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Short report

MASS Level III – Exploration of Current Issues from an Operational Point of View*

Darijo Mišković

Abstract: Despite all efforts to ensure the safety of ships, available statistics show that the human factor remains the biggest problem in the maritime industry. The desire to improve the safety of ships and the related protection of the environment has been at the heart of the Maritime Autonomous Surface Ships (MASS) concept, which is supported by the International Maritime Organisation (IMO). Although the concept itself seems feasible in principle, there are still a number of open questions from an operational point of view. Furthermore, the economic feasibility of the concept is unknown. This paper addresses questions to which there are currently no answers.

Keywords: Ship safety, System reliability, Maintenance, Human factor, Risk

1. Introduction

The fact that more than 80% of the world's goods are transported by sea underlines the importance of international maritime transport [1]. Stopford [2] notes that the shipping industry is often seen as the lifeline of the global economy. In the past, the shipping industry has had to deal with a high number of accidents and incidents at sea caused by human error. The situation is still similar today, with almost 66% of all accidents caused by human error [3].

In addition to human error, organisational factors have also been identified as one of the problems. The industry has responded to the above problems in different phases over the last two decades: a) International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW); b) International Safety Management Code (ISM), which was later added to the SOLAS Convention chapter IX; and c) Maritime Labour Convention (MLC).

The main objective of the 1978 STCW Convention, which was later amended several times, is to promote "the safety of life and property at sea through the consensual establishment of international standards of training,

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certification and watchkeeping for seafarers" [4] (p.4). In other words, the real objective behind STCW was the need to establish universally accepted training standards for seafarers, as there was no agreement on this subject in the past. After the accident of the "Herald of the Free Enterprise" in 1986, organisational problems came to the surface, especially the question of safety culture. The aim of the ISM Code is to promote and improve safety culture in the maritime industry [5], i.e. to improve work place safety [6]. Numerous studies have recognised that a 'good' safety culture is the leading indicator of 'good' safety outcomes (e.g. [7, 8]).

Nevertheless, the International Maritime Organisation (IMO) openly states that the ISM Code only offers general guidelines to achieve the set goals [9] and that the real work of improvement has to be done by the shipping companies themselves. The last attempt to improve human factors was made in 2006 with the Maritime Labour Convention (MLC). The MLC aims to ensure comprehensive rights for seafarers in relation to working and living conditions, focusing on occupational safety and health (OSH) issues. OSH is defined as "the anticipation, recognition, evaluation and control of hazards arising in, or from, the workplace that could impair the safety, health and well-being of workers" [10] (p.3). Given the regulations in place for maritime transport, the shipping industry can be considered one of the most regulated industries in the world.

At the same time, the shipping industry has undergone significant changes with regard to the increasing automation and digitalisation of the ship and related ship systems. It was expected that the new standards would validate general human capabilities and reduce the occurrence of human errors [11]. However, numerous studies have pointed out the side effect of technology on the human factor [12-15]. Despite the above-mentioned regulations and new technologies introduced in the shipping industry, the situation regarding human error remains unchanged.

With the aim of improving safety on ships, the current approach goes in two directions (phases): unmanned ships and autonomous ships. What both concepts have in common is the exclusion of seafarers from the ships. The benefits of these measures can be seen in the reduction of crew operating costs (salaries, food costs, travel costs...), fuel consumption and pollution [16].

However, there are still a number of unanswered questions that may ultimately create new challenges or risks for the maritime industry. Without adequate solutions, the proposed measures for unmanned vessels may have significant consequences not only for shipping but also for related industries.

2. MASS approach

The introduction of concepts for unmanned and autonomous vessels has attracted everyone's attention. For example, classification societies have set out their views on the subject in the form of guidelines [17-20].

Global standards and regulations for the shipping industry are set by the International Maritime Organisation (IMO). Therefore, the IMO is responsible for introducing new regulations, in this case for unmanned and autonomous vessels, so that they can fulfil their purpose in a safe and environmentally friendly manner. In 2018, the IMO has started to look at the introduction of autonomous and remotely operated ships by involving all maritime countries in the regulatory scope exercise. For the purposes of the regulatory scoping exercise, the term 'Maritime Autonomous Surface Ships (MASS)' is used and defined as "a ship which, to a varying degree, can operate independently of human interaction" [21]. This definition explains the end result, an autonomous ship. At the same time, it was concluded that this progress should be made in phases; hence the levels in autonomy are also defined (Table 1).

Table 1 – *MASS levels of autonomy*

Level 1	*Ship with automated processes and decision support*	*Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.*
Level 2	*Remotely controlled ship with seafarers on board*	*The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.*
Level 3	*Remotely controlled ship without seafarers on board*	*The ship is controlled and operated from another location. There are no seafarers on board.*
Level 4	*Fully autonomous ship*	*The operating system of the ship is able to make decisions and determine actions by itself.*

Source: adopted from [21]

The first level is common to all ships, meaning that these ships are manned and modern propulsion and navigation systems are used. Levels two and three mean that the vessel is controlled from a remote location, usually the Shore Control Centre (SCC). The operators of the SCC are responsible for navigation and all other aspects of the operation.

The key difference between these levels is that level two vessels are manned; the crew's role is to take control and resolve issues at all times. At level three, the responsibility for vessel control, related operations and problem solving should rest solely with the SCC operators. Level four vessels will be controlled by artificial intelligence and remote communication [22, 23].

In addition, the MASS concept will have varying degrees of impact on related industries such as ship design and shipbuilding, including port infrastructure development and cargo handling. Cooperation and communication between all stakeholders involved will also be crucial to the success of the concept.

It is undeniable that at some point all four ship types will coexist. A corresponding regulation does not yet exist, but that is not the scope of this paper.

3. Maritime safety and related risks

Traditionally, maritime safety can be divided into several different components. Ship safety is a part of maritime safety that focuses on the ship itself and its operational use [24].

The operational use of the ship, in turn, is associated with a whole range of risks. Most of these risks are caused by organizational and technological actions. To manage these risks, safety management system is used, which aims to control the probability of an undesirable event as well as its consequences. This task is one of many tasks performed by the ship's crew. Furthermore, there are other safety issues that are related to the operation of the ship in all circumstances, especially monitoring and control tasks. In addition, the required maintenance of the vessel and its equipment is of utmost importance for successful operation, while saving time and company resources.

3.1. Preconditions for a safe vessel

Considering the unmanned vessels, one can conclude that they face similar or even the same safety problems as conventional vessels. The basic problems are related to the marine environment, the movements of other vessels in the vicinity and the operation of the vessel itself.

What distinguishes unmanned vessels from conventional ships is the prediction and response to situations that arise. In unmanned vessels, the response to such situations is transferred from the ship's crew to the operator in the control centre ashore, who monitors the situation and makes decisions based on data from connected sensors. It is therefore clear that the networked systems required for remote operation may pose new risks that need to be considered before the system is developed and commissioned.

However, answers to the basic elements for the safe operation of unmanned vessels are required:

- Preparation of valid voyage plan and ensuring readiness of the vessel;
- Execution of the voyage plan and navigation;
- Cargo management;

- Ensuring the seaworthiness and safety of the vessel in heavy weather;
- Safe response and adaptations to the critical events;
- Responding to unauthorised intrusion into vessel systems (security and cyber security);
- Interventions related to search and rescue operations.

3.2. Reliability of navigational/safety equipment

Conventional ships rely heavily on the ship's crew as a resource for immediate rectification of faults as well as for carrying out preventive maintenance programmes while the ship is underway. This allows for the use of cheaper on-board systems and machinery that require frequent maintenance and have lower reliability.

The lack of a permanent ship's crew severely limits the possibilities for on-site monitoring and preventive and corrective maintenance of the ship's equipment during the voyage. This means that systems that are important for operation and safety must be designed so that they can be maintained remotely or are resistant to failure. As for monitoring and controlling the condition of machine systems, Jalonen et al. [24] emphasise the trend towards remote monitoring and control from shore centres, often operated by the manufacturer itself. In addition, the condition of important equipment other than the main machinery should also be monitored.

Felski and Zwolak [25] examined the hazards posed by the specific nature of unmanned vessels and find that unmanned vessels pose a risk to the safety of other sea users, the cargo and ultimately to themselves. They conclude that unmanned vessels should be tested under real traffic conditions, considering limitations of situational awareness sensors and self-diagnostic systems.

A recent study [26], looking at the safety equipment required for autonomous vessels, found critical components that can contribute to failure (e.g. route planning, voyage management, collision avoidance and situational awareness) only in good weather and daylight operations. According to their findings, the main problems are related to:

- Autonomous Navigation System (ANS) hardware, software and power supply;
- Echo sounder system;
- Electronic Chart Display and Information System (ECDIS);
- Microphone.

Backup is required for the above systems to increase reliability. As for the other various systems and sensors, they are not critical in good weather and daylight.

Felski and Zwolak [25] emphasize the navigational aspects, noting that positioning should be done by multiple sources and that redundant sensors should be present, especially with regard to monitoring speed and water depth, all with the aim of ensuring a high level of data accuracy.

3.3. Shore Control Centre (SCC) operator

In line with the IMO proposal for unmanned vessels, which states: "Remotely controlled ship without seafarers on board: the ship is controlled and operated from another location - there are no seafarers onboard"[21], the conclusion is straightforward; control of vessel should be from another location, i.e. from a shore-based control centre (SCC). In this context, human and/or technical factors need to be considered. According to [27], the future SCC operator will control six vessels simultaneously and make decisions.

This imply that the operator will rely heavily on technology and that information overload may affect the assessment of the decision-making process. In such a scenario, loss of situational awareness is a real possibility.

Furthermore, the issue of documenting operations on remotely operated vessels is still unexplored [28]. The same author states that the gap between the operator's core tasks and safety management needs to be addressed in future research.

The most important issue is the question of operator skills, i.e. the requirements of the operator's post requirements. From the available literature, it can be concluded that there are currently no regulations for the qualification of unmanned vessel operators. According to Mallam et al. [29], future requirements could include "a traditional seafaring education, certification and at sea experience, to non-seafarers who have a computer science background with coding skills, to video game enthusiasts comfortable with command and control of virtual agents and virtual worlds"(p.7).

Felski and Zwolak [25] state that work should be done in the near future to clarify the theoretical and practical requirements and that open discussions between all stakeholders are essential to address this issue.

3.4. Economic Impact of Unmanned Vessels

Ziajka-Poznańska and Montewka [30] conducted a literature review on the economic aspects of MASS vessels and concluded that great effort has been put into the costs associated with construction and operation, including the development of appropriate economic models for the aspects of operating a single as well as a fleet of MASS vessels. They believe that there are still some uncertainties that may affect the associated costs. The authors note that the "immaturity of the technology" and the various concepts of vessels and fleets may still have a significant impact.

Furthermore, the results of their study indicate that proper financial models for MASS vessels are lacking and uncertainties may influence cost estimates.

The costs of potential casualty events involving one or more vessels and of later-stage salvage operations are still unknown. The associated costs for cyber security and insurance rates for the MASS vessels are also unknown.

4. Conclusions

The concept of developing unmanned vessels certainly has its merits: reducing accidents caused by human error, saving on crew costs, reducing fuel consumption and, finally, contributing to environmental protection.

However, there are a number of unknowns behind the concept, mainly reflected in the reliability of the machinery, communication and navigation equipment. Furthermore, it is justified to question the human factor, even if it will be located in the onshore centre.

Finally, the economic impact in terms of price and associated costs is unknown. In light of the above, it can be concluded that there are a number of unknowns that may affect the purchase price of the vessel itself, associated equipment and insurance. In any case, it can be assumed that all associated costs will be passed on to the final price of the transport service, i.e. to the shipping company's customer and consequently to the price of the cargo itself. Therefore, one can only conclude that it is necessary to carry out a series of studies that will provide adequate answers to the current questions.

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Darijo Mišković,
University of Dubrovnik,
Maritime Department
Ćira Carić 4, 20000 Dubrovnik,
Croatia
Email: darijo.miskovic@unidu.hr