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METHODOLOGY FOR IDENTIFICATION, ANALYSIS AND EVALUATION OF RISKS IN THE MARITIME INDUSTRY. STUDY CASE: CONTAINER MARITIME TRANSPORT

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Abstract: The paper proposes a methodology for identifying, analyzing, and evaluating risks for the maritime industry, presented systematically. In the research, the methodology we applied to container ship, for a generic model of the fully cellular containership type and three modes of operation. The conceptual framework of the research was organized into three stages, which are detailed in the paper. Risk analysis and evaluation took into account the provisions of the IMO (Revised Guidelines for Formal Safety Assessment - FSA for use in the IMO rule-making process). The major / priority risk factors were grouped into 12 risk scenarios, and the consequences of their materialization were related to 4 types of risk (the risk for human life, risk for the environment, risk for cargo, risk for the ship. The authors consider that the proposed research can be used by adapting it to identify, analyze, and evaluate the risks for the other types of ships.

Key words: maritime transport, container ship, maritime risk.

1. The current state regarding the risk in maritime transport

The analysis of maritime transport, from the perspective of risk management, implies certain difficulties due to a large number of factors and causes that directly condition this type of activity. The issue is hotly debated in many papers, which emphasize that from the perspective of their nature and even transportation insurance, risks can be grouped into maritime risks, special risks, and excluded risks [1].

In the paper [2] it is shown that the maritime risks (Sea Perils) are those possible but uncertain events that may occur during the transport and which may cause total or partial loss or damage to the transported goods and/or the means of transport and / or any other pecuniary means related to the shipping expedition.

It is emphasized that the situations or events that endanger the ship, the cargo, or any pecuniary interest related to the maritime expedition are determined by natural phenomena and the dangers of the sea. In most works, natural phenomena (recorded outside force majeure - Act of God) are limited to the violent action of wind and waves, [3] For an accident to be considered as due to force majeure, natural forces, it must occur outside of the normal course of things, be unpredictable, cannot be removed by ordinary diligence. The specialized literature is particularly focused on the issues of sea hazards (Sea Perils). These are highlighted as all the accidents that can happen at sea: failures, collisions, approaches, moving the stacked goods on board, fires or explosions on board, goods on deck being taken by the waves, the penetration of water in the ship's stores, etc., [4]

From the foregoing considerations, we can conclude that the main sources of risk for the ship are: storm, shipwreck, explosions on board, collisions (including those with other ships), failure, approach, throwing of goods overboard, fire, theft, wrong maneuvers, etc.

From ancient times and until now in the "risks of the sea" are included both piracy and terrorism. Moreover, in the 21st-century, pirates are portrayed as sea thieves, attacking and robbing commercial ships. The most well-known risk areas for such practices are: in West Africa (Ivory Coast, Liberia); East Africa (Somalia coasts, Gulf of Aden); in SE Asia (Malaka, Indonesia); in S America (Peru, Colombia); in the Mediterranean (Algerian N coast), [5].

From the same perspective of risks, "Special Risks" include risks due to the nature of the goods being transported as well as those due to special causes, such as war, strikes, embargoes, etc. Among the special risks, which arise as a result of physical and chemical properties of the goods, are mentioned: leaking, rusting, spillage, breaking, smashing, sweating, heating, deterioration, etc. [1] and [6]. In the field of maritime insurance, the risks mentioned are excluded (Exclusions), which means those risks for which the insurer does not bear any liability in the event that they would occur during an insured transport.

The analysis presented above shows that the issue of risk in maritime transport is extremely complex. The diversity of the goods transported by highly specialized vessels, the hydrometeorological conditions, sometimes extreme, associated with each trip, as well as the complex transfer process within the port system, complete this picture of the logistics chain of maritime transport.

The paper proposes a risk analysis for container vessels. The research was carried out within the framework of the PSCD projects: "Assessment of the risk of accident in the maritime industry" and PSCD 137/2019: "Management of the risk of pollution with hydrocarbons in the maritime and fluvial area of Romania with specialized information and communication tools."

2. The risk management framework in the maritime industry

A coherent scientific approach to risk management for sectors of the maritime industry includes both mathematical modelling and established management techniques. In this context, the organizational framework of the risk management for a ship it is shown in Figure 1. In the process of identifying risks, relevant to the operation of a ship, the following modes of operation have been taken into account: (1) - Loading/unloading at berth; (2) - Operations in port, restricted and coastal waters; (3) –open sea voyage.

In the research carried out, the analysis and evaluation of the risks were performed based on the gravity-probability couple, using quantitative and qualitative methods. The analysis considered the following variables: type of ship (size of the ship, construction, and operating characteristics), age of the ship, technical level characteristic of on-board and deck naval systems, navigation systems and equipment, etc. The risk analysis was performed based on the frequency of occurrence of an event and the associated consequences.

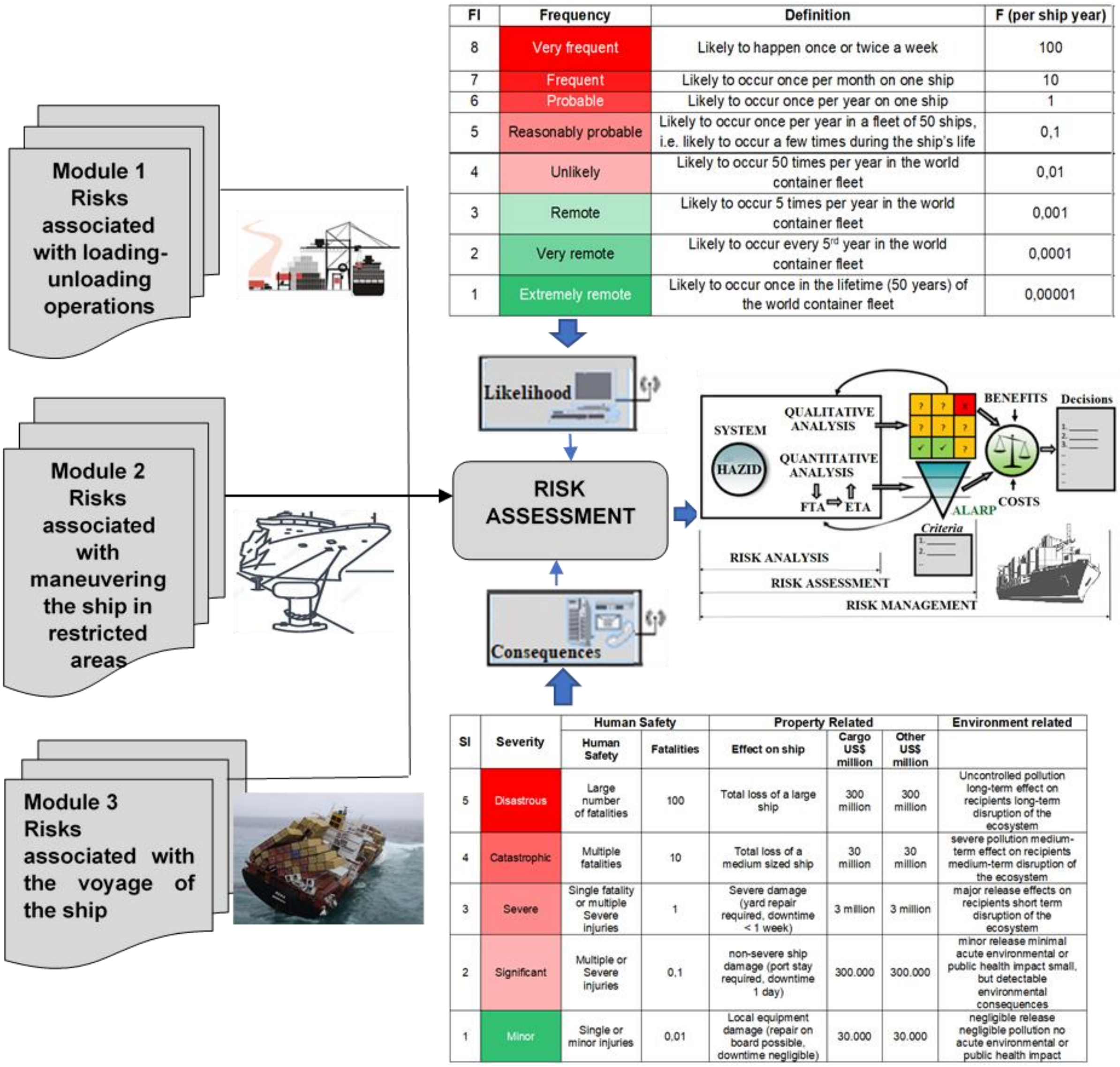


Fig. 1. The organizational framework of risk management on a seagoing vessel.

These quantities are converted into frequency indices and severity indices, based on which the risk index will be determined. Later these indices will be used to determine the impact, impact materialized by: the risk on human life, the risk on the environment, the risk on the cargo, the risk on the ship.

For a transport vessel, risk analysis is aimed at developing an understanding of it, providing input data for the evaluation stage. Risk is analyzed through its two components, probability/frequency, and severity/severity, but also through other relevant attributes. Thus, risk analysis becomes a process of both qualitative and quantitative impact assessment, which each risk may have for each of the 3 operating modules of the ship. The cost-benefit analysis completes the evaluation and facilitates the establishment of a set of useful criteria for the decision-making process.

The results obtained from the risk analysis and ranking are used for cost-benefit analysis.

The decisions will take into account a broader context of risks and risk tolerance of stakeholders, as they complement the risk management process.

3. The methodology for identifying, analyzing and evaluating the risks of a maritime vessel

Practice shows us that risk management is a continual process, which takes place throughout the course of an activity. The process is cyclical, carried out during five mandatory stages: establishing the organizational context and risk planning, risk identification, risk analysis (quantitative, semi-quantitative and qualitative), establishing risk management strategies, monitoring, and control [3], [8]. The research carried out in this paper is focused on the problem of risk management in maritime vessels. The methodology highlights how the risks can be identified, the methods of their analysis and evaluation. The research method can be used, after any adaptation, to identify, analyze, and evaluate the risks for other types of ships.

3.1 Risk identification methodology

The conceptual framework for risk identification has been substantiated in accordance with the Formal Safety Assessment (FSA) method and IMO regulations in this area [9], [10]. In this sense, the research was structured in 3 stages: RISK-CON1, RISK-CON2, and RISK-CON3, figure 2.

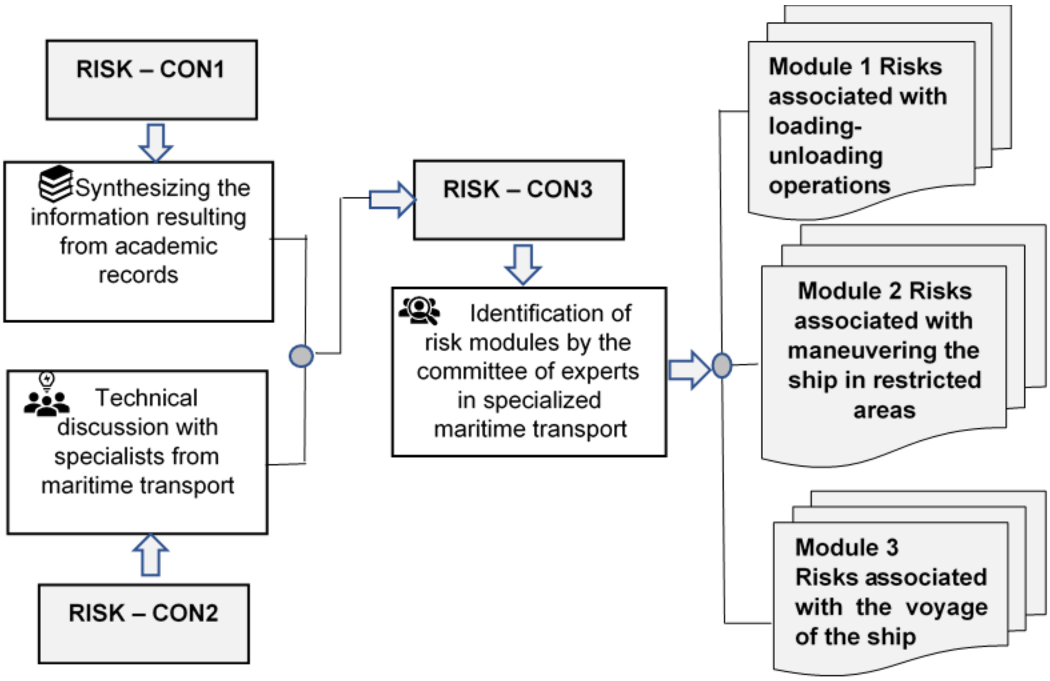


Fig. 2. The conceptual framework for risk identification in specialized maritime transport.

RISK-CON 1. In the first stage, the authors of the research make a synthesis of the information present in the analysis of the specialized literature, regarding the risks associated with the operation of specialized vessels. The study took place onboard ships between 1990 and 2015 and was completed with reports from the investigation of accidents, considering the risk-safety relationship in maritime transport. Databases used: Marine Accident Investigation Branch, IMO's Global Integrated Shipping Information System - Marine Casualties and Incidents Module, Lloyd's Register FairPlay - Lloyd's Register of Ships, CEFOR's Nordic Marine Insurance Statistics Database, The Norwegian Maritime Directorate Accident Database.

RISK-CON 2. This stage uses the technical consultation of specialists in specialized maritime transport (navigating personnel at the managerial and operational level; representatives of port operators; responsible for risk and safety in maritime transport; specialists in naval architecture and shipbuilding). Each round of discussions is recommended to be led by an integrating expert, who has the role of organizing and leading the debates in the following directions: introduction of the purpose of the research; presentation of the synthesis obtained within the RISK-CON1 module. The identified risk sources and risk factors are organized in a technical report of the RISK-CON2 stage, which will be used in the RISK-CON3 stage.

RISK-CON 3. In the case study organized in this research, the analyzed subject was that of containerized maritime transport. From this perspective, the RISK-CON3 expert commission was composed of 16 experts, with theoretical and practical experience in the field of container ships: 6 long-haul commanders, 4 chief mechanics; 2 operations managers in container terminals; 2 naval architecture experts; 1 marine machinery and installation expert; 1 university professor with expertise in the field of maritime risk and safetyNone of the members of this team participated in the RISK-CON2 module. The debates took the form of 3 workshops. Results obtained: 3 modules in which the risk sources were validated and grouped. In each round of discussions, the integrative expert, as a representative of the research team, aims to reduce the inhibitions that occur in groups and therefore stimulate the generation of new ideas. Within each approach, the integrating expert will favor divergent creativity, with the increase of the number of ideas, being identified the relevant risk sources for containerized maritime transport. Risk factors are identified and detailed for each source, and the maximum foreseeable causes and consequences are identified. At this stage, the probability/frequency level and the severity/severity level were established.

3.2 Risk analysis and assessment methodology

In the case of maritime transport, the risk analysis involves an assessment of the premises underlying the changes in the internal or external environment of the system that is the maritime vessel. Without full knowledge of the situation, one cannot anticipate the system's reaction to the manifestation of critical factors and vulnerabilities, as they amplify the level of risk. Vulnerabilities will have to be quantified, as they only increase the effect of the unfavorable evolution of the external environment on the activities carried out, the state of functionality of the analyzed system, in this case, the seagoing vessel. Knowledge and understanding of risk are essential in another aspect, risk being a multidimensional concept, which in many situations can not be easily expressed in the form of a figure or an indicator. Risk is an aggregate notion that provides a synthetic picture of the degree of risk to which an activity is exposed the operation of the ship [2], 11]. As will be seen, one or more of the elements under analysis may have an extremely high level, which could jeopardize the achievement of the objectives of the sub-activities involved. In these conditions, in order to be able to solve the risk equation, a breakdown of the ship operation process is used, corresponding to the 3 operating modules, highlighted in point 3.1 of the paper. For maritime transport, it is necessary to estimate the degree of risk exposure with emphasis on: risk for human life, the risk for the environment, risk for cargo, risk for the ship. [9].

In the maritime transport the problems generating risk can be represented by: the ship itself as a means of transport, the transported goods, the specific conditions of the marine environment, and the navigating personnel [12]. Without hyperbolizing the subject, it can be said that the maritime sector is, by definition, a world full of risks, with variable consequences and scenarios, the impact of which can quickly shift from negligible to catastrophic [1]. Even if the problem of risk management is continuously evolving, we must emphasize that risk analysis is mandatory, this emphasis being valid for any field of activity, not only for the maritime one.

The research emphasized that after identifying the risks, analyzing and evaluating them means determining the probability and the impact they would have if they materialized. As it looks [1], [2], [8], in the field of risk assessment, there are differences of opinion regarding the use of qualitative and/or quantitative analysis methods, the qualitative-quantitative factor being the fundamental property of hazard/hazard analysis methods. The level of risk determination on ships, depending on the probability/frequency of occurrence of a hazard (hazard) and the severity/consequences associated with it, was performed within an analysis and evaluation algorithm, figure 3.

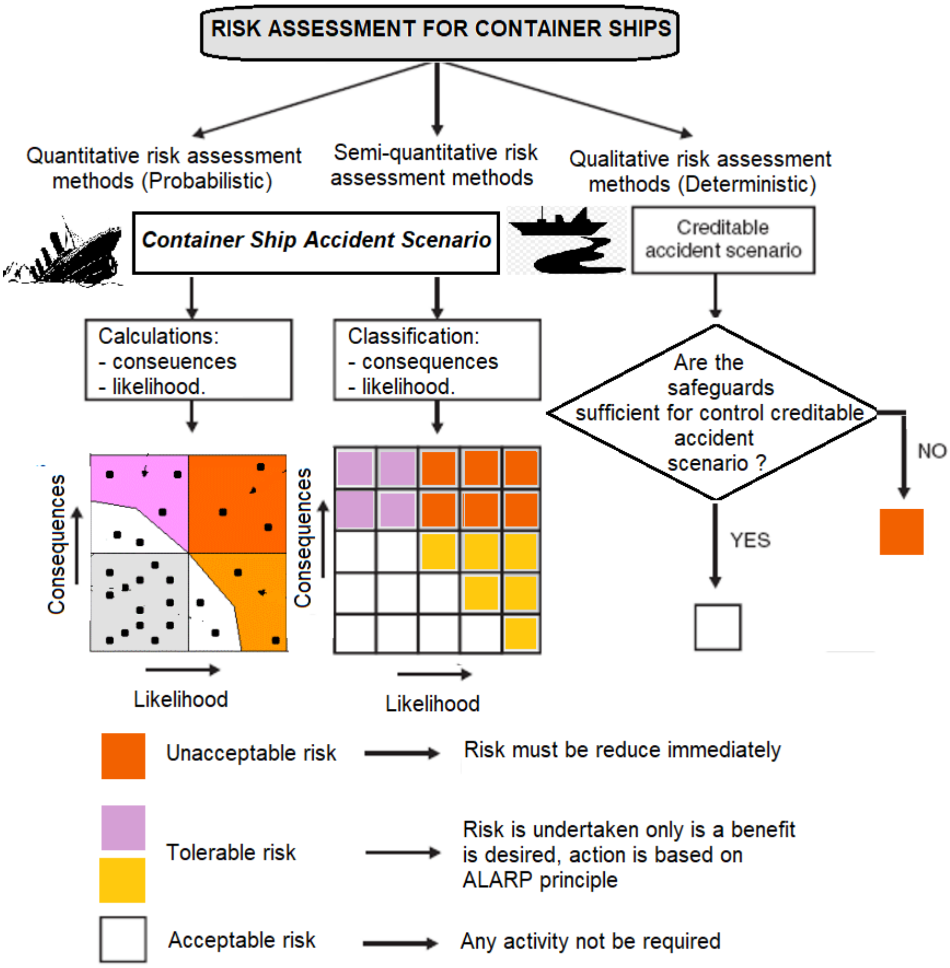


Fig.3 Methods of risk assessment (author's adaptation of source [8])

Within the quantitative risk analysis, numerical values are assigned to both the probability of occurrence and the resulting impact if the risk would materialize, [3]. Similarly, the benefits and costs associated with the implementation of corrective measures and the risk management process are quantified. The analysis must reflect the fact that these corrective measures must ensure that the risk is reduced to the point where the marginal cost resulting from the application of the action becomes equal to the total expenses corresponding to undesirable events, which may result in losses. Quantitative analysis is much more objective and accurate, including the use of numerical or quantitative data, providing quantitative results, which can be significantly affected by the accuracy and validity of input parameters. For this reason, quantitative results, in the case of risk analyzes, should not be considered as exact numbers, but as estimates on a variable scale, which depends on the quality of the data.

The risk analysis from qualitative point of view is based on the operation with relative values, most often performed through questionnaires, diagrams, and views expressed in collaborative discussion groups [2]. On the other hand, in the case of qualitative analysis, there are situations in which the evaluation process requires a smaller number of engaged persons. In other situations, even if the qualitative analysis is expensive, see the case of the technical consultation method and the experts RISK-CON2 and RISK-CON3, the results obtained are more useful in risk management [9]. From a practical point of view, it should be noted that, along with the advantage due to the simplicity and flexibility of this method, we also record the disadvantage due to the results, which are often vague, obtained based on relative values. Qualitative analysis involves the use of specific criteria, using different categories to separate the parameters, with qualitative definitions that establish the scale for each risk category analyzed, ensuring a higher degree of generalization, [10], [12], [13].

From the aspects outlined above, the information resulting from the analysis of the ship/risk modules can be processed by the commission of specialized maritime transport experts RISK-CON3.

In the research carried out, in this paper, the generic model analyzed corresponds to a ship of the fully cellular containership type. The goods are represented by TEU (20ft) and FEU (40ft) type containers, including refrigerated containers. The following variables were taken into account in the analysis: the type of container ship (size of the vessel, construction, and operating features), age of the ship, the main functional systems of the container ship, fig. 4.

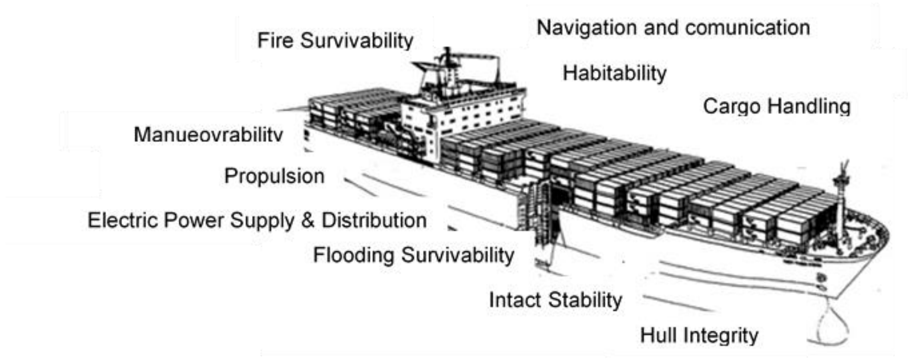


Fig.4 Container ship – main functional systems

From an operational point of view, the risk analysis and assessment were performed for the following situations, which correspond to the ship's mode of operation: (1) - loading/unloading at berth; (2) –Operations in port, restricted and coastal waters; (3) –open sea voyage. As mentioned above, the Failure Mode and Effect Analysis (FMEA) method was used to identify the potential failure modes, the causes, and effects of each failure on the operation of the entire system, which is the container ship. The elements estimated in this analysis are the severity / maximum predictable consequences and the frequency of occurrence/probability. According to the IMO methodology [9], risk (R) is defined as the product between probability/frequency (F) and maximum predictable consequence/severity (S):

$$R = F \cdot S$$

After converting the expression to logarithmic form, we obtain the relation::

$$\ln(R) = \ln(F) + \ln(S) \quad \text{or} \quad RI = FI + SI$$

where: RI – risk index; FI - probability/frequency index ; SI – index of maximum foreseeable consequences, hereinafter referred to as the severity index. According to the regulatory guide proposed by the IMO index $FI \in [1,8]$ and $SI \in [1,5]$. By using the logarithmic scale the increase of an index with the unit value corresponds to an increase of the associated quantity between 10^{-3} and 10^{-2}.

From this perspective, the frequency index is defined as a number that shows how often a dangerous event is expected to occur. While FI = 1 shows a very low frequency of occurrence of an event, FI = 8 indicates events that have a higher frequency than once a month. To make a comparison between different indices, the regulatory guide proposed by the IMO proposes the term “ship year.”

As it look [9] the term "ship year" is the equivalent of the period in which a ship operates for one year, and 10 years ship is the equivalent of a ship operating for 10 years or 10 ships operating for one year. The correlation between the frequency index, the linguistic value in terms of probability, and the term “ship year” is shown in table 1.

Table 1. Frequency index [9]

FI	Frequency	Definition	F (per ship year)
8	Very frequent	It probably happens once or twice a week on a ship	100
7	Frequent	Probably to be held once a month on a ship	10
6	Probable	Probably to be held once a year on a ship	1
5	Reasonably probable	Likely to occur once a year in a fleet of 10 ships, likely to occur several times during the life of a ship	0,1
4	Unlikely	It will probably appear once a year in a fleet of 100 ships	0,01
3	Remote	It will probably appear once a year in a fleet of 1,000 ships	0,001
2	Very remote	It is likely to appear once a year in a fleet of 10,000 ships	0,0001
1	Extremely remote	Likely to appear once in the life of a ship (20 years) in a fleet of 5,000 ships	0,00001

According to www.statista.com, the Global Merchant Fleet - number of ships by type in 2019 - the container vessels were 5150 ships [14]. Under these conditions, in order to use the frequency index information by the RISK-CON3 team, the standardized form of Table 1 was adapted and transformed into table 2.

Table 2. Frequency index update for 2019 (information taken from [9] and author's updated)

FI	Frequency	Definition	F (per ship year)
8	Very frequent	Likely to happen once or twice a week	100
7	Frequent	Likely to occur once per month on one ship	10
6	Probable	Likely to occur once per year on one ship	1
5	Reasonably probable	Likely to occur once per year in a fleet of 50 ships, i.e., likely to occur a few times during the ship's life	0,1
4	Unlikely	Likely to occur 50 times per year in the world container fleet	0,01
3	Remote	Likely to occur 5 times per year in the world container fleet	0,001
2	Very remote	Likely to occur every 5th year in the world container fleet	0,0001
1	Extremely remote	Likely to occur once in the lifetime (50 years) of the world container fleet	0,00001

The severity index is defined as a number that shows how severe the consequences of a particularly dangerous event are expected to be. While index 1 indicates an event with negligible consequences / minor effect, index 5 indicates events with catastrophic consequences, [6].

As stated above, the risk is the combination of frequency and the consequences of an unwanted event. Using the properties of the logarithmic calculation, it was observed that the risk index is expressed as the sum of the frequency index and the severity index, [9]. Table 4 brings together all possible combinations in the form of a matrix that is used to identify regions with an unacceptable, generally acceptable or potentially acceptable risk with improvements.

Table 3. Severity index [9]

SI	Severity	Human Safety		Property Related			Environment-related
		Human Safety	**Fatalities**	**Effect on ship**	**Cargo US$ million**	**Other US$ million**	
5	Disastrous	Large number of fatalities	100	Total loss of a large ship	300 million	300 million	Uncontrolled pollution the long-term effect on recipients long-term disruption of the ecosystem
4	Catastrophic	Multiple fatalities	10	Total loss of a medium-sized ship	30 million	30 million	Severe pollution medium-term effect on recipients medium-term disruption of the ecosystem
3	Severe	Single fatality or multiple Severe injuries	1	Severe damage (yard repair required, downtime < 1 week)	3 million	3 million	Significant release effects on recipients short term disruption of the ecosystem
2	Significant	Multiple or Severe injuries	0,1	non-severe ship damage (port stay required, downtime 1 day)	300.000	300.000	Minor release minimal acute environmental or public health impact small, but detectable environmental consequences
1	Minor	Single or minor injuries	0,01	Local equipment damage (repair on board possible, downtime negligible)	30.000	30.000	Negligible release negligible pollution no acute environmental or public health impact

Table 4. Risk index matrix [9]

Risk index RI						
		Severity index SI				
		1	2	3	4	5
FI	Frequency	Minor	Significant	Severe	Catastrophic	Disastrous
8	Very frequent	9	10	11	12	13
7	Frequent	8	9	10	11	12
6	Probable	7	8	9	10	11
5	Reasonably probable	6	7	8	9	10
4	Unlikely	5	6	7	8	9
3	Remote	4	5	6	7	8
2	Very remote	3	4	5	6	7
		2	3	4	5	6

During the analysis session, for each ship's operating module, identified in point 3.1, figure 2, a workshop was organized with the participation of members of the Risk-CON3 team of experts.

Table 5. Questionnaire for determining the risk index by sources and risk factors.

HAZID Worksheet				FI	Consequences (SI)				Risk (RI)				Remarks
ID	Failure Mode	Failure Effects	Failure Causes		Human	Env.	Cargo	Ship	Human	Env.	Cargo	Ship	

During the debates, the most relevant accidents (present in the syntheses made at the RISK-CON1 stage and in the technical report of the RISK-CON2 stage) were used as initiating elements of the debates and analyzes, by the brainstorming method, in the RISK-CON3 stage.

For each source of risk and risk factor separately, each expert completed table 5, highlighting: the effects, causes, and associated consequences. The consequences were detailed from the following perspective: loss of life, environmental pollution, loss of cargo, or total loss of the ship.

4. Detailing the way of working within the expert group

During the research, a particular emphasis was placed on consulting experts, especially in the RISK-CON3 stage. The method of using the opinion of experts and the interpretation of the results, after consulting them, is detailed extensively in the paper [2]. The critical role of experts should be emphasized both in the risk identification phase and in the risk analysis and assessment phase.

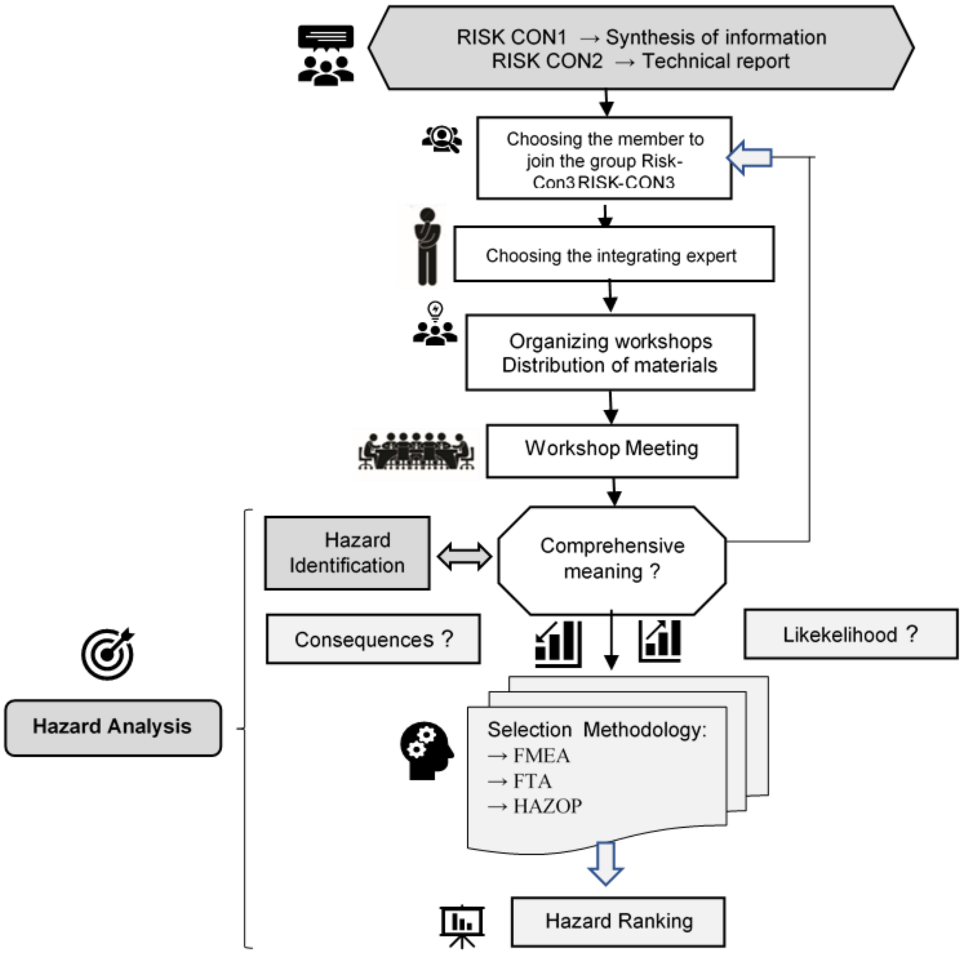


Fig. 5 The integrated process of managing the opinion of experts to identify, analyze and assess risks

The process of selecting experts, organizing debates, and processing information are presented in stages in the logic diagram in Figure 5. The activity within the RISK-CON3 expert group was rigorously organized, each expert participating responsibly and proactively in this research.

After the completion of the questionnaires by the experts, presented in table 5, the information is consolidated in a summary table. The harmonization of the results obtained by processing the individual questionnaires was achieved by the method of the concordance matrix, [2].

5. Results

The results were obtained by applying the methodology of identification, analysis, and risk assessment to a container ship within the collaboration of the research team with filed experts in the RISK-CON3 stage.

5.1 Identification of risks on container vessels. Results.

For risk module 1 associated with the operating mode (1) - loading/unloading at berth in the RISK-CON3 stage, 7 risk sources were highlighted for which 25 risk factors were identified.

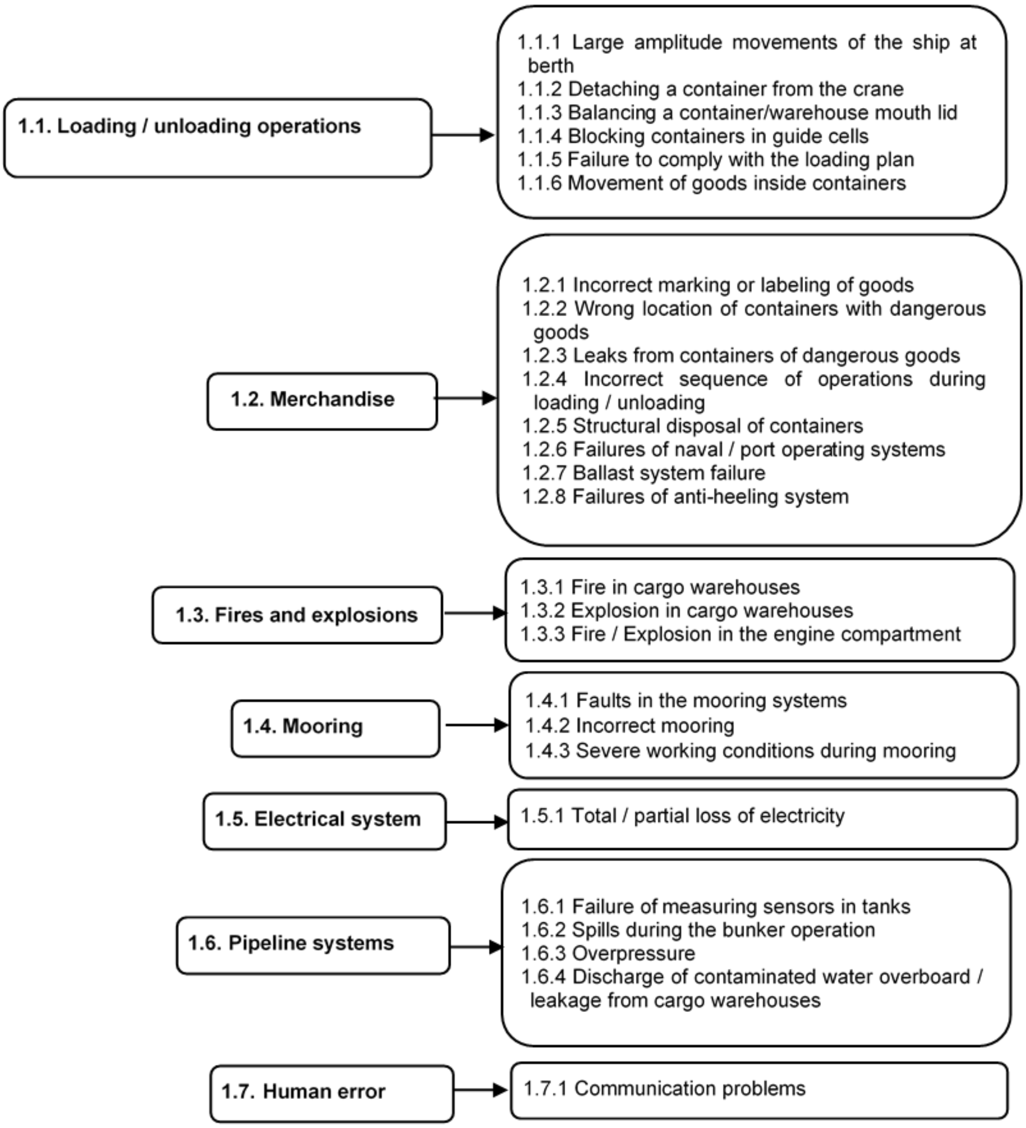


Fig. 6. Identification of risk factors. Module 1: Risks associated with loading-unloading operations

For risk module 2 associated with the operation mode (2) - operations in port, restricted and coastal waters in the RISK-CON3 stage, a number of 8 risk sources were highlighted, for which 39 risk factors were identified.

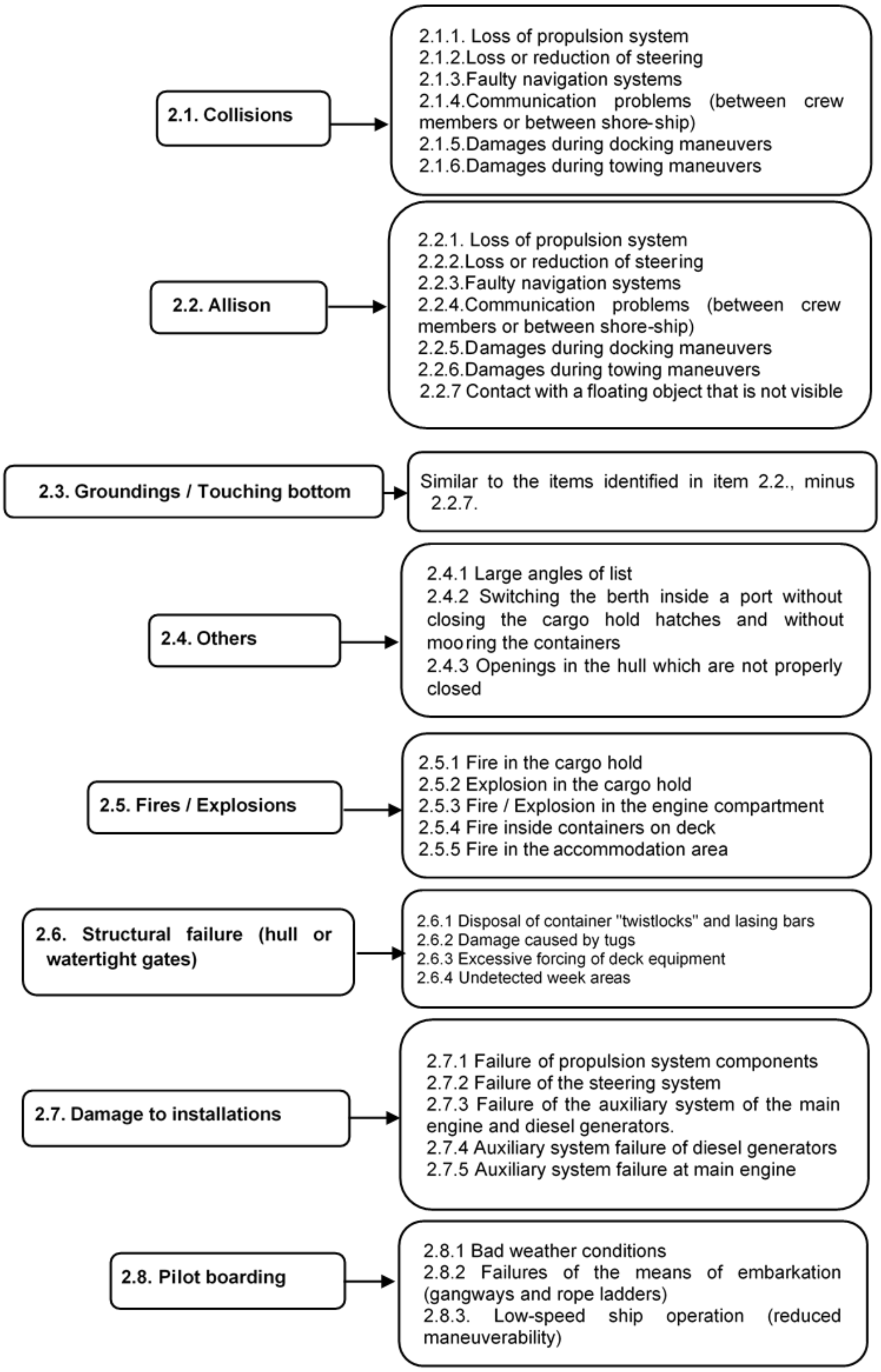


Fig 7 Identification of risk factors.
Module 2: Risks associated with maneuvering the ship in restricted areas

For risk module 3 associated with the operating mode (3) - open sea voyage in the RISK-CON3 stage, a number of 7 risk sources were highlighted, for which 29 risk factors were identified.

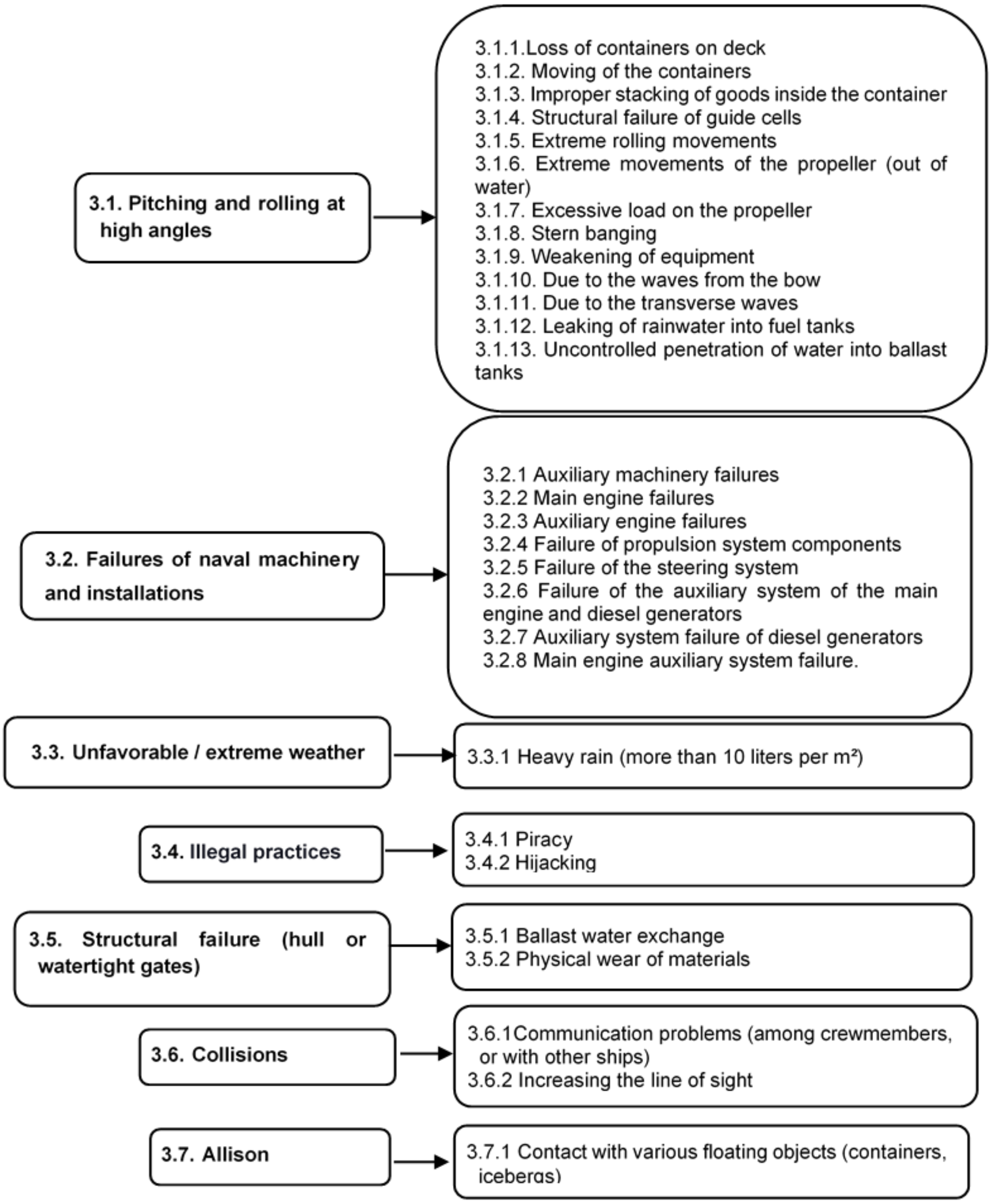


Fig. 8. Identification of risk factors. Module 3: Risks associated with the ship's / ship's voyage

From the above, it can be seen that the risk identification process is a qualitative process, based mainly on the experience of experts and their expertise. The evaluated system, the container ship has been decomposed into subsystems, whose functionality is significant for the regular operation of the ship. The integrative expert creatively led each debate, the results obtained were discussed and documented, in order to render the vision of the whole group and not of a single individual.

5.2 Risk index (RI) of container vessels. Results

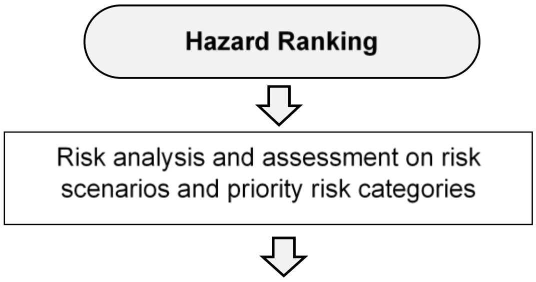
Further, results obtained in point 5.1 are used for for determining risk index. The expert feedback from Table 5 was summarized in Table 6.

Table 6. Risk index for risk scenarios and priority risk categories

	Category	ID	Failure Mode Description	RI
Human Life	Human Error	1.7.1	Injuries or fatalities due to communication problems	7.5
	Large Ship Motions	3.1.9	Injuries or fatalities due to loosening of equipment	7.4
	Extreme Weather	3.3.1	Injuries or fatalities due to bad working conditions	7.4
	Lashing	1.4.3	Injuries or fatalities due to bad working conditions during lashing	7.4
	Structural failure	3.5.1	Injuries or fatalities due to ballast water exchange	7.2
	Large Ship Motions	3.1.6	Injuries or fatalities due to extreme pitch motions	7.1
$RI_{Human\ Life}$ = 7,33				
Environment	Large Ship Motions	3.1.3	Pollution due to inappropriate stowage of cargo inside	9.6
	Large Ship Motions	3.1.11	Pollution due to green water due to beam and following seas	9.4
	Large Ship Motions	3.1.2	Pollution resulting from shifting containers	8.6
	Structural failure damage by tug	2.6.2	Pollution due to damage by tug	8.4
	Cargo	1.2.1	Pollution due to wrong declaration (labelling) of cargo (DG)	8.2
	Human Error	1.7.1	Pollution due to communication problems	8.2
	Collision	2.1.4	Pollution due to communication problem (ship, ship-shore)	7.8
	Large Ship Motions	3.1.10	Pollution resulting from green water due to head seas	7.0
	Grounding / Stranding	2.3	Pollution due to grounding or stranding	7.6
	Machinery failure	2.7.4	Pollution by the failure of the auxiliary system to diesel generators	7.6
	Contact	3.7.1	Pollution due to contact with floating obstacle	7.4
	Large Ship Motions	3.1.6	Pollution resulting from extreme pitch motions	7.0
$RI_{Environment}$ =8,07				
Cargo	Large Ship Motions	3.1.6	Extreme pitch motions → damage or loss of cargo	8.0
	Large Ship Motions	3.1.11	Green water due to beam and following seas → loss of cargo	7.2
	Lashing	1.4.2	Incorrect lashing → loss of containers due to	7.3
	Large Ship Motions	3.1.3	Inappropriate stowage of cargo inside container / on flat racks→ damage or loss of cargo	7.8
	Human Error	1.7.1	Loss of cargo due to communication problems	7.5
	Fire / Explosion	3.5.1	Fire in the cargo hold → damage or loss of cargo	7.0
	Contact	3.7.1	Contact with floating obstacle → damage or loss of cargo	7.5
	Machinery failure	3.2.3	Auxiliary engine failure → damage or loss of cargo	7.0
	Large Ship Motions	3.1.10	Green water due to head seas → damage or loss of cargo	7.0
	Collision	2.1.4	Communication problem → damage or loss of cargo	7.0
	Unlawful act	3.4.1	Piracy → damage or loss of cargo	7.0
	Lashing	1.4.1	Damaged lashing gear → loss of containers	7.0
RI_{Cargo} =7,9				
Ship	Structural failure	3.5.1	Ballast water exchange → damage or loss of ship	9.4
	Collision	2.1.3	Navigational failure → collision → damage or loss of ship	8.6
	Structural failure	3.5.2	Fatigue material → damage or loss of ship	8.4
	Contact	2.2.3	Navigational failure → contact damage/ loss of ship	8.2
	Unlawful act	3.4.1	Piracy → damage or loss of ship	8.0
	Fire / Explosion	2.5.3	Fire/explosion in the engine room → damage or loss of ship	7.8
	Collision	2.1.4	Communication problem → damage or loss of ship	7.7
	Human Error	1.7.1	Communication problems → damage or loss of ship	7.5
	Contact	3.7.1	Contact with floating obstacle → damage or loss of ship	7.3
	Cargo related	1.2.1	Wrongly declared dangerous goods → damage to ship structure	7.2
RI_{Ship} =8.01				

For the 3 modes of operation of the ship, 93 risk factors were identified. For each risk factor, the average risk index was determined as an arithmetic means of the natural number values given by each expert. In the debates conducted within RISK-CON3, it was established that the major / priority risk factors, which have priority in monitoring and risk management onboard the ship, corresponding to a threshold value $RI_{lim} \geq 7$. For these reasons, 40 major / priority risk factors have been highlighted and detailed in Table 6, the value being higher than the limit value RI_{lim}.

Risk factors were grouped into 12 risk scenarios, as follows: large ship motions, structural failure, human error, collision, contact, lashing, cargo, machinery failure, fire/explosion, unlawful act, extreme weather, grounding/stranding. The consequences of the materialization of risk factors/risk scenarios were reported to 4 types of risk, for which the average risk index was calculated, as an arithmetic means of the associated risk factors, as follows: risk for human life ($RI_{Human\ Life}$), the risk for the environment ($RI_{Environment}$), the risk for cargo (RI_{Cargo}), risk for the ship (RI_{Ship}). The results are centralized in figure 9.



Types of risk	Loading / Unloading at berth (1)	Operations in port, restricted and coastal waters (2)	Open sea voyage (3)	Total	RI_{med}
Human Life	2	0	4	6	7,33
Environment	2	4	6	12	8,07
Loss cargo	3	1	8	12	7,9
Loss ship	2	4	4	10	8,01
Total	9	9	22	40	

Risk Scenarios	Types o risk				
	Risk for human life	Risk for the environment	Risk for cargo	Risk for ship	Total
Large Ship Motions	2	5	4	0	11
Structural Failure	1	1	0	2	4
Human Error	1	1	1	1	4
Collision	0	1	1	2	4
Contact	0	1	1	2	4
Lashing	1	0	2	0	3
Cargo	0	1	0	1	2
Machinery Failure	0	1	1	0	2
Fire / Explosion	0	0	1	1	2
Unlawful act	0	0	1	1	2
Extreme Weather	1	0	0	0	1
Grounding / Stranding	0	1	0	0	1
Total	6	12	12	10	40

Fig. 9. Risk analysis and assessment of risk scenarios and priority risk categories

6. Conclusions and future research directions

It is unanimously accepted that the issue of risk in maritime transport is particularly complicated. The diversity of goods transported by highly specialized ships, the hydrometeorological conditions, sometimes extreme, associated with each voyage, as well as the complex process of transfer of goods within the port system, complete this picture of the logistics chain of maritime transport.

The paper substantiates the organizational framework of risk management on a container ship.

From a risk perspective, the paper proposes a methodology for identifying, analyzing, and assessing risks for the maritime industry, subsequently applied to container vessels, for a generic model of fully cellular containership and three modes of operation. The conceptual framework for risk identification was substantiated in accordance with the Formal Safety Assessment (FSA) method and IMO regulations in the field; the research is structured in 3 stages: RISK-CON1, RISK-CON2, and RISK-CON3.

The research was performed for 3 modes of operation of the container ship, for which 93 risk factors were identified. For each risk factor, the average risk index was determined, and 40 major / priority risk factors were established in the report. with a threshold value $RI_{lim} \geq 7$.

The major / priority risk factors were grouped into 12 risk scenarios, and the consequences of their materialization were reported to 4 types of risk (risk for human life, the risk for cargo, environment and for ship). The results were centralized, for each type of risk, the average risk index was calculated as the arithmetic means of the associated risk factors.

In future research, the authors intend to use the research method, after a possible adaptation, to identify, analyze and assess the risks for the following types of ships: oil tank, chemical tank, bulk carrier, Ro-Ro ferryboat, etc.

The research will be adapted in the field of the navy, a field for which the method will be customized and rethought within another group of experts.

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References

[1] Kristiansen, S. (2013). Maritime transportation: safety management and risk analysis. Routledge.
[2] Nicolae F. (2015). Risk management. Concepts. Methods. Applications. Mircea cel Batran Naval Academy Press. 2015 ISBN 978-606-642-109-6.
[3] 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.
[4] Walters, D., & Bailey, N. (2013). Lives in peril: Profit or safety in the global maritime industry?. Springer.
[5] Dabrowski, J. J., & De Villiers, J. P. (2015). Maritime piracy situation modelling with dynamic Bayesian networks. Information fusion, 23, 116-130.
[6] Tallack, R.L., 1996. Commercial Management for Shipmasters a Practical Guide. The Nautical Institute, 202 Lwnbeth Road, London SEI 7LQ, UYL, ISBN 1 870077 33 4
[7] Todd, P. (2013). Maritime fraud and piracy. Taylor & Francis.
[8] Tomasoni, A.M., 2010. Models and Methods of Risk Assessment and Control in Dangerous Goods Transportation (DGT) Systems, Using Innovative Information and Communication Technologies. Chemical Sciences. Ecole Nationale Sup´erieure des Mines de Paris; Universit`a degli studi di ´ Genova - Italie, 2010.
[9] IMO, 2018. Revised Guidelines for Formal Safety Assessment (FSA) for use in the IMO rule-making process MSC-(MEPC.2/Circ.12/Rev.2 9 April 2018).
[10] Berle, Ø., Asbjørnslett, B. E., & Rice, J. B. (2011). Formal vulnerability assessment of a maritime transportation system. Reliability Engineering & System Safety, 96(6), 696-705.
[11] Langbecker, U., Lloyd, G., & Krapp, R. (2005). Hazard Identification for Container Ships.
[12] Rausand, M. (2013). Risk assessment: theory, methods, and applications (Vol. 115). John Wiley & Sons.
[13] Soares, C. G., & Teixeira, A. P. (2001). Risk assessment in maritime transportation. Reliability Engineering & System Safety, 74(3), 299-309.
[14] ***, 2019. Global merchant fleet - number of ships by type 2019 www.statista.com

[15] Marine Accident Investigation Branch, https://www.gov.uk/government/organisations/marine-accident-investigation-branch.
[16] IMO's Global Integrated Shipping Information System - Marine Casualties and Incidents Module http://www.imo.org/en/OurWork/MSAS/Casualties/Pages/Default.aspx
[17] Lloyd's Register FairPlay - Lloyd's Register of Ships. https://www.maritime-database.com/company.php?cid=211933
[18] CEFOR's Nordic Marine Insurance Statistics Database. https://cefor.no/statistics/nomis/
[19] The Norwegian Maritime Directorate Accident Database. https://www.sdir.no/en/shipping/accidents-and-safety/safety-investigations-and-reports/