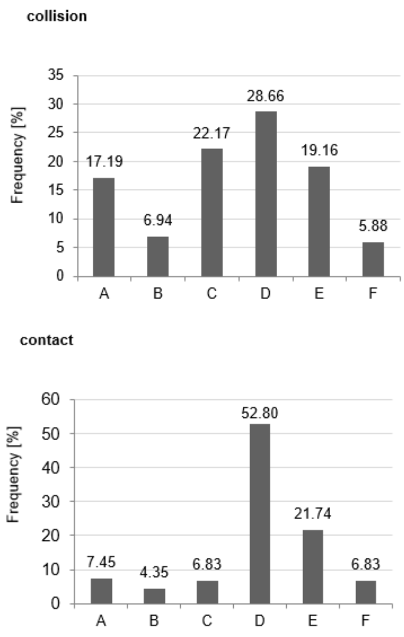

Figure 11. Consequences of collision and contact for people, ship and sea environment (A – loss of life, B – serious injuries, C – total loss of the ship, D – ship rendered unfit to proceed, E – ship remains fit to proceed, F – pollution). Source: own study based on data for years 2004-2021.

5 CONCLUSIONS

Accurate and comprehensive statistics on accidents at sea can be challenging to obtain, as reporting practices and data collection methods vary among different countries and organizations [67-73]. According to the IMO, the number of reported marine casualties and incidents worldwide has shown a declining trend over the years [35]. Accident statistics can vary significantly by region due to factors such as traffic density, weather conditions, navigational challenges, and enforcement of safety regulations. Some regions with heavy maritime traffic or challenging navigational conditions may experience a higher number of accidents. It's important to note that data presented in the paper provide a general overview and should not be considered as comprehensive or definitive. The availability and accuracy of accident data can vary, and not all incidents may be reported or included in official statistics. Lloyd's List Intelligence, a maritime intelligence provider, reported that between 2004 and 2021, there were around 150-200 shipwrecks and total losses per year globally [71,74]. These numbers include vessels of various types and sizes. The number of fatalities resulting from maritime accidents can vary significantly from year to year. Major accidents, such as ship sinking or large-scale disasters, can result in a high number of fatalities. However, it's difficult to provide precise global statistics due to the diverse nature of accidents and reporting practices.

Investigations of sea accidents provide not only valuable evidence and information for legal proceedings and insurance claims. Understanding the circumstances of the accident and investigations contribute to the overall body of knowledge within the maritime industry. By analyzing accident data, trends, and patterns, lessons can be learned, and best practices can be developed and shared [21,75-77]. This knowledge sharing helps in raising awareness, promoting safety culture, and improving operational procedures. The document MSC-MEPC.3/Circ.4/Rev.1 [40] also plays this role by emphasizes the importance of investigating marine casualties and incidents to enhance safety at sea and protect the marine environment. The circular encourages the identification of safety deficiencies, the determination of causal factors, and the development of measures to prevent similar incidents in the future. The circular promotes cooperation and information sharing among member states, authorities, and organizations involved in marine casualty investigations. It encourages the exchange of investigation reports, lessons learned, and best practices to enhance safety and prevent accidents.

Maritime organizations and regulatory bodies continually work to improve safety practices and reduce the occurrence of accidents at sea through various initiatives, including training programs, safety regulations, and technological advancements. Accident frequencies can vary from year to year, and improvements in safety measures and regulations can have a positive impact on reducing accidents in certain areas. Efforts are continuously being made by maritime authorities and organizations to enhance safety practices, enforce regulations, and mitigate risks in accident-prone regions.

Avoiding accidents at sea, including collisions and contacts, requires a combination of proper navigation practices, effective communication, and adherence to established regulations and procedures [78-82]. In addition to taking steps to avoid accidents at sea, there are several mitigation strategies and actions taken to reduce the impact or consequences of a collision or a contact once it has occurred. Mitigation measures are aimed at minimizing damage to the vessels involved, preventing loss of life, and mitigating the environmental impact. There are some steps that can help prevent collisions and contacts at sea:

- follow established navigation rules, such as the International Regulations for Preventing Collisions at Sea (COLREGs) that provide guidance on navigation and the actions that should be taken to avoid collisions,
- maintain proper lookout at all times by vessels, using all available means, including radar, visual observation, and radio communications, to detect and avoid other ships,
- operating at a safe speed (that allows the vessel to stop or alter course quickly in case of an emergency), taking into account the conditions and the presence of other vessels,
- use communication tools effectively (it is important to transmit own intentions and receive acknowledgement from other vessels) to communicate between vessels through the use of signals and radio communications or radar, sonar, and Automatic Identification Systems (AIS) to provide information about their position, course, and speed to help detect other vessels and potential hazards,
- maintain situational awareness by keeping track of other vessels in the vicinity, monitoring weather conditions, and staying informed about any changes in the vessel's surroundings,
- avoid distractions, such as using mobile phones or engaging in non-navigation related activities, as it can increase the risk of collision and other accidents,
- design vessels with structural reinforcements by usage of thicker hull plates or strengthening of critical areas such as the bow or stern to help minimize damage in the event of a collision or a contact,
- properly maintaining vessels and equipment to ensure they are functioning properly and to avoid equipment failure or malfunction which can lead to a collision and other accidents,
- equip vessels with proper safety equipment, such as life rafts, life jackets, and emergency signaling devices, in case of an emergency, and also with emergency response plans in place that outline procedures for responding to a collision, that include procedures for damage control, search and rescue, and communication with authorities,
- international cooperation includes sharing information on best practices, providing mutual assistance in emergency situations, and working together to develop and implement effective regulations and guidelines,
- train the crew members in navigation and safety procedures to ensure that all crew members know how to respond in an emergency.

Following these steps, vessels can help reduce the risk of collisions at sea and ensure the safety of crew members and passengers as well as the environment.

ACKNOWLEDGMENT

The paper presents results developed in the scope of the research project “Monitoring and analysis of the impact of selected substances and materials in terms of environmental protection”, supported by Gdynia Maritime University (project grant no. WZNJ/2023/PZ/10).

REFERENCES

[1] “Shipping: Indispensable to the World” Selected as World Maritime Day Theme for 2016. Available online: https://www.imo.org/en/MediaCentre/PressBriefings/Pages/47-WMD-theme-2016-.aspx (accessed on 13 March 2023).
[2] Benamara H., Hoffmann J., Youssef F. 2019. Maritime transport: The sustainability imperative. Sustainable Shipping: A Cross-Disciplinary View, 1-31 (doi: 10.1007/978-3-030-04330-8_1).
[3] Fratila A., Gavril I.A., Nita S C., Hrebenciuc A. 2021. The importance of maritime transport for economic growth in the European Union: A panel data analysis. Sustainability, 13(14), 7961 (doi: 10.3390/su13147961).
[4] Georgescu C. 2014. The role of maritime transport in the development of world economy. Knowledge Horizons – Economics, 6(2), 177-184.
[5] Liang Y., Guo L., Li J., Zhang S., Fei X. 2021. The impact of trade facilitation on cross-border e-commerce transactions: Analysis based on the marine and land cross-border logistical practices between China and countries along the “Belt and Road”. Water, 13, 3567 (doi: 10.3390/w13243567).
[6] Aalberg A.L., Bye R.J., Ellevseth P.R. 2022. Risk factors and navigation accidents: A historical analysis comparing accident-free and accident-prone vessels using indicators from AIS data and vessel databases. Maritime Transport Research, 3, 100062. (doi: 10.1016/j.martra.2022.100062).
[7] Blokus-Roszkowska A., Montewka J., Smolarek L. 2012. Modelling the accident probability in large-scale, maritime transportation system. Journal of Polish Safety and Reliability Association, 3(2), 237-244.
[8] Bogalecka M. 2013. Analiza współzależności liczby wypadków od liczby statków w regionie Morza Bałtyckiego. Rocznik Bezpieczeństwa Morskiego, VII(4), 205-213.
[9] Fowler T.G., Sørgård E. 2000. Modeling ship transportation risk. Risk Analysis, 20(2), 225-244 (doi: 10.1111/0272-4332.202022).
[10] Goerlandt F.; Montewka J. 2015. Maritime transportation risk analysis: Review and analysis in light of some foundational issues. Reliability Engineering System Safety, 138, 115–134 (doi: 10.1016/j.ress.2015.01.025).
[11] Szubrycht T. 2020. Marine accidents as potential crisis situations on the Baltic Sea. Archives of Transport, 54(2), 125-135 (10.5604/01.3001.0014.2972).
[12] Ugurlu O., Yildirim U., Yuksekyildiz E. 2013. Marine accident analysis with GIS. Journal of Shipping and Ocean Engineering, 3(1-2), 21-29.
[13] Marine Traffic. Available online: https://marinetraffic.com (accessed on 13 March 2023).
[14] Baker H.K., Puttonen V. 2017. Investment Traps Exposed: Navigating Investor Mistakes and Behavioral Biases. Emerald Group Publishing.
[15] Smith C. 2013. ‘We Never Make Mistakes’: Constructing the Empire of the Pacific Steam Navigation Company. The Victorian Empire and Britain’s Maritime World, 1837–1901: The Sea and Global History, 82-112. Palgrave Macmillan, Division of Macmillan Publishers Limited.
[16] Abbassi R., Khan F., Khakzad N., Veitch B., Ehlers S. 2017. Risk analysis of offshore transportation accident in arctic waters. International Journal of Maritime Engineering, 159(A3), 213-224 (doi: 10.5750/ijme.v159iA3.1025).
[17] Akyildiz H., Mentes A. 2017. An integrated risk assessment based on uncertainty analysis for cargo vessel safety. Safety Science, 92, 34-43 (doi: 10.1016/j.ssci.2016.09.009).
[18] Grech M.R. 2016. Fatigue risk management: A maritime framework. International Journal of Environmental Research and Public Health 13(2), 175 (10.3390/ijerph13020175).
[19] Jepsen J.R., Zhao Z., van Leeuwen W.M. 2015. Seafarer fatigue: a review of risk factors, consequences for seafarers’ health and safety and options for mitigation. International Maritime Health, 66(2), 106-117 (doi: 10.5603/IMH.2015.0024).
[20] Joseph A., Dalaklis D. 2021. The international convention for the safety of life at sea: highlighting interrelations of measures towards effective risk mitigation. Journal of International Maritime Safety, Environmental Affairs, and Shipping, 5(1), 1-11 (doi: 10.1080/25725084.2021.1880766).
[21] Kulkarni K., Goerlandt F., Li J., Banda O.V., Kujala P. 2020. Preventing shipping accidents: Past, present, and future of waterway risk management with Baltic Sea focus. Safety Science, 129, 104798 (doi: 10.1016/j.ssci.2020.104798).
[22] Marino M., Cavallaro L., Castro E., Musumeci R.E., Martignoni M., Roman, F., Foti, E. 2023. Analysis on a database of ship accidents in port areas. Data in Brief, 48, 109127 (doi: 10.1016/j.dib.2023.109127).
[23] Sur J.M., Kim D.J. 2020. Comprehensive risk estimation of maritime accident using fuzzy evaluation method – Focusing on fishing vessel accident in Korean waters. The Asian Journal of Shipping and Logistics, 36(3), 127-135 (doi: 10.1016/j.ajsl.2019.12.013).
[24] Ghanem M. 2009. Investigating and reporting accidents at sea. Seafarers International Research Centre Symposium Proceedings, p. 25.
[25] Lan H., Ma X., Ma L., Qiao W. 2023. Pattern investigation of total loss maritime accidents based on association rule mining. Reliability Engineering & System Safety, 229, 108893 (doi: 10.1016/j.ress.2022.108893).
[26] Li B., Lu J., Li J. 2021. Investigation of accident severity in sea lanes from an emergency response perspective based on data mining technology. Ocean Engineering, 239, 109920 (doi: 10.1016/j.oceaneng.2021.109920).
[27] Fadda P., Fancello G., Frigau L., Mandas M., Medda A., Mola F., Pelligra V., Porta M., Serra P. 2021. Investigating the role of the human element in maritime accidents using semi-supervised hierarchical methods. Transportation Research Procedia, 52, 252-259 (doi: 10.1016/j.trpro.2021.01.029).
[28] Roed-Larsen S., Stoop J. 2012. Modern accident investigation – Four major challenges. Safety Science, 50(6), 1392-1397 (doi: 10.1016/j.ssci.2011.03.005).
[29] Ugurlu O., Yıldırım U., Yüksekyıldız E., Nişancı R., Kose E.R.C.A.N. 2015. Investigation of oil tanker accidents by using GIS. International Journal of Maritime Engineering, 157(A2), 113-124 (doi: 10.3940/rina.ijme.2015.a2.323).
[30] Wang H., Liu Z., Wang X., Graham T., Wang J. 2021. An analysis of factors affecting the severity of marine accidents. Reliability Engineering & System Safety, 210, 107513 (doi: 10.1016/j.ress.2021.107513).
[31] Weng J., Yang D. 2015. Investigation of shipping accident injury severity and mortality. Accident. Analysis & Prevention, 76, 92-101 (doi: 10.1016/j.aap.2015.01.002).
[32] Zhang C., Zou X., Lin C. 2022. Fusing XGBoost and SHAP models for maritime accident prediction and causality interpretability analysis. Journal of Marine Science and Engineering, 10, 1154 (doi: 10.3390/jmse10081154).

[33] Zhang S., Pedersen P.T., Villavicencio R. 2019. Probability and Mechanics of Ship Collision and Grounding, Butterworth-Heinemann, Elsevier: Amsterdam (doi:10.1016/C2017-0-02422-9).
[34] IMO. Resolution MSC.255(84) (adopted on 16 May 2008) Adoption of the Code of the International Standards and Recommended Practices for a Safety Investigation into a Marine Casualty or Marine Incident (Casualty Investigation Code). Available online: https://www.liscr.com/sites/default/files/liscr_imo_resolutions/Res%20MSC.255(84)%20-%20Casualty%20Investigation%20Code.pdf (accessed on 13 March 2023).
[35] IMO. Global Integrated Shipping Information System, Marine Casualties and Incidents. Available online: https://gisis.imo.org/Public/MCI/Default.aspx (accessed on 13 March 2023).
[36] Abuelenin A.H.M. 2017. Obligations of authorities investigations towards the improvement of procedures of marine accident investigation. Journal of Social Science Studies, 4(1), 117-122 (doi: 10.5296/jsss.v4i1.9976).
[37] Psarros G., Skjong R., Eide M.S. 2010. Under-reporting of maritime accidents. Accident Analysis & Prevention, 42(2), 619-625 (doi: 10.1016/j.aap.2009.10.008).
[38] Puisa R., Lin L., Bolbot V., Vassalos D. 2018. Unravelling causal factors of maritime incidents and accidents. Safety Science, 110, 124-141 (doi: 10.1016/j.ssci.2018.08.001).
[39] Hänninen M., Kujala P. 2014. Bayesian network modeling of Port State Control inspection findings and ship accident involvement. Expert Systems with Applications, 41(4), 1632-164 (doi: 10.1016/j.eswa.2013.08.060).
[40] IMO. Casualty-Related Matters Reports on Marine Casualties and Incidents; MSC-MEPC.3/Circ.4/Rev.1; IMO: London, UK, 2014. Available online: https://www.imo.org/en/OurWork/MSAS/Pages/Casualties.aspx (accessed on 13 March 2023).
[41] Bogalecka M. 2010. Analysis of sea accidents initial events. Polish Journal of Environmental Studies, 19, 5-8.
[42] Ma X.-F., Shi G.-Y., Liu Z.-J. 2022. TAR-based domino effect model for maritime accidents. Journal of Marine Science Engineering 10, 788 (doi: 10.3390/jmse10060788).
[43] Chen J., Bian W., Wan Z., Yang Z., Zheng H., Wang P. 2019. Identifying factors influencing total-loss marine accidents in the world: Analysis and evaluation based on ship types and sea regions. Ocean Engineering, 191, 106495 (doi: 10.1016/j.oceaneng.2019.106495).
[44] Cockcroft A.N. 1981. The estimation of collision risk for marine traffic. The Journal of Navigation, 34(1), 145-147 (doi: 10.1017/S0373463300024310).
[45] Coldwell T.G. 1983. Marine traffic behaviour in restricted waters. The Journal of Navigation, 36(3), 430-444 (doi: 10.1017/S0373463300039783).
[46] Hu S., Zhang J. 2012. Risk assessment of marine traffic safety at coastal water area. Procedia engineering, 45, 31-37 (doi: 10.1016/j.proeng.2012.08.116).
[47] Montewka J., Krata P., Goerlandt F., Mazaheri A., Kujala P. 2011. Marine traffic risk modelling – an innovative approach and a case study. Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability, 225(3), 307-322 (doi: 10.1177/1748006X11399).
[48] Wen Y., Huang Y., Zhou C., Yang J., Xiao C., Wu X. 2015. Modelling of marine traffic flow complexity. Ocean Engineering, 104, 500-510 (doi: 10.1016/j.oceaneng.2015.04.051).
[49] Zaman M.B. 2016. Study on Safety of Navigation using Automatic Identification System for Marine Traffic Area Case Study: Malacca Straits. International Journal of Marine Engineering Innovation and Research, 1(1), 26-30 (doi: 10.12962/j25481479.v1i1.1462).
[50] Luo M., Shin S.H., Chang Y.T. 2017. Duration analysis for recurrent ship accidents. Maritime Policy & Management, 44(5), 603-622 (doi: 10.1080/03088839.2017.1319983).
[51] de Vos J., Hekkenberg R.G., Banda O.A.V. 2021. The impact of autonomous ships on safety at sea–a statistical analysis. Reliability Engineering & System Safety, 210, 107558 (doi: 10.1016/j.ress.2021.107558).
[52] Bogalecka M. 2015. Wiek statku a prawdopodobieństwo wystąpienia wypadku na morzu – analiza współzależności. Logistyka, 3, 515-520.
[53] Papanikolaou A., Eliopoulou E. 2008. Impact of ship age on tanker accidents. Proceedings of 2nd International Symposium on Ship Operations, Management and Economics, The Greek Scetion of the Society of Naval Architects and Marine Engineers (SNAME), Athens, Greece.
[54] Uğurlu Ö., Yıldız S., Loughney S., Wang J., Kuntchulia S., Sharabidze I. 2020. Analyzing collision, grounding, and sinking accidents occurring in the Black Sea utilizing HFACS and Bayesian networks. Risk Analysis, 40(12), 2610-2638 (doi: 10.1111/risa.13568).
[55] Talley W.K., Jin D., Kite-Powell H. 2005. Determinants of crew injuries in vessel accidents. Maritime Policy & Management, 32(3), 263-278 (doi: 10.1080/03088830500139760).
[56] Yip T.L., Jin D., Talley W.K. 2015. Determinants of injuries in passenger vessel accidents. Accident Analysis & Prevention, 82, 112-117 (doi: 10.1016/j.aap.2015.05.025).
[57] Eliopoulou E., Papanikolaou A., Voulgarellis M. 2016. Statistical analysis of ship accidents and review of safety level. Safety Science, 85, 282-292 (doi: 10.1016/j.ssci.2016.02.001).
[58] Akten N. 2006. Shipping accidents: a serious threat for marine environment. Journal of Black Sea/Mediterranean Environment, 12(3), 269-304.
[59] Bogalecka M. 2019. Consequences of maritime critical infrastructure accidents with chemical releases. TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation, 13, 771-779 (doi: 10.12716/1001.13.04.09).
[60] Bogalecka M. 2019. Modelling consequences of maritime critical infrastructure accidents. Journal of Konbin, 49(2), 477-495 (doi: 10.2478/jok-2019-0046).
[61] Bogalecka M. 2020. Consequences of Maritime Critical Infrastructure Accidents. Environmental Impacts. Modeling – Identification – Prediction – Optimization – Mitigation. Elsevier: Amsterdam, Oxford, Cambridge (doi: 10.1016/C2019-0-00396-2).
[62] Bogalecka M., Dąbrowska E. 2023. Monte Carlo simulation approach to shipping accidents consequences assessment. Water, 15(10), 1824 (doi.org/10.3390/w15101824).
[63] Dąbrowska E. 2023. Oil discharge trajectory simulation at selected Baltic Sea waterway under variability of hydro-meteorological conditions. Water, 15(10), 1957; (doi: 10.3390/w15101957).
[64] Galieriková A., Dávid A., Materna M., Mako P. 2021. Study of maritime accidents with hazardous substances involved: Comparison of HNS and oil behaviours in marine environment. Transportation Research Procedia, 55, 1050-1064 (doi: 10.1016/j.trpro.2021.07.182).
[65] Giziakis K., Bardi - Giziaki E. 2002. Assessing the risk of pollution from ship accidents. Disaster Prevention and Management, 11(2), 109-114 (doi: 10.1108/09653560210426786).
[66] 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 (doi: 10.1177/1748006X187689).
[67] Allianz Global Corporate & Specialty SE. Safety and Shipping Review 2022. An Annual Review of Trends and Developments in Shipping Losses and Safety; Allianz Global Corporate & Specialty SE: Munich,

Germany, 2022. Available online: https://www.agcs.allianz.com/news-and-insights/reports/shipping-safety.html# download (accessed on 13 March 2023).
[68] Bužančić Primorac B., Parunov J. 2016. Review of statistical data on ship accidents. Maritime Technology and Engineering, Guedes Soares & Santos (Eds), Taylor & Francis Group, London, 809-814.
[69] European Maritime Safety Agency. European Maritime Safety Report 2022. Available online: https://safety4sea.com/wp-content/uploads/2022/11/EMSA-Annual-Overview-of-Marine-Casualties-and-Incidents-2022-2022_11.pdf (accessed on 13 March 2023).
[70] ITOPF. Oil Tanker Spill Statistics 2021; ITOPF Ltd.: London, UK, 2022.
[71] Lloyd's List Intelligence and DNV Whitepaper. Maritime Safety 2012-2021 — A Decade of Progress. Available online: https://www.dnv.com/Publications/whitepaper-maritime-safety-2012-2021-a-decade-of-progress--213588 (accessed on 13 March 2023).
[72] Luo M.; Shin S.-H. 2019. Half-century research developments in maritime accidents: Future directions. Accident Analysis & Prevention, 123, 448–460 (doi: 10.1016/j.aap.2016.04.010).
[73] Pagiaziti A., Maliaga E., Eliopoulou E., Zaraphonitis G., Hamann R. 2015. Statistics of collision, grounding and contact accidents of passenger and container ships. Proceedings of the 5th International Symposium on ship Operations, Management and Economics (SOME), Athens, Greece, 28-29.
[74] The Mare Foundation. Dangerous shipwrecks. Available online: https://fundacjamare.pl/en/shipwrecks/ (accessed on 11 November 2022).
[75] Bogalecka M.; Popek M. 2008. Proaktywne i reaktywne strategie zapobiegania zagrożeniom środowiska morskiego, In Europejski Kontekst Bezpiecznego i Efektywnego Gospodarowania na Morzu; Piocha, S., Ed.; Środkowopomorska Rada Naczelnej Organizacji Technicznej w Koszalinie, Politechnika Koszalińska, Morska Służba Poszukiwania i Ratownictwa w Gdyni, Koszalin/Kołobrzeg, Poland, 235-240.
[76] Mojtahedi M., Oo B.L. 2017. Critical attributes for proactive engagement of stakeholders in disaster risk management. International Journal of Disaster Risk Reduction, 21, 35-43 (doi: 10.1016/j.ijdrr.2016.10.017).
[77] Yang Z.L., Wang J., Li K.X. 2013. Maritime safety analysis in retrospect. Maritime Policy & Management, 40, 261-277 (doi: 10.1080/03088839.2013.782952).
[78] Bekir E. 2007. Introduction to Modern Navigation Systems, World Scientific: Singapore (doi: 10.1142/6481).
[79] Dominguez-Péry C., Vuddaraju L.N.R., Corbett-Etchevers I., Tassabehji R. 2021. Reducing maritime accidents in ships by tackling human error: A bibliometric review and research agenda. Journal of Shipping and Trade, 6, 20 (doi: 10.1186/s41072-021-00098-y).
[80] National Research Council. 1996. Vessel Navigation and Traffic Services for Safe and Efficient Ports and Waterways: Interim Report, The National Academies Press: Washington, DC (doi: 10.17226/9262).
[81] Rivkin B.S. 2016. The tenth anniversary of e-navigation. Gyroscopy and Navigation, 7, 90-99 (doi: 10.1134/S2075108716010107).
[82] Størkersen K.V. Safety management in remotely controlled vessel operations. 2021. Marine Policy, 130, 104349 (doi: 10.1016/j.marpol.2020.104349).