THE NEXT STEP ON THE MARITIME EDUCATION AND TRAINING IN THE ERA OF AUTONOMOUS SHIPPING: A LITERATURE REVIEW

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Abstract

The development of autonomous shipping is in continuous growth; technology evolution is going on faster steps and new projects are being developed looking for more efficient, more sustainable and safer shipping operations. Autonomous vessels feature a technology that uses a large range of physical sensors to control autonomous functions, as well as a high advance in monitoring and control systems, including the use of the newest communications technology. This technological emergence has been driving concerns about the decline in the number of seafarers and jobs, which are expected to be replaced by Artificial Intelligence and the Autonomous Systems. However, the trend will be the opportunity for new businesses and job creation, which will require highly skilled crews and operators. As far as further steps are being developed on higher autonomy, the landscape of jobs related to seafarers will change. For instance, remote operations will transfer most of the seafarers to land-based control centres, causing that the main skills to be developed should drive to more expertise in technology, communication and network administrators without losing the standards as per STCW Convention. This literature review addresses this new and emerging topic to lead to an initial conceptualization of the new Maritime Education and Training (MET) framework and find eliciting information for developing new academic assessment. At the end, this contribution discusses published research in the era of autonomous shipping in order to describe the next step for MET, developing qualifications standards for the new crew and on-shore operators.

1 INTRODUCTION

The new developments on telecommunications, computing and sensors have been moving into different transportation vehicles; from planes, helicopters, cars, trains and of course into the vessels. Ships are now becoming more autonomous, moving forward to the new projects as a fully autonomous way of transport those will build towards the fleets of the future. Interest in autonomous ships is growing rapidly and also bringing changes to the industry and transportation infrastructure and influencing all maritime sectors, including shipbuilding and port operations (Wright, 2020; and Komianos, 2018). For most of the companies and shareholders involved, the main objective is to obtain high levels of safety and efficiency, having the potential to provide solutions for problems in the maritime industry, such as for the prevention of marine accidents and the improvement of the work environment. Some examples of those new advances and operational developments are the two full unmanned containerships: YARA BIRKELAND (Yara International ASA, 2021), the world's first electric and self-propelled container ship; and MV MIKAGE (Ocean Insight, 2022), a coastal container vessel.

The International Maritime Organization (IMO) uses the term "Autonomous ship" as a merchant ship that has some ability, to different degrees, to operate independently of human interaction (IMO 2021). IMO's Maritime Safety Committee at its 103rd session in May 2021 (MSC 103/3,2021), has just completed a regulatory scoping exercise to analyse the regulations involve for the use of Maritime Autonomous Surface Ships (MASS). On this document the degrees of autonomy were organized taking into account that MASS could be operating under one or more degrees of autonomy for the duration of a single voyage: (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. (2) Remotely controlled ship with seafarers on- board: the ship is controlled and operated from another location, but seafarers are on-board. (3) Remotely controlled ship without seafarers on-board: the ship is controlled and operated from another location; there are no seafarers on-board. (4) Fully autonomous ship: the operating system of the ship is able to make decisions and determine actions by itself. Classification Societies and other International Associations (DNV GL, 2018 and Lloyds Register, 2016) placed other classifications into more specific subdivisions. On them, the technical autonomy is separated from operational control, combining different levels of autonomy with the presence or absence of personnel on-board. Based on those different degrees of autonomy, various situations can occur at the same time and on the same vessel so it will involve that crewmembers and control centres staff should be capable of dealing with all those circumstances. Therefore, the recruitment of specialized and qualified staff capable of dealing with all those scenarios will involve a specific and complete Maritime Education and Training (MET) on MASS and its new technologies.

MET can be defined as the educational system which aimed to provide with qualified personnel mainly as seafarers for merchant vessels as well as specialized staff for all related maritime industry. Being important to provide skilled and competent human resources to all the shipping related areas those will required to handle billions of assets worldwide. Any MET program should follow up the minimum requirements established on the International Convention on Standards of Training, Certification and Watchkeeping (STCW) (International Maritime Organization 2010). The IMO passed the responsibility for STCW implementation to national governments and the European Union (EU) established The European Maritime Safety Agency (EMSA) to ensure the STCW standards are implemented in the EU member states (EMSA, 2021). Therefore, since January 2020, EMSA has been providing support for trials of unmanned vessels and surely will be involved in all discussions and changes related to the academic sector. In this respect, the direct application of artificial intelligence (AI) (Smith, 2020), the development of new communication and data transmission systems, optimizing of sensors, control of ship routing are leading to the design of the Remote-Control Centres (RCC). Those centres will be the operative base of the autonomous vessels controlling one or more of them at the same time. However, the emergence of autonomous ships has been driving concerns about the decline in the number of seafarers and jobs; beside that, many experts believe that actually there will be new opportunities for new job creation (Abilio Ramos, Utne, Mosleh 2019). The development of higher autonomy will change the landscape of jobs related to seafarers as well as the development of new ways of teaching and training. It is clear that the new training and education will still rely on issues such as navigation, safety,

planning, navigational equipment, positioning, meteorology and emergency procedures, among others, but adding knowledge on artificial intelligence, remote operations, cybersecurity, data transmission and communications, and further.

The main objective of this paper is to know where we stand at this moment and addresses the following questions:

1. What new MET development for autonomous shipping can be found in the literature today?
2. What are the topics and qualifications standards for the new crew and on-shore operators regarding MASS?

Following the introduction and background section (Section 1), this paper continues with the description of the methodology followed to conduct the literature research (Section 2). Afterwards, main findings are discussed in Section 3 in order to point out work done regarding the MET and MASS and present some conclusions (Section 4).

2 METHODS

This section will introduce the methodology followed to conduct a systematic literature research in order to identify suitable and relevant peer reviewed publications for our study. The methodology was divided in the following steps: (1) searching the most common terms and keywords concerning Autonomous Shipping issues in relation to Maritime Education and Training, (2) searching relevant literature in two relevant databases, (3) reading abstracts and selecting the significant literature and (4) discussing and synthesising the findings.

2.1 Keywords selection

An initial search was conducted to find out the most common terms and keywords concerning Autonomous Shipping issues in relation with Education and Training and with Maritime. After a preliminary search, the keywords selected can be seen in Table 1.

Table 1. List of selected search terms

Main Keywords	Relation Keywords	Second Relation Keywords
Autonomous ship	Maritime	Education
Autonomous vessel	Marine	Training
Unmanned ship	Shipping	MET
MASS	Crew	Maritime Education and Training
Crewless ships	Seafar*	

2.2 Relevant literature search

With these keywords, a Boolean search was carried out in two interdisciplinary databases, namely, Clarivate Analytics Web of Science (WoS, 2021) and Elsevier's Scopus (Scopus, 2022). The query was conducted in December 2021 following a systematic approach. Combination of different searches were performed with Scopus database always keeping Autonomous or Unmanned ships and then including the Education and Training as combination or as separate together to Maritime or Marine. The reason for this was the small number of entries encountered for autonomous vessel issues relative to MET. The incorporation of some of the search terms gave us twenty-nine publications but taking into account all main keywords together then only nine publications appear on the list. From the Web of Science similar Boolean searches were followed up and the results were even more scarce. In this case, the inclusion as essential keywords of Autonomous ships and Education and Training gave us just three publications.

To identify the more relevant publications, papers must be related to maritime education and training domain as well as the autonomous or unmanned ships, so even though the first review conducted without the

incorporation of all main keywords gave us more documents it was clear that not all publications give us the information as a whole. Some of the papers were related to the remote-control vehicles and the use of new technologies but not on the maritime training regarding autonomous ships and they were removed from the list. Finally, eight full-text papers were included in the final analysis and listed in Table 2.

Table 2. Overview of the relevant reviewed literature

No	Year	Author (s) (year)	Title
1	2020	Bartusevičienė, I.	Maritime education and training as a tool to ensure safety at sea in the process of introduction of maritime autonomous surface ships in shipping
2	2018	Lokuketagoda, G., Miwa, T., Jayasinghe, S.G., Ranmuthugala, S.D.	Training engineers for remotely operated ships of the future
3	2018	Mogensen, J.	Rethinking STCW education to cope with increased autonomy and autonomous shipping
4	2017	Ahvenjärvi, S.	Unmanned ships and the maritime education and training
5	2017	Lokuketagoda, G., Miwa, T., Ranmuthugala, D., Jayasinghe, S., Emad, G.R.	Moving the boundaries of MET with high fidelity ERS training
6	2021	Chirea-Ungureanu, C.	Preparing for an Unknown Future. Autonomous Ships Versus Position of the Maritime English/IMO Standard Marine Communication Phrases (ME/IMO SMCPs) in Maritime Practice. How Are We Going to Solve this Problem?
7	2021	Belev, B.; Penev, A.; Mohovic, D.; Hadzic, A. P.	Autonomous ships in maritime education model course 7.01
8	2018	Baldauf, M.; Kitada, M.; Mehdi, R.; Dalaklis, D.	E-Navigation, digitalization and unmanned ships: challenges for future Maritime Education and Training

Even though first papers we could find about MASS are dated on 2009, analysing the list obtained we can see that only from 2017 the MET is introduced in some papers and the interest on this area has increased in recent years. All of them are conference papers published on Scientific Journals or on the Annual Compilation done after IAMU (International Association of Maritime Universities) Assembly.

3 FINDINGS

Considering the timeline of the documents involved, it is clear that during the last five to six years the education and training related to autonomous shipping is a topic that some researchers are bringing forward from different points of view. For that reason, in this section, each publication will be presented and discussed so it can be drawn the attention all the work done and to guide future research and the one to come.

3.1 The proper Maritime Education and Training in order to increase safety at sea while introducing MASS to shipping (paper 1, Bartusevičienė, 2020)

In this paper, the researcher submits as a main factor to ensure safety during the transition process of MASS introduction into shipping and after that, a proper education and training of all personnel involved.

The challenges to overcome in order to implement changes in MET are identified in this document according to different literature that the author has been reviewed. Some of those issues are: the existing legal framework, the interaction between humans and technology, the management of interconnected systems and, last one but not less important, the new skills and competences to be achieved. Author also introduces the logical extension of a revised (or newly developed) STCW convention.

On this last issue, it is stablished the points that need more research in order to set up the proper skills and competences of the personnel involved in MASS operations, as: seagoing experience, communication and engineering functions, abilities in challenging and critical situations, between others. To complement this document, the researcher determined as an important point to achieve a proper MET, the upgrade of qualification of the trainers and instructors.

As a conclusion, it is set out the need of research regarding MET to achieve safe operations of MASS, establishing the main topics to be included in the project.

3.2 Obstacles and disadvantages for MASS operation (paper 6, Chirea-Ungureanu, 2021)

In a complementary way, we can find the analysis of how to achieve safe navigation on mixed traffic situation when no crew is on-board. On this document the author points out that students should be trained to face the severity of the possible problems appearing when keeping the vessel safe regarding maritime cyber security issues and training. Takes into account that the people at Shore Control Centres will be the seafarers of the future so in one side they will need to meet the requirements of STCW convention and in the other side they will need to complement their competences within operational technology; this crew is presumed to be specialized as operators with navigation tasks and operators in engineering tasks.

As part of his conclusion, the author noted the importance of some changes on different regulations as the ISM code that will be needed on the near future, in order for crewless vessels to navigate on international waters.

3.3. Analysis of actual regulations (paper 7, Belev et al., 2021)

Focusing on the possible changes to be done on the STCW convention and therefore on the IMO ship modelling courses 7.01 and 7.03, the authors show the results of interviews carried out to crew members from different vessels.

The analysis of different questions (through a questionnaire) regarding the actual regulation and the new competences to add, it proves that changes are required in maritime education, STCW convention and the IMO courses. The researchers show that all participants believe they need a mastering on new aspects as Internet of the Things, Big Data, simulation of new environments as well as personal skills on teamwork. They add, as other authors pointed already, to include on the competences to work under cyber-attack conditions as well as being trained with simulator tools using virtual and augmented reality.

3.4 The impact of the introduction of unmanned ships to MET (paper 4, Ahvenjärvi, 2017)
In this document the author is going beyond on his approach to the introduction of unmanned ships into education and training, not only regarding the future crew or operators but also pointing out the new skills needed for different groups, like port operators, VTS operators and inspectors, authorities, lawyers, etc.

All people involved on maritime industry, design, operation and maintenance will need training on new subjects and capabilities so that unmanned ships navigation and operation is reliable in all situations. The researcher also pointed out the change of legislation needed but in the meanwhile is introducing to us the ELSA project that use a model-scale platform to test all the new technology regarding unmanned ships, giving the opportunity to increase the knowledge about all this emerging technology while the new skills are being established.

3.5 Recommendations for new skills and topics to add to the actual MET (paper 3, Mogensen, 2018)
On this point of view, it is shown a comparative between two different studies in order to justify new topics to be implemented on the maritime training of the future. The researcher analyses the main differences in teaching approaches and study programs between Design of Marine Cybernetics from Norwegian University of Science and Technology (NTNU) and the maritime studies at the Svendborg International Maritime Academy (SIMAC) that follows the STCW convention to train their students. As a result, the gaps found between what he called "education for design and education for operation and maintenance" is the fault of matrix calculus that should be taught together with ship control systems architecture and control theory related to navigation and ship guidance; adding to his recommendation the use of cross-disciplinary teams as a beneficial learning method.

3.6 Simulator- based training for MASS operation (papers 2 and 5, Lokuketagoda et al., 2018 and Lokuketagoda et al., 2017)
Focusing on the way of how to achieve a proper Education and Training of the next generations we can find those two articles. The authors highlight the use of simulator technologies in training engineers to manage autonomous vessels.

On their first article (paper 5), they established the advantages of the engine rooms simulators as part of the Education and Training, recognized already on the STCW. The better interaction, the building on confidence and connecting learnings to real -life scenarios are some of those benefits listed as proof of their study.

Following with their analysis of how to address future with the introduction of automated ships, they already pointed out that the exponential change in technology should move to an adaptation of the actual regulation regarding Education and Training, focusing into marine engineers, the competences in a fully autonomous vessel will role from on-board operation to remote operators, so some of the competences as the maintenance and repair will not have sense.

Continuing with this study, the researchers are going a step further (paper 2). They assume that in the moment that the technology requirements are achieved regarding accuracy and reliability of the instrumentation and control systems it comes the time for the remote operators to be prepared and make decisions based on the data received. Based on the above and presuming that at the end all vessels will become full autonomous, they stated that the future operators will need to be marine engineers with a strong engineering background, and those personnel will require knowledge and skills received through training and assessment programs using simulators as main tool.

The researchers pointed out that the STCW code needs modifications and changes to provide with the new standards for remote controllers' competences and skills but they lay down as a prime option the use of simulators to develop education programs and an assessment tool for an interactive training. They sustain that a dynamic real-time simulator can compress years of experience and give to engineers the knowledge and confidence to face crucial events in their remote-control daily operations.

3.7 Studies in progress (paper 8, Baldauf et al., 2018)
Some of the documentation reviewed is showing that research is still in progress, a good example is the one from (Baldauf, Kitada, Mehdi, Dalaklis 2018). The idea of simulate mix traffic scenarios with manned, unmanned and remote-controlled vessels, together with experienced and non-experienced crew in order to get job profiles and training needs shows the big challenge that it will be faced in the near future and how difficult will be to include the proper data in the future maritime training schemes. Even though the author explained the study is a part of an on-going research, the analysis of those exercises can give a good vision on the way to move to regarding changes on regulations and steps for the new MET.

5 CONCLUSIONS

After conducting a literature review and evaluating all research carried out, we can point out that there is much work to do regarding the Maritime Education and Training with reference to unmanned ships. The main focus is, of course, the search for those skills and competences that the future crew will need to achieve considering, the legislation barrier. The STCW code has not changed yet regarding new or updated STCW, however many of the researchers concur that this is the main and basic gap and need to go steps further on the preparation of new training of future bachelors' or masters' degrees.

Arriving to this point, this research offers some guidelines on how to conduct and follow up into the new advances and then we reach to those applications and tools that relate the technology with the training: the simulators. Therefore, we can understand why most of the authors concentrate their efforts on the search of those new simulators and show to everyone the advantages of their use into the education and training programs.

If we concentrate our efforts to get ready for the moment that the legislation changes and the new capabilities has to be granted for the crew of the future; changes on the actual curricula could be done in advance on different ways. For instance, applying new technologies, more advance simulation on the actual programs, as well as complementing with new situation involving cyber-attacks, data transfer analysis, and other similar skills.

Finally, taking into account that there are already two full unmanned vessels those completed their first trips (the Norwegian YARA BIRKELAND in 2021 and the Japanese MV MIKAGE on February 2022), we should obtain first-hand information about their technologies, applications, simulators and data exchange to build the knowledge and capabilities that the future seafarers will need to achieve; including the ones that still will sail and the ones who will be on the remote-control centres.

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