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Autonomous ships in maritime education model course 7.01

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ABSTRACT

The fourth industrial revolution is already a fact. It is manifested in the emerging automation of many processes in shipping, which until recently have been highly dependent on the competence of the people who manage them. The analysis of navigational accidents invariably touches the human factor and involves it in the reasons for their occurrence. The statistics are discouraging and the lack of competence of seafarers is always present in the reports of the investigating authorities. The idea of creating and implementing autonomous ships is cited as a lifeline to overcome the shortcomings that disturb the industry due to the human factor. A few authors in their publications point out many unresolved issues, one of which is related to the education and competence of service personnel. The existing International Convention for Standards of Training, Certification and Watchkeeping of Seafarers does not cover unmanned ships. The mandatory and recommended competencies in it are addressed to the people on board. Some maritime educational institutions have introduced the concept of "autonomous ship" in their curricula, such as Nikola Vaptsarov Naval Academy, Varna and Faculty of Maritime Study, Split. There are probably others who think ahead, but this approach is not enough because unmanned ships are already a fact in the maritime industry. This article aims at exploring the possibilities for supplementing the curricula of maritime training institutions with appropriate subjects for the new realities in shipping.

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1 Introduction

The fourth industrial revolution officially took a place on the agenda of the World Economic Forum (WEF) in Davos in 2016 (WEF, 2016). With this act, it was informally announced to the world that economic and social changes were imminent. The development of the communication and the information technologies is a key factor in the fourth industrial revolution. Hyun Park et.al. define in particular its three pillars – the Internet of Things, Artificial Intelligence and Big Data (Park et al., 2017). History shows that every industrial revolution is accompanied by technological innovations, which in turn requires new higher education and training of employees. At the same time, changes are taking place in human life, the social structure and the relationships between people.

The revolution is taking place today in shipping as well. It is carried out in the scientific sphere and in all correspondent branches of science. Its influence can change both the nature of shipping and strategic thinking in shipping. As a result of these changes, large companies in the industry are developing projects for design, construction and operation of unmanned and autonomous ships (Rolls-Royce, Yara, Kongsberg, DNV GL, NYK), some of which are planned to be finalized by 2025. The future use of the results of these projects in the world transport system will require a number of changes in the existing rules in the organization of shipping in general. The implementation of the IMO E-Navigation strategy by the Member States and its organizational completion would have a natural transition to the entry of the autonomous ships into the maritime transport system.

Maritime education is an integral part of the global strategy for development of world shipping. The seemingly

calm territory of the International Maritime Organization's agenda faces the challenges of the new age – the gradual realization of the idea of constructing and using autonomous vessels. The introduction of standards for execution of any activity in shipping is a common practice. Education and training of the ships and the shore personnel is an essential part of the accident-free operations and servicing of the increasingly “high-tech” systems and mechanisms. The International Convention for Standards in Training, Certification and Watchkeeping – 78 (STCW-78) is one of the four pillars of shipping, which regulates fundamental standards for the training and certification of the seafarers.

The human concept of using autonomous ships is still limited by the traditional thinking for transporting goods and people by sea. Indicative is the fact that shipping is the transport sector in which the idea of vehicle autonomy has recently entered. The traditional approach for solving systemic problems, as well as the numerous regulatory institutions, are often an obstacle or slowdown of the development and application of the new technologies in the industry. Practice logically raises the question of whether today's seafarers and their theoretical and practical training are sufficiently adequate to the modern technologies used in shipping. This rhetoric is reflected in IMO Resolution A.1138 (31) “Procedures for Port State Control, 2019” (IMO, 2020), which instructs inspectors to strengthen controls on the competence of seafarers in every level of responsibility.

Another question that finds its natural environment in the mass maritime community concerns the place of autonomous ships in modern shipping. The skepticism of more than half of the participants in the survey conducted by the authors among students of the Nikola Vaptsarov Naval Academy, shows that the idea is difficult to break through. Similar sentiments are evident in the comments to the article of the blogger Wolf Richter (2018), published on September 1, 2018 on his website wolfstreet.com. Within five days, from September 1, 2018 to September 6, 2018, the eighty-two people who participated in the discussion expressed polarized opinions about the introduction of autonomous ships.

In the maritime sector, there is a lack of research for seafarers' opinions of the problem, which potentially threatens their jobs. The need for ship crews is still major. Statistics on the shortage of seafarers of all levels of responsibility are published periodically and it seems that these statistics give reassurance and a sense of irreplaceability to crews (BIMCO, 2015; Tester, 2017). Undoubtedly, the current maritime professions, both those directly related to ships and those related to ports and coastal services, will change. It is likely that some of the ship's traditional positions will require additional skills and qualifications. Such a conclusion is drawn in several studies (Johns, 2018; Yamada, 2020). In them, the authors point out that current and future seafarers have no reason to worry about their jobwork. Autonomous ships will not cause job cutsclosures but will even help to create new ones (Felski & Zwolak, 2020).

The COVID-19 pandemic caused serious problems with organizing and launching crew changes. The human factor in shipping is the main issue again in the analysis of the specialist and attracts the attention of unions (Berlan, 2020). The International Maritime Organization (IMO) is also closely following this issue, which is so important for the safety of shipping and its resolution (WPERSUADER, 2020; IMO, 2020). Thus, the use of unmanned and autonomous ships offers a solution to yet another problem related to the human factor (Yamada, 2020; Höyhty, 2017).

Managing ships from a distance in conditions of heterogeneous traffic and maneuvering in special conditions requires skills that current maritime education does not offer. The competencies in the IMO ship modeling courses 7.01 and 7.03 are designed to meet the requirements of the STCW-78 Convention, which covers manned ships. As the human will be involved in the management of all unmanned ships to the last level of autonomy, a number of publications allude to the need to adapt the convention to the new realities and even to a new convention. Some authors take the example of the newly created STCW-F, which reflects the specifics of fishing activity and the competencies of the crews of fishing vessels (Carey, 2017).

Except for each crew member, the STCW Convention personalizes the competencies of the Master of a ship with a crew. This position on board is of paramount importance, as the Master is responsible and decides on practically everything on board. Carter et al introduce a general definition of “Captain”, according to which he/she is the person responsible for the ship, all crew members and cargo, as well as for adequate application of the rules of the Administration of the flag under which the ship sails (Carter et al., 2009). In this definition, as in other publications (Relling et al., 2018; Noma, 2016, Gundic et al., 2020), the key word is “responsibility” and its personalization. This issue is still open and represents a serious barrier to the legal framework for vehicle autonomy. Other authors focus their research on the concept of “autonomy”, on the basis of which staff competencies are formed (Hult, et al., 2019 Praetorius et al., 2019).

From the point of view of social development, autonomous ships present a number of significant opportunities:

- environmental protection through fuel economy and the use of alternative sources of propulsion;
- increased level of safety on the open seas and in port areas;
- a significant increase in the economic effect and productivity of the ships;
- optimization of the supply chain by using of the information technologies;
- improved transport infrastructure between nearby ports and places with heavy ship traffic.

From the analyzes so far it can be concluded that the process of construction and subsequent operation of the autonomous and unmanned ships is high-tech and envi-

ronmentally friendly. The successful implementation requires specialists with adequate education, qualifications and skills to meet the requirements of the new high-tech age.

The article examines the processes of transformation of conventional maritime education to future education, which will serve the operation of unmanned and autonomous ships, as well as the overall process of changing maritime logistics. The purpose of the study is to analyze the competencies of the navigators – management level of responsibility as recorded in IMO model course 7.01, Master and Chief mate. The limitation is imposed by the understanding that the autonomy of ships will require a minimum presence of crew on board and much of the competencies of officers on watch will be inapplicable to the new vessel management organization. The results of the research are reflected in the new training plans in the specialty “Navigation” of the Faculty of Navigation at the Nikola Vaptsarov Naval Academy – Varna.

2 Research method

The study was accomplished among 79 participants in qualification courses conducted at the Department of Navigation of the Nikola Vaptsarov Naval Academy for 5 months. The sociological method “interview” was used to gather the necessary empirical information. The participants are deck officers aged 27 to 51 and have positions of Officers on watch, Chief mates and Masters, working

on ships of various purposes. Table 1 and fig. 1 show the distribution of participants according to the position and types of ships on which they work. The study is limited to competencies that apply to deck officers according to IMO model courses 7.01 and 7.03, as the authors are representatives of the Department of Navigation and working in the research processes in this area.

The interview was conducted in the period from the beginning of September 2020 to the middle of February 2021. Due to the changing situation in the way of conducting the qualification activity, the pre-selected participants were sent e-mail questions, which they agreed to answer in writing.

The questions to the interviewees are presented in Table 2.

For the purposes of the study, the classification of unmanned and autonomous ships adopted by the IMO during the 99th session of the MSC (May 16-25) in 2018 was used. According to the presence of a crew on board, ships are divided into four levels of autonomy (IMO, 2018):

- ship with automated processes and decision making with crew on board. Some of the operations may be automated;
- a ship with a crew on board, but operated remotely from shore;
- unmanned ship, no crew onboard, operated from shore;
- fully autonomous ship.

Table 1 Distribution of the participants in the interview according to position and type of ship

Position	Number of participants	Tanker	Bulk carrier	Car carrier and ferry	Offshore	Other
Officer on watch	36	8	6	17	3	2
Chief Officer	18	4	2	7	2	3
Master	25	6	3	12	1	3

Source: Authors

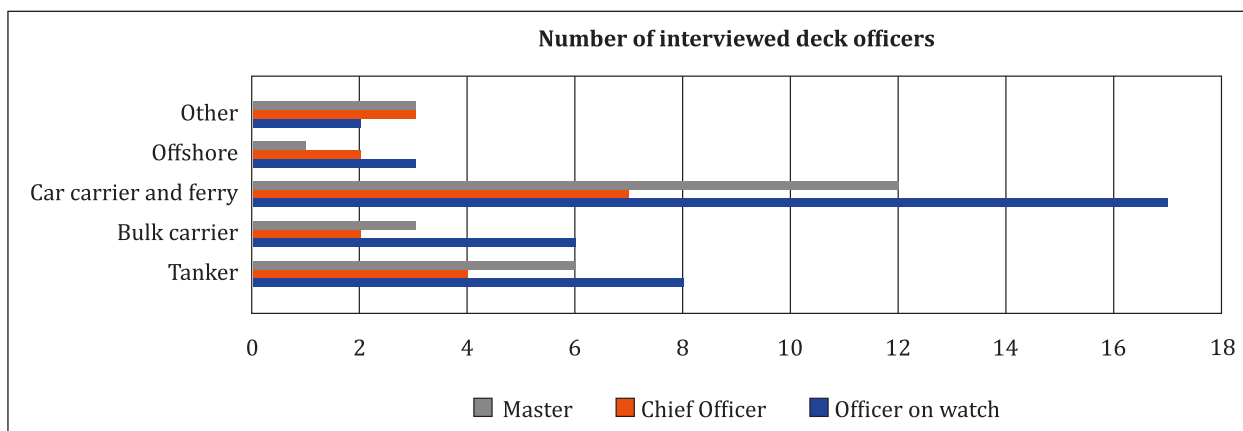


Fig. 1 Image of distribution of interviewed deck officers according their position on board and type of ships

Source: authors

Table 2 Questions to the interviewees

No	QUESTION
Q1	Are changes needed to the STCW Convention and IMO Model Courses 7.01 and 7.03 to adapt to the use of UMS and AS?
Q2	Do you think that the competencies from IMO model course 7.03 can be dropped out and only those from IMO model course 7.01 can be applied?
Q3	Are the current simulators applicable to the training of the personnel who will manage and operate UMS and AS?
Q4	Which competencies from IMO Model Course 7.01 are also valid for the staff engaged in the management of UMS and AS?
Q5	Is it necessary to create a new STCW convention aimed only at the operation of UMS and AS?
Q6	Specify future competencies required for the operation of UMS and AS:

Source: Authors

The questions asked and the discussion are based on the above classification. For the purposes of the discussion, the individual levels are denoted by L1, L2, L3 and L4. The expertise of the participants is confirmed by the declared participation of each in seminars on the issues of future development of shipping, changes in the basic conventions of the IMO, future competencies of deck officers and engineers. In each of these seminars, the organizing company addressed the issues of technology development in the industry and potential changes in the work environment.

3 Results and discussion

The answers of the participants in the study show that everyone unites around the understanding that changes in maritime technology will significantly affect ship's crews. Changes are expected in the requirements for the qualification and skills for application of technologies and in the short term for their integration with the existing reality. New competencies will be created, the need for mastering and applying the new fields of application in science and practice will increase, such as the Internet of Things, big data, simulation of environments and events, expanding the personal skills for teamwork. This requires changes in the documents on maritime education – STCW Convention, IMO model courses, national legislation.

The analysis of the results of the survey shows the participants' concern about the state of the maritime labor market. Although at this stage the market is in need of staff at all levels of responsibility (ICS, 2021), like other sectors of the world economy, technology is expected to solve the labor problem in the shipping industry.

A summary of the answers and an analysis of the results of the interview are given below for each of the questions in Table 2.

3.1 Q1 – Are changes needed to the STCW Convention and IMO Model Courses 7.01 and 7.03 to adapt to the use of UMS and AS?

In their answers, all participants confirmed the need for changes in the convention and respectively in the mod-

el courses for navigators. 81% of them believe that some subcompetences should be eliminated, such as:

- determining ship's position using landmarks
- determining the position of the ship by astronomical methods;
- operation and maintenance of a magnetic compass:
- determining the deviation of a magnetic compass.

The interviewees argue with their practical experience that in the modern working conditions of ships there is no sense and time of such activities. With their withdrawal from the convention and model courses, the possibility of checking their implementation by the Port State Control will be eliminated, which in addition takes up the time of the deck officers.

14% of the interviewees pay attention that over the years of its existence, the convention and model courses have been supplemented several times. They express concern that additional supplements would create conflict situations in the requirements and suggest that radical changes should be considered. As such a change, 8% of the interviewees suggested the creation of a separate model course aimed for training of staff for a shore center specialized in the management of unmanned ships.

3.2 Q2 – Do you think that the competencies from IMO model course 7.03 can be dropped out and only those from IMO model course 7.01 can be applied?

72% of the interviewees considered that the competencies in IMO Model Course 7.03 may be dropped out, as some of them are not applicable to unmanned vessels, and a large part of them are included in the IMO Model Course 7.01. The following given examples are supporting the statement:

- the competences concerning the classical methods of determining the position of the ship are not applicable in Unmanned Ships (UMS) and Autonomous Ships (AS);
- the competences related to keeping a navigational watch and a port watch;

- competence for search and rescue at the sea, man overboard and render assistance to a ship in distress;
- monitoring of the ship's cargo handling operations in ports and at sea;
- **inspection and report of problems with cargo**, cargo holds and ballast tanks during the voyage of the ship;
- prevention, control and fire fighting on board;
- maintenance of life saving appliances on board;
- medical care on board.

63% of the participants accept the dropping out of model course 7.03 with the argument that the management of unmanned ships from the shore will require mastery of competencies at the management level. The competencies set in model course 7.01 are fundamental and the skills for managing the new generation of ships should be upgraded on them.

Two of the participants agreed that the model course 7.01 needed more serious changes. They even propose that the current grouping by function be abolished and replaced by common competencies. Attention deserves the idea of these participants to seek interdisciplinarity of the education such as the classical educational system takes care of basic training. The further development and improvement of the qualification performs with consistently increasing training through the application of the Lifelong learning strategy. Digitization, globalization and sustainability are the new directions in which the strategy can be developed, thus overcoming the barriers in the various disciplines of the maritime education system.

3.3 Q3 – Are the current simulators applicable to the training of the personnel who will manage and operate UMS and AS?

Only 12% of interviewees believe that current simulators can also perform their functions for training coastal management staff. They offer adapting the software to the new way of managing unmanned ships by creating appropriate scenarios.

The remaining 88% believe that the current simulators have played their role and should be replaced by a new generation. They propose to simulate a complete cockpit, like the control center in modern ship simulators. Such a step would draw a clear line between the simulation preparation of existing crew ships and the future unmanned ships.

25% of the interviewees suggest in the simulation preparation of the new generation to pay serious attention to the communication in the new technological conditions – work in the Internet environment, use of the cloud services, big data and high speed processing, drone control, remote control of devices and systems. From the same group of participants it is proposed that this type of simulation

must include a work in cyber attacks conditions. The failure that can be simulated with the current simulators should be replaced by damages caused by unscrupulous interference in the management of third parties. 7% of this group of participants are having an opinion that the current simulators can be adapted to solve cyber problems as companies producing such training equipment offer a cloud service for their products. According to them, the cloud environment is suitable for developing exercises of this type.

3.4 Q4 – Which competencies from IMO Model Course 7.01 are also valid for the staff engaged in the management of UMS and AS?

Only those proposals that were submitted by more than 50% of the participants are included in the analysis of this question. We believe that competencies noted by less than half of the participants are not acceptable in their current form and need to be revised. Here we focus only on model course 7.01 because from the answers and analysis of question Q2 it is necessary to conclude that the majority of the interviewees accept the dropping or merging of model course 7.03 with 7.01.

The numbering of the competencies listed below follows their numeration in model course 7.01 (IMO Model course 7.01):

- 1.1. Plan a voyage and conduct navigation;
- 1.2.1.3. Determine position and accuracy of resultant position fix by modern electronic navigational aids;
- 1.4. Coordinate search and rescue operations;
- 1.7. Maintain safe through the use of ECDIS and associated navigation systems to assist command decision making;
- 1.8. Forecast weather and oceanographic conditions;
- 1.9. Respond to navigational emergencies;
- 1.10. Manoeuvre and handle a ship in all conditions;
- 1.11. General knowledge of remote control of propulsion plant and engineering systems and services;
- 3.1. Control trim stability and stress;
- 3.2. Protection of marine environment;
- 3.4. Develop emergency and damage control plans and handle emergency situations.

62% of the interviewees believe that function 2 (Cargo handling and stowage) in its current form should drop out due to the need for adjustments. Proposals for adjustments focus on the need for new ways and technologies to monitor the condition and seaworthiness of a loaded ship, as well as the ability to monitor the condition of the cargo. This is also the reason why the participants in this group believe that today unmanned ships can be used to transport only certain types of cargo, such as cargo in containers. For other types of cargo it is necessary to offer adequate technological solutions.

3.5 Q5 – Is it necessary to create a new STCW convention aimed only at the operation of UMS and AS?

The answers of the participants in the interview on this issue show hesitation, which is attributed to the superficial knowledge of the mechanisms for creation and adoption of international conventions. Indeed, the matter is far from experts in the category of interviewees, which is why not much weight is given to opinions on this issue. Proposals are accepted as information only.

However, 58% believe that a new convention similar to the STCW-F, which reflects the specifics of fishing activity and the competencies of the crews of fishing vessels, can be created. The participants have opinion that creating a model course to the existing STCW-78 convention would be sufficient for the initial stage of operation of unmanned ships. Over time, practice will show what the next steps should be.

3.6 Q6 – Specify future competencies required for the operation of UMS and AS

- Knowledge and skills for environmental protection aimed at reducing harmful emissions from ships – for this competence there are proposals for studying the design and operation of hybrid engines as well as engines without harmful emissions. Therefore, we see a future in the development and implementation of dual training – education and certification of navigators and engineers. It is most likely that in the near future this idea will find a wider place in shipping due to the reduction of the crews, but not in the classic form.
- Cyber security – this competence needs to be present in future training due to the imposition of technologies and digitalization in the industry. Even today's L1 autonomous ships need cybercrime protection, as evidenced by the Maritime Safety Committee Resolution MSC.428 (98) (98) (MSC, 2017), which came into force on 01.01.2021.
- Internet of Things and work in the cloud – it is considered that the exchange of information will require high-capacity devices with high speed ability to access information via the global network.
- Work with small aircraft – drones – the growing use of drones in various industries shows that some activities in future shipping also have the potential to apply such technology. The current proposals for certain types of ship inspections are the beginning of the development of new ideas.

4 Conclusion

The results of the research were reported to the group of lecturers from the Department of Navigation, charged with the task of developing new curricula for bachelor's and master's degrees. The aim of the study has been achieved and this is reflected in the proposed plans. In addition, the curricula of the disciplines in the department

will be enriched with the suggestions of the interviewees as summarized in this article.

Future maritime education should provide ample opportunities for flexible realization for graduates. Training institutions must face the new methods and forms of education, rely on the strategy Lifelong learning as a means of rapid retraining from ship to work on shore. Maritime professionals are called upon to transfer their experience from ships to coastal control centers, and maritime training institutions (MET Institutions) must take an active part in this process. Institutions, for their part, need to be an active participant in the research process by working closely with the maritime industry (Wang et al., 2020).

The management of unmanned ships is a new activity that needs an environment for development. New technologies allow the simulation of different options for ship management from all levels of autonomy. Along with the training, the simulators and their use will also be developed in a new way, focusing on the needs and trends in the maritime industry. Advanced simulation tools using virtual reality and augmented reality will enable marine professionals to explore, understand and prepare processes and procedures at a conceptual and detailed level.

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