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Study of the risk assessment quality dependence on the ships accidents analysis

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Abstract. Safety is undoubtedly a qualitative basis for the efficient functioning of maritime transport. Particularly important is safety of shipping, freight and passenger transportation. The impetuous growth of ship quantity, increase of their movement along the sea ways as well as the factors of external environment influence underline the necessity to consider the problem of shipping safety as the most priority and actual one in the focus of consideration of the current state and tendencies of the shipping development. As the statistics shows, the main reason of marine accidents are breakdown, damages or failure of engines and equipment. They account for over a third of all recorded cases over the past ten years. The same reason has led in recent years to the most expensive insurance payments, amounting to impressive sums. This explains why risk assessment as a structured process of analysing the consequences and probabilities of dangerous situations is an effective tool for achieving safety goals. The aim of this research is to study the peculiarities of risk assessment process and compare the quality of execution of this process with the accident rate of the world trading fleet. The causes of accident consequences have been systematized, pointing to the fact that seafarers could have prevented most accidents if they had paid proper attention to conducting a risk assessment of the operation, especially the impact of certain elements of the human factor.
Keywords: human factor, risk assessment, safety of shipping, shipping operations, maritime transport.

1. Introduction

Ship accidents continue to disturb the shipping community around the world. Statistical data made public by the institutions that deal with this issue indicate that the total number of accidents is steadily decreasing. This is also noted by all market research centers. There are small discrepancies in the estimates between the data of different organizations, but the general trend is clear. Moreover, there are differences even in the data of Allianz Global Corporate & Specialty Safety and Shipping", which is one of the leading companies in this field, In its own report for 2020 the number of ships killed in the world is 49, and in 2021 this figure was changed to 65 ships [1]. A number of factors causes this, but overall the constant reduction in the number of accidents is ensured. As a result of the efforts of IMO, the implementation of the latest requirements for the safety of shipping, there is a clear trend towards a reduction in the number of accidents during the last ten years. A fact that is supported by many research centers in the industry and does not cause any doubts. Another question that today excites scientists - whether there is a possibility of further reducing the number of accidents of ship losses in the world? In the view of the authors of this article, such a possibility exists and lies in the need to improve the quality of risk assessment of operations in the global fleet, in comparison with the current methodology endorsed by [3]. From the viewpoint, the content of IMO circular letters [2, 4-6], the legal term of application leaves much to be desired. Based on analysis of accident statistics, need to conclude that further reduction of the number of shipwrecks will be possible only if the human factor is taken into account during the risk assessment, or, more precisely, the individual elements of human factor.

A large number of works are devoted to the problems of maritime safety. Thus review and analysis of methods for assessing maritime waterway risk based on non-accident critical events detected from AIS data and statistical analysis of ship accidents reviewed in [8-11]. A methodology for assessing and analyzing the risks of a ship navigating in cramped conditions with a pilot and on approach to a pilot pickup point, bridge crew interaction with a pilot during pilotage and while handling tugboats is and development of collision avoidance system proposed in [12, 23, 24]. General safety issues related to the shipping highlighted in [13-16, 25]. Classification and assessment of risks associated with the bridge organization and determination of the damage cost and injury of vessel accidents and risk assessment models studied in [18-21]. Safety and security aspects in shared mobility systems [22].

As the analysis of the conducted works shows, there is a need for further development of approaches to the issues of shipping safety and improving the quality of risk assessment of shipboard operations as a stage of scientific research, aimed at determining the accurate, reliable characteristics of risk, their feasibility. The main trend of the research is to establish the relationship between the quality of risk assessment performance and the dependence of risk assessment itself on the individual elements of the human factor, outrunning the degree of influence of this relationship on the general indicators of fleet accidents.

2. Materials and methods

The basic way for the presented research is the theoretical analysis of problems of international shipping safety ensuring on the basis of the modern methods synthesis of a risk assessment at performance of ship operations and to analyze the classification of general statistics of fleet accidents by type in relation to time periods. On this basis, using the deductive method to determine the dependence of reduction of maritime accidents due to the influence of individual elements of the human factor during risk assessment and development of a new approach that includes evaluation of individual elements of the human factor and its integration into the procedure of risk assessment at performance of ship operations.

In recent years, the most advanced achievements of science and technology have been introduced into ship design and shipbuilding practice, implementing innovative technologies. Science has made particular progress in the field of all aspects of ship navigation and navigational equipment. Particularly, considerable progress is being made in the development of navigational facilities, resolution capabilities of navigational instruments and navigational practice. The accuracy of determining the ship's position at sea has reached several meters and ships are equipped with automatic identification devices. Electronic cartography, satellite navigation, improvement of ship control systems and power plants actively develop and inspire confidence in favorable solution of navigation safety problems, reduction of ship accidents and decrease of number of maritime disasters. However, it cannot be claimed that this has helped significantly to reduce the number of accidents and disasters at sea.

The history of safety management requirements implementation on ships began with the adoption of IMO Resolution No. A.741 (18) of 04 October 1993 [2] which put safety at the forefront of the global shipowners business. The safety management system was implemented in the companies, which is aimed at constant control over the state of safety, implementation of a set of actions not only for control, but also for increasing the safety condition of ships. Technical maintenance of ships, staffing of crews, certification, accommodation conditions and limits of working hours are the priorities of IMO, shipping managers and flag state authorities.

A special focus on safety issues was given by the provision on the necessity of risk assessment of ship operations. This issue was first raised for discussion in 1993, following a proposal by the British Maritime Safety Committee (MSC) that investigated this methodology. Great Britain itself requested to use the term Formal Safety Assessment (FSA). As a result of discussions that lasted until 1995, IMO presented a report, in which FSA was divided into 5 stages in presented order (Fig.1):

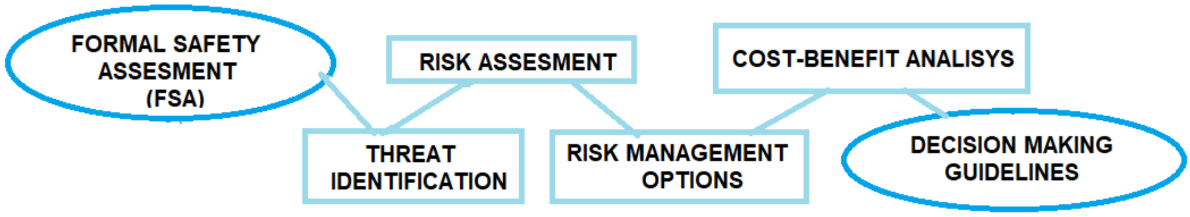

Figure 1. Formal safety assessment sequence

Differences between the MSC and IMO remained only in one, but very important issue: whether the FSA has to give a definition of "acceptable" level of risk. Some felt that this was necessary to comply with the safety level of the measures proposed by the new way of risk control. Others believed that FSA should only identify the greatest risks and define ways of managing them, and the acceptable risk level can be determined prospectively, in an empirical manner, that is, as the experience of using the FSA methodology is accumulated. It was found compromise in the form of recommendations to use FSA for preliminary analysis and risk assessment when approaching amendments to international rules and standards of ship safety, i.e. to provide a quantitative, not biased assessment of the feasibility of the proposed innovations. The value of the FSA methodology lies in the fact that it provides the necessity of changes and improvement of the existing rules and therefore is used increasingly in ensuring the safety of navigation.

In 1999 the MSC IMO meeting also reviewed the developments of the MSC special group which worked on the FSA application perspective on the "human factor" problem. It analyzed the reliability of people when using FSA and gave a definition of this concept, that is, the correctness of people's actions within the framework of the methodology, the consistency of these actions, their dependence only on this methodology.

At the 72nd session of the MSC, which took place in 2000, the objectives of FSA in IMO were proposed, namely - formal safety assessment is a structured and systematic methodology, aimed at enhancing maritime safety and security, including protection of life, health, marine environment and property, using cost/benefit and risk assessments, Also, that the formal safety assessment can be used as a tool to help evaluate the new safety regulations, to compare them with the existing and possibly improved regulations, to achieve a balance between different technical and operational problems, including people, and between safety and costs [3].

The text of the FSA regulation concerning revised guidelines for formal safety assessment (FSA) for use in the IMO rule-making process included a new section that was relevant to the performance of the human reliability assessment (HRA). Scientists recognized that there is a quantitative analysis of human reliability as well as a qualitative one. The main criterion for the quantitative analysis of human reliability, IMO proposed the indicator "Human error probability (HEP)", which is determined by the following formula:

$$\text{HEP} = \frac{Number\ of\ human\ errors\ that\ occurred}{Number\ of\ human\ error\ possibilities}; \qquad (1)$$

In addition, several methodological solutions for performing an efficient risk assessment were provided. Insanely, these circular letters have had an effect on improving the state of general safety, but, for the most part, this approach continues to be ineffective for use on ships of the world fleet. Fig. 2 shows the number of incidents of vessel deaths over the past ten years.

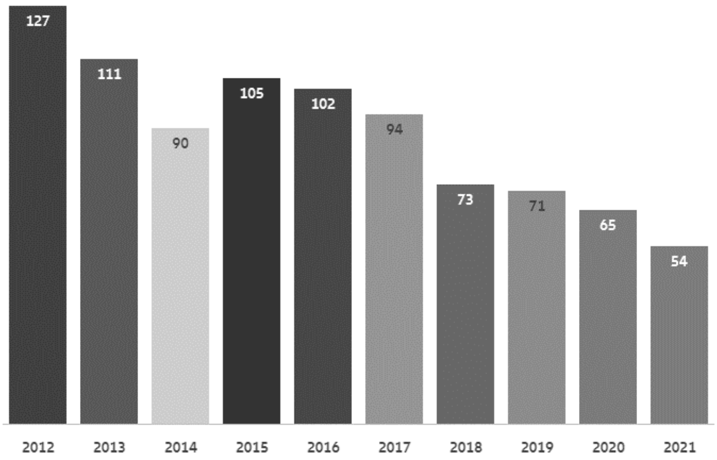

Figure 2. Number of ship losses over last decade

Among the causes of ships' losses, the most present are five, which are shown in Fig. 3;

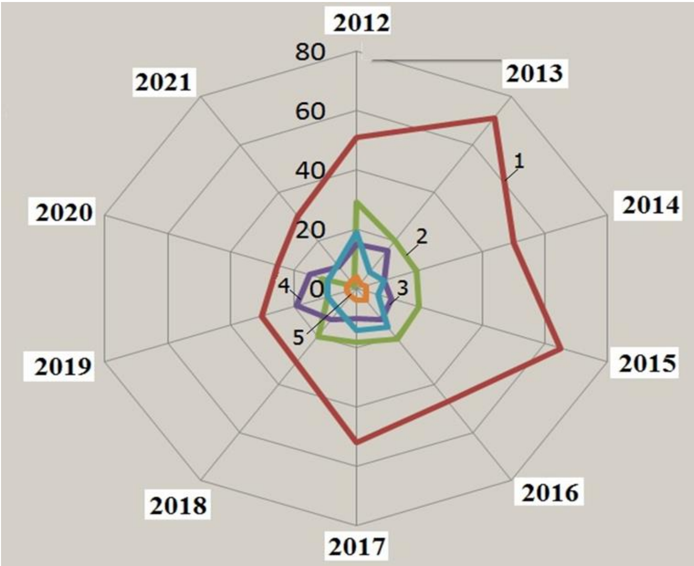

Figure 3. Top five causes of ship losses in last decade [1]

In last ten years, among all the cases of ships' loss was recorded:

- 1 - 452 incidents of ships lost due to flooding;
- 2 - 168 incidents of ships lost due to grounding;
- 3 - 130 incidents of ships destroyed by fire;
- 4 - 109 incidents of ships resulting from engine trouble;
- 5 - 33 incidents of ship losses due to collisions at sea [1].

Most of all ships were lost due to flooding, landings, fires, breakdowns and collisions. If we look at these accidents more closely, the result can hostile to the fact that most of the accidents were caused by the "human factor". The most experienced experts believe that more than 85% of accidents occurred, and the U.S. Coast Guard believes it was more than 95%. As an average, human error contributes to the total number of accidents on board ships in the world fleet by more than 90%. On this basis it can be assumed that despite all the peculiarities of ship accidents, close to 90% of accidents occurred there was a chance to avoid the accident, to save ships and human lives. In other words, if seafarers could have prevented the effects of the "human factor", a large number of ship losses would have been avoided.

One of the most powerful tools for maintaining general safety on ships is the Risk Assessment. The procedure exists to prevent any shipboard safety incidents. Experts consider that if the risk assessment of any ship operation is carried out properly, the necessary measures for carrying out the operation are supported, safety incidents can be prevented with a high degree of probability. However, the current procedure for performing risk assessment is not up to date, because it does not take into account the actual condition of the person at the time of the operation.

The introduced indicator " human error probability" (HEP) is not effective in general, because there is no statistical data on the number of human errors that occurred during the operation, Also, there are no statistical data on the number of human casualties that occurred during the performance of the operation in the ship managers' risk assessment. Therefore, the proposed IMO method of risk assessment does not meet the requirements of the present time. This, according to the authors, is a hindrance to the improvement of the general state of ship accident rate. Furthermore, according to the experts, among the human factor the attention should be focused on the personal component - the individual elements of the human factor. Most of these elements affect the general state of ship accidents. These elements are stress, fatigue, limited communication, cultural discord, situational awareness, leadership (Fig.4).

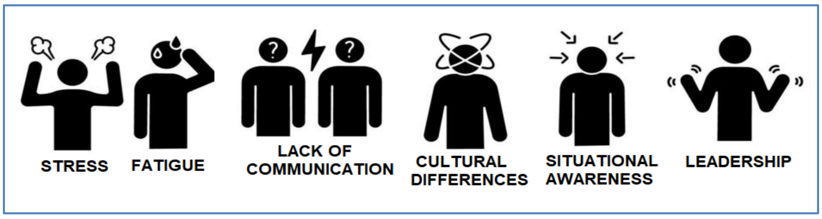

Figure 4. Factors affecting the general state of ship accidents

These are the factors that have the greatest impact on the level of accidents. Namely these factors most often cause deviation during decision making, which leads to ship accidents. It is specified in many IMO documents, for example: IMO Model Courses 1.39, 1.40. Also the IMO experts draw the attention to the necessity of constant consideration of individual elements of the human factor while performing ship operations, i.e. while performing risk assessment it must be obligatory. In reality the authors verified this fact by conducting a survey among seafarers on several issues. First survey concerned question is there a link between risk assessment and individual elements of human factor, where is affirmative answer indicated in blue (A) and negative in red color (B), (Figure 5).

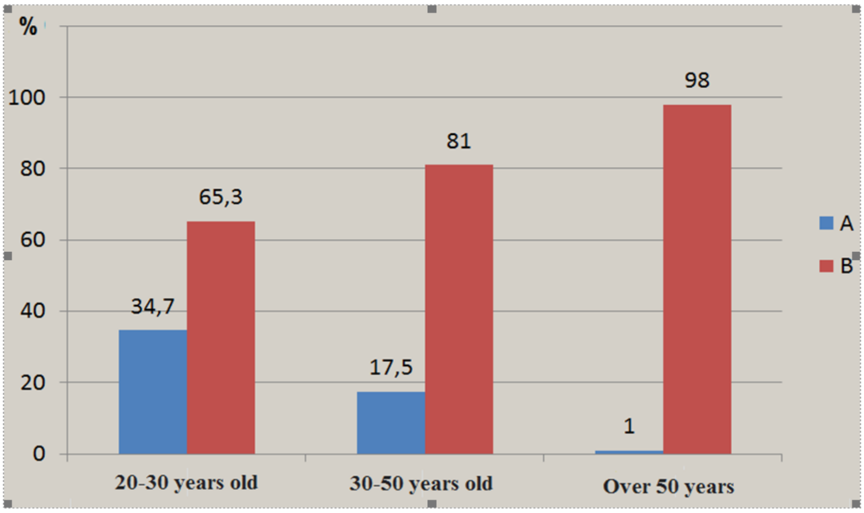

Figure 5. Relationship between risk assessment and individual elements of the human factor [based on the authors' research]

As can be seen from the survey results, among seafarers of young age (20-30 years old) more than 65% of respondents think they exist, and among the more senior age group (30-50 years old) more than 82%, and among the representatives of the older age group (over 50 years), registered the full understanding that such a link exists. That is, seafarers who have professional experience understand very clearly that human condition greatly affects the quality of risk assessment performance, and through risk assessment performance, the general safety of the ship.

This finding fully confirms IMO's efforts aimed at increasing attention to the condition of people who involved in shipping, in other words, to the permanent control of the individual elements of human factor. Equally interesting were the answers of the interviewed seafarers to the following question: "Does the company's risk assessment procedure require that the impact of the human factor be taken into account?" The received responses fully confirmed the opinion of the authors that there are no risk assessment guidelines which would contain a provision on the necessity to check the seafarers' ability to perform their duties during any ship operation.

Therefore, in spite of the importance of taking into consideration people's condition while performing ship operations, the IMO's constant recommendations on the importance of this issue, many companies' safety management systems have no provision for checking people's ability to perform the operation. But, as statistics show, the procedures of most companies are not requiring to take into account the impact of the human factor.

The study involved the suggested Tarot Yamane method (Yamane, 1973) with a confidence level of 95%. This formula is given below:

$$n = \frac{N}{1+N(e)^2} \qquad (2)$$

where: n - number of respondents; N - number of sailors in the country; f - possible error (+/-5%).

For the survey the age groups of 20-30 years old, 30-50 years old and over 50 years old were identified. The number of respondents in each sample group was 400 sailors. Therefore, the authors consider the obtained result with 95% confidence.

In view of the above, to further reduce the number of lost ships, it is necessary to make changes to the standard procedure for completing the risk. Above was given the idea of using the requested indicator of human error probability" (HEP), but this has proven to be unproductive. That is why in the standard procedure of risk assessment review it is recommended to introduce a check of the person's condition according to the main personal factors. Thus, it would be possible to get a more realistic picture of the real risk and impact on it. Mainly there are three reasons for all ship losses: technical, human and external environment factors. Indeed, this is a slightly simplified statement [4], but it is enough to explain this idea (Fig. 6)

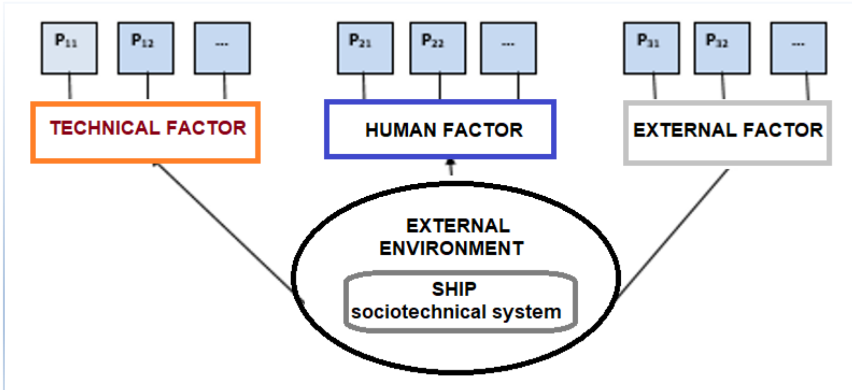

Figure 6. The threat factors

To assess the impact of each threat factor on the occurrence of an emergency situation on the vessel we introduce the following indicators: for the factor of technical condition - technical indicator F1; for the external factor - F3; for the human factor - F2. The factor of the technical condition of the ship equipment, which in one way or another can influence the occurrence of an accident situation. The external risk factor is characterized by the presence of force majeure circumstances, elements of human factor is taken into account, according the Tab.1;

Table 1. Factors of impact on ships safety

Ship's technical condition factor	External threat factor	Human factor
- compliance of the vessel with the standard requirements; - level of a ship's technical condition or some of her structural elements to standard requirements; - compliance of ship's equipment with the international standards.	- the complexity of the weather conditions; - state of visibility; - ice conditions; - earthquake; - piracy, etc.	- compliance of the level and skills of the staff with the technological requirements and the used equipment; - accuracy, timeliness and integrity of management level; - human personality traits in management (education, training, professionalism, physical condition, tolerance to safe work, etc.); - level of interaction and socio-psychological cohesion between members of functional groups that carry out the corresponding processes.

The weight coefficients *Wni* of the parameters, as a rule, are calculated by means of the simple ranking method, the proportional method or the method of pairwise comparison. If it is possible to rank all parameters of the *n-th* factor in the order of their importance *(Wn1> Wn2> ···> WnN)*, then the value of the *i-th* parameter can be determined by the Fishburn rule:

$$w_{ni} = \frac{2(N-i+1)}{N(N+1)}, \tag{3}$$

where: N - the number of parameters of the given factor;

For example, for the case of 4 parameters the distribution diagram of their values will be as follows: 0.4; 0.3; 0.2; 0.1. If all the parameters are of equal importance, the value of each parameter is determined by the formula:

$$w_{ni} = \frac{1}{N} \tag{4}$$

The integral indicator of the safety factors characterizes the level of influence of all the safety factors on the occurrence of an accident situation, which can be presented in the form of an average value of the indicators of the analyzed factors of a given situation:

$$F = \sum_{j=1}^{J} F_j \cdot w_j, \tag{5}$$

The weight coefficients *Wj* of the risk factors can be determined by any method among those used in calculating the variability of the parameters within one factor.

On the basis of the calculation of the value *F* we will determine the probability of an emergency situation under this rule:

- is extremely small, if 0 < F <= 0.2;
- small, if 0,2 < F <= 0,4;
- medium, if 0,4 < F <= 0,6;
- large, if 0,6 < F <= 0,8;
- is not safe, if F >= 0.8.

Based on the above, it is recommended to include the assessment of the state of individual elements of the human factor in the procedure of risk assessment in the form of checklist before commencement of any shipboard operations.

Table 2. Checklist for determining the probability of an emergency situation in the process of ship operations (risk monitoring)

Type of operation: ____

1. Technical factor			
			$F_1 = \sum f_{ij} \cdot w_{ij}$
Ship elements involved in the operation	Value	Weight	
1.1. Element 1 ____________________	f_{11}	w_{11}	
1.2. Element 2 ____________________	f_{12}	w_{12}	
1.3. Element 3 ____________________	f_{13}	w_{13}	
1.4. Element 4 ____________________	f_{14}	w_{14}	
		$\Sigma w_{1j} = 1,0$	
2. Human factor			
Parameters of the participant group of the operation			$F_2 = \sum f_{ij} \cdot w_{ij}$
Type of parameter	Value	Weight	
2.1. Level of proficiency	f_{21}	w_{21}	

2.2. Working experience	f_{22}	w_{22}	
2.3. Physical condition	f_{23}	w_{23}	
2.4. Psychological compatibility	f_{24}	w_{24}	
2.1. Corrections to the functional group status			
2.5. Stress	Δf_{25}	- 0,05 …+ 0,05	
2.6. Fatigue	Δf_{26}	0 …+0,05	
2.7. Efficiency of communication	Δf_{27}	- 0,05 …+ 0,05	
2.8. Situational awareness	Δf_{28}	- 0,05 …+ 0,05	
2.9. Cultural variety	Δf_{29}	- 0,05 …+ 0,05	
2.10. Leadership	Δf_{210}	- 0,05 …+ 0,05	
	$\Delta F_2 = \sum \Delta f_{2j}$		
3. External factor			
External factor parameters			$F_3 = \sum f_{ij} \cdot w_{ij}$
Type of parameter	Value	Weight	
1.1. Temperature	f_1	w_{31}	
1.2. Wind speed	f_{32}	w_{32}	
1.3. Probability of illegal intrusion	f_{33}	w_{33}	
1.4. Visibility	f_{34}	w_{34}	
$F_4 = f_{41}*w_{41}+ f_{42}*w_{42}+ f_{43}*w_{43} + f_{44}*w_{44} =$		$\Sigma w_{3j} = 1,0$	

Results

Thus obtained pattern can be considered the most accurate, as it takes into account the actual condition of the persons involved in the operation. Thereby it is established that further reduction of ship accident indicators and minimization of maritime accidents will be possible only if the human factor is considered at the time of risk assessment performance, or, more specifically, the human factor's individual elements are taken into account. To achieve this goal the technique to improve approaches to risk assessment of shipboard operations in the form of analysis of the state of elements of human factor in the procedure of risk assessment are proposed. Resumed necessity of the account of a human factor at consideration, development and realization of new and existing requirements, including sphere of maritime education and professional training, and also human opportunities, restrictions and needs.

Conclusion

Continuous analysis of accidents and, primarily, the causes of disasters in the world fleet is necessary to search for the directions of development of the methodology of ship operation safety assurance, improvement of personnel training programs, identification of necessary management steps for reduction and avoidance of maritime accidents. Statistics on accidents give ample opportunities for determining promising trends of development of the maritime industry in order to improve safety of navigation.

On the basis of the survey of the world fleet ships' accident rate, it is clearly seen that there is a constant tendency to reduce the number of ship accidents during the last ten years, but there are doubts about the continuation of the current tendency. The conducted research shows that one of the main principles which may have an impact on further reducing the number of accidents is the human factor, or, more precisely, the consideration of individual elements of the human factor during the risk assessment of the shipboard operations. Unfortunately, this issue is given scant attention today by all shipowners around the world. Therefore, to make progress in further reducing shipboard accidents, the focus should be on performing operational risk assessments and consideration of the physical condition of seafarers at the time the operation is being performed. Fleet accident rate indicators are inextricably linked to the quality of ship crew training, their mastery of the required number of competencies in the process of training and professional development. To reduce the accident rate, it is necessary to ensure that the criteria of maritime training meet the requirements of modern reality, where it is necessary to realize that the human factor is the main ground in preventing ship accidents and marine disasters. The future direction of research is the introduction of control over these individual human elements in the form of development of appropriate training programs for seafarers, in particular, training on modern simulators, which would take into account the influence of these aspects in the training process.

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