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# The Maritime Safety: an Overview of the Events that Shaped their Evolution in the World up to the Present Day

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*ABSTRACT*

This study aims to provide a comprehensive perspective on the historical evolution and current trends in maritime safety. Through an analysis of significant events and technological advancements, the ongoing importance of addressing the challenges facing the maritime industry is sought to be understood. Maritime safety is of paramount importance today, as it ensures the protection of human lives, property, and the environment. Over the past century, international regulations and technological advances have been implemented to enhance safety in this realm, although challenges such as high human incidence in accidents persist. The methodology employed involves a historical analysis and examination of modern technologies and systems used to enhance safety. The growing interconnectedness and collaboration among different stakeholders, as well as the integration of environmental concerns, are highlighted. In summary, the need for continuous adaptation and improvement is underscored, not only to protect lives and assets but also as essential for the global economy and the sustainability of the marine environment.

## 1. Introduction.

This article aims to provide a perspective on the evolution of maritime safety, exploring the historical events and significant developments that have shaped its progress to the present day. Technological advancements, international regulations, and current challenges that define the landscape of merchant ship safety are examined. Furthermore, it seeks to highlight the ongoing importance of addressing these challenges and promoting a safer and more sustainable future for maritime transportation.

It is important to note that several organizations oversee merchant ship safety; however, this study focuses on the perspective of the shipping company, which naturally includes the vessel. In this regard, to contextualize the topic properly, maritime safety is considered, according to López and Ramírez, as "a set of activities (good practices) carried out by the shipping company and the vessel, aimed at preventing risks when adverse conditions may produce undesired effects on people, the vessel, its cargo, and/or the environment" (2023: 244).

Throughout this study, the historical trajectory is analyzed, and future perspectives in this fundamental field for the global economy and society's well-being are considered. This article focuses on safety; it does not delve into the topic of maritime security, which refers to illicit acts that may affect the vessel and its crew.

For centuries, this mode of transportation has been an essential pillar in global interconnectedness, facilitating trade, the movement of people, and the distribution of goods and food. The significance of this medium is such that the Secretary - General of the International Maritime Organization (IMO) stated: "Currently, around 90% of global trade is carried by international maritime transport. Without it, the import and export of goods on the scale necessary to sustain the current world would not be possible" (Sekimizu, 2015:1).

However, this mode of transportation has been exposed to various risks and challenges that have affected its safety since its inception. This safety has been and continues to be a critical factor in adhering to vessel itineraries and ensuring optimal

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cargo conditions.

The magnitude of the world fleet and the volume of goods it transports are evident in data provided by the United Nations Conference on Trade and Development (UNCTAD).

In 2022, UNCTAD reported that the fleet had reached a total of "102,899 vessels with a gross tonnage equal to or greater than 100" (UNCTAD, 2022:2).

In the following sections, these aspects will be explored in detail to offer a comprehensive view of the evolution and current state of maritime safety, allowing an understanding of its relevance and influence in the contemporary world. In this regard, the background and context section will generally highlight the history of maritime transportation and its importance in the world economy, summarize the challenges of safety throughout history, and international regulations related to this topic. Regarding evolution, an overview of key milestones in advancement and a description of events and progress that have influenced maritime navigation safety will be presented.

Another area of study is related to technologies, describing these and modern systems used to enhance safety, presenting examples of technological innovations that have had a positive impact. Current challenges are also highlighted, identifying current threats and challenges facing merchant ship safety. Additionally, a section will examine some emblematic cases that reactively led to safety improvements. Finally, future perspectives, conclusions, and bibliography are presented.

## 2. Methodology.

This research article employs a qualitative approach, focusing on the method of documentary research. This method involves a historical analysis and examination of modern technologies and systems utilized to enhance maritime safety.

The design of the study was flexible, characterized as propositional and based on exploration. This flexibility allowed for adaptability to the evolving nature of the subject matter, enabling the researchers to delve into historical contexts while also exploring contemporary advancements in maritime safety technologies and systems.

The documentary research method facilitated the gathering of data from various sources such as academic literature, reports, regulations, and historical documents relevant to the evolution of maritime safety. Through meticulous analysis and synthesis of these documents, the researchers aimed to construct a comprehensive understanding of the factors and events that have shaped maritime safety over time.

Additionally, the exploratory nature of the study encouraged the researchers to remain open to unexpected findings and insights. This approach enabled the exploration of emerging trends, challenges, and innovative solutions within the field of maritime safety, contributing to a nuanced and up-to-date analysis.

Overall, the methodology employed in this research article integrates historical analysis with an examination of contemporary technologies and systems, underpinned by a flexible and exploratory design suited to the dynamic nature of the subject matter.

## 3. Background and Context.

From the dawn of navigation to the present day, this sector has witnessed a series of events and challenges that have shaped its evolution and established the groundwork for addressing safety issues. In this context, this section aims to explore the background and historical context that have shaped the safetyty of merchant ships, identifying the milestones and circumstances that have influenced the current configuration of this field for international maritime trade.

### *3.1. Genesis, Development, and Relevance of Maritime Transport.*

The beginnings of the relationship between humans and the sea date back to ancient times when ships were built with wooden logs and covered with natural materials to cross small bodies of water (Karan, 2019). It is inferred that maritime transport has a documented history of nearly 5000 years (Stopford, 2010).

Now, according to the opinion of certain authors, possibly influenced by religious beliefs and with questionable scientific rigor, it is pointed out that approximately 5000 years ago, a vessel called Noah's Ark was built. Additionally, according to The Mariners' Museum and Park (2022), "the Egyptians built some of the earliest ships with papyrus reeds and were rowed between 6000 BCE and 3000 BCE."

In the centuries that followed, a civilization known as the Phoenicians emerged, who stood out as prominent traders and sailors in antiquity. Their skill in navigation enabled them to exchange a wide range of goods. They developed robust vessels and advanced navigation techniques that allowed them to explore territories beyond the known coasts, establishing trade routes to distant places (Álvarez-Mon, n.d.).

Over many generations, the Roman Empire consolidated its influence at sea, closely related to the need to establish commercial networks in the Mediterranean. Their naval dominance focused on the construction of shipyards and vessels for both peace and war. This led to innovations in ship design, naval construction techniques, port infrastructure, and maritime regulations that laid the foundation for trade and exploration in the Mediterranean and beyond. Rome's naval and maritime supremacy lasted from the 6th century BCE to the 5th century CE, spanning almost nine centuries (Peñaloza, 2019: 151).

A landmark in the development of maritime transport was the Industrial Revolution, due to technological advances, changes in production, and the expansion of trade it facilitated. Thus, maritime transport became, from those times, the "executive arm" of international trade for countries, as from that time on, the great world markets emerged (Bernardos et al., 2018).

The emergence of container ships is directly linked to the appearance of containers, which began to be used during World War II for the safe transport of war materials. This event marked the beginning of a revolution in maritime transport by demonstrating the efficiency and convenience of containerized cargo transport (Moldtrans Group, 2015). The growing globalization of containers has generated an urgent need for greater efficiency and profitability in maritime transport, leading to a growing demand in this sector. As a consequence of economies of scale, there has been a marked increase in the size and capacity of vessels (Diez and Calatayud, 2018).

Furthermore, after World War II, there was also a proliferation in the expansion of the number and size of the tanker fleet, leading to the specialization of this type of vessel in chemical and gas carriers. Likewise, the expansion of the bulk carrier, container ship, and other fleets continued their upward trajectory, as seen, for example, between the years 2020 and 2021, in Table 1.

Table 1: World fleet by main types of vessels, 2020-2021 (In thousands of deadweight tons [DWT] and percentages).

| Main types | 2020 | | 2021 | | Percentage variation between 2021 and 2020 |
|---|---|---|---|---|---|
| | Thousands of DWT | % | Thousands of DWT | % | |
| Bulk vessels | 879.725 | 42,47 | 913.032 | 42,77 | *3,79 %* |
| Oil tankers | 601.342 | 29,03 | 619.148 | 29,00 | *2,96 %* |
| Container ships | 274.973 | 13,27 | 281.784 | 13,20 | *2,48 %* |
| Others: | 238.705 | 11,52 | 243.922 | 11,43 | *2,19 %* |
| Offshore supply vessels | 84.049 | 4,06 | 84.094 | 3,94 | *0,05 %* |
| Gas tankers | 73.685 | 3,56 | 77.455 | 3,63 | *5,12 %* |
| Chemical tankers | 47.480 | 2,29 | 48.858 | 2,29 | *2,90 %* |
| Others/n.d. | 25.500 | 1,23 | 25.407 | 1,19 | *-0,36 %* |
| Passenger ships | 7.992 | 0,39 | 8.109 | 0,38 | *1,46 %* |
| General cargo ships | 76.893 | 3,71 | 76.754 | 3,60 | *-0,18 %* |
| **World total** | **2.071.638** | | **2.134.640** | | ***3,04 %*** |

**Note: Self-propelled seagoing merchant ships with a gross tonnage of 100 or more, figures as of the beginning of the year.**
Source: Own elaboration with calculations from UNCTAD (2021:9), based on data provided by Clarksons Research.

The types of vessels indicated in Table 1 made it possible to mobilize "11 billion tons transported by sea in 2021" (UNCTAD, 2022:3), highlighting the immense importance of this mode of transport for international trade and the global economy.

The relevance of this mode of transport is not a recent phenomenon. Adam Smith already described in his work "The Wealth of Nations" the economic benefits offered by maritime transport in the XVIII century. He stated: "Thus, with the help of water carriage, six or eight men can carry between London and Edinburgh, and vice versa, the same quantity of goods which fifty wagons, attended by a hundred men and drawn by four hundred horses, could carry" (Smith, 1996:51). He further elaborated on the implications of transporting two hundred tons of goods by land in the most economical way possible. To this, one must add the sustenance of those hundred men for three weeks and the wear and feeding of the four hundred horses. Clearly, what Smith described is essentially what is known as economies of scale applied to maritime transport, meaning larger volumes transported over longer distances at lower costs.

### 3.2. *Challenges of Merchant Ship Safety in the Last Century.*

One ongoing challenge that has persisted for over a century is the delayed response of international organizations responsible for making pertinent decisions to enable maritime administrations to supervise, verify, and control the compliance of shipping companies and their fleets in implementing regulatory instruments to prevent safety risks.

For example, a primary reference is related to the sinking of the passenger ship Titanic in 1912. Diez de Ulzurrun highlights that this ship by no means had "a watertight compartment deck running from bow to stern like decks E, F, and G, where all the watertight bulkheads ended" (1998:4). This meant that when each compartment filled with seawater, it would begin to flood the adjacent compartment, and so on, which is what occurred.

Already in 1914, during a conference held in London, the first version of the International Convention for the Safety of Life at Sea (SOLAS) was adopted; however, this version, due to the outbreak of World War I, never came into force. It was not until 1933 that the 1929 version of SOLAS came into force, but only with eighteen countries (National Library of Congress of Chile, n.d.).

In this same vein, the most comprehensive version of SOLAS, which introduced the mandatory requirement for watertight compartmentalization in ship construction, was the 1948 edition. The modification made to the convention introduced more rigorous aspects related to the design and construction of vessels. Among these regulations was the requirement to divide the hull into watertight compartments, with the aim of enhancing safety and preventing the possibility of flooding in situations of collisions or groundings. These provisions played a fundamental role in ensuring the structural integrity and safety of vessels in the maritime transport sector (National Library of Congress of Chile, n.d.). In other words, thirty-six years after the sinking of the Titanic, much of the maritime community agreed on the matter of watertight compartmentalization.

There are several examples that can be cited. However, the case related to fires on RoPax vessels stands out. According to the European Maritime Safety Agency (EMSA), in 2015, after the Norman Atlantic disaster in which 11 people lost their lives, it was highlighted that "the new regulations developed to address this issue are likely to be mandatory in 2026" (2022b:12). This demonstrates the prolonged time before the entry into force of regulations that, although reactive, are necessary to prevent new risks of this type affecting ship safety.

Another constant and highly relevant challenge that has affected the international maritime community for decades is the effort to reduce the human incidence of merchant ship accidents. The human factor has been a persistent challenge in maritime safety, as navigation errors, fatigue, lack of adequate training, and incorrect decision-making have led to numerous incidents. Continuous training, strict regulations, and supervision are essential to mitigate these risks. In this regard, the 2019 EMSA Annual Review of Maritime Casualties highlights that "65.8% of all maritime accidents are due to human action" (EMSA, 2022b:41).

More surprising data is observed in the 2022 Annual Review of Maritime Accidents and Incidents by the European Maritime Safety Agency, which states that in safety investigations conducted from 2014 to 2021, "59.6% of accidents were due to human action and 68.3% of contributing factors were related to human behavior" (EMSA, 2022a:9). When both human action events and contributing human behavior factors were analyzed together, "they were related to 81.1% of maritime accident and incident investigations" (EMSA, 2022a:9).

Table 2: An overview of key milestones in the evolution of maritime safety.

| Date | Milestone/Event | Meaning/Impact | Consequences |
|---|---|---|---|
| Between the XII and VI centuries BC. | Construction of the Phoenician "gaulós". | A ship with raised bow and stern, whose propulsion relies almost entirely on sail. | Sailing ships could move from one place to another on longer voyages. |
| XII Century | Application of the magnetic compass for maritime navigation. | It allowed navigators to determine the direction of magnetic north. | Reduced the risk of deviating from the planned route. |
| XII Century | The Crusaders painted a cross on the sides of the ships. | The loading of animals, goods, and/or equipment would begin, and when the ship's draft reached these lines, the loading operation would stop. | Safety measure to prevent the ship from foundering, as it had a reserve of buoyancy. |
| XIII Century | The emergence of cartography (portolan charts). | They visually represented coastal geography, following courses indicated by the needle and recording distances. | They allowed marking the routes to follow for coastal navigation. |
| XV Century | The use of the astrolabe and sextant for astronomical navigation. | The ship's position at sea was determined more accurately by observing celestial bodies. | Uncertainty about the vessel's location at sea and involuntary deviations off the planned route were reduced. |
| 1896, 1901 | The invention of the telegraph (1896) and radio (1901) on ships. | Communication at sea expeditiously and effectively. | They allowed faster response to emergencies at sea. |
| Mid-XVIII century and second half of the XIX century | Development of steam engines, diesel propulsion, propellers, and riveted steel ships. | It increased the efficiency of navigation and the speed of ships. | Ships more resistant to the onslaughts of the sea and with their own means of propulsion. |
| First half of the XX century | Construction of ships with welded steel hulls and watertight compartments. | Welding, by joining the steel plates forming the hull, provides strength and watertightness to the ship. | Strengthening structures to withstand adverse conditions at sea helps maintain buoyancy reserve. |
| From 1945 | Use of radar. | It provides real-time information about the location of other ships and enables determination of the vessel's position. | Prevention of collisions, groundings, as well as navigation in reduced visibility. |
| 1948 | Creation of the International Maritime Organization (IMO). | International regulations are established to ensure the safety and sustainability of maritime transportation. | Promoting standardization and coordination among nations on critical aspects such as safety, pollution prevention, and security. |
| Decade of 1990 | Advancement of Global Positioning Systems (GPS). | They provide ships with precision in determining their location at sea. | Preventing groundings, maintaining safe routes, and ensuring efficient navigation. |
| 1992 | Mandatory double hulls for tanker ships. | New amendments to Annex I of the MARPOL 73/78 Convention made double hulls mandatory. | Preventing oil spills from tanker ships due to groundings or collisions. |
| 1998 | Entry into force of the International Safety Management (ISM) Code | Implementation of safety management systems. | Preventing accidents that could affect the crew and passengers, the ship, cargo, and the environment. |
| 2002 | Creation of the European Maritime Safety Agency (EMSA). | To support Member States in the field of maritime safety and the prevention of pollution caused by ships. | Preventing and combating environmental damage caused by both ships and oil and gas installations. |

Source: Own elaboration with information and data from (Álvarez-Mon, n.d.), (Mgar.net, n/da), (Piniella, 2016:65), (Dehbozorgi, 2022), (Ibáñez, 2011:211), (Mgar.net, n/db), (Bernardos et al., 2018), (Diez de Ulzurrun, 1998:5), (National Library of Congress of Chile, n/d), (Petzold et al., 1994), (International Maritime Organization [IMO] n/da), (OMI, 2018), (OMI, 2020), (OMI, 2023), (Fallas, 2002), (Czaplewski & Goward, 2016), (Presura & Chirica, 2017) y (EMSA, 2022b)..

Reviewing history always provides a valuable perspective that can surprise us by revealing old solutions to problems we might consider current. In the late XIX and early XX centuries, there was a widespread belief that technological advancement would solve all challenges, but certain catastrophic events of that period questioned this idea. A notable example in the maritime field was the sinking of the Titanic, which, despite being considered unsinkable, raised doubts about blind trust in technology as the sole guarantee of safety at sea (García, 2000).

It is evident that maritime safety has evolved in response to these challenges, adopting advanced technologies, establishing novel regulations, and promoting a culture of safety to ensure safe maritime transport. However, the previously mentioned data show that the challenge of preventing human incidence in maritime accidents remains present.

## 4. Results and Discussion.

### *4.1. Evolution of Safety in Merchant Ships.*

Over the years, the international maritime community has witnessed a significant transformation in practices and technologies related to maritime safety. From the early days when navigation was driven primarily by the skill and courage of sailors to the current era of advanced navigation systems, international regulations, and specialized training, ship safety has undergone constant evolution. This retrospective analysis not only allows us to understand the historical trajectory of safety measures but also to identify the current and future challenges faced by this sector in its unwavering pursuit of increasingly safer maritime operations. Observe Table 2.

These milestones have significantly contributed to the improvement of merchant ship safety throughout history. From early vessel models like the Phoenician "gaulós" to modern technological advancements like GPS and radar, each of these milestones has represented a significant step in risk reduction and protection of the marine environment.

The introduction of the magnetic compass, cartography, the astrolabe, and the sextant improved navigation accuracy and enabled mariners to plot safer routes. The establishment of international standards and regulations through organizations like the International Maritime Organization (IMO) and the implementation of codes like the International Safety Management (ISM) have set benchmarks to promote safe practices in the maritime transport.

Advancements in communication technologies like the telegraph and radio have enabled faster responses to emergencies at sea, while developments in shipbuilding such as welding in steel hulls and watertight compartments have enhanced ships' resistance to potential structural damage.

The mandatory double hull requirement for tanker ships and the establishment of agencies like the European Maritime Safety Agency (EMSA) have strengthened spill prevention measures and fostered international cooperation on maritime safety issues.

### 4.2. *Modern technologies and systems used to enhance ship safety.*

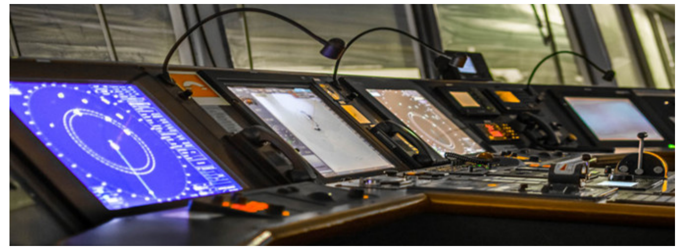
In the current context, ship safety has undergone a significant transformation driven by the advancement and adoption of modern technologies and systems. These advancements have redefined how risks are addressed and ensure the protection of lives, assets, and the environment in the maritime transport. From advanced monitoring and communication systems to prevention and emergency response technologies, the importance for safety in three areas, namely navigation, maritime communications, and artificial intelligence, is discussed below.

Improvements in ship construction; technologies applied to navigation equipment, communications, and machinery; national and international regulations, and risk management have contributed to a 50% decrease in reported losses in maritime transportation (Allianz Global Corporate & Specialty [AGCS], 2021:10).

As for navigation on the bridge of a ship, a fundamental system that has been developed is the Electronic Chart Display and Information System (ECDIS). This system goes far beyond simply replacing paper charts with electronic ones, as it incorporates electronic navigation software that integrates with various navigation equipment signals, such as radar, gyrocompass, log, echo sounder, automatic identification system, GPS, among others (Sifón, 2019).

In a study (Baric et al., 2023) conducted between 2008 and 2019, ship groundings were analyzed, and none of the examined accidents occurred under the influence of data overload from the ECDIS (see Figure 1), highlighting its importance for ship safety. However, the study also highlights that with this new technology in practice, new difficulties affecting operators have arisen. The authors identified what they call another "demon" that influenced grounding accidents, which is referred to as "complexity growth," which could be reduced by providing officers with more appropriate training (Baric et al., 2023).

Figure 1: Photograph of a section of the ship's bridge showing the ECDIS.



Source: https://www.myseatime.com/blog/detail/ecdis-passage-plan.

In 2006, the IMO Maritime Safety Committee initiated the "e-navigation" project through two technical subcommittees: the Navigation Safety Subcommittee (NAV) and the Subcommittee on Radiocommunications, Search and Rescue (COMSAR) (Korcz, 2023).

The modernization of the GMDSS was closely related to the development of the e-navigation project and the detailed role of radiocommunications in this process. Undoubtedly, the network of Information and Communication Technologies of the modernized GMDSS is one of the most important elements of e-navigation (Korcz, 2023).

Following Korcz's reflection (2023), considering the advancements resulting from the modernization of the GMDSS, which encompass legal and technical aspects, as well as the updating of existing systems and devices along with the adoption of new communication technologies, it is envisioned that NAVDAT systems will play a relevant role in improving digital communications for e-navigation and modernizing the GMDSS. This progress, as a whole, will contribute to strengthening safety in maritime transportation.

As for Artificial Intelligence (AI), it can impact ship safety in various ways, such as developing advanced collision detection and prediction systems, enabling ships to identify and avoid obstacles more effectively, even in adverse weather conditions or dense traffic situations. Additionally, AI algorithms can analyze large amounts of real-time data, including weather information, sensor data, and maritime traffic, to assist in more informed decision-making by the crew and autonomous control systems.

In a paper by Mohamed-Seghir, an approach is proposed to develop a ship operations control model to address the challenge of establishing a safe trajectory for a ship in collision situations. This model integrates the peculiarities of fuzzy processes to more accurately represent reality. In this context, the author states that: "in many instances, the navigator's decisions are subjective. An artificial neural network was employed to solve this problem, characterized by minimum and maximum operations in its configuration" (2023:283).

The research demonstrated the algorithm's ability to address highly complex situations. A key advantage is that the vessel's route returns to its initial course when there is no longer a risk. Additionally, the outcome of the presented neural network is chosen among several connections, enabling obtaining the optimal trajectory in a given situation (Mohamed-Seghir, 2023). In summary, the created algorithm can be used as a resource to assist the navigator in decision-making, contributing to ensuring safe navigation at sea. The encouraging results of the simulations conducted demonstrate the remarkable potential of this algorithm and the general importance of artificial intelligence for formulating risk control models for maritime transportation.

Artificial intelligence (AI) is being used to optimize, enhance, and implement the best possible strategies to address various complex situations of ships. However, according to a recent study by Sardar et al., they express that: ”the approach has been limited to emergency situations, while human error contributes equally to daily operational tasks” (2023:290).

In this regard, this research aims to provide a potential solution to reduce the risk of human error during daily operational tasks on ships. They propose an algorithm based on what they call ”Ant Colony Optimization (ACO)” to design and validate a verified set of instructions to carry out each operational task, which is integrated, globally accessible, and standardized (Sardar et al., 2023).

Overall, the study by Sardar et al. (2023) has the potential to contribute to the safety and efficiency of maritime transportation. Additionally, complex studies of multiple factors can be conducted using this model to assess large-scale implementation and validate its use in optimizing onboard operational processes.

### *4.3. Emerging Trends in Maritime Safety.*

Future perspectives on maritime safety represent a crucial aspect in the evolution of this industry vital for global trade. As the XXI century progresses, this sector faces a set of challenges and opportunities that will redefine how safety is addressed on ships. The increasing automation and digitalization of maritime operations, the expansion of navigation in polar regions, as well as the need for greater sustainability and resilience in the face of extreme weather events, are just some of the key issues that will shape the landscape of maritime safety in the years to come. In this context, emerging trends on the horizon are explored with the aim of promoting safer and more efficient maritime transportation in an ever-changing world.

#### *4.3.1. Digitization and automation.*

The adoption of digital technologies, such as autonomous navigation and remote monitoring systems, is transforming how ships are managed and operated, which can enhance safety by contributing to the reduction of human errors.

A 2023 study highlights the use of virtual reality as a potentially significant change in facilitating real-time remote inspections on merchant vessels. In situations where high-speed internet access is available, it is feasible to equip remotely controlled inspection robots or vehicles, such as drones, crawlers, unmanned aerial vehicles, among others, with Remote Inspection Technologies (RIT), advanced optical cameras, and sensor arrays, together with wearable devices and smart/mobile devices. This represents a significant advancement in the ability to conduct accurate and timely inspections in the maritime industry (Sheriff et al., 2023), which enhances safety due to the support received by the crew from the shore office for informed decision-making.

In another study on the application of digital neural networks in the context of ship technologies, the authors reviewed various algorithms of these networks in terms of ship technologies to evaluate the effectiveness of the methodology and propose a new concept for applying an artificial neural network. They then developed a simulation of a fire detection system based on data from thermal cameras to evaluate the efficiency of the proposed concept with a Multilayer Perceptron (MLP) algorithm integrated into the designed 3D model (Konon & Konon, 2023).

The results of the experiments demonstrated that the temperatures of fire sources determined by the MLP can be obtained with sufficient accuracy (less than ± 10°C), with a position prediction that does not exceed the value of two units in any direction (from a ”row-floor” area). The authors also highlight that to improve the presented concept and increase the performance accuracy, as well as to enable its application in various loading conditions and hold configurations, it is necessary to collect and process more data to sufficiently train the Deep Neural Network (DNN) (Konon & Konon, 2023).

#### *4.3.2. Maritime cybersecurity.*

With the increasing connectivity of onboard systems, cybersecurity has become a concern for the international maritime community. In June 2017, A.P. Moller-Maersk, with business units ranging from ports to logistics, ship operation, and oil drilling, with 574 offices in 130 countries around the world and about 800 vessels, suffered a cyberattack that could have cost up to $300 million (Palmer, 2017).

This event led to a new edition in 2018 of the ISM Code (IMO, 2018), incorporating in the document of that edition Resolution MSC.428(98) ”Maritime Cyber Risk Management in Safety Management Systems” and guideline MSC-FAL.1/Circ.3 ”Guidelines on Maritime Cyber Risk Management.” These IMO standards demonstrate that protection against cyberattacks has become an essential trend to ensure the safety of maritime operations.

A recent study (Erstad et al., 2023) proposes the creation of a cyber incident response procedure, providing a framework for shipping companies to facilitate the response of their onboard and onshore teams to a cybersecurity incident, considering their operational environment. This procedure, based on an operations flowchart, provides detailed guidance that directs the crew's decision-making process in the face of a cyber incident.

#### *4.3.3. Sustainability and environmental protection.*

Maritime transport is under pressure to reduce its environmental footprint. This includes measures to prevent pollution of the seas and the adoption of cleaner and more fuel-efficient technologies.

In 2020, the IMO conducted an analysis that revealed a 9.6% increase in greenhouse gas (GHG) emissions from maritime transport. It was determined that the increase in global maritime trade was the main factor contributing to this rise, underscoring the need to pay greater attention to the use of low-carbon alternative fuels (Klakeel et al., 2023).

This study conducted by Klakeel and colleagues (2023) focused on evaluating the effectiveness of currently available technologies in reducing GHG emissions from ships, examining a total of 68 articles published between 2018 and 2022. The technologies were classified into four groups: those using fossil fuels, those harnessing renewable energies, those using fuel cells, and those utilizing low-carbon alternative fuels.

Among these alternative fuels, ammonia stood out as the preferred choice due to its carbon-free nature, higher energy density, and feasibility in production; however, it is imperative to conduct further research to optimize its use and ensure its safety (Klakeel et al., 2023).

*4.3.4. Data-driven risk management.*

An illustrative example of applying a data-driven approach to risk management is found in the planned maintenance system of main ship engines. In a study (Anantharaman et al., 2019), relevant data obtained from various sources were examined to identify the most pertinent failure model for a particular component. This approach, ultimately, can reduce engine failures, contributing to a decrease in incidents in maritime transportation.

During the analysis, the authors evaluated the subjectivity and variability of the collected data, and it was observed that this was less than 10%. This finding increases confidence in the reliability and general applicability of the data. The results of Anantharaman et al.'s study indicate: "that not all data for a component of a main propulsion engine subsystem follow the same behavior. Based on the observations and current data, a Weibull model is suggested to estimate the reliability of the main engine cooling water system" (2019:406).

## Conclusions.

Over the last century, maritime safety has undergone significant evolution, adapting to the emerging challenges of the sector and leveraging technological advancements to implement more efficient systems. Throughout the years, from the introduction of the first international regulations to current standards, there has been a steadfast commitment to protecting human life, property, and the marine environment.

Despite progress, significant challenges such as reducing collisions, fires, and human errors still require robust prevention strategies and modern technologies like advanced monitoring and artificial intelligence. The expansion of the global market and the need for operational efficiency press for maintaining high safety standards without compromising productivity. Effective collaboration among maritime administrations, international organizations, industry, and academia is crucial to overcoming these obstacles, also integrating an increasing environmental awareness into safety practices.

To end, maritime safety remains a critically important and constantly evolving area, essential not only for protecting lives and assets but also for the global economy and environmental sustainability. Maintaining a proactive and adaptable approach is essential to address current and future challenges, thereby ensuring a safe and sustainable future in maritime navigation.

## References.

Allianz Global Corporate & Specialty [AGCS] (2021) An Annual Review of Trends and Developments in Shipping Losses and Safety. Safety and Shipping Review (SSR) 2021. Munich, Germany.

Álvarez-Mon, D. (n.d.). La gran aventura de los navegantes fenicios. Sociedad Geográfica Española. Boletín No. 23. Available from: https://sge.org/publicaciones/ numero-de-boletin/boletin-23/la-gran-aventura-de-los-navegantes-fenicios/ [Accessed 1 March 2024].

Anantharaman, M., Islam, R., Khan, F., Garaniya, V. and Lewarn, B. (2019). Data analysis to evaluate reliability of a main engine. *The International Journal on Marine Navigation and Safety of Sea Transportation*, 13(2), 403-407. https:doi.10.-12716/1001. 13.02.18.

Baric, M., Grbić. L., Pericin, L. and Jelic, R.(2023). The Role of the ECDIS on the development of situational awareness – a study on grounding accidents. *The International Journal on Marine Navigation and Safety of Sea Transportation*, 17(1), 219-225. https:doi.10.12716/1001.17.01.24.

Bernardos, J., Hernández, M. and Santamaría, M. (2018). La revolución industrial y el crecimiento económico moderno. Universidad Nacional de Educación a Distancia (UNED). Available from: https://www.studocu.com/es/document/uned/historia-economi ca/revolucion-industrial-uned/6592339 [Accessed 8 December 2023].

Czaplewski, K. and Goward, D. (2016). Global navigation satellite systems - perspectives on development and threats to system operation. *The International Journal on Marine Navigation and Safety of Sea Transportation*,10(2),183-192. https: doi.10.127 16/1001.10.02.01.

Dehbozorgi, A. (2022). Historia del transporte marítimo. Blog Historia del Transporte. Available from: https: //www.samatrans.ir/history-of-maritime-transp [Accessed 11 March 2024].

Diez de Ulzurrum, I. (1998). Aspectos estructurales del hundimiento del Titanic. ResearchGate. Available from: https:-//www.researchgate.net/publication/344036677 [Accessed 5 January 2024].

Diez, E., and Calatayud, A. (2018). Grandes cambios en la industria marítima en estas décadas. Moviliblog. Available from: https://blogs.iadb.org/transporte/es/cuales-son-los-grandes-cambios-de-la-industria-maritima-en-estas-decadas/ [Accessed 5 January 2024].

Erstad, E., Hopcraft, R., Palbar, J. and Tam, K. (2023). CERP: A maritime cyber risk decision making tool. *The International Journal on Marine Navigation and Safety of Sea Transportation*, 17(2), 269-279. https:doi.10.12716/1001.17.-02.02.

European Maritime Safety Agency [EMSA] (2022a) Annual Overview of Marine Casualties and Incidents. Available from: https://www.emsa.europa.eu/newsroom/latest-news/item/-4867-annual-overview-of-marine-casualties-and-incidents-2021-.html.

European Maritime Safety Agency (EMSA) (2022b) European Maritime Safety Report. Available from: https://emsa.europa.eu/publications/item/4735-emsafe-report. html.

Fallas, J. (2002). Sistema de posicionamiento global. Tele-SIG-UNA, 01-46. Available from: https://ucipfg. com/Repositorio/MGAP/MGAP-05/BLOQUE-ACADE MICO/Unidad3/complementarias/Sistemas_de_posici onamiento_global.pdf [Accessed 14 January 2024].

García, J.A. (2000) El factor humano en la toma de decisiones de los oficiales de puente en las tareas de navegación. Thesis (PhD). Universidad Politécnica de Cataluña. Available from: https://www.tdx.cat/handle/10803 /7007#page=1.

Ibánez, I. (2011). Evolución de la navegación astronómica en el siglo XIX. ResearchGate, (57) 209-243. Available from: https://www.researchgate.net/publication /334249530_Evolucion_de_la_Navegacion_Astronomica_en_el_siglo_XIX/citation/download (25/09/2023) [Accessed 24 March 2024].

International Maritime Organization [IMO] (n/da). Breve reseña histórica de la OMI. Reino Unido: Historia. Available from: https://www.imo.org/es/About/HistoryOf IMO/Paginas/-Default. aspx [Accessed 25 October 2023].

International Maritime Organization [IMO] (2018). International Safety Management Code (ISM Code). London, United Kingdom: IMO Publications.

International Maritime Organization [IMO] (2020). Constitution of the International Maritime Organization (IMO Convention) Available from: https://www.imo.org/es/About/Conventions/Pages/Convention-on-the-International-Maritime-Organization.aspx

International Maritime Organization [IMO] (2023). 50 years of MARPOL: our commitment continues. Available from: https:-//wwwcdn.imo.org/localresources/es/Me diaCentre/Documents-/World%20Maritime%20Theme%202023%20-%20Background-% 20 paper_SP.pdf.

Karan, C. (2019). La historia de los buques: mundo marítimo antiguo. Marine Insight. Available from: https://www.marineinsight.com/maritime-history/the-history-of-ships-ancient-maritime-world/ [Accessed 30 January 2024].

Klakeel, T., Anantharaman, M., Islam, R. and Garaniya, V. (2023). Effectiveness of current technology in GHG Reduction – A literature survey. *The International Journal on Marine Navigation and Safety of Sea Transportation,* 17(1), 171-176. https:doi.10.12716/1001.17.01.18.

Konon, V. and Konon, N. (2023). Application perspective of digital neural networks in the context of marine technologies. *The International Journal on Marine Navigation and Safety of Sea Transportation*,16(4), 743-747. https:doi.10.12716/1001.-16.04.16.

Korcz, K. (2023). Key points of the modernized GMDSS system. *The International Journal on Marine Navigation and Safety of Sea Transportation,*17(1),139-146. https: doi.10.127-16/1001.17.01.14.

López, M. and Ramírez, M. (2023). La seguridad marítima como valor; más allá del cumplimiento con la certificación. *InterSedes,* 24(49), 238-254. Available from: https:// revistas.ucr.ac. cr/index.php/intersedes/issue/view/3227.

Mgar.net (n/da). Historia: Navegación: Brújula. Available from: https://www.mgar.net/var/brujula.htm [Accessed 25 March 2024].

Mgar.net (n/db). Radiotelegrafía y Navegación. España: Historia/Canarias/ Navegación. Available from: https://www.-mgar.net/mar/ondas.htm [Accessed 25 March 2024].

Mohamed-Seghir, M. (2023). Modern method based on artificial intelligence for safe control in the marine environment. *The International Journal on Marine Navigation and Safety of Sea Transportation,* 17(2), 283-288. https: doi.10.12716/1001-.17.02.03.

Moldtrans Group (2015). Origen e historia de los contenedores del transporte marítimo. Blog del Grupo Moldtrans. Available from: https://www.moldtrans.com /origen -e-historia-delos-contenedores-del-transporte-marítimo/ [Accessed 5 January 2024].

National Library of Congress of Chile. (n/d). SOLAS: Convenio Internacional para la seguridad de la vida humana en el mar, 1974. Available from: https://obtiene archivo.bcn.cl/obtienearchivo?id=documentos/10221.1/43947/27/26.pdf [Accessed 18 February 2024].

Palmer, D. (2017). Petya ransomware: cyberattack costs could hit $300m for shipping giant Maersk. ZDNET Tech Today. Available from: https://www.zdnet.com/article/ newly-discovered-android-malware-has-infected-thousands-of-devices/ [Accessed 18 March 2024].

Peñaloza, M. (2019). Portus, classe naviculariusque: Roma y el control del mar Mediterráneo (s. VI a.C- IV d.C). *Revista de historia (Concepción),* 26(1), 149-170. Available from: https://dx.doi.org/10.4067/S0717-88322019000100149.

Petzold, H., Blumtritt, O. and Aspray, W. (1994) Tracking the history of radar. A publication of the IEEE – Rutgers Center for the History of Electrical Engineering & the Deutschers Museum. Available from: https://ethw.org/w/images/0/0e/Tracking-_the_ History_of_Radar.pdf.

Presura, A. and Chirica, I. (2017). Collision analysis of the unconventional double hull of a ship. *World Journal of Engineering and Technology,* 5, 601-612. https://doi. org/10.4236/-wjet.2017.54051.

Piniella, F.(2016). La seguridad marítima: una visión retrospectiva. *Revista Oratores*, 4(4), 64-68. https://doi.org/10.375-94/oratores.n4.83.

Sardar, A., Anantharaman, M., Garaniya, V. and Khan, F. (2023). Optimization of daily operations in the marine industry using Ant Colony Optimization (ACO) - An artificial intelligence (AI) approach. *The International Journal on Marine Navigation and Safety of Sea Transportation*, 17(2), 283-288. https://doi.10.12716/1001.17.02 .04.

Sheriff, A., Anantharaman, M., Islam, R. and Nguyen, H. (2023). Application of virtual reality for remote ship inspections and surveys – A systematic review. *The International Journal on Marine Navigation and Safety of Sea Transportation,* 17(3), 587-594. https://doi.10.12716/1001.17.03.10.

Sekimizu, K. (2015) The maritime transport: indispensable for the world, Presentation to the Council of the International

Maritime Organization (IMO) at its 28th Extraordinary Session, 15 November 2015. Available from: https://www.imo.org/es/MediaCentre/Press Briefings/Paginas/47-WMD-theme-2016-.-aspx.

Sifón, M. (2019). Cartografía náutica electrónica, una mirada al futuro. *Revista de Marina*, 136 (970). https://revistamarina.cl/es/articulo/cartografia-nautica-electronica-una-mirada-al-futuro.

Smith, A. (1996). La riqueza de las naciones. Madrid: Alianza Editorial, S.A.

Stopford, M. (2010). How shipping changed the world. Global Maritime Environmental Congress SMM Hamburg. Available from: http://www.clarksons.net /archive/research/freestuff-/Martin%20Stopford%20How%20shipping%20has%20changed-%20the%20world%20(paper).pdf [Accessed 1 November 2003].

The Mariners' Museum and Park (2022). Egyptian ships. Available from: https://exploration.mariners museum.org/watercraft/egyptian-ships/ [Accessed 1march 2003].

United Nations Conference on Trade and Development [UNCTAD] (2021) Review of Maritime Transport. Available from: https://unctad.org/system/ files/official-document /rmt2021summary_es.pdf.

United Nations Conference on Trade and Development [UNCTAD] (2022) Review of maritime transport. Available from: https://unctad.org/system/files/official-document/rmt2022_en.pdf.