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MARITIME SITUATIONAL AWARENESS AS A KEY MEASURE FOR SAFE SHIP OPERATION

Summary. The maritime industry is a high-risk industry, which constantly has to make decisions in a rapidly changing environment. Therefore, understanding the essence of "situational awareness" is very important for making the right decision. In this regard, it is obvious that a correct situation analysis, based on a theoretical basis, creates the proper prerequisites for making the right decision in a developing situation, and vice versa. Considering this fact, this article proposes to study the factors that influence this phenomenon, their regularities and connections. It presents the data of a survey among seafarers to determine the level of understanding of situational awareness as a predominant component of the human factor in most accidents in the maritime industry.

Keywords: maritime safety, human element, situational awareness

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1. INTRODUCTION

The importance of situational awareness among other human factors confirmed reviews of casualty investigations conducted by several researchers. Speaking about situational awareness [1, 6], it is worth mentioning the fact that this phenomenon is closely interconnected with other components of the individual human factor, such as fatigue, stress, health fitness, communication, alcohol, etc. This is evidenced by the numerous studies carried out in [3, 7, 12, 13]. One of the most important aspects of the human element – situational awareness, was defined as "being aware of your surroundings" in [5]. An early study of situational awareness was administered in [11]. The study, aimed at defining human factors associated with accidents in the maritime industry, was conducted at a time when the seriousness of human error had not been fully realized. Initially, it was supposed that marine casualties are a result of some factors and human error is a contributing, if not the fundamental factor. Summarizing the scientific works on this problem, it is necessary to say that since long ago in maritime educational institutions there was a practice according to which situational awareness was understood as a requirement to keep oneself closer to danger.

2. MATERIALS AND METHODS

There is no doubt how important situational awareness is to maritime safety in general, so let us consider this factor in detail. The term "situational awareness" means:

- having a good perception of your surroundings at all times;
- comprehending the happenings around your ship;
- predicting how this will affect your ship.

Indeed, looking at the global statistics of maritime losses in recent years (Figure 1), one can see how much loss has been incurred by shipping companies around the world from maritime incidents.

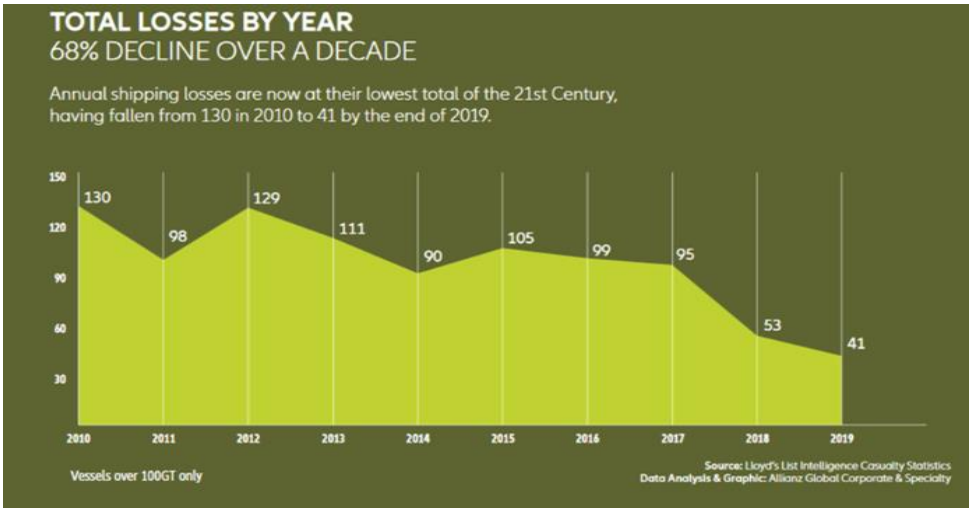

Fig. 1. Total losses by the year 2019 [1]

Costs for losses and consequences from losses to the marine environment is on the increase. This reality is well understood if we consider only a few accidents with ships of the US Navy, NATO countries, for example, the accidents of the US Navy destroyer "FITZGERALD" with the container ship "ACX CRYSTAL", the accidents of the US destroyer "JOHN MCCAIN". with the tanker "ALNIC MC", the accident of the Norwegian Navy frigate "HELGE INGSTAD" with the tanker "SOLA TS", the collision of the Greek Navy minesweeper "KALLISTO" with the container ship "MAERSK LAUNCESTON". Due to these four incidents alone, over the past 4 years, an accrued total loss in expenses of over two milliards of USD was incurred, 17 sailors were killed and about 307 were injured. According to the definitions of the investigations, the main reason for these accidents was the "human element", however, among the factors of the "human element", a large percentage is accounted for by the factor of "situational awareness". This motivated us once more to take up on the topic of "situational awareness".

The meaning of the term leads us to the unique phenomenon – situation awareness is, therefore, a state, as well as a process [2]. Hence, to have good situational awareness, mariners should focus on the following factors, which could be classified into four groups (Figure 2).

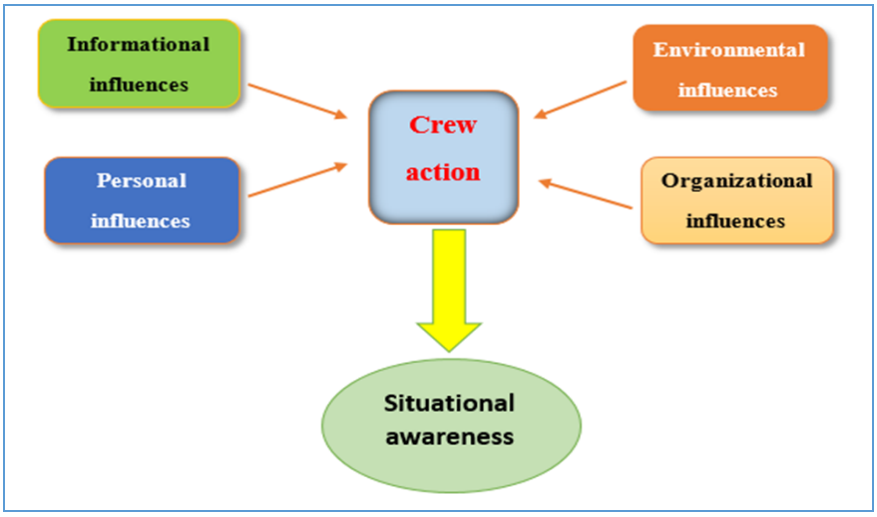

Fig. 2. Interconnectivity between factors and situational awareness

Tab. 1

Functional elements of situational awareness

Informational influences	Environmental influences	Organizational influences	Personal influences
traffic density including concentrations of fishing vessels or any other ships	state of visibility	familiarization with the working environment in a way of construction, design and interface of used equipment	fitness for duty

maneuverability of own ship; the draft concerning the available depth of water	state of the wind, sea, current or tide, indoors and outdoors temperature	presence and following of well introduced watchkeeping procedures, instructions, orders	working overload (fatigue; stress)
knowledge of characteristics and limitations of used equipment including its design, interface, variety, quality and reliability; level of automation	vibration; noise	flexible composition of watch personnel depending on many personal factors	communication (on a bridge; with a pilot or VTS)
accuracy of own position, course, speed and proximity of navigational hazards	part of a day (lights/darkness)	maintenance of a proper voyage planning procedure	competency; experience, training, skills
N/A	N/A	good maintenance of interaction between a man and a machine	relationship between crewmembers
N/A	N/A	N/A	dependence on navigational aids and landmarks; navigational equipment and various alarms

Each functional element presented in Table 1 above has a particular role to play in the development and maintenance of situational awareness. This list could be continued, for instance: presence of cellular phones in a wheel house could greatly compromise the whole situational awareness, or gender and marital status of watchkeeping personnel and so on. These factors are further discussed in this work.

We can reflect the interaction of these elements in a structural form and show how the predominant factor can be addressed to mitigate its effect on situational awareness. It is also pertinent to mention here that the term ‘situational awareness’ is highlighted on the global scene to build up a useful model in the maritime industry to train the decision making processes and the interdependencies in safety issues of the operations [4, 5].

Having the above information, we can declare that situational awareness means an accurate understanding of the happenings around you and what is likely to happen, or in other words, a duty officer shall:

- perceive what is happening;
- understand what is happening;
- think ahead based on this.

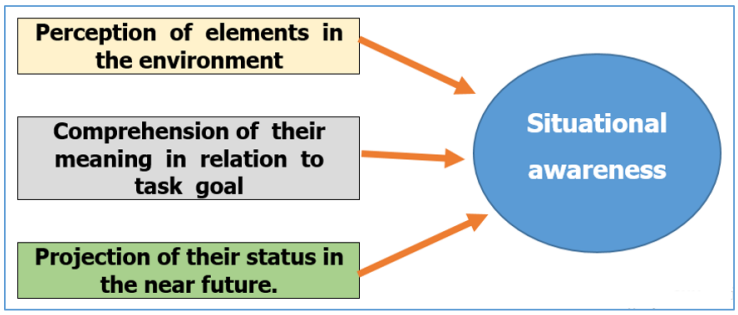

Fig. 3. Phases of situational awareness [2]

Let us take a more precise look at each phase's element of situational awareness.

The first phase (1 Level) – Perception of the Elements (use of own senses) involves perceiving the status, attributes and dynamics of task-related elements in the surrounding environment. The data perceived by the individual undergoing the decision making process depends on a variety of factors, which includes the nature of task, complexity of the operation, nature of input information, level of difficulty, dependent variables, operator goals, the experience of the individual, expectations of the process and operator, design interface, system design complexity, man-machine interaction, capabilities and automation of the machinery [5]. It looks simple but it is a process that requires discipline, as well as knowing what to look for, when to look for it and why.

The second phase (2 Level) – Comprehension of the current situation (creating a mental picture) involves understanding how important the data is concerning the task and goals ahead. It is a very important stage as the goals of the task depend on the understanding of important data, which can accomplish a particular work task in a much more effective and safe way. During level 2, "the decision maker forms a holistic picture of the environment, comprehending the significance of objects and events" [5].

The third phase (3 Level) – Forecasting future system states (thinking ahead). It simply is "sailing ahead of the ship". Features in the environment are mapped to mental models in the operator's mind, and the models are then used to facilitate the development of situational awareness [3, 4]. Indeed, it considers future system states meaning that it involves determining future states of the system and its elements for the complex and different decision making processes, which involves intense thinking and assessment to achieve a desired goal in the future event. This step is crucial in the decision making process and requires that one's understanding, based on gathered data, is as accurate as possible.

2.1. Losing situational awareness

However, situational awareness could be compromised at each level of the previously described process. For instance – Figure 4.

It is very important to bear in mind factors, which could compromise situational awareness. Almost all of them have psychological roots. Mainly, we need to recall the importance of the following factors: boredom, carelessness, channelized attention, complacency, confidence, distraction, expectancy, human information processing, inattention, judgment, motivation, non-compliance with orders, pressing, technique, training [7, 8].

Among these factors, first, it should be called a distraction from the performance of official duties. From a technician's point of view, distractions come in many forms such as a cold wind through a door, excessive movement of the ship and presence of working seafarers on

deck, frustration over lack of parts and tools to perform tasks effectively and efficiently. Causes of attention lapses include, but are not limited to phone calls, games in the workplace, shift change, sleep deprivation, illness, poor morale, problems at home, poor housekeeping on board ship, visitors, etc. [9]. The aforementioned points shall be duly counted by the watchkeeping personnel otherwise we will not be able to maintain a proper situational awareness on board a ship.

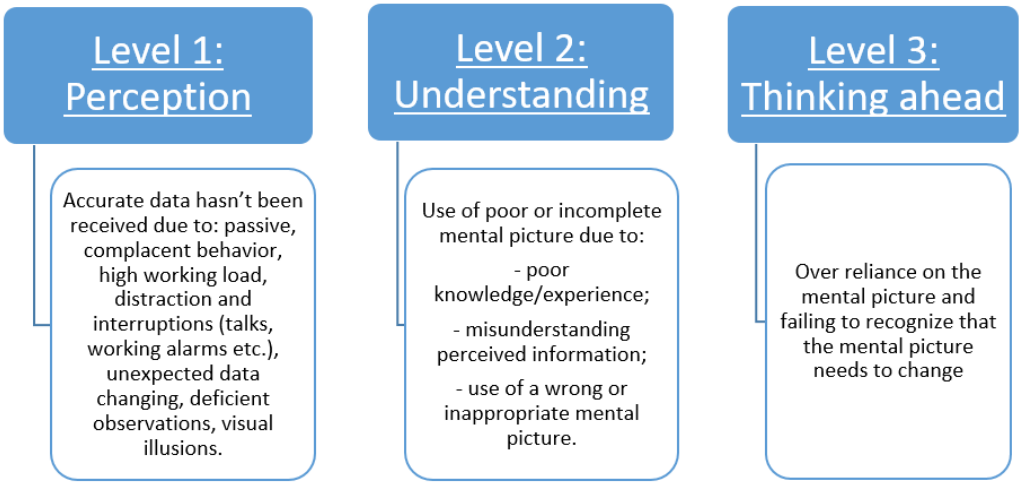

Fig. 4. Disruption factors of situational awareness at each level

2.2. Recovering situational awareness

Below are a few pieces of advice, which could be useful when faced with the need of situational awareness recovering:

- follow the rules and standard operating procedures, call master, at least;
- change from automation to manual, if you expect any course alteration;
- advance time either by slowing down and/or altering course;
- do not hesitate to use communication - ask for help;
- seek the nearest stable, simple and safe method; go back to the last thing that you are sure of;
- assess the situation from different perspectives with different sources;
- expand your focus to avoid fixation;
- take time to think, use that time and be willing to be delayed [14].

3. RESULTS AND DISCUSSION

We conducted a study among seafarers of different age groups to determine the following:

- the degree of study of the factor "situational awareness";
- understanding of the essence of "situational awareness" among seafarers;
- measures to improve the current situation.

So, we have initial basic knowledge regarding situational awareness and will take a step further toward assessment of understanding of this phenomenon factor among seafarers. For obtaining as accurate figures as possible, we select some respondents using Yamane's or Sloven's formula (1):

$$n=N/(1+N(e^2)) \quad (1)$$

where:
n – corrected sample size,
N – number of seafarers,
e – margin of error (MoE).

We estimate the number of active seafarers equaling 100 hundred thousand seafarers. For research purpose, the margin of error is taken= +/- 5%. So, in this case, a minimum number of respondents would be: n=100000/(1+100000(0,05^2) ; after simple calculation, we will get a number n=398 seafarers. For accuracy, all respondents were officers of deck and engine departments (Table 2).

Tab. 2

Survey results of respondents of different age groups

No	Age of respondents	Experience at sea in years	Official rank	Quantity of respondents	Percentage of respondents
1	20-30	0-10	Officers	270	67,8 %
2	30-50	10-20	Officers	112	28,2%
3	Over 50	20-30	Officers	16	04,0%

All of the respondents filled anonymous questionnaires, which were later evaluated by the researchers.

There were five questions in the survey:

1. Did you study situational awareness in marine school? (Figure 5);
2. Did you study situational awareness during your training at maritime training centers? (Figure 6);
3. Do you know how to evaluate the situation, its algorithm and procedure? (Figure 7);
4. Do you know the factors that form the mental picture of decision making? (Figure 8);
5. Which data is more reliable for the assessment of collision: Radar or AIS? (Figure 9).

The result was well estimated because the requirement for the study of human element was inserted in the educational program after the Manila conference in 2010. Seafarers that graduated from marine educational centers before 2010 did not study this subject. The term "Human Element" is a part of the subject "Maritime Resource Management" and logistically should be studied by the cadets in marine educational centers. On the other hand, the value of affirmative answers (21,5%) of those respondent groups sounded a serious alarm for the

general quality of the educational process. Furthermore, respondents from the second group could not help denying the compulsory requirements by STCW-78, as amended (Regulation I/11) and national requirements of refreshing educational and training courses. The latest reports showed that updating courses, programs and probably instructors do not duly respond to the international requirements stated in the IMO resolutions.

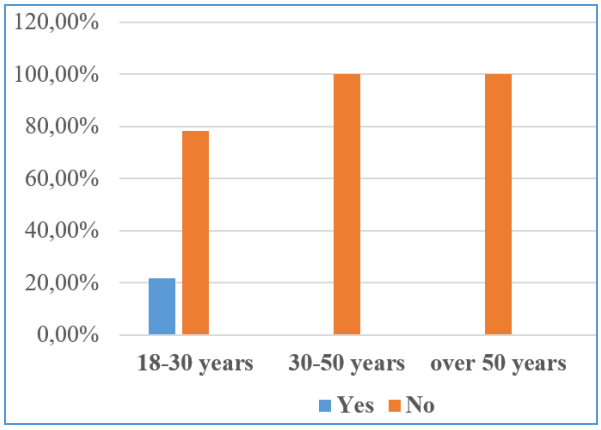

Fig. 5. Understanding situational awareness during the educational process

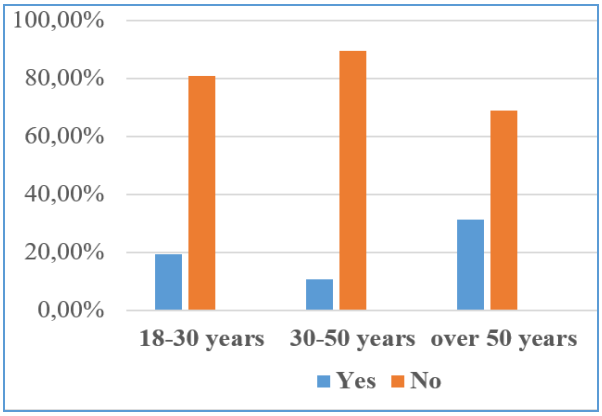

Fig. 6. Study of situational awareness in seafarers' training centers

Obtained figures confirmed the fact that the quality of training conducted in Ukraine contradicts current international requirements. We are talking about requirements of IMO model courses 1.21, 1.39, 1.40 which in black and white requires considering factors of the human element indicated in them when organizing and conducting trainings. The lack of this knowledge leads both to a decrease in the quality of expertise in training centers and a decrease in the level of competence of seafarers. Such an approach in the organization of training and educational processes in Ukraine fully compromises the requirements stated in the STCW-78, as amended, as far as the IMO Resolution A.947(23) “Human Element Vision, Principles and Goals for the Organization” dated November 27, 2003.

Obtained results confirmed the following facts:

- proper situational awareness can be developed by experience (100% of respondents over 50 years old stated that they understand the algorithm and procedure of situational awareness);

- respondents of the group 30-50 years old did not study this factor either in a marine school or in a seafarer's training center (with exception of a small number of respondents), some of them were not able to develop the sense of situational awareness due to lack of experience (46.4%);
- respondents of the group 18-30 years old showed a better understanding of the term (64,4%), they probably had some knowledge or training; nevertheless, 35,6% of respondents did not know how to deal with situational awareness. In other words, confusion, loss of self-control among the representatives of this group due to unsatisfactory quality of education and simulator's training, is expected.

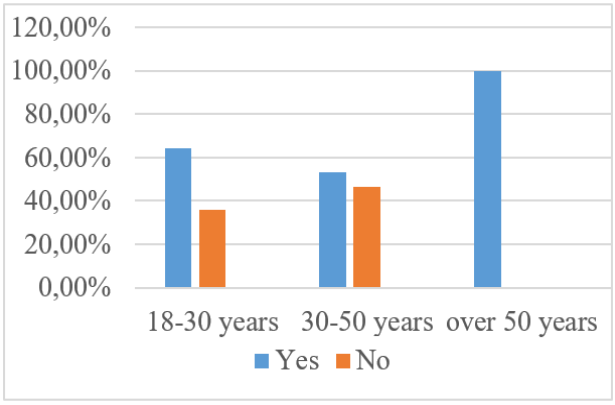

Fig. 7. Situation assessment of situational awareness algorithm and sequence of actions

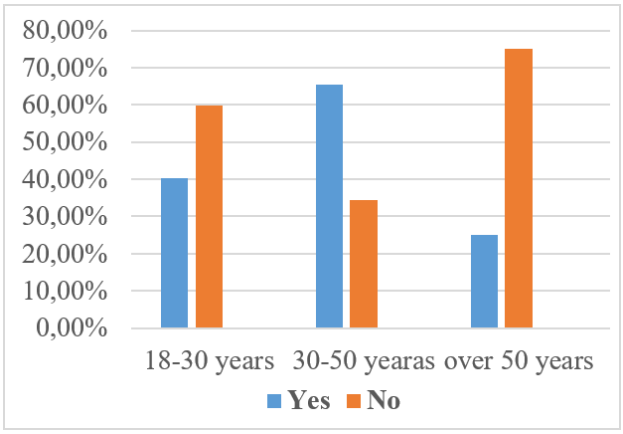

Fig. 8. Understanding the factors that shape the mental picture of decision making

Again, the results of this research revealed a gap. Generally, it is related to all groups of respondents. In other words, our respondents' knowledge and skills are distant from the industry requirements and do not work to improve maritime safety. In addition, it should be recalled that in evaluating the answers of the respondents, it was observed that some respondents, for whatever reason, gave a positive answer to the questions, which would worsen the results of the questionnaire.

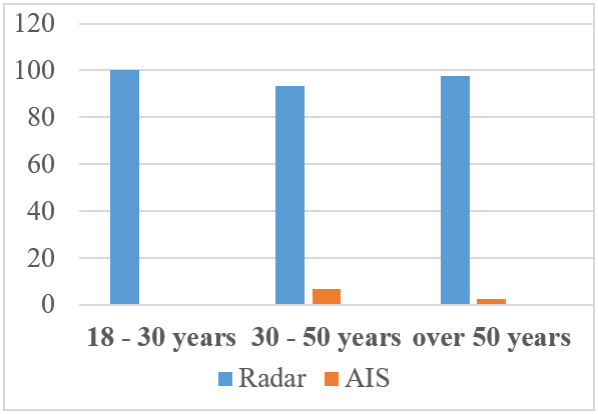

Fig. 9. Preference of devices for collision assessment: Radar or AIS?

Result of the questionnaire shows that all age groups have academic knowledge and training skills, which do not meet the requirements of the STCW-78 or IMO model courses. This misunderstanding could seriously compromise a ship's safety during routine maneuvering to avoid a collision. The case of the collision of the Norwegian warship *"Helge Ingstad"* readily comes to mind. A 5,290 tons frigate was completely sunk to the bottom of a Norwegian fjord after smashing into a Maltese flagged oil tanker "Sola" off the coast of the Scandinavian country near Bergen on November 08, 2018. Eight people were injured in the crash. The main reason for this collision is the lack of situational awareness caused by insufficient knowledge of principles of the marine radar with automatic radar plotting aid (ARPA) work by the female-gender crew of the Norwegian's frigate. The direct losses exceeded 700 million dollars. Having evaluated the answers of the Ukrainian seafarers and cadets, we could not assume that the Ukrainian seafarers would be able to avoid collision under the same circumstances, because their answers showed the same problem.

4. CONCLUSION

Because the respondents worked in different companies or were educated in different training centers, they had different levels of experience and different sets of professional skills. The obtained data allows us to believe that the answers of our respondents can be regarded as a lack of basic knowledge about the phenomenon of situational awareness, as well as a lack of skills due to insufficient training in the training center. The results obtained in the course of the survey clearly show significant shortcomings in planning and implementation of seafarers' training at the maritime educational institutions. Therefore, it is necessary to focus on improving the level of training of both ship crewmembers and instructors, by including new training modules to study certain elements of the human factor in the training program. The existing system of seafarers' training generally meets the needs of the shipping industry; however, given the constant updating of international requirements to ensure the safety of navigation, new requirements to the training of crews and masters of seagoing ships should be formed, therefore, the approaches to the range of courses and programs offered should similarly change.

References

1. *An annual review of trends and developments in shipping losses and safety*. 2020. Allianz Global Corporate & Specialty Safety and Shipping.
2. Baumann M., T. Petzoldt, J. Krems. 2006. "Situation Awarenss beim Autofahren als Verstehensprozess". *MMI Interaktiv* 11. ISSN: 1439-7854. [In German: "Situation awareness when driving a car as a process of understanding"].
3. Cooper S., S. Frasher. 1996. *Report of the Coast Guard - AWO Quality Action Team on Towing Vessel Crew Fatalities*. Washington, D.C.: U.S. Coast Guard.
4. Endsley M.R. 1988. "Design and evaluation of situation awareness enhancement". *Proceedings of the Human Factors Society 32nd Annual Meeting*.
5. Endsley M.R. 1995. "Measurement of situation awareness in dynamic systems. Human Factors". *The Journal of the Human Factors and Ergonomics Society* 37(1).
6. Hetherington Catherine, Rhona Flin, Kathryn Mearns. 2006. "Safety in shipping: The human element". *Journal of Safety Research* 37: 401-411.
7. Koester Thomas. 2003. "Situation Awareness and Situation Dependent Behavior Adjustment in the Maritime Work Domain". *Proceedings of the Tenth International Conference on Human-Computer Interaction*. Mahwah.
8. Koester Thomas. 2007. *Terminology Work in Maritime Human Factors*. Frydenlund Publishers. ISBN: 978-87-7887-562-4.
9. Komarniski Richard. 2004. "The human factor of distraction". Grey Owl Aviation Consultants Inc. Available at: https://www.greyowl.com/articles/11-2001_amt.pdf10.
10. Kumar Vivek. 2014. *Situational awareness in demanding marine operations*. Aalesund University College. Master's degree thesis. 79 p.
11. Margetts Barry D. 1976. *Human Error in Merchant Marine Safety*. Washington, D.C.: National Research Council.
12. McCallum Marvin C., et al. 2000. *Communications Problems in Marine Casualties*. Groton: U.S. Coast Guard Research and Development Center.
13. Sanquist Thomas F., Mirelle Raby. 1996. *Fatigue and Alertness in Merchant Marine Personnel: A Field Study of Work and Sleep Patterns*. Washington, D.C.: Battelle Seattle Research Center.
14. *Situational awareness*. 2017. Maritime Safety Queensland. Queensland government. Available at: https://www.msq.qld.gov.au/Safety/Situational-awareness.

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