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*Review paper*

# Challenges for Seafarers Education and Training in the Context of Autonomous Ships Development*

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**Abstract:** Education and training of seafarers are defined in the provisions of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW Convention) and elaborated by the set of the International Maritime Organization (IMO) Model Courses. These documents represent minimum requirements for the education and training of seafarers at the international level. IMO member states shall integrate these requirements as appropriate into their maritime high school and college training programs and into training programs leading to STCW certification. Although there are different views in the literature and in practice about the existing seafarers training system, this system is standardized worldwide. This allows consistent acquisition of knowledge, skills, and competences for seafarers on merchant ships. The development and gradual introduction of autonomous ships raises numerous questions about the future trends of world shipping. Various researches are currently being conducted on autonomous ships. This technological progress brings with itself many challenges and one of them is the education of the personnel who will control and monitor these ships. It is clear that a new approach to seafarer's education needs to be developed. The development of this concept opens numerous questions from different segments of shipping and maritime security in general, particularly in the context of maritime cyber security. The paper analyses the education concept for seafarers in the Republic of Croatia, paying special attention to trends related to the development and deployment of Maritime Autonomous Surface Ship (MASS).

**Keywords:** Autonomous ships, Education of seafarers, STCW Convention, IMO Model Courses.

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## 1. Introduction

Improvements in areas such as artificial intelligence, machine learning, and sensor technology have enabled the development of autonomous systems that can navigate ships, monitor their surroundings, and make decisions based on real-time data. Efforts are currently underway to implement the concept of autonomous transportation in the shipping industry with the introduction of the Maritime Autonomous Surface Ship (MASS), which is expected to usher in a new paradigm in maritime transportation [1].

The term Industry 4.0 is often referred to as the fourth industrial revolution [2]. It represents a shift toward smart factories that use automation, data exchange, and the Internet of Things (IoT) to improve productivity, quality, and efficiency. Key technologies driving Industry 4.0 include artificial intelligence (AI), robotics, Big Data analytics, cloud computing, and the Industrial Internet of Things (IIoT). These technologies are used to enable real-time monitoring and control of manufacturing processes, predictive maintenance, and remote operation and maintenance of industrial systems.

Autonomous ships are expected to bring several benefits, including increased safety, reduced costs, and improved efficiency. Without the need for crew quarters and support facilities, autonomous ships can be designed with more streamlined and optimized layouts, leading to reduced fuel consumption and improved performance. History shows that every industrial revolution is accompanied by technological innovations, which in turn requires new higher education and training of employees [3].

Education can be formal, informal, and non-formal. Both formal and informal education play a significant role in maritime education. Formal education is the acquisition of knowledge in an educational institution where the teachers have a college degree. It follows a set program and schedule, and a diploma is awarded upon completion. In 2001, the European Commission defined formal education as structured education acquired in educational institutions [4]. For the maritime profession, formal education in the Republic of Croatia takes place in elementary school, maritime secondary schools and maritime faculties.

Formal education often does not cover all the skills needed in the labour market, so informal education develops [5]. It is adapted to the needs of the individual and usually includes programs aimed at acquiring skills needed for the world of work [6]. The characteristics of informal education are a flexible curriculum and methodology, and through the completion of education, additional knowledge is acquired that is required for the

profession or job that the person will perform. In the case of maritime officers, informal education is provided through the programs prescribed in the STCW Convention and the programs prescribed by the shipping companies depending on the type of ship. Non-formal education for seafarers involves learning through work experience, which can be difficult to quantify and assess.

The IMO develops and maintains a number of IMO Model Courses to guide maritime training institutions and instructors to deliver consistent, high-quality training programs for seafarers. These courses cover a range of topics related to shipping and navigation, including safety, security, environmental protection, and technical skills. The IMO has developed and published a total of 97 IMO Model Courses (as of September 2021) [7]. The IMO Model Courses and the International STCW Convention are closely linked. The STCW Convention establishes minimum standards for the training, certification and watchkeeping of seafarers worldwide, and the IMO Model Courses provide guidance for meeting those standards.

The introduction of the MASS concept represents a significant development in the maritime industry and is likely to have a significant impact on the education and training of seafarers.

This paper is analyzing education for maritime officers in Croatia with regard to autonomous ships. Croatia is a member of the IMO and participates in the development of international regulations and standards for shipping and maritime activities. By participating in IMO, Croatia advocates for safe and environmentally sound shipping practices worldwide. The paper consists of 5 sections. Section one is the introduction, section two presents the formal education for maritime officers, section three discusses the informal and non-formal education for maritime officers and section four presents education and training for MASS. Section five is the conclusion.

## 2. National formal education for maritime officers

The term formal education appeared in the late sixties of the last century. It stands for a hierarchically structured educational process that begins in elementary school and is usually financed by the state [5]. The characteristics of formal education are:

1. Learning takes place in specific educational institutions.
2. Learning takes place according to a predetermined program.
3. The educational institutions are recognized by the state.
4. Learning is usually provided by professors and/or experts in a specific field.
5. This form of education is considered more credible than other forms.

The above form of education is conducted according to strict regulations and standards with a program of well-defined learning outcomes, content, and methods.

Formal education in Croatia (Figure 1) includes elementary schools, high schools, and faculties. Children's schooling begins with elementary school, which lasts 8 years.

In the Republic of Croatia there are 7 maritime high schools [8]. The Maritime High Schools have a total of about 1,330 students, and about 330 students graduate each year. They are governmental, non-profit, and offer curriculums in accordance with IMO Model Courses 7.01. to 7.03. All Maritime High schools in Croatia have the same curriculum [9]. The Ministry of Education and Ministry of the Sea, Transport and Infrastructure prescribe that all curriculums are harmonized. Students usually choose programs offered for working on ships:

- Nautical training program for the position of nautical officer (respecting the recommendations of IMO model course 7.01.),
- Ship's engineering program for training as a ship's engineer officer (respecting the recommendations of IMO model course 7.02.).

These programs include 44 maritime subjects, and none of them deals with the introduction of development of new technologies. In their curricula there are no subjects related to new technologies and autonomous ships. While it is reasonable that maritime high schools may focus on the practical and operational aspects of the industry, they should also incorporate modernization and new technologies into their programs. This is because the maritime industry is rapidly evolving and it is crucial for maritime professionals to keep up with the latest trends and technologies.

The introduction of autonomous ships, for example, is a major development in the maritime industry that is likely to have significant impacts in the coming years. It is therefore crucial for maritime high schools to prepare their students for this new reality by including courses on autonomous ship technology and related topics in their curricula. Today, the Higher Maritime Education and Training (MET) education in Croatia follows the university standards accordingly to the so-called Bologna model. It starts with three years of undergraduate study (Bachelor degree), followed by two years of graduate study (Master degree) and three years of Postgraduate study (Ph.D. degree), as per Figure 1 [10] .

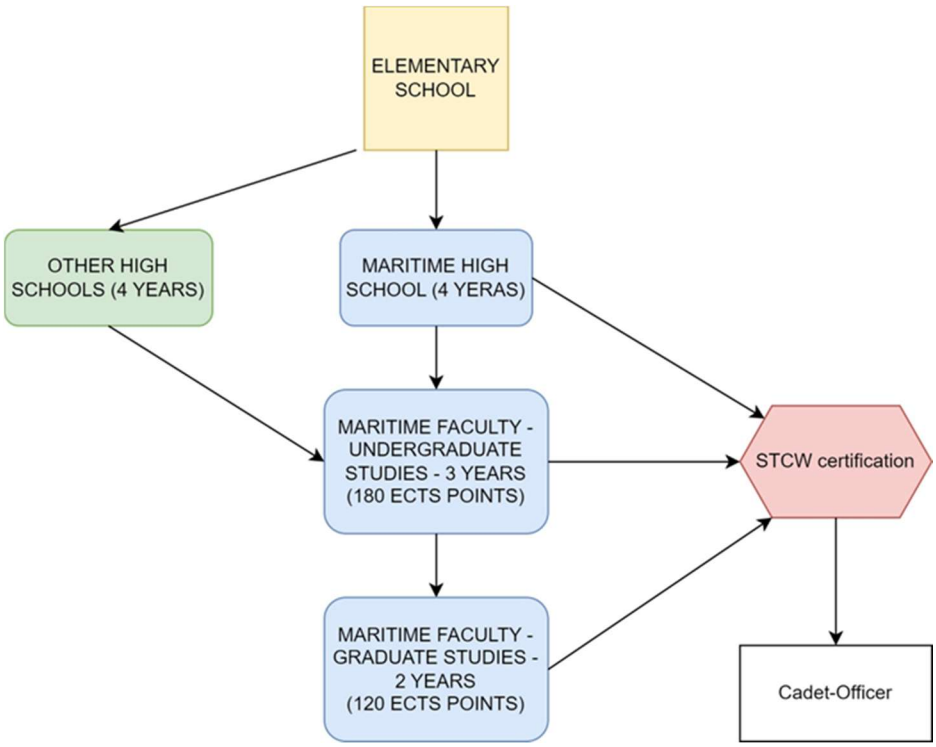


**Fig. 1** – *Diagram of formal education for officers in Croatia.*

Faculties of maritime studies in Croatia provide education for various maritime professions. These faculties offer a range from undergraduate to postgraduate studies, as well as other courses and training programmes for maritime professions. Faculties of maritime studies in Croatia are: Faculty of Maritime Studies in Split, Faculty of Maritime Studies in Rijeka, Department of Maritime Studies Dubrovnik and Department of Maritime Studies Zadar. All of them offer specialized study programs for prospective professionals in the maritime industry. The undergraduate program lasts three years (6 semesters), while the postgraduate program takes two years (4 semesters). Graduates receive diplomas at management level, focusing on the development of leadership and management skills along with technical expertise.

Nautical and maritime engineering programs are the most popular among students, as they enable them to work effectively on ships. The undergraduate curriculum is aligned with the IMO Model Courses and the STCW Convention. By looking at the curricula of the above-mentioned faculties it may be noted that only Faculty in Split offers a course on

"autonomous ships" [11]. The course takes place in the third year of undergraduate studies (6th semester). In the 45-hour course, autonomy of ships and their remote control, artificial intelligence, cyber security and navigation are studied. In other courses, especially in the 4th and 5th year of postgraduate studies, there are some courses that deal with modernization and new technologies.

Other faculties in the country do not have a subject named autonomous ships [12], [13], [14]. In the process of modernization and modification of certain study programmes, the subjects of autonomy and remote control are introduced, but no study programmes have been created yet that would train students directly for autonomous ships.

In addition to regular training at maritime universities, there is also special training and education for seafarers in accordance with the regulations of the Ministry of the Sea, Transport and Infrastructure [15]. Seafarers who do not have a university degree and have 36 months of sea service experience as officers on ships can apply for special education and training. They can be trained in the fields of nautical science and marine engineering. The marine engineering consists of 795 hours and 21 courses, while the nautical consists of 760 hours and 17 courses, with no topics directly related to autonomous ships.

## 3. Informal and non-formal national education for maritime officers

Informal education is adapted to the needs of the individual and usually includes programs aimed at acquiring the skills needed for the world of work [6]. Characteristics of non-formal education include a flexible curriculum and methodology. Qualifications acquired through non-formal education are not recognized at the same level as qualifications acquired through formal education. Informal education involves programs, workshops, and seminars with limited funding whose sustainability and quality are sometimes questioned [16]. Formal education programs for seafarers are not adapted to the rapid development of technology. It is almost impossible to ensure that formal education provides all the knowledge needed to work at the management level on board. For this reason, informal education programs are being developed to enable the acquisition of the expertise needed to work on board. Informal maritime education includes additional training programs, which can be divided as follows:

1) programs prescribed by the STCW Convention,
2) programs prescribed by shipping companies.

Currently, the STCW Convention does not specifically address autonomous ships. However, the Convention does require seafarers to be able to operate and maintain ship systems and equipment. Even if a ship becomes autonomous, it would still need to meet the training and certification requirements of the Convention, although these may need to be adapted to reflect the different skills and knowledge required to operate an autonomous ship.

The programs prescribed by the companies are a result of the needs of the industry and/or company. The content of these programs varies depending on the type of vessel, the cargo the vessel is carrying, navigation in a particular area, the equipment installed on the vessel, and the needs of the company. Part of the program was created as a result of inspections conducted on board by the company's inspectors. After the deficiencies found during the inspection, the companies very often organize additional training for the seafarers sailing on their vessels.

Presently, IMO Model Courses do not specifically address autonomous ships. However, as the development of autonomous ships progresses, IMO will likely need to update its model courses to reflect the changing skills and knowledge required to operate and maintain autonomous ships. In 2018, IMO established a working group to develop guidelines for the safe operation of autonomous ships, which will include recommendations for the training and certification of seafarers [17]. Once developed and adopted by IMO, these guidelines can be incorporated into IMO Model training Courses to ensure that seafarers are trained to operate autonomous ships safely and effectively. It should also be noted that some of the existing IMO Model Courses, e.g., for navigation, engineering, and communications, are also applicable to autonomous ships, as these courses cover basic principles and skills relevant to all ship types. Still, as technology and operational requirements for autonomous ships evolve, IMO will need to update its model courses accordingly to ensure that assistants are adequately trained and certified to operate these ships.

Non-formal education of seafarers includes the skills that seafarers acquire through their work on board. It is usually not organized or structured. The fundamental problem is to recognize its value and measure the knowledge acquired in this way [6]. The importance of non-formal learning has been recognized in the maritime industry, and the problem of assessing knowledge acquired in this way has been solved to some extent. Some shipping companies require the documentation of seafarers' informally acquired knowledge in practice such as notebooks and diaries available to all crew members. These systematically summarize the

activities and practical actions recorded by crew members while performing their duties.

## 4. Education and training for maritime autonomous ships (MASS)

A number of initiatives have been developed in this area. One of them is Industry 4.0, a strategic initiative of Germany that deals with the ongoing transformation of manufacturing and industrial processes in conjunction with the dynamic evolution of technology [18]. This includes expertise in areas such as software programming, data analytics, cybersecurity and artificial intelligence. Therefore, educational institutions should prioritize the education and training of students in these areas to prepare them for the jobs of the future. Education in the field of environmental protection and the needs of the future management and operation of autonomous ships are some of the shortcomings in human knowledge in maritime sector today [19].

The development of maritime autonomous surface vessels (MASS) has raised questions about the appropriate process for conducting trials to test the technology and systems for their operation. For this reason, interim guidelines have been developed for MASS trials [20]. These guidelines outline key consideration and best practices for conducting safe and effective trials. One of the key considerations for MASS trials is to conduct an appropriate risk assessment. This should include a thorough analysis of the technologies and systems involved and the potential risks to personnel, the environment, and other nearby vessels. Risk mitigation strategies should also be identified and implemented as needed. The guidelines also emphasize the importance of ensuring that personnel involved in the experiments are properly trained and qualified. This applies not only to crew members and operators, but also to additional personnel involved in the experiments, such as technicians or engineers. Overall, the interim guidelines for testing MASS aim to ensure the safe and effective conduct of such trials while encouraging innovation and progress in the development of autonomous surface vessels. MASS is a complex technology that involves the integration of various advanced systems. These include cyber-physical systems, integrated bridge systems, environmental sensing technologies, collision avoidance algorithms, track control mechanisms, Internet of Things (IoT) networks, cloud computing, Big Data analytics, automation, network security protocols, remote control capabilities, satellite communications, and systems for fault diagnosis and monitoring of devices and systems [21]. Together, these technologies enable autonomous operation of ships and facilitate safe and efficient navigation in various maritime environments.

Although artificial intelligence (AI) skills are becoming increasingly notable for MASS operations, they are not sufficient on their own. Seafarers still need to possess traditional maritime skills, such as the ability to navigate a ship, communicate effectively, and make decisions based on their own observations and judgment [22]. In many situations, the ability to think independently and make the right decision quickly will be essential for the safe and effective operation of MASS. Although AI can provide valuable support and assistance to crew members, it cannot replace human judgment and decision making. It is notable to remember that AI is not infallible and can still make mistakes or run into unexpected situations that require human intervention. It is critical that mariners working with MASS are properly trained and prepared to deal with a range of scenarios, including emergencies, technical failures, and unexpected weather conditions. While AI is a valuable tool for MASS operations, it cannot replace the importance of traditional maritime skills and the need for human judgment and decision-making. A combination of AI and human expertise is likely the most effective approach for the safe and efficient operation of autonomous maritime surface vessels.

## 5. Conclusion

The STCW and IMO Model Courses are designed for a traditional approach to seafarer education and training. Programs focus on developing the skills and knowledge required to operate conventional ships. However, the introduction of autonomous ships will require an entirely new approach to education and training. Seafarers will have to acquire a new set of skills and knowledge related to the operation, maintenance, and monitoring of autonomous ships. These skills include knowledge of data analytics, artificial intelligence, cybersecurity and remote-control systems.

The IMO has recognized the need for a new approach to education and training for autonomous ships and has begun developing new guidelines and model courses for seafarers working on these ships. IMO's Maritime Safety Committee has already adopted interim guidelines for autonomous surface ships (MASS) that provide guidance for the design, construction, and operation of these vessels. The development of these new guidelines and model courses will be critical for ensuring the safety and efficiency of autonomous ships. It will also be crucial for shipping companies and training institutions to invest in the development of new training programs and technologies to support the education and training of seafarers in this new field. This will help ensure that seafarers are adequately prepared for the transition to autonomous ships and skillful to operate these ships safely and efficiently.

Current maritime education system should definitely include training in the operation and monitoring of modern technologies such as autonomous ships. As technology continues to advance, the skills and knowledge required to operate and monitor these new technologies will become increasingly significant. Autonomous ships are an excellent example of how technology is transforming the industry, particularly the maritime sector. The development and deployment of these ships will require specialized skills and knowledge of those who operate and monitor them. Therefore, educational institutions should prioritize education and training of students in these areas to prepare them for the jobs of the future. In addition, ongoing education and training programs are needed to ensure that current industry professionals keep up with the latest developments and remain competitive in the job market. Overall, investing in education and training to operate and oversee advanced technologies such as autonomous ships will not only help individuals succeed in their careers, but also ensure that our industries continue to innovate and evolve with the times.

It is expected that shipping companies and educational institutions will develop new training programs and technologies to support the education and training of seafarers in this new field. This development will help ensure that seafarers are adequately prepared for the transition to autonomous ships and can operate these ships with the highest level of safety and efficiency.

Implementing subjects regarding autonomous ships into education and training programs requires careful planning and consideration, starting with identifying the target audience and determining the learning objectives. Collaboration with industry experts and stakeholders is essential to keeping the program relevant and up-to-date, while continuous improvement based on feedback and changing industry trends is crucial for effectiveness. An effective education and training program can prepare maritime industry professionals for the rapidly evolving field of autonomous shipping.

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