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Analysis of ship accidents based on European statistical surveys

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Abstract

The International Maritime Organization (IMO) introduces, adopts, and implements new instruments, such as conventions, resolutions, and guidelines, to prevent and minimize the number and severity of accidents involving ships at sea. The results of international maritime safety requirements introduced in recent years are presented in this paper. The impact of these regulations on ship safety improvement in European marine waters was determined via an analysis of accidents over a seven-year period of 2014–2020. The analysis was based on the classification of accidents by their severity, by the type of ship involved, and by the identified causes or contributing factors. Evident, still existing "weak points" of maritime safety monitoring are emphasized, such as low reporting of incidents and superficial identification of contributing factors. It is worth noting that the technological development of marine electronic systems introduced both positive effects and novel threats to the safety of navigation. An example is an uncritical overreliance on technology and information provided via electronic means and sensors. In this context the usage of integrated, digitized bridge systems in contemporary maritime vessels and future remote control systems was stressed.

Introduction

The maritime accident investigation bodies of the European Union member states provide statistics of ship accidents and casualties covering in detail the years from 2014 onwards (EMSA, 2015–2021). These statistics formed the basis for our analysis of the various types of maritime accidents presented in this paper and for the identification of those relevant to European Union maritime shipping that had the greatest impact on navigation safety, ship operations, the economy, and the environment. During the analyzed period, both safety improvements and the neglect of safety culture / procedures were observed in the maritime domain (Kim, 2020; Jung 2021). Reviewing the literature, it can be noted that a regional proactive approach to maritime safety is still needed (Haapasaari et al., 2015). Strategic planning tools could also lower the risk of accidents by making use of a multilayered risk estimation framework, which accounts for ship specific risk (micro level), vessel traffic densities, and sea/ocean conditions at the macro level (Hoorn & Knapp, 2019). It is important to focus on the role of leadership, its effectiveness, and particularly on how the leadership style can be a factor for building an improvement in individual performance and safety outcomes (Beşikçi, 2019).

Generally, despite technological and crew training improvements and the continuous development of new instruments for maritime safety (Necci et al., 2019; Zalewski 2020), including evidence-based probabilistic risk models (Mazaheri, Montewka & Kujala, 2016), the number of accidents at sea continues to increase together with the number of active vessels. Technological progress, the global expansion of the fleet and ship traffic monitoring systems, and, on the other hand, an increasing number of old vessels, continue to force further updates in local, regional, and international regulations and the resultant shipboard procedures. Such conclusions are also confirmed by research of maritime accidents not covered by EMSA (Bayazit, Toz & Buber, 2020).

Organizations and legal instruments involved in maritime safety

There are several international and national organizations responsible for maintaining maritime safety. The International Maritime Organization was established in 1948 by the Geneva Convention as a United Nations specialized agency to promote maritime safety, security, efficiency of navigation, and the prevention of environmental pollution by ships (IMO, 2021a). The IMO Convention entered into force in 1958, and the IMO's first task was to adopt the International Convention for the Safety of Life at Sea (SOLAS) in 1960, the most important of all treaties dealing with maritime safety. IMO also introduced a series of measures designed to prevent ship accidents and to minimize their consequences. The most important of all these measures were 1) the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs), which came into force in 1977 replacing the Collision Regulations of 1960, and 2) the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978. The latter convention covered not only accidental and operational oil pollution, but also pollution by chemicals, goods in packaged form, sewage, garbage, and air pollution. The next two initiatives were especially important in relation to the human element in shipping. In 1978 the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers entered into force, being further amended in 1995 and 2010. In 1998 the International Safety Management Code was adopted and became applicable to passenger ships, oil and chemical tankers, bulk carriers, gas carriers, and high-speed cargo craft of 500 gross tonnage and above. It became applicable to other cargo ships and mobile offshore drilling units of 500 gross tonnage and above from 1 July 2002.

Nowadays, there are 172 member countries and three associated states in the organization, whose headquarters is in London (IMO, 2021b). Contemporary IMO instruments, which mostly originated from the Maritime Safety Committee, cover e-navigation, GNSS, and specific guidelines on PNT and navigation system usage.

In the European Union, after the tanker Erika disaster in 2002, the European Maritime Safety Agency (EMSA) was founded. The objective of this agency was to increase maritime safety and reduce the number of marine accidents and the pollution of the environment from ships. The structure of the EMSA consists of agencies providing technical expertise and operational support. The establishment of national maritime accident investigation boards followed the establishment of the EMSA, according to Art. 8.1 of Directive 2009/18/EC (EU, 2009) requiring each member state to have an impartial permanent investigative body competent in matters relating to marine casualties and incidents. A marine safety investigation, as defined in IMO Code (IMO, 2008), is an investigation conducted with the objective of preventing marine casualties and marine incidents in the future. There are 30 national investigation bodies in the EU (EMSA, 2020). The maritime safety investigation board in Poland is the State Marine Accident Investigation Commission (SMAIC) (SMAIC, 2021) created in 2012 to deal with maritime accidents in Polish territorial waters, those involving passenger and ro-ro ships whose last port of call was in Poland, and ships under the Polish flag or operated by Polish companies. The purpose of the commission is to report on maritime accidents and incidents, investigate their causes, and recommend prevention measures. It is not the task of the commission to settle the guilt or liability of a person involved in an incident. Such a task is in the domain of the Maritime Chambers (specialized courts) in Poland, working at the request of interested parties or the maritime administration. The investigation reports do not serve as evidence in criminal proceedings or other proceedings for the purpose of the determination of guilt or liability for the cause of an accident. The commission has no control over the navy fleet, coastguard, police, non-power driven vessels, wooden ships of simple design, vessels operating a special state service or operated by the state for non-commercial purposes, fishing vessels of total length up to 15 m, recreational yachts (except for

very serious accidents), or accidents on fixed drilling platforms where no ships were involved. The Commission is required to undertake an accident investigation in the event of the death of Polish seafarers at sea.

Maritime accidents

Maritime accidents are commonly categorized using criteria based on their consequences (IMO, 2008) as follows:

Very serious accident – when the total loss of a ship occurred, human death, or severe damage to the natural environment (irreversible for months).

Serious accident – the type of accident which results in extensive damage to the accommodation area, a change to a ship's stability state, serious damage to the underwater hull, failure to meet the classification requirements for the vessel, or severe damage to the environment. This kind of accident causes a threat to the safety of the ship's occupants or the environment, and consequently the ship is unfit to continue the voyage.

Less serious accident – when material damage to a ship, to the marine infrastructure external to a ship, or to the environment is lesser and reversible in a short time.

Incident – an event or several successive events that have or at least could have an adverse impact on the safety of a ship or its occupants.

Maritime accidents can be analyzed according to several criteria, such as the severity of accident, location of accident, and the type of a ship involved. In the next subparagraphs various types of accidents are analyzed, starting from the general classification of severity and further focusing on more detailed statistics.

Analysis by the severity of accident

Figure 1 shows the overall accident and incident numbers (marked by a blue dashed line) based on (EMSA, 2015–2021) covering very serious accidents, serious accidents, less serious accidents, and minor incidents in years 2014–2020, with linear regression lines fitted.

From the results presented, it can be concluded that all types of accidents occur from year to year with almost constant frequency. The R-squared coefficient of determination, showing how close the data are to the fitted regression line, was approximately 0.3 for all types of accident. This was due to the statistically outlying year 2020. This coefficient value reached 0.6 if preliminary data from 2020 were omitted. Except for the "incidents" category, all other types of accidents were significantly lower in number in the year 2020. Values for the year 2020 have to be treated with caution due to their incompleteness in the preliminary EMSA report (EMSA, 2021) and the general reduction in maritime traffic, especially passenger ships, due to the COVID-19 pandemic. In 2019, the number of very serious casualties decreased by 30% in comparison to the year 2018, but was at a level similar to years 2015–2017. An increase was noted for the less serious casualties. An alarming conclusion, based on a comparison of more than 16,000 accidents resulting in casualties with 3,160 incidents during 2014–2020, is that a significant underreporting of marine incidents can be assumed.

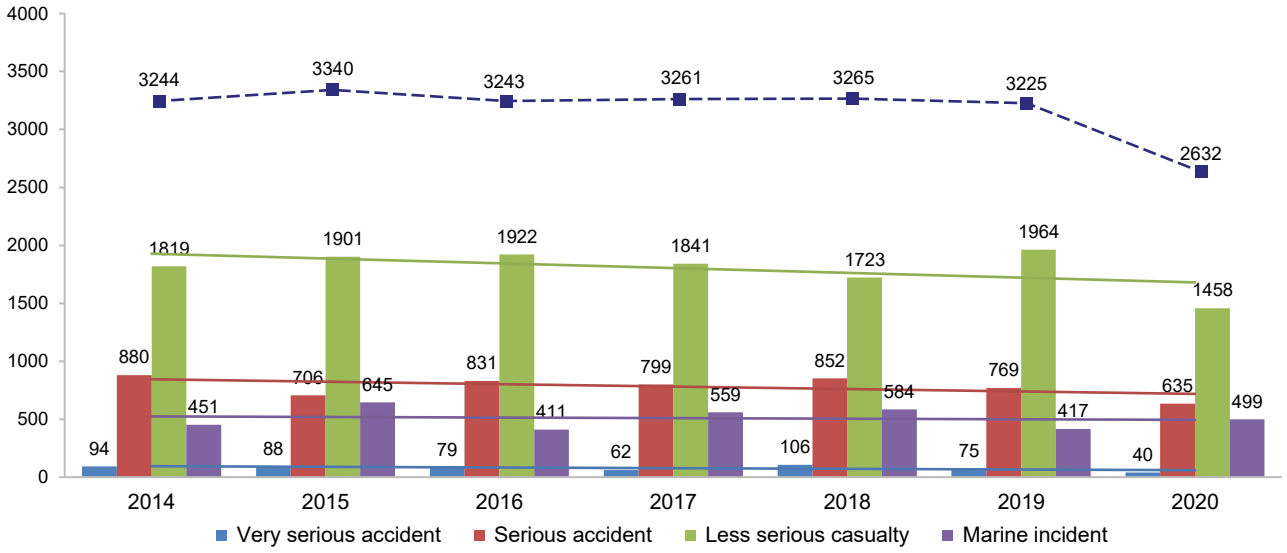

Figure 1. Maritime accidents by their severity based on (EMSA 2015–2021)

Analysis by contributing factors

Figure 2 shows the numbers of maritime accidents associated with contributing factors. The underlying data are based on the EMSA's "Annual Overview of Marine Casualties and Incidents" for the years 2014–2019 (EMSA 2015–2020). The EMSA's "Annual Overview" issued up to March 2021 contain cumulative numbers of causes made up of "accident events" (underlying factors) and "contributing factors" for the years from 2011 to 2019. The preliminary annual overview of 2020 does not contain contributing factors data (EMSA, 2021).

The reporting scheme used was the one recommended by the European Marine Casualty Information Platform (EMCIP). A detailed model of EMCIP is shown in the Figure 3.

According to this model, more than one accident event can be associated to a casualty event. Such an association and the presentation of cumulative data from the years 2011 up to 2014 in (EMSA, 2015) raised issues while extracting the data for Figure 2. The authors dealt with this problem via the reverse calculation of associated and cumulative data for each year in the range 2014–2019.

In general, it is evident that the majority of accidents in the years 2014–2019 were caused by a human factor. What is also evident is the very high number of accidents not analyzed according to EMCIP or not classified to any identified group of contributing factors. In 2018 there was a significantly large increase in contributing factor identifications, but in 2019 it decreased to the previous years' average. The conclusion can be drawn that national investigative boards providing data to EMSA in many cases are reluctant to clearly indicate the cause. This trend is probably due to either contradictions between the need to establish the cause while avoiding settling guilt or because of national policies.

Accidents in the human action category were not only attributed to human error, which can be defined as decision-making error that could have been avoided, but they also covered workplace conditions and crew resource management. Nevertheless, personnel, emergency preparedness, and seafarer stress constitute 32% of the human action category in the analyzed years. Studies performed in the UK (CHIRP Maritime, 2019), and by the authors during deck officer bridge team management training, show that the common mistakes of officers on watch (OOW) leading to serious or very serious accidents are:

- arriving on the bridge later than planned and without time for a proper watch handover, resulting sometimes in no handover at all;
- turning off the alarm for the navigation system, having confidence only in his/her abilities to guide the ship;
- misjudging safe distances to navigation obstacles;
- carrying out navigation on the paper or electronic chart and radar display using a wrong scale or range for accurate assessment of the hazards to navigation;
- maintaining an inappropriate speed for the prevailing meteorological conditions, visibility, darkness, or other ships.

Guiding a ship without large diversions in route and without affecting the safe passage of other ships in the vicinity requires skills and effective team management as humans are incapable of processing more

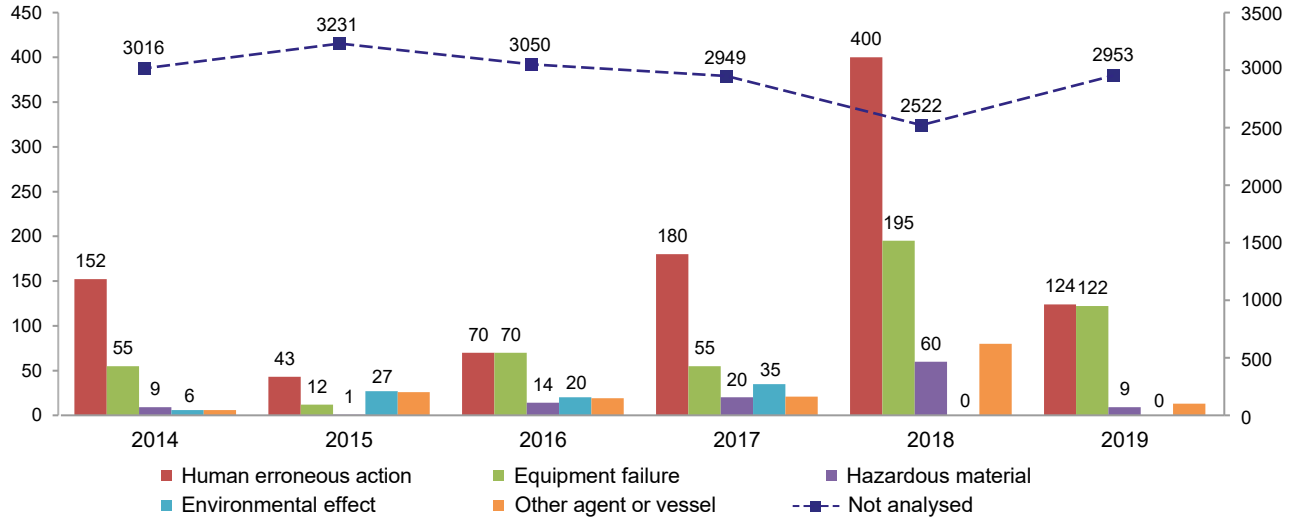

Figure 2. Maritime accidents related to contributing factors based on (EMSA, 2015–2020)

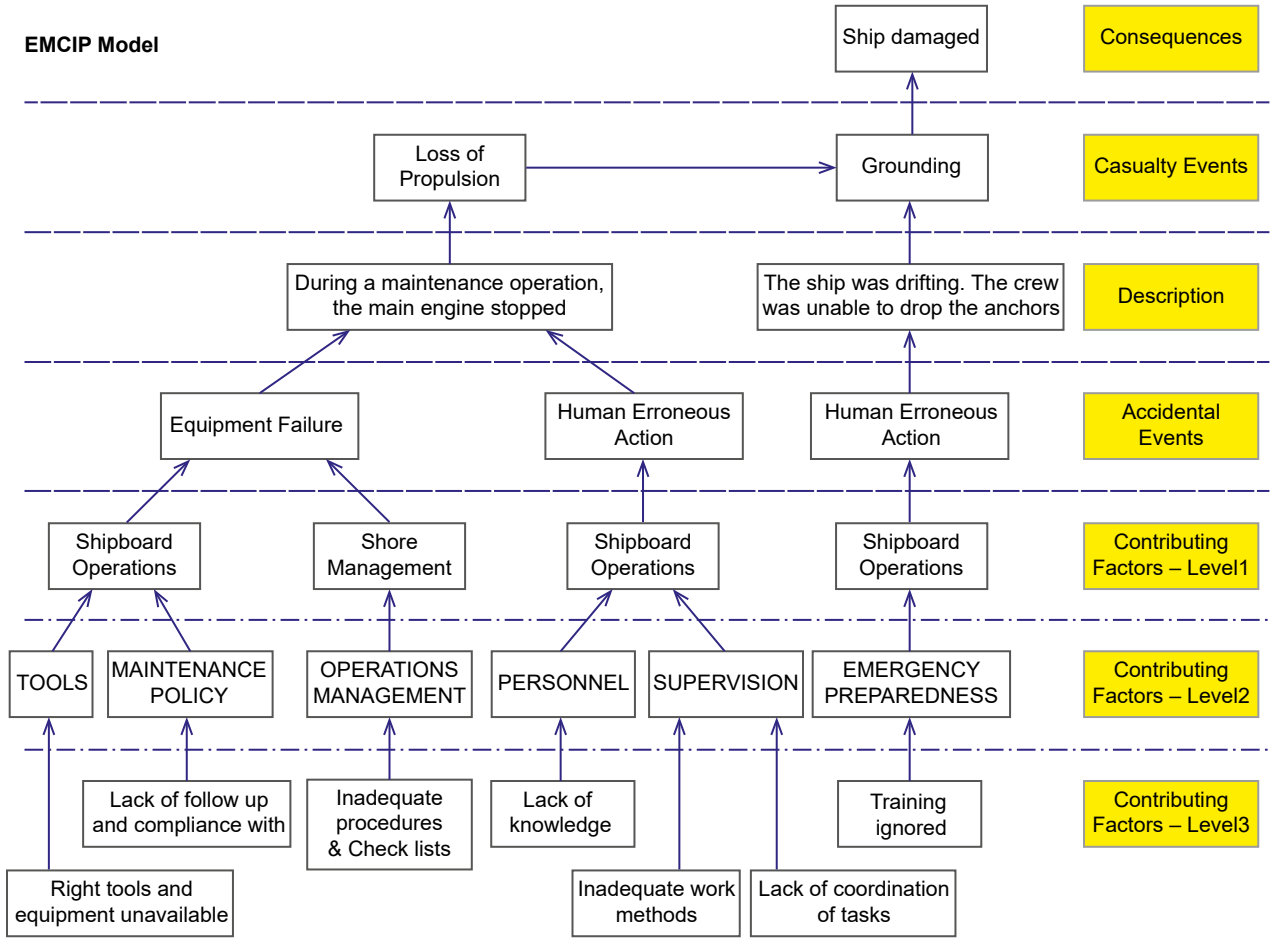

Figure 3. EMCIP reporting model (EMSA, 2020)

than a few pieces of information at any one time. Situational awareness is always critical in order to avoid erroneous decisions while working onboard ship. That is why, even if a ship is equipped with an integrated bridge, dynamic positioning systems, or steered remotely as a marine autonomous surface ship (MASS) (Felski, 2020; Zalewski, 2020), the crew competences and awareness must always be priorities.

The second contributing factor by number is equipment failure, which can lead to electrical problems, information restrictions, mechanical hazards, and so on.

The fewest events are caused by hazardous material. This is a positive sign that international policy with regard to the transportation of dangerous goods is effective. The IMO IMDG Code (IMO, 2020), was initially adopted in 1965 as a recommendatory instrument, but in 2002 was adopted by resolution A.716(17), achieving mandatory status from 2004. Amendments to the IMDG Code are made on a two-year cycle and originate not only from proposals submitted directly by member states but also from the United Nations Recommendations on the Transport of Dangerous Goods (UN, 2019), which set the basic requirements for all transport modes. Nevertheless, accidents originating from hazardous materials can be extremely severe. An example is the poisoning of the Polish general cargo m/v Nefryt's crew after cargo fumigation in the African port of Abidjan, leading to all 17 crew member being poisoned with two fatal casualties (PKBWM, 2016).

To take a closer look at the main contributing factors for serious accidents, Figure 4 presents more details based on analysis of the Polish SMAIC during 2015–2020.

Analysis of the contributing factors of accidents presented in the Figure 4 identifies three groups of predominant factors: errors in navigation or during maneuvering, loss of control usually accompanied by critical equipment failure, and lack of caution at work. It is evident that two of these groups are 100% human dependent.

The presented data can be supplemented by general conclusions from EU 2020 investigations (EMSA, 2021). There were 923 EU investigations launched, 757 of which were concluded by investigation reports. Among the 2011 safety recommendations

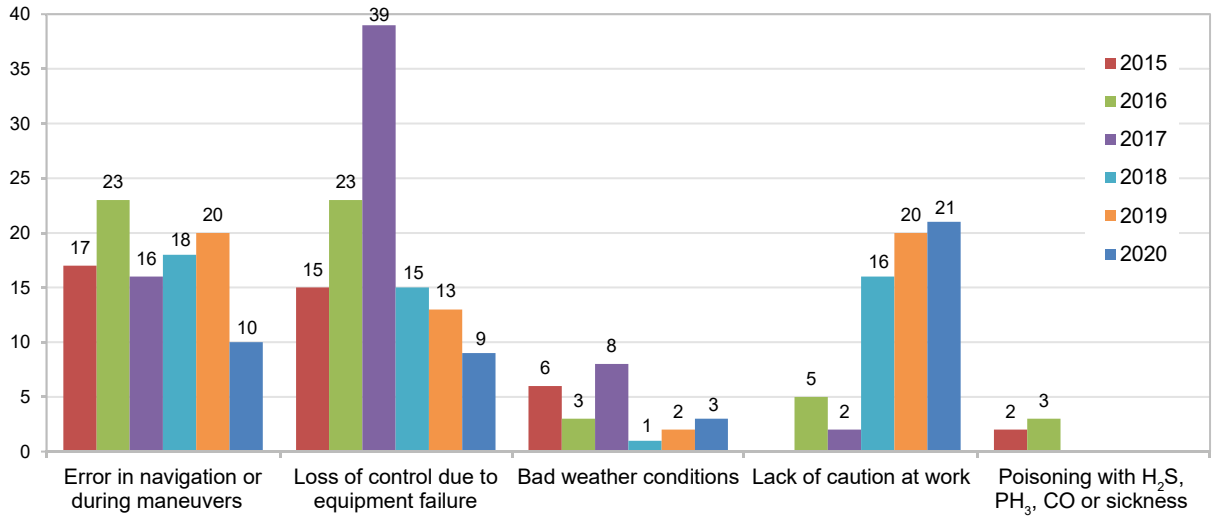

Figure 4. Causes of accident (SMAIC, 2021)

in these reports, 20% were associated with human factors (49% of which related to training and skills), 47% to ship-related procedures (40% of which related to operations), 15% to ship structure and equipment (36% of which related to ship engine room and navigation systems), 3% to shore and water equipment (27% of which related to shore and water aids to navigation, including virtual aids to navigation provided via AIS).

Analysis by location of accident

Figure 5 shows the number of maritime accidents associated to the location or area of water where they occurred in 2014–2019 (EMSA, 2015–2020).

Internal waters were the location where more than half of the casualties take place. The subcategory "harbor area" represented almost 42% of all accidents. However, a steady reduction in accidents in harbor areas was noted since 2015. Over the same time, an increase of casualties in open seas was recorded. The high number of accidents in open sea areas can be explained by the long time ships usually spend in such areas, which is confirmed by the high number of en route accidents presented in the Figure 6. In any case, the reduction of accidents in harbor approaches and harbors remains the greatest maritime safety challenge.

Figure 6 shows that while the departure is the safest segment for all types of ship, the en route

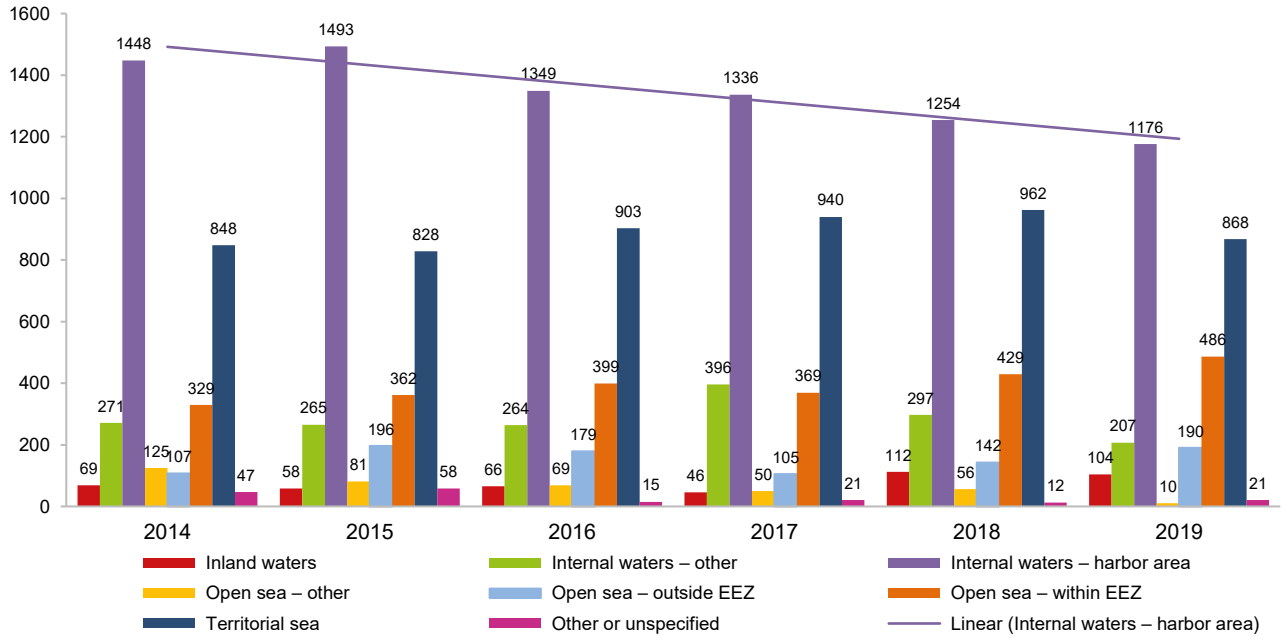

Figure 5. Accidents by locations based on (EMSA, 2015–2020)

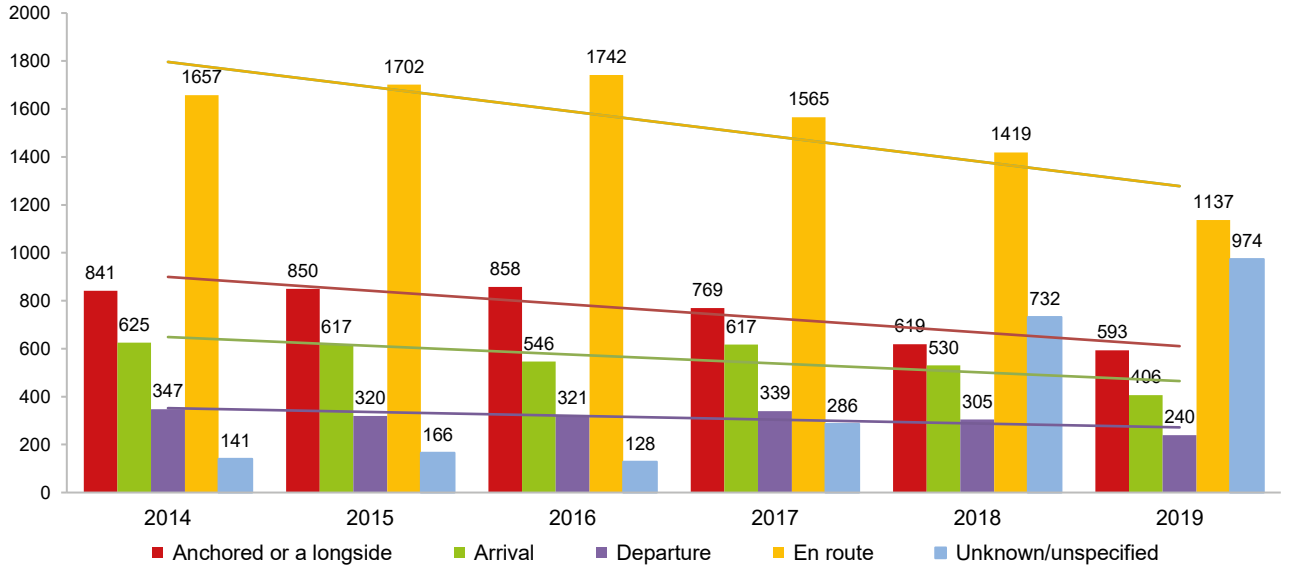

Figure 6. Accidents by route segments based on (EMSA, 2015–2020)

phase is the least safe in general (43%). The high rate of occurrences during the arrival segment is also remarkable, in comparison to the departure one.

Accidents analysis by ship type involved

Figure 7 shows accidents in the years 2014–2020 by ship types involved based on (EMSA, 2015–2021) together with fitted linear regression lines.

Among these types of ships, cargo ships followed by passenger ships caused the highest number of accidents. This number dropped in 2020 mainly due to the reduction in traffic caused by globally introduced restrictions to combat the COVID-19 pandemic. The chart also shows other types of vessels. This category includes marine yachts, recreational motorboats, and various other ships not counted in the four main categories. In the whole of the analyzed period, the highest number of accidents was recorded with sailing boats, reaching approximately 40% of affected ships in the "other type" category. From 2015 a decreasing trend for cargo and service ship accidents is evident, though it needs confirmation in the present and future years. Service ships, which encompass offshore vessels mainly with DP capability, tugs, pilot boats, etc., are subjected to more stringent regulations and guidelines, and their operation was also greatly affected by lower maritime traffic in 2020.

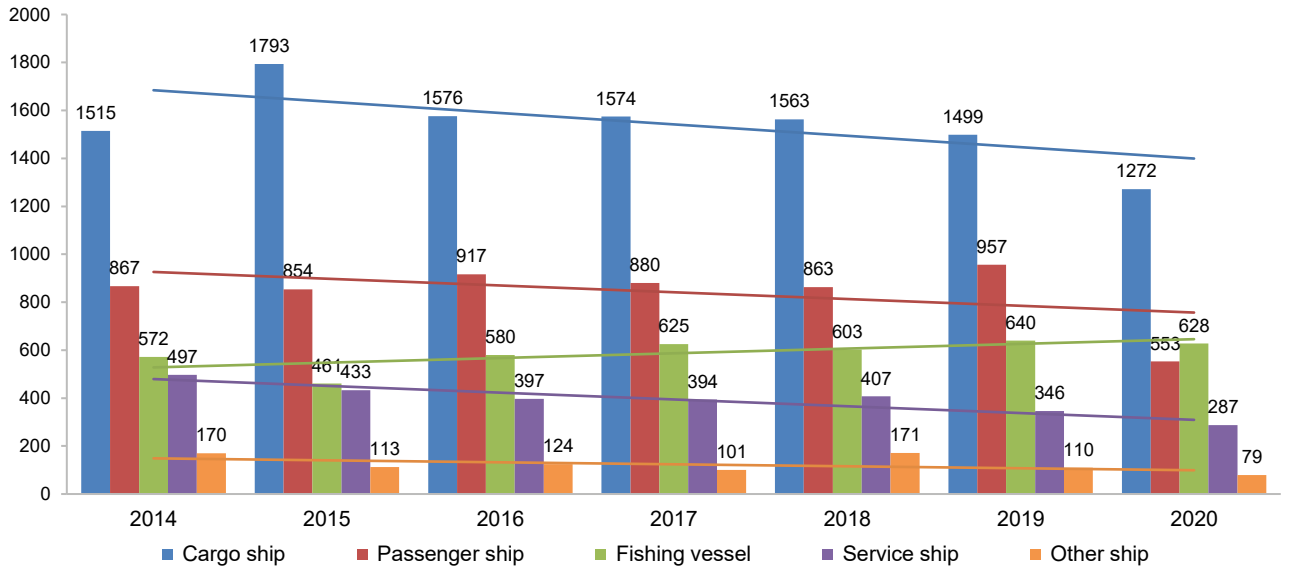

Figure 7. Accidents by ship type (EMSA, 2015–2021)

Analysis results

The presented analysis makes it clear that the biggest problem is irresponsibility and a lack of safety culture / experience, even on the most modern or technologically advanced ships. According to the EMSA, in the last two years (2019–2020) accidents of a navigational nature, such as contacts, grounding/stranding, and collisions accounted for 44% of all occurrences related to ships. It was, however, noted that the main type of accident to a ship was the loss of control (mainly propulsion or steering), which reached 22%. Regarding occurrences to people, 37% were attributed to their slipping, stumbling, and falling due to negligence. The departure phase appeared to be the safest phase of a voyage and the en route portion the most unsafe. It was noted that half of the casualties occurred in depth-restricted waters, more precisely in harbor areas.

Conclusions

After analyzing the results, it can be concluded that there are multifactorial contributions to all accidents and incidents, but that the most common factors in all investigations are human error, negligence, or ignorance. This shows that the risk of human error is the most difficult to reduce. The training of seafarers to be competent and strict obedience to safety management systems are the best recommended preventive actions.

In the case of navigational accidents, the fewest accidents are due to natural causes, such as bad weather. This trend may be caused by technological progress and wide access to updated data via satellite links on ships. Today access to route optimization data and weather forecasts on commercial and recreational vessels is more common and complex. It leads to an almost negligible number of accidents caused by the weather and other external factors that are inherently difficult to predict.

Accident causation analysis also leads to the conclusion that the adoption and implementation of IMO rules and guidelines, as well as conventions such as SOLAS, MARPOL, and STCW, had a significant impact on shipping safety. This conclusion can be confirmed by the fact that the majority of accidents occur on fishing vessels or yachts, vessels that are often managed and directed by unqualified personnel. In any case, an uncritical overreliance on technology and information provided via electronic means and sensors emerged as a new contemporary threat to the safety of navigation. This threat should be adequately taken into account during the training of OOWs and future maritime autonomous surface ship operators as the human factor remains the main one contributing to marine casualties.

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