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# Current analysis of risk factors in maritime navigation

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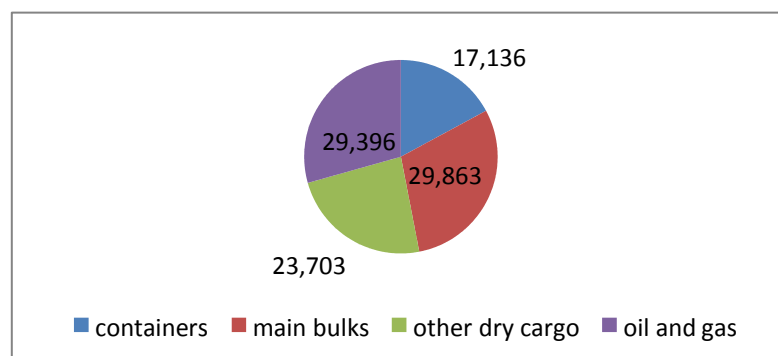
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**Abstract:** any maritime voyage is exposed to sea hazards, natural and artificial dangers, as well as naval accidents and incidents. Maritime risk management issues have so far been relatively predictably connected to: natural disasters, technical faults of ships and naval equipment and human errors. Today, the particular rise in international maritime trade and the use of new technologies in the naval industry are generating new, ever-changing risks. Identifying and counteracting these risks is crucial, as the success or failure of the maritime industry can have important effects on world trade and economy. The main risk trends faced by the maritime industry at present include: natural disasters, emergence of new arctic routes, unmanned ships, autonomous transport, piracy.

## 1. Introduction

At the present stage of human civilization, maritime transport is able to provide the traffic of the huge volume of cargo which is the subject of the world trade.

The international maritime transport is characterized today by obvious complexity. Over the past 37 years (1980-2017), the volume of transported oil and main bulk cargo (iron ore, grain, coal, bauxite / alumina and phosphate, and starting from 2006 iron ore, grain and coal only) has increased significantly. Thus, in 2017 the world seaborne trade in crude oil and petroleum products and gas was 3.15 million tons, which accounted for 29.4 % of total, and the seaborne in major dry bulk commodities (coal, iron ore and grain) trade, accounted for 29.86 % of total, and was estimated at 3.19 billion tons, imposing measures to increase the effectiveness and safety of this activity. In containerized maritime transport (1.83 million tons, 17.3% of total) [23, 24], technical changes were so profound that traditional marine practices became, for the most part, anachronistic (Graph 1).



Graph 1 International seaborne trade in 2017, %

It is a well-known fact that any marine expedition is naturally exposed to risks at sea, to natural and artificial dangers, as well as accidents of human origin. The technical, economic and legal measures taken in order to reduce these risks are indispensable in the modern age (taking into account the long shipping routes, the large volume of transported cargo, the crossing of several different climatic zones during the same voyage, etc.).

As an economic activity, maritime transport cannot be limited to measures for increasing the profitability of sea trade, since it is an objective necessity for the development of the current human society.

Maritime trade continues to expand, generating benefits for consumers around the world through competitive transport costs. Due to the increased efficiency of maritime transport as a means of transport and due to an increased economic liberalization, the prospects for the continued growth of the industry continue to be strong. There are over 94,000 merchant ships in the world fleet, with a total tonnage of 1.92 billion TDW, carrying all kinds of goods, with a volume of 10.7 billion tons [24], registered in over 150 states, for which more than one million navigators of many nationalities work. This powerful, globally-expanding industry, of great complexity generates and is affected by risks of various origins, with simple and complex effects, that are constantly changing.

## **2. Materials and Methods**

The present study was conducted using official information from international sources: IMO, UNCTAD, P&I, World Bank, Review of Maritime Transport, trusted specialist studies. The statistical data cover periods of time of several years in order to better understand the impact of some factors on the emergence and evolution of risks in marine navigation. The methods used for data analysis refer to the comparative analysis of the evolution of the main marine navigation risk factors for the same period of time. The data obtained were compared with the evolution of the world merchant fleet over the same period of time in order to detect the way in which these parameters influence each other.

## **3. Results and Discussions**

Although, at present, the seas and oceans of the world are safer than ever, the maritime industry has to continue to act constantly in order to mitigate classical risks, and proactively against new risks. The significant present risks with future implications recognized internationally are: the reduction of a ship's crew, which compromises the margin of maritime safety and may increase the risk of "human error", the increase in onboard bureaucracy, the risk linked to increasing marine traffic in crowded maritime areas, the risk of the increasing size and speed of merchant vessels, the risk of piracy in various parts of the globe, the change of the ocean ice regime as a result of the frequent descent of the floating ice toward middle latitudes, hence the emergence of new complications regarding navigation safety.

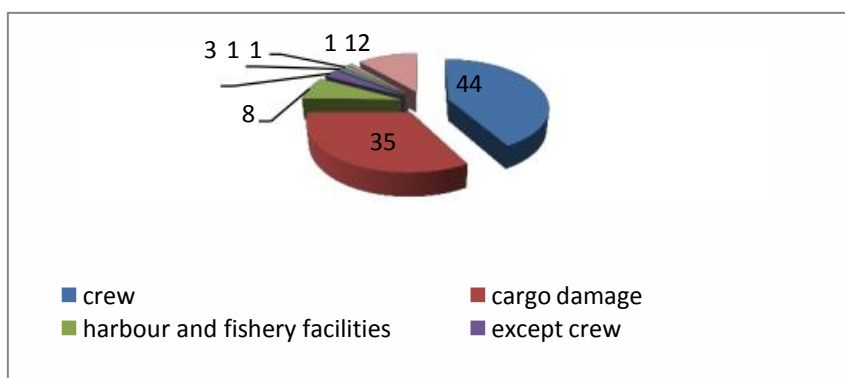
### **3.1 The human error risk**

Current statistics show that human errors account for about 75% to 96% of the total of maritime accidents, with losses of over \$ 1.6 billion. This has generated interest in the construction of autonomous ships capable of transporting more cargo in safer conditions. In order for this to work, the naval industry will have to determine the amount of human factor intervention in avoiding the collision between manned and autonomous ships. Recent studies have shown that human error contributes to: 84-88% of onboard tankers accidents; 79% of the towboats' failure; 89-96% of all the collisions at sea; 75% of all maritime accidents; 75% of all fires and explosions. Most of these accidents were not caused by a single error, but they were caused by a series of errors [5, 7].

The total number of accidents researched by P&I between 2008 and 2016 was 29,836, most of which - 13,185 - caused by the vessels' crew (44%), 10,483 - cargo damage (35%), 2,481 - damage regarding harbour and fishery facilities (8%), and 750 - regarding other people, crew excepted (3%), comprising 90 % of the total [22] (Table 1 and Graph 2).

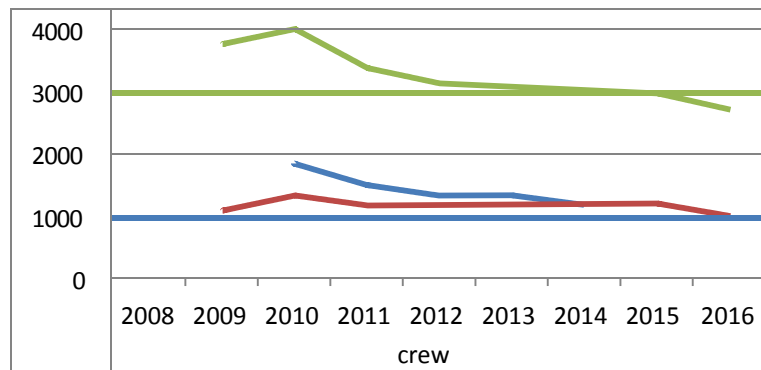
Table 1 Number of accidents and accident rate fluctuation

By accident type	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total	%
Crew	1,880	1,904	1,833	1,491	1,321	1,326	1,173	1,182	1,075	13,185	44
Cargo damage	1,135	1,078	1,321	1,161	1,157	1,201	1,248	1,193	989	10,483	35
Damage report regarding harbour and fishery facilities	342	324	328	283	257	230	232	246	239	2,481	8
Other people, crew excepted	93	95	99	106	73	76	67	67	74	750	3
Collision	72	60	64	45	32	32	42	32	42	421	1
Oil spill	55	34	34	47	35	40	26	30	34	335	1
Groundings, sinking and fire	18	9	12	19	7	11	10	11	11	108	1
Others	253	247	301	213	237	180	204	201	237	3,687	12
Total	3,848	3,751	3,992	3,365	3,119	3,096	3,002	2,962	2,701	29,836	100
Number of vessels	2,745	2,866	2,880	2,757	2,576	2,500	2,475	2,406	2,333	23,538	
Accident rate	140.2	130.9	138.6	122.1	121.1	123.8	121.3	123.1	115.8	126.8	



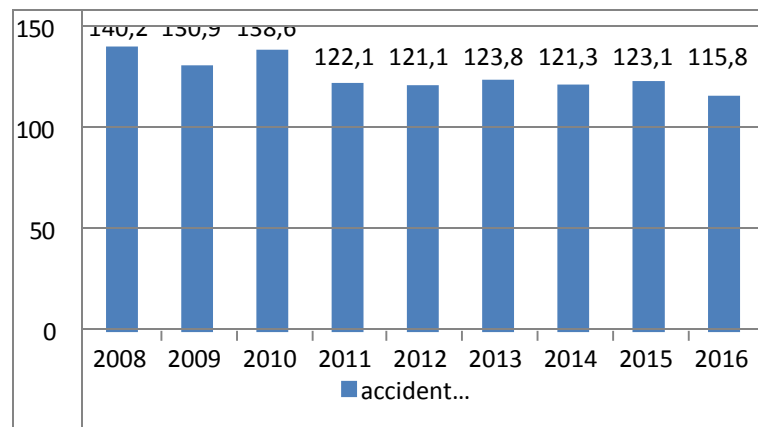
Graph 2 Number of maritime accidents by type

The data above show, for the 2008-2016 period, a downward trend in accidents caused by ships' crew, from 1880 in 2008, to 1075 in 2016, down by 42.81%, accidents resulting from the deterioration of the cargo, from 1135 in 2008, to 989 in 2016, down by 12.86%. Moreover, one can notice the decrease in the total number of accidents, from 3848 in 2008, to 2701 in 2016, down by 29% [22] (Graph 3).



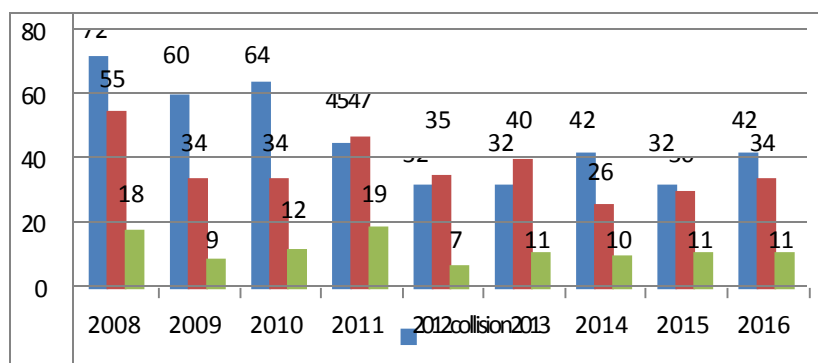
Graph 3 Accidents caused by the crew, cargo damage and total

Furthermore, the total accident rate in 2008-2016 had a downward trend, from 140.2 to 115.8 in 2016 [22] (Graph 4).



Graph 3 Accident rate in the 2008-2016 period

The analysis of maritime accidents caused by classical causes, such as collision, oil spill, groundings, sinking and fire shows a general decreasing trend, with an oscillating evolution, however. The number of collisions at sea dropped from 72 to 42 in 2016 (a 41.66% decrease), the number of oil spills dropped from 55 to 34 in 2016 (down by 38.18%), and the number of groundings, sinking and fire decreased from 18 to 11 in 2016 (a 38.88% decrease) [12, 22] [Graph 5].

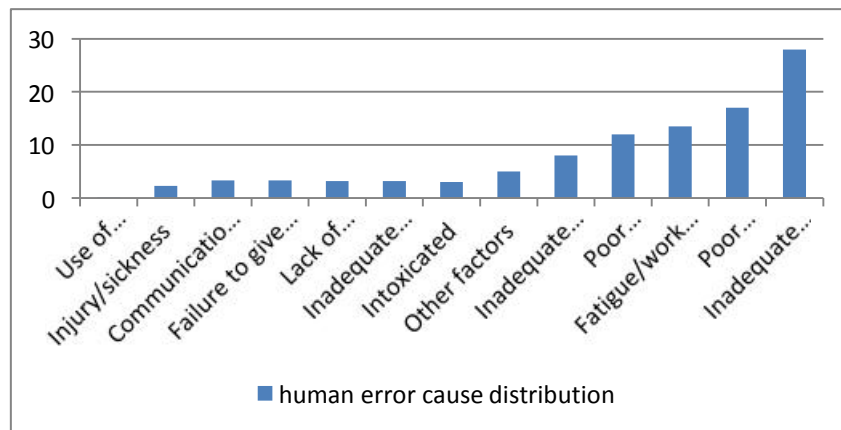


Graph 5 Number of collisions, oil spills, groundings, sinking and fire, 2008-2016

According to IMO [International Maritime Organization, International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, International Maritime Organization, London, 2011], the causes that lead to human errors onboard ships are presented below in Table 2, and their distribution in Graph 6. One can easily notice the incidence of the last five causes connected directly to human judgment (inadequate planning of voyage, poor judgement of other factors, fatigue/work overload, poor judgement of ship, inadequate observation).

Table 2 The main causes of human error onboard ships [30]

1.	Use of defective equipment	8.	Other factors
2.	Injury/sickness	9.	Inadequate planning of voyage
3.	Communication problems	10.	Poor judgement of other factors
4.	Failure to give way	11.	Fatigue/work overload
5.	Lack of knowledge	12.	Poor judgement of ship
6.	Inadequate use of navigation	13.	Inadequate observation
7.	Intoxicated		



Graph 6 Human error cause distribution

### 3.2 The piracy risk

In 2016, 191 piracy incidents were reported, down by 22% from 2015, the lowest figure recorded since 1998. In particular, piracy off the coast of Somalia dropped dramatically, with only two incidents in 2016, compared to 160 in 2011 [6,13]. This decrease is due to measures taken in order to counteract the action of pirates in the Gulf of Aden and the Indian Ocean, including the use of warships and a multinational maritime force. Formed in 2009 by warships from Australia, Pakistan, South Korea, Turkey, the United Kingdom and the United States, its role is to protect global maritime affairs from the pirate attacks in the Gulf of Aden. However, the threat of piracy has not been completely eliminated, as this activity has increased in other areas, including in the waters around West Africa, Malaysia and Indonesia. This new form of piracy, however, is different, in the sense that it focuses more on armed robbery than on the hijacking of ships.

### 3.3 Cyber-attacks risk

Although in the past it was seen as a marginal problem for the maritime transport, today cyber-risk is considered one of the greatest threats to the international economic environment. While computer systems onboard ships are autonomous, they are vulnerable to internal threats, such as disgruntled

crew members. Attacks from outside are also possible by hijacking ships from the planned route by interested external forces. The cyber-attack of NotPetya Virus in 2017 also had an international target - A.P. Møller-Mærsk A/S company, one of the largest container operators in Europe. In just two days after the attack, it was able to resume orders from customers, but it was enough to incur huge losses between \$200 and \$300 million [21]. The attack has attracted the attention of the maritime industry through the resulting losses and its consequences, such as the temporary closure of the largest cargo terminal in the Port of Los Angeles [21]. With the increasing cybernetic dependence of the ships on land-based steering centers, the risk of intrusion from unauthorized entities into the steering networks of ship companies and ships with the aim of hijacking or other unauthorized actions will increase.

### 3.4 The risk related to the emergence of new navigation routes

In recent years, as a result of climate change, there is talk and action taken in order to set up new arctic maritime routes. As time goes on, while the surface of the ice in the Arctic Ocean will diminish, the northern areas, free of navigation, will expand, which could lead to the use of permanent northern trade routes. So far, these routes have been limited to ships belonging to Arctic Class Ships, but in the future one can count on shorter northern routes between the Atlantic Ocean and the Pacific Ocean ports.

In recent years, the value of maritime transport in the northern North Sea - the northern Russia area - has increased considerably. Total traffic has exceeded seven million tons and is expected to increase tenfold to 75 million tons by 2025. Moreover, in the Northwest Passage an increased maritime transport activity has been noticed over the same period. At an international level there are considerable concerns about opening sea routes to the north. Pending the opening of an ice-free northern route, some companies have decided to invest in ships that can navigate in these areas. Specialty literature shows China's intention to form a "*silk arctic road*" across the northern North Sea, on which the duration of a voyage would be shorter by about 20 days than the traditional route through the Suez Canal.

Over the last three decades, the volume of international maritime transport has steadily increased, with the exception of short periods during the global economic crises (1985-1990 and 2009-2010), from 3,704 million tons in 1980 to 10,702 million tons in 2017, an increase of 63.4%. The largest increase in cargo traffic was recorded on the oceanic routes in the Indian Ocean and the West Pacific Ocean. In the Mediterranean Sea, the Red Sea and the North American West Coast significant increases were also noticed. Major studies, of which we mention the one published by UNCTAD in Review of Maritime Transport 2018, show an annual increase in world maritime trade of 3.8% in the 2018-2023 period [9, 23, 24] (Table 3)

Table 3 UNCTAD – forecast of global maritime trade evolution in the 2018-2023 period [28]

Seaborne trade type	%
World seaborne trade	3.8
Dry bulk	4.9
Containerized trade	6.0
Crude oil	1.7
Refined petroleum products and gas	2.6

### 3.5 Risks related to increased sea passenger traffic

The number of passenger ocean liners has increased significantly lately and an average annual growth of 7.4% is forecast for the period 1990-2019 [24]. Over 22 million seaborne passengers are estimated in 2019, compared to 19.2 million in 2018.

Concerning the distribution of the areas with the most onboard passenger ships accidents, these include South China, Indo-China, Indonesia and the Philippines, with a percentage of 17% between 2001 and 2018. These are followed by the Eastern Mediterranean and the Black Sea (13%) and by Japan, North Korea and North China (12%), and the waters of the British Isles - 8% [1].

### 3.6 Risks related to the construction of larger ships

Today, in maritime transport *the bigger the ships, the bigger the risks* is considered a true jest. Very large vessels are a special concern for naval designers and shipbuilders in order to find new theories, technologies and materials to ensure the structural integrity of these vessels, with lengths of over 400 meters and displacements of hundreds of thousands of TDW. Furthermore, these ships also pose great challenges for insurers due to the size, value and enormous damage they can produce in case of a maritime accident. The size itself does not make these ships riskier, but the increase in construction dimensions entails specific risks that need to be taken into account when navigating through crowded areas, during emergency or search and rescue of people fallen into water maneuvers, etc. Also, the tendency of increasing the size of transport vessels, and the increasing pressure of the operating cost have prompted ship owners to hire teams from emerging countries, where the standards of seafarers' training and assessment do not meet world-wide requirements represent new important risk factors in modern maritime navigation.

### Conclusions

Human error is the weakest link in the chain of errors, a factor which remains critical despite hundreds of years of technological improvements and despite safety regulations. More than 75% of maritime damage can be attributed to a wide range of "human error" factors, including: fatigue, inadequate risk management, competitive pressure, and deficiencies in the training of the crew.

The more the technological improvements reduce the risk, the more important the human factor becomes. This is an area on which industry should focus more so that best practices in risk management and a culture of safety could become second nature at the level of the world's merchant fleet.

In addition to the human factor, the new threats, such as: global warming, economic challenges, with their cyclical crises, technological, related to oversizing, increasing speeds at sea, agglomeration, new routes, financial, related to profitability, become current and future risk factors for maritime navigation.

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