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# BASIC ASPECTS ENSURING SHIPPING SAFETY

**Summary.** Widespread use of innovative technologies in all spheres of life has brought the maritime transport industry, in particular, the process of ship navigation, to a completely new qualitative level. Various navigation systems recently introduced and used only as additional devices have gradually become an obligatory element of shipboard equipment and navigation complexes of modern vessels, extending their functionality and capabilities. The human factor influence caused by automation of ship operation processes becomes a separate challenge. Risks to shipping safety and consequences of breach of safety standards for crew, vessel and cargo are far from being a full list of the problems to be solved. This paper offers an overview of general issues of ensuring the level of safety of shipping, by examining the concept of "vessel safety", considering its individual

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sides, features, as well as constituent aspects of the concept, systematization of the vessel safety structure to develop solutions toward improving the integral safety and optimization of decision-making in emergencies. Achievement of the general purpose of shipping safety thus means the realization of ways of reducing the influence of the human factor on several accidents and an estimation of the degree of influence of a set of factors on a ship during operation.

**Keywords:** safety of shipping, vessel operation, safe port

## 1. INTRODUCTION

The issues of studying the "safety of navigation", which is understood as a set of measures aimed at preventing any accidents with ships during voyages, are devoted to several works. Many of them reveal general issues, while many attempted to assess individual accidents in a bid to analyze and establish a cause-and-effect relationship between maritime accidents.

Scientific researches on shipboard technical systems and complexes operation are worth highlighting since a significant share of marine accident statistics falls into this category. Thus, the analysis of indicators of operational safety of shipboard technical equipment is presented in [1,25]. In [23], the enhancement of the operational safety of the engine room machinery through training on computer base training of the engine room simulator on board ships. Environmental performance of inland navigation vessels and regulation of operational and accidental pollution of the environment by water transport, estimation of potential impacts and natural resource damages of oil [2-4]. Modeling oil spill response and damage costs in [5,16]. Issues related to the safety of maritime transport, review and application of ship collision and grounding analysis procedures and analysis of factors affecting the safety of maritime container transportation were studied in [6, 7, 13, 18]. The international convention for the safety of life at sea: highlighting interrelations of measures toward effective risk mitigation [8]. Research on maritime safety issues, nature and origin of major security concerns and potential threats to the shipping industry and maritime situational awareness as a key measure for safe ship operation and methods to predict future risk with a machine learning approach [10,12,24]. Paper [9] is devoted to the probabilistic assessment method of hydrometeorological conditions and their impact on the efficiency of ship operations. Cyber security in the maritime industry, systematic survey of recent advances and future trends were studied in [11]. Actual ship stability problems and the influence on the safety of navigation, improvement of ship safety through stability research and innovations [15, 17, 19]. Works [20-22] deal with the human factor especially regarding the predictive power of inspection outcomes for future shipping accidents – an empirical appraisal with special attention to the human factor aspects and exploring organizational and regulatory factors of shipboard safety.

It is impossible to create the basis for absolute shipping safety, as this specific human activity is inseparable from various kinds of dangers, including navigational, but it is quite realistic to determine the aspects of shipping safety and related potential hazards for the vessel and crew on board and take timely measures to eliminate or mitigate their consequences.

## 2. MATERIALS AND METHODS

Safety of shipping is ensured if an accident-free navigation process is maintained, the propulsion and technical equipment are operated following proper parameters, and the ship's crew complies with the regulations and procedures related to safety. The main criterion for the quality of operation of both the vessel as a whole and its power plant is the statistics of incidents, accidents and disasters.

Introduction of new technical solutions and operational procedures for a ship's power plant or a vessel cannot instantly change the safety level. The main purpose of increasing the level of operational safety is to prevent errors and accidents by in-depth analysis of their causes.

In this perspective, the definition of the safety concept is a multifactor result, which is determined by a set of functioning of such a system, where an important basis is the theoretical and technical skills of specialists, their practical experience in the implementation of the ship management processes and operation of the ship power plants, knowledge and determination of factors causing emergencies. Presently, the safety level is assessed by statistics and analysis of accidents and emergencies and identification of their causes.

Given the duties and responsibilities of masters and crews of seagoing vessels that the international safety management code imposes on companies, all possible measures must be taken to ensure these key points:

- the safety of the crew (human life);
- the safety of the vessel;
- the safety of the cargo;
- protection of the environment.


Fig. 1. Factors affecting the ship during operation

Several factors have an impact on the ship in the process of operation. They can be divided into three groups - external, internal and environmental or climatic factors. External factors are those that influence the commercial operation of the vessel regarding the organization, management and provision of its production activity and achievement of maximum economic

and commercial efficiency of the transportation process. A set of internal factors can be considered as the operation of a vessel as a technical object, including handling and maneuvering, technical operation of vessel systems and complexes, as well as ensuring safe carriage of cargoes. And finally, environmental factors, among which are geographical, defining navigation area, hydrometeorological, defining the state of the sea, atmospheric conditions at the current moment and in the relevant sailing area; navigational, characterizing sailing area from the viewpoint of navigational safety. Therefore, the vessel as a system is simultaneously a technical, economic and social object (Table 1).

Tab. 1

Impact of a combination of factors on the ship during operation

| **External** | **Internal** | **Environment** |
|---|---|---|
| Organizational (loading and unloading, port operations) | Management of the ship and its operations on board | Hydrometeorological (wind, sea currents, depths) |
| Managerial (company management, port, class, flag requirements) | Technical Ship operation (M/E, machinery and systems operation, operating procedure) | Geographic (straits, channels, rivers, passages) |
| Functional (repairs, maintenance, bunkering, supply) | Cargo stowage, distribution, handling. Safe cargo carriage | Navigational (handling, collision avoidance, maneuvering, |

Many authors in various sources proposed the definition of «ship safety». Based on the rules of safe operation of ships according to the ISM code, it can be concluded that a ship is considered to meet the requirements if she is in a good technical condition and is manned by a qualified crew, which can imply the actual declaration of her seaworthiness, in other words, potentially safe. Other safety criteria to be considered include navigation safety, which in turn includes shipping safety, the safety of the vessel to perform its functions for its specialization and designated purpose, operational safety, habitability, satisfactory living conditions and maintenance of optimum living conditions for the vessel's crew. In the aggregate, according to these requirements, the degree of vessel safety is defined. Shipboard safety, systematically, can be represented in terms of aspects in accordance with their subject orientation. The main structural components of ship safety which are proposed for consideration include:

- technological safety or cybersecurity (state of security of the ship and its information and operational systems against external and internal threats caused by the use of hardware and technology);
- technical safety (ensuring the operational and functional condition of all shipboard technical systems and complexes and preventing negative operational factors from affecting the ship as a technical system);
- ergonomic safety (ensuring the proper state of human activity onboard, excluding the effect of harmful manufacturing factors on the working conditions, health and professional activity of the crew);
- ecological safety (ensuring environmental safety against possible negative impact and marine pollution from ships);
- navigational safety (ensuring the safety of the ship as a navigable moving object).


Fig. 2. Basic aspects of shipping safety

Thus, shipping safety is the whole complex of measures aimed at ensuring the reliability of the transport process, regardless of whether or not there have ever been accidents for one reason or another. An important role is played by accident prevention, which includes measures aimed at the prevention of certain accidents. Hence, it follows directly from the definition of "shipping" that navigation safety is that aspect of shipping safety connected with the use of ships for transportation of cargoes and passengers.

Recently, significant attention has been directed toward the creation and implementation of intelligent decision-making systems aimed at providing an accident-free navigation process. Such systems should provide the navigation officer with unique data, which cannot be obtained based on the ship's technical documentation or navigational equipment available. The specified system autonomously analyzes the situation, evaluates and forecasts the dynamics of environmental changes and gives practical recommendations on ship control in a difficult situation or ensuring its seaworthiness in different operational states.

Environmental safety of shipping from the perspective of performing and monitoring ship operations should be understood as the state of protection of the marine ecosystem through the application of preventive, predictive and proactive measures to avoid pollution and marine environment deterioration, as well as to reduce the danger of long-term or irreversible negative effects on it, and ensure the environmental interests of human activity arising through achieving a balanced coexistence of the marine ecosystem. As a concept, ecological safety is called to estimate the probability of prevention of possible harmful influence on the environment of wastes of industrial activity of ships and is unavoidable at the operation of technical means and the equipment losses of working environments and products of incomplete combustion of fuel. A quantitative measure of environmental safety, namely, the indicator of ecological efficiency, should be a dimensionless or percentage measure of the prevention of harm caused to the environment by the above wastes and pollutants. Such wastes include oily (bilge) water, sewage (waste) water, garbage, atmospheric emissions of harmful substances with exhaust gases, and noise.

The technical basis of the intelligent system is the shipboard information and measuring systems, which controls the power plant characteristics, the state of the auxiliary machines and mechanisms, vessel technological systems and devices, and monitor many parameters, such as power, voltage, current, energy, steam, fuel and water flow rate, speed, pressure and temperature. Quantitative information on numerical values of these parameters is provided by measuring instruments (sensors and alarms) and devices sensitive to deviations of parameters from set values. Thus, developed intelligent data processing services for technical systems should be flexible and reliable to make supplements and changes to the system, ensuring its ability to perceive new information and methods of information processing. Implementation of the reliability principle allows, in case of failure of part of the system or impossibility of control of some parameters of the controlled object or external environment, to operate and provide practical recommendations, which ensure the safety of the engine room operations, and consequently, ensure the safe operation of the vessel.

Ergonomics is also closely related to engineering psychology, which studies the composition and structure of mental processes underlying human-operator activity. In this regard, ergonomic research is understood as the development of methods that consider the human factor when creating technical means, designing and organizing the activities of specialists in operating systems. A system is ergonomic if it optimally distributes functions between human and machine parts and solves other tasks for the ship's safety. The distribution of functions in the system between human and machine aims at the optimal use of the characteristics of the machine and human link. Each function is assigned to a technical device or operator, depending on how it is matched to the capabilities of one or the other link in the system.

In the human-machine interaction system, the following functions should be included in the advantages of using machines and the operator (Table 2);

Tab. 2

Comparative characteristics of the activity of the operator and the machine

| **Machine** | **Operator** |
|---|---|
| - Processing of information according to a given program (solving navigational and operational tasks); | - The ability to recognize objects regardless of changing perceptual conditions and by implication; |
| - Maintaining a set value of the parameter (maintaining the set course, ensuring the set frequency of propeller rotation); performance of operations and alarming about malfunctions, parameter limit value, etc.); | - Acquisition of generalized concepts based on disparate facts; |
| - Storing large amounts of data in memory and providing it in a specified form (electronic cartography, information systems); | - Solving tasks unintended by instructions given by a program or an algorithm; decisions connected with high responsibility for possible consequences, especially in extreme conditions and high-risk situations. |

Thus, ways of optimal presentation to the operator of information about the state of the control object and the external environment are based on the concept of the information model - a set of information display tools, the perception of which in the mind of the operator is formed by a set of ideas about the state of the processes and objects displayed. In case of a deviation of the process course from the norm, the operator interferes with it and has to restore the normal

course of the process within a certain time.

Other factors ensuring the safety of navigation are, primarily, the safety of a vessel, which is expressed in the coordination of actions of coastal and ship components, their optimum interaction excluding the occurrence of emergencies the precondition of that interaction defects.

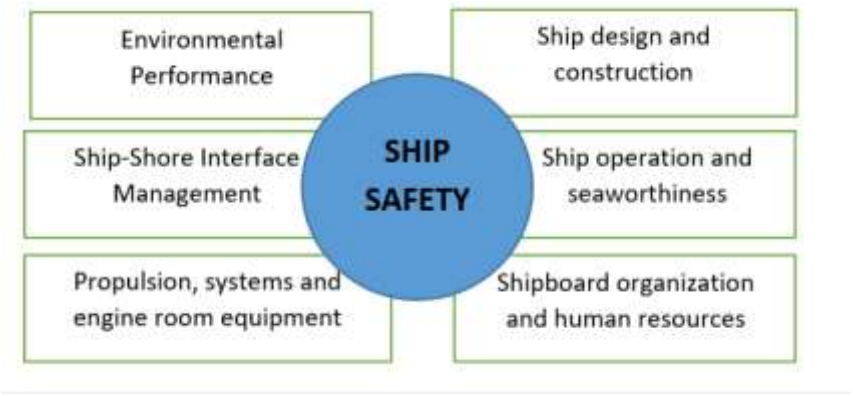


Fig. 3. Components of safe ship operation

For navigational safety, it is necessary to emphasize that the navigator's workplace in the ship's control system is the navigation bridge, which is an area consisting of the steering and navigating wheelhouse and the bridge wings. The bridge design should enable one person to control the vessel from a single command post, which is especially important when working in tense situations requiring urgent assessment of the situation and immediate decision-making. Equally, the bridge design should enable a group of people (the captain, watch officer, pilot, helmsmen and lookouts) to work together under any sailing conditions and circumstances. Furthermore, the bridge officers and others on watch must be able to observe the horizon in as large a sector as possible without having to move around the bridge while at the same time following the readings of the most important indicators.

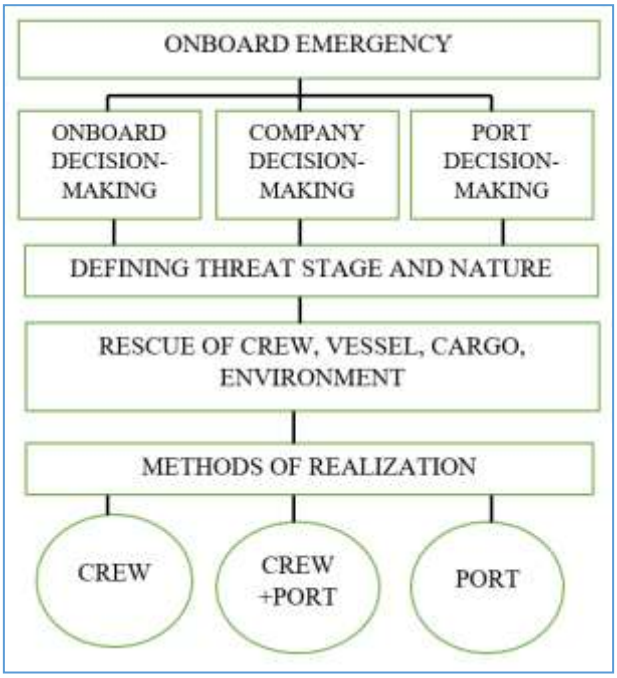


Fig. 4. Algorithm of action in case of an emergency on board

Safety management systems have an indisputable priority and actively influence the management system of the main production activity of the shipping company and regulate its activity following the rules and norms of shipping safety and environmental protection. Shipping companies must ensure a stable two-way communication of ships with the shore, timely reports of captains on the operational situation and condition of their ships, arising problems and actions taken to eliminate them, as well as the development of emergency plans and readiness of the company to promptly respond to dangers that may arise on the ships.

In turn, Masters, being properly qualified to operate a ship, must be fully aware of the company's safety management system, fully implement the company's safety policy on board the ships, and be the shipowner's trusted and authorized representative. Companies shall not prevent the master from taking such actions as may be deemed uniquely necessary for protecting human life, ensuring the safety of the ship, maintaining the safety of the cargo and preventing pollution of the environment.

Modern views and approaches to the protection of transport infrastructure facilities and vehicles against acts of illegal intrusion should be actively implemented in the security system of commercial seaports as critical infrastructure objects. Recently, along with obvious issues such as unauthorized access and theft of cargo and smuggling, the problem of illegal migration has become particularly acute. In the opinion of industry experts, developing effective solutions to ensure the safety of ports is an extremely urgent task. Of course, among the effective ways of implementing these solutions is the use of video surveillance in seaports; however, other issues remain unresolved. Current conditions of seaports functioning are one of the most favorable for the implementation of an ideal security system. Given the large number of port equipment, machinery and mechanisms used for technological processes, the integration of seaport security systems entails certain difficulties. Additionally, regardless of the security equipment and systems in use, the daily operation of the port must not be disrupted.

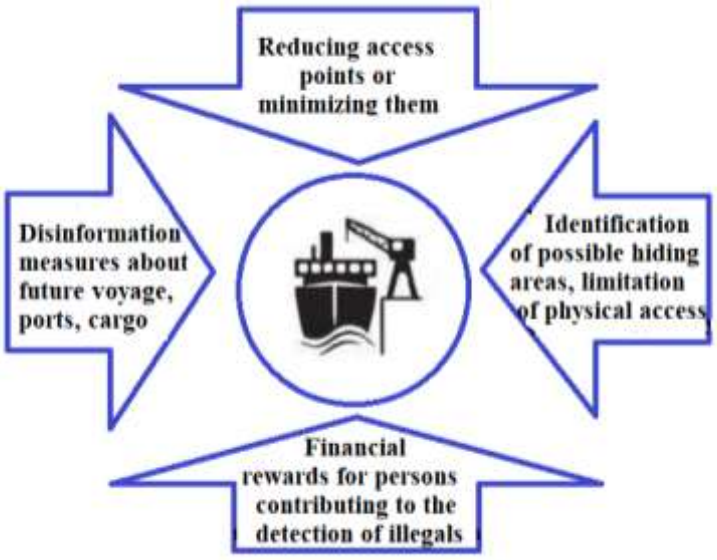


Fig. 5. Measures to ensure the safety of the ship in port

The concept of a safe port also plays an important role in the system of ensuring the safety of shipping. Two main elements to be considered are the socio-political situation in the country of the proposed port of call, as well as the level of technological and technical equipment of the port security and resources for its protection, which can provide adequate measures to protect

the crew, the vessel and the cargo. In addition, are navigational factors such as safe water depth at the berth, sufficient room for maneuvering, shelter from adverse weather conditions and safe anchorage. Approach channels of sufficient width with safe depths, right-lined sections and minimum curvature of turns, passages under bridges and tolerable current speeds. Berths must meet the criteria of sufficient overall dimensions, reliable berthing, mooring facilities and equipment for cargo operations. Hence, safe weather and climatic conditions should be carefully studied and considered during all operations planning throughout the period of port time.

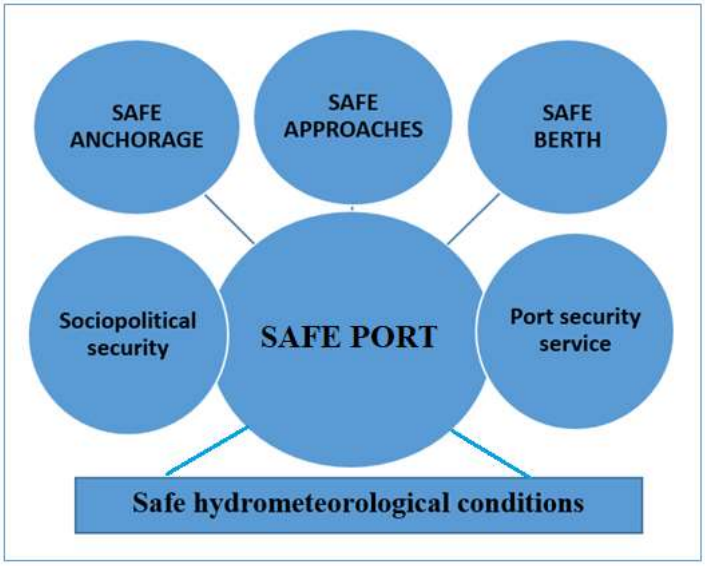


Fig. 6. Safe port concept

## 3. CONCLUSION

The most important principle in the system of ship operation is ensuring the safety of shipping and the protection of human life at sea, which is achieved by the effective solution of the set tasks. The most important components of accident-free fleet operation are based on a complex of organizational and technical measures aimed at the implementation of national and international requirements in the field of safety of shipping, as well as the prevention of environmental pollution. Due to considerable progress in the study of the problems of accident-free shipping, referring to the analysis of ship operation problems, including statistics of accidents and emergencies, it has been made clear that to reduce and prevent the loss of life and serious accidents, it is necessary to improve ship design, construction and equipment, and develop the scientific basis of ship navigation and her technical operation. However, the number of accidents and failures at sea, which affects the general shipping safety indicators, is still significant. It is necessary to establish procedures for the identification and characterization of probable transport accidents, hazardous situations and emergencies, and incidents on the board and develop methods of response to them. Systematic training of ship crews to act in identified or encountered and unforeseen or potentially possible emergencies should be carried out by ship-owning companies to establish and implement measures. This ensures the constant readiness of the company to promptly, adequately and effectively respond to different potentially possible emergencies and set standards for all kinds of potentially possible risks, which together will contribute to improving the safety of shipping.

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