Marine Incidents Management and Information Exchange Technologies in the Process of Safe Ship Operation

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Summary

Maritime transport is dominant in the overall volume of all international transportation. Existence and overcoming of problems, which cause pressure on shipping safety, remain actual and fully concern both maritime and inland transport. Increasing speed and cargo capacity of the ships along with the reduction of crew members lead to the automation of a growing number of work processes, which indicates the need to actively introduce appropriate measures in the security system of sea-going ships and commercial ports and to develop modern approaches to minimize negative events and incidents in the process of ship operation. Advantages in use of modern methods of monitoring the safety of ship operations, management of possible events and incidents, including investigation of accidents, first, aimed at prevention of negative occurrences and ways of prevention on this basis. Considering statistics on incidents increase, this work presents analysis of general ship accident rate, study of major accidental events growth annually, and investigation of causes of incidents, which most frequently occur in port waters and at open sea. A survey of current approaches to ensuring the safety of shipping by implementing effective tools, such as event and incident management, has been conducted.

Keywords:

Maritime safety, Maritime transport, Shipping and Logistics, Marine incidents, Incidents management, Safety of ship operation, Marine navigation, Maritime information technologies, Maritime communication, Sea carriage.

1. Introduction

Recently, the application of information technologies in the field of merchant shipping has made significant progress and promising development. The key areas have become e-Navigation and autonomous navigation technologies. The International Maritime Organization (IMO) has focused its initiatives on these aspects [1]. Numerous scientists have devoted their works to the implementation of the concept of electronic navigation such as satellite navigation and radio navigation to enhance the safety of navigation. This particularly reflected in the works [2-4] where the set of components and elements of the e-navigation concept and its application connection with the influence of the human element are considered.

In scientific works [5-7], attention given to communication systems to ensure the safety and security of ships and the study of the main factors of the implementation of electronic navigation. The issue of improving the initial programs and the need to update the standards of training of navigators and users of e-Navigation in [8]. The use of modern technologies, ship's computer systems and their integration into the navigation process, analysis of the state of existing technologies and prospects for the implementation of electronic navigation technology in [9-12]. Study of the prospects for technological development and implementation of the concept of crewless ships and vehicles in [13,14], special attention given to energy efficiency of ships in [15,16]. Nature and origin of major security concerns and potential threats to the shipping industry, maritime situational awareness and methodology for assessing the level of ship safety reviewed in [17-20]. Study of the risk assessment quality dependence on the ships accidents analysis [21]. Issues of safety of maritime transport operation and development of modern methods for assessing the level of ship safety and ways to improve it in [22,23]. Integrated ship cybersecurity management studied in [24]. Technical systems and complexes control during ship's operation

Manuscript received January 5, 2023
Manuscript revised January 20, 2023
https://doi.org/10.22937/IJCSNS.2023.23.1.9

researched in [25-27]. Developing and deploying intelligent incident detection system proposed in [30,31].

It should be noted that in all these aspects there is a need to develop and implement a toolkit aimed at preventing emergencies during the ship operation and its technical systems where monitoring of negative events will prevent the occurrence of incidents and emergencies on board, thereby increasing the overall safety measures of ship operations.

2. Statistical review and concepts analysis

The International Maritime Organization (IMO) regulates and coordinates maritime safety activities. The safety of seagoing ships can be assessed by means of accident rates, the statistics of which show the current situation and ideally should be kept to a minimum.

The results of the world statistics on ship accidents are published annually by various competent authorities of the IMO, as well as by maritime agencies and insurance companies. Types of maritime accidents distribute the picture of general accidents in maritime transport. The statistical data are distributed according to the following principles:

- by the nature of the location of their occurrence;
- according to the stages of the voyage;
- by cause of occurrence.

The most frequent serious marine events take place in port waters at the moment of vessel calls and exits, and account for about 60%, compared to vessels sailing in the open sea, where about 20%, and in coastal waters about 10%. Among the most frequent reasons for serious marine incidents can be listed as organizational, which are mainly caused by violation of collective management style, lack of preparedness of vessel's crew, so 37% of such incidents happen in harbor waters; technical reasons account for 80% of cases and result from damage to the vessel, engine or propeller complex, leading to ship sinking in over 70% of situations. Fires and explosions also make up a significant part and are related to port waters in most cases. Navigational, most often with a share of 40% emergency maritime events occur at the beginning of a voyage and are caused by crew fatigue, disruption of control continuity, with the most characteristic share of accidents in this segment being collisions and grounding of the vessel.

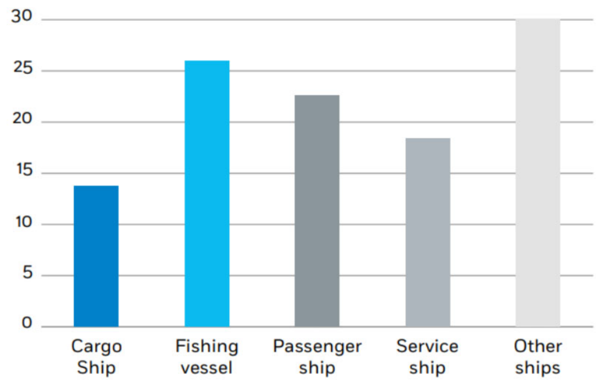

Fig.1 Average age of ships involved by main category (Safety4sea)

The statistics of general ship accidents indicate the dynamics of annual growth. An emergency event is characterized as an event that occurred as a result of errors and miscalculations in the operation of a vessel, and caused or could have caused human lives, or cause harm to human health, shipwreck or loss of seaworthiness, as well as environmental pollution. A maritime accident event differs from an emergency event in the place of occurrence in established water area, limited by natural, artificial or conditional boundaries, which ensure safe maneuvering and/or mooring of ships in a certain area of navigability. By types of occurrence of accident are classified into: very serious accidents; serious accidents and marine (serious) incidents.

Marine incident - an event or sequence of events, other than a marine accident, which occurred in direct connection with the operation of the vessel and related actions of the crew members, committed without direct intent and did not lead to negative consequences, but would create a threat to safety or increase the risk to the vessel, people or the environment. Regarding the classification of accidents and incidents at sea, there is no unity in this respect neither in legal acts nor in scientific research. Depending on the classification criteria, in some cases the necessary classification of accidents and incidents can be carried out. The criteria may be both the degree of hazard of the consequences that have occurred and the cause of the disaster. Classification by consequence is necessary to determine whether the State is obliged to investigate the accident (any very serious accident that has resulted in the total loss of a vessel or the death of a person or has caused serious environmental pollution must be investigated). Classification by cause can be used to maintain accident and incident records, generate statistical reports and identify performance weaknesses.

As is obvious from the preceding explanation a marine incident may include the following: death of, or injury to, a person associated with the operation or navigation of a vessel, the loss or presumed loss of a vessel, collision of a vessel with another vessel, collision by a vessel with an object. It also includes the grounding, sinking, flooding or capsizing of a vessel, fire on board a vessel, loss of stability of a vessel that affects the safety of the vessel, ehe structural failure of a vessel, a close quarters situation and dangerous occurrence, which is an occurrence that could have caused the death of, or serious personal injury to, any person on the vessel.

Annual Report from RMI in 2020, on marine safety investigations shows steady decline of marine casualties however marine incidents remain stable and even increased slightly over the past five years (Fig.1).

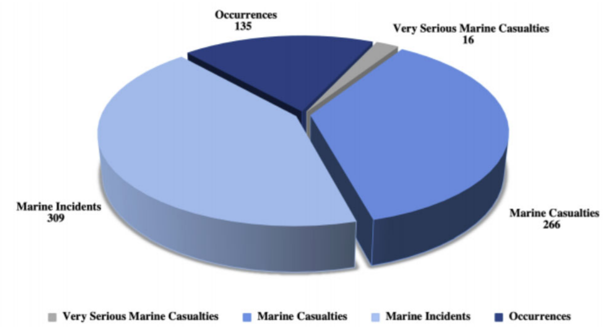

Fig.2 Marine incidents and casualties annual report - 2020

3. Events and Incidents management

Event and incident management is defined as a process that tracks all events that occur within the structure of an object, in our case a seagoing vessel. This can be considered during the life cycle phase of any voyage-level operations and is responsible for identifying problems and changes occurring on the vessel, both expected and unexpected.

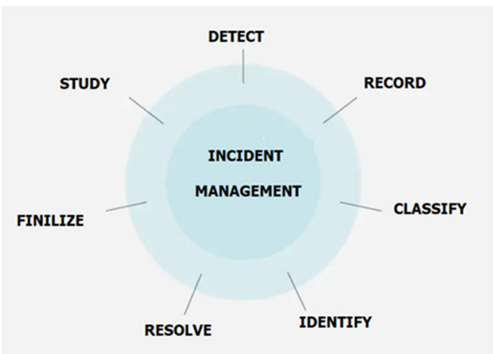

Fig.3 - Basic tools of incident management

This means that the purpose of the practice of event monitoring and management is to systematically monitor the condition of the vessel and its systems (navigation, engineering, cargo, etc.) and their components, and to record and report individual changes in condition, defined as events. It is typical in the practice of event and incident management that the study of the incidents themselves and the reasons that led to them, which the shipping company can effectively use the incident management tool.

Before considering the benefits of an incident management tool, it is first necessary to explain what "event" means in management. An event is essentially any change that occurs from any elements in the ship's system. For example, it could be any system, facility, subsystem, etc. These changes are not necessarily negative. Sometimes an event simply alerts you to something.

Take, for example, the ship's automatic course control system. An event occurs when the state of the system changes due to deteriorating weather conditions. Events can tell you about the normal operation of the ship as a whole, just as they can tell you about abnormalities in the ship's systems.

The practice of information security can also serve as an example where there are three main types of events:

1. Information. These events inform that something has changed, but no action is required. As in the example above, the ship's automatic course control where the notification system has worked properly and no action is necessary.

2. Warning. This is a more serious type of event and may actually require some action. For example, resetting the vessel's course keeping in automatic mode or threatening to collide with a potentially dangerous target due to exceeding the guard zone limit, so a warning is issued to let the crew or watch crew know that some manual intervention will be required. If no action is taken, the current situation will result in an incident. In such situations, warning events can help prevent incidents.

3. Malfunction. This event means that something has gone wrong. This is the most serious type of event that will require immediate intervention, investigation, and resolution. In all cases, an incident or problem management team (crew members, watch officers) must be involved.

Three main types of events should be distinguished (Fig.4).

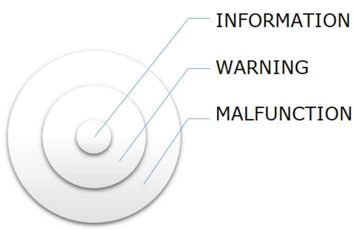

Fig.4 – Three main types of events

All incidents are events because they signal negative changes in your overall vessel condition, but not all events are incidents. Some changes that create events are quite normal and expected.

The events indicate whether all systems in the ship's structure are operating efficiently, and event management provides the opportunity to reduce incidents, highlight problems in their operation and assess the degree of efficiency of the ship's operations. With a complete picture of the ship's overall condition, the ability to manage problems and continuous improvement is greatly enhanced.

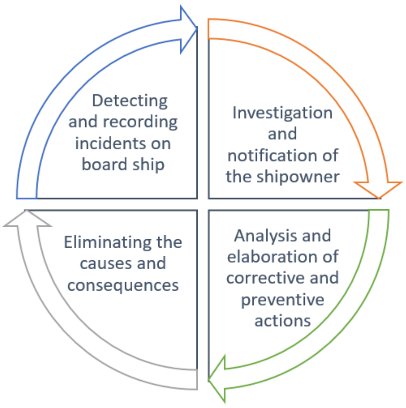

Fig.5 - General cycle of the incident and response

By managing incidents, the probability of achieving objectives for regulatory safety levels can be increased, identification of opportunities and threats can be improved, and resources can be efficiently allocated to manage risk. Incident management, the process responsible for managing the lifecycle of all incidents, ensures that their impact on the safety process is minimized and that the safety service is restored to normal operation in the fastest way possible. Incident management is performed to improve security effectiveness in resolving actual or potential failures and malfunctions of facilities or erroneous actions of their safety forces and crew. Incident management involves the integration of various information systems, automated rounds and inspections.

Now, by understanding the importance of events and incidents and their management, we can consider the benefits that an event management tool can bring to the operating company.

1. Improve response time and incident detection. Using the event management tool, incident detection and reaction time can be improved. If during the operation of the ship the crew members report failures of machinery and systems to the management personnel, who in turn report them to the relevant company services, this tool is very effective. Depending on the type of incident, instead of information from the Master to the shipowner's company, the event is alerted before any of the crew notices the failure or malfunctioning of the system. The event management tool alerts the necessary specialists and individuals to begin diagnostics and actions to resolve the incident. If it's a "malfunction" event, the added benefit of improving detection and response times means you also reduce downtime for the system that's out of service. And if it is a warning event, then there is the possibility of avoiding the failure altogether.

2) Automation Capabilities. With an event management tool, workflows can be created for the entire lifecycle of these events. This means that when an event is initiated, the tool can automatically notify the right specialists, assign the event to the appropriate service group, and resolve/close the event when it is complete. Events can also automatically turn into alerts or incidents, speeding up the logging process. Moving these types of tasks into an automated workflow instead of manual processing will not only speed up processes, but also ensure consistency and accuracy in event processing.

3) Efficient decision-making and action by automatically sending reports. Reports can be used to highlight problem areas (recurring alerts or deviation warnings) and therefore help the shipping company in its efforts to better support the execution of processes on board. The event management tool already provides ready-made reports that can be used by the shipping company. It is then possible to customize the reports that are generated, as well as automate their distribution to the appropriate people without any additional manual intervention.

4) Improved quality of shipboard operations. The event management tool provides a more comprehensive view of both the current state of the vessel's operational condition and its systems, and allows you to monitor the processes and operations on the vessel to identify possible problems. Increased transparency allows not only proactive fixes, but also longer-term investments in incident prevention and reduced vessel downtime, as well as easier and faster analysis of the root causes of incidents.

5) Operational expense savings. With any investment, the question arises as to how effective the use of an event management tool is in saving the shipping company money in the long run. It should be considered that the event management tool provides the following features:

- Improved detection and response time to off-nominal situations;
- Decrease of ship demurrage time (loss of freight and related costs);
- Ship operation processes are automated;
- Identifies problem areas to be monitored;
- Emerging problems are handled proactively.

Savings in operating expenses and the required calculations for the mid-term maintenance of the vessel become compelling. In addition, the cost of supporting operational standing will also be reduced as the environment becomes more manageable and continuous improvement efforts are made easier. The standard sequence of actions can be presented as given on (Fig.6).

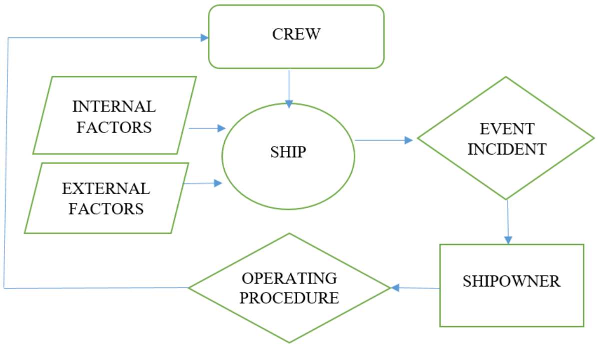

Fig.6 – Sequence of actions

4. Incident management implementation complexities and measures development

However, the incident management process is fraught with some difficulties such as clearly establishing roles in the process. If the roles are clear enough in the shipowner's company units, it will be difficult for the technical teams involved to adequately assess, act or quickly respond to and investigate the incident.

Collecting data from a variety of sources involves logs in a variety of formats. There is a need to look at all these sources, to correlate events with the ability to build an attack vector. Resource constraints are a problem for most companies. Resources (human and technological) imply costs, and if the issue with human resources can be solved by automation of processes, then without the necessary infrastructure, which can be compensated by various organizational measures.

Automation of incident management process. Given the abundance of target systems, possible incidents and risks, we get a huge number of parameters that need to be monitored. We need a centralized monitoring that can identify incidents that are made up of routine events. In other words, we need to automate the incident management process. The event management system is a deeply integrated system with other processes. Of course, most of the steps can be made local, but then the efficiency of automation would be seriously reduced. Incident management is an integral part of comprehensive safety of a shipping company.

The effectiveness of the information interaction system on ships and in shore-based services is ensured through analysis and processing data from electronic charts and sources, weather information, positioning systems, information on the route, course, maneuvering elements of the vessel, exchange of navigation information using AIS in the modes "ship-to-ship", "ship-shore" and "shore-to-ship", display of current information on ships and in coastal services using ECDIS; warning and alarm systems on board and on shore in case of dangerous situations, transmission of distress signals and information on navigation safety. In general, it is assumed that the capabilities of information exchange technologies will be equally useful for shipowners and ship operators, as well as for various services related to shipping.

The choice of the most effective levels of abstract description (from the point of view of safety and the possibility of technical implementation of safety measures and simultaneous quality assurance of the processes of ship management and individual ship technical systems and complexes) in the study of ship safety management systems is responsible, controversial and largely determines the effectiveness of the applied application of the theoretical foundations of the construction of automated control systems. A review of the current state of abstract systems theory allows us to consider that the following levels of abstract description are appropriate for the analysis of the ship's safety management system: linguistic, set-theoretic, abstract-algebraic, topological, logical-mathematical, theoretical-informational, dynamic and heuristic.

The upper level of analysis (description) is linguistic, which should be represented as a certain set of statements in the form of requirements and/or technical specifications aimed at further improvement of ship safety management systems (SMS), which are composed in grammatical natural language. The database for the linguistic description is the information obtained as a result of the analysis of operating experience, technical, economic, ergatic and ergonomic studies of existing safety management systems (field conditions and/or simulation models). Thus, there are tasks of abstract description of the ship's SMS and its complex technical systems at different levels of management. System analysis of the problem shows that the solution of the main task of incident and event management is characterized by interdependence and closeness of analysis and synthesis procedures. In general, the construction of a ship's safety management system based on modern automated SMS can be formalized in the form of a logic algorithm diagram (LAD):

$$S_S \overset{1}{\downarrow} \mathrm{TR.SR.}x_1 \overset{1}{\uparrow} A_1 A_2 \overset{2}{\downarrow} A_3.x_2 \overset{2}{\uparrow} A_4.x_3 \overset{2}{\uparrow}\overset{3}{\downarrow} A_5.A_6.x_4 \overset{3}{\uparrow} A_7.S_F, \quad (1)$$

where Ss, S_F are the operators of the beginning and end of the LAD; TR - formulation of the research objective; SR - formulation of the main research task; A_1 - selection and development of the system of basic principles of building the SMS and management of technical systems; A_2 - conducting systematic, ergatic and ergonomic studies of the ship's SMS and company's SMS, existing fleet, analysis of research results, drawing up technical-ergatic and ergonomic requirements for promising SMS; A_3 - development (or selection) of the initial physical structure of the SMS and description of the general rules of functioning at the theoretical-set level of abstraction; A_4 - analysis of functional tasks and implementation of the contour decomposition of the SMS; A_5 - selection and development of new methods for solving functional tasks, development of missing devices for connecting individual elements of the SMS with control objects; A_6 - solving control tasks, development of algorithmic and software; A_7 - verification of algorithms by simulation and experimentation methods, analysis of results; x_1 - conditions of compliance of the goal with the problem; x_2 - conditions of compliance of the chosen system with the principles of construction; x_3 - conditions of satisfaction of tasks with goals, requirements and principles; x_4 - conditions of satisfaction of partial and general principles of SMS effectiveness.

It is clear that each i-th functional task can be assigned a certain target function C(i) that determines the effectiveness of its solution. The full set of such private functions reflects the effectiveness of the SMS as a whole. Since the significance of individual target functions in the complex evaluation of the effectiveness of the SMS and individual systems is not the same, the generalized evaluation can be constructed by composing private target functions taking into account their contribution to the overall efficiency E:

$$\mathrm{E} = \overset{n}{\Sigma} P_{ji} C_{ji}, \qquad (2)$$

where Pji - weighting coefficients for each of the functional tasks (common for all compared systems), and Pji and Cji are connected by mutual unambiguous correspondence.

Consequently, when solving the problems of ensuring the efficiency of the SMS, it is necessary to use the following criteria: minimization of the intensity of failures; specific fuel consumption for electricity generation; time of transients of the main systems of the ship; maximization of the uninterrupted power supply; overall performance; coverage of the object parameters by the control and management functions; marginal probability of the initial information required for decision-making; accuracy of the control processes, the degree of automation; minimization of the cost of management and others.

These conflicting criteria complicate the choice of one best criterion that ensures the highest efficiency of the SMS, since in most cases different criteria are represented by functions that do not have explicit extremes, or have fuzzy descriptions, such as expert ones.

In this regard, it is of interest to apply the criteria of "technical utility" to assess the effectiveness of the SMS. In the theory of technical utility, the effectiveness of the system is considered as an a posteriori assessment of the quality of the system, and "technical utility" is an assessment of the quality of the system as a means to achieve the goal. Moreover, the achievement of some goal TGTj by the object OBJi is judged with some probability Pji. To achieve the goal requires time tji and resources (costs) EXPji. If the goal is partially achieved, there are additional losses (time and/or other resources) LOSji. Thus, we can determine the mathematical expectation of the amount of resources E Pji that will be needed if the probability of achieving the goal TGTj in the interval tji is Pji:

$$E\ P_{ji} = EXP_{ji} + LOS_{ji}(1 - P_{ji}) \qquad (3)$$

Probabilistic estimates of Pji are determined, for example, as reliability characteristics (probability of failure-free operation for the time interval required to achieve the objective) or by expert evaluation. Given that E Pji is defined as the mathematical expectation of losses (time, material), when combining several objects OBJ(NOBJ) to achieve one or more goals TGT(NTGT), the total utility is described as:

$$\left| E\ P(N_{OBJ} \times N_{TGT}) \right| = \sum_{ji} E\ P(j,i) \,|\, TGT(N_{TGT}) \quad (4)$$

Since the mathematical expectation of the sum of random variables is equal to the sum of their mathematical expectations. Technical utility determines the cost of achieving the goal, therefore, as a criterion, should be minimized. Especially effective is the use of technical utility indicators for comparing different (competing) principles of SMS construction. If objects OBJ(i) and OBJ(k) are suitable for achieving the goal TGT(j), then the one for which E Pji is smaller is more important.

5. Conclusion

Measures including the need to identify and analyze accumulated hidden failures, negative events and incidents in ensuring the complex safety of the vessel, should be reduced to the fact that the accident which has a high probability share eventually did not occur. This will allow the application of more effective measures to improve safety and reduce the probability of recurrence of adverse events. Routine vessel operations, like events, occur all day long, as this is essentially the nature of the vessel's operations. So at any stage of ship operations, whether it's port entry, cargo operations, bunkering, sea passage, activities never stop, so does the actual event management tool. With this in mind, understanding the importance of events and incidents and their management highlighted the characteristic benefits that the event and incident management tool can bring to the shipping company. The application of the mathematical apparatus allows not only to increase the efficiency of event and incident management, which leads to ship safety, but also to ensure the optimal and energy efficient modes of operation of the vessel's technical systems and, as a consequence, to maintain its safety.

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