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A Comprenhensive analysis: confronting challenges and developing solitions for maritime education and training in the era of maritime automous surface ships

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A COMPREHENSIVE ANALYSIS:

CONFRONTING CHALLENGES AND DEVELOPING SOLUTIONS FOR MARITIME EDUCATION AND TRAINING IN THE ERA OF MARITIME AUTONOMOUS SURFACE SHIPS

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DECLARATION

I certify that all the material in this research dissertation that is not my work has been identified, and that no content is included for which a degree has previously been conferred on me.

The Contents of this dissertation reflect my personal views and are not necessarily endorsed by the University.

Signature:

Date: 28 May 2023

Supervised by: ZHAO Jian

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ABSTRACT

Title of Dissertation: **A Comprehensive Analysis: Confronting Challenges and Developing Solutions for Maritime Education and Training in the Era of Maritime Autonomous Surface Ships**

Degree: **Master of Science**

The purpose of this dissertation was to analyze the challenge the Maritime Education and Training (MET) faced in the MASS era and to provide solutions to develop the MET for a better future. The analysis shows a strong correlation between MET and STCW Convention and Code. Any impact of MASS on STCW Convention and Code will lead to changes in MET. By a comprehensive use of literature review, questionnaire survey, semi-structured interview and other methods, the impacts of MASS on MET at different stages are clear. The key standards of the competence the seafarers should have in the MASS era were identified.

The findings underscored that, as navigation autonomy increases, new skills such as cyber-security management, remote control operation, MASS status recognition, etc. will gain prominence. The results underscored the necessity for MET to adjust to MASS advancements by revamping training standards in line with STCW conventions and Code.

This study endeavored to devise a functional module suited for shore-based operators in the MASS era, stipulating specific standards of competences. Additionally, an effort was made to construct the corresponding course outline based on the new functional module, offering a substantial reference for future MET evolution in the MASS epoch.

In summation, the research highlights that MET, as an integral contributor to human resources in the shipping industry, falls short of matching strides with MASS innovations. The STCW Convention and Code must consider incorporating functions, standards of competences, and training courses tailored for shore-based MASS operators. A collaborative effort by all MET stakeholders is imperative to harness their unique strengths and collectively facilitate MET's evolution to confront the challenges presented by the MASS era.

KEY WORDS: MET, MASS, STCW, Competence, Standard

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LIST OF ABBREVIATIONS

ABS	American Bureau of Shipping
AI	artificial intelligence
AMO	Autonomous Maritime Operations
BC	Before Christ
BIMCO	Baltic and International Maritime Council
BV	Bureau Veritas
CCS	China Classification Society
CoC	Certificate of Competency
DNV	Det Norske Veritas
ECDIS	Electronic Chart Display and Information System
EMSA	European Maritime Safety Agency
FAL	Facilitation Committee
GMDSS	Global Maritime Distress and Safety System
HTW	Human Element, Training and Watchkeeping
ICS	International Chamber of Shipping
ITF	Intergovernmental Organization
IGO	Intergovernmental Organization
IMO	International Maritime Organization
IAMU	International Association of Maritime Universities
IoT	The Internet of Things
JWG	Joint Working Group
KR	Korean Register of Shipping
KUP	Knowledge, Understanding and Proficiency
LEG	Legal Committee
MASS	Maritime Autonomous Surface Ships
MET	Maritime Education and Training
METI	Maritime Education and Training Institution

MSC	Maritime Safety Committee
MarTID	Maritime Training Insights Database
MSA	Maritime Safety Administration
NGO	Non-Governmental Organization
RCC	Rescue Coordination Center
RSE	Regulatory Scoping Exercise
STCW	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers
UNCTAD	The United Nations Conference on Trade and Development

Chapter 1. Introduction

1.1 Background

From the crafting of stone tools to the development of microchips, humanity's technological evolution has been remarkable. This evolution has spurred multiple industrial revolutions: first, the advent of steam power, then the introduction of electrical energy for mass production, followed by the dawn of automated production supported by electronics and the internet, culminating in Industry 4.0, where machines supersede human roles (Muhuri et al., 2019; Lu, 2017).

The shipping industry, bearing the mantle of the backbone of global trade and managing 80% of long-distance transportation (UNCTAD, 2022), is a sector as venerable as human civilization itself (Stopford, 2009). Archaeological evidence traces the earliest sea-going vessels back to the Persian Gulf in the sixth/fifth millennia BC (Carter, 2006). Advancements in telecommunications, computing, and sensor technology are now migrating into various modes of transport, including ships. Consequently, vessels are gradually becoming more autonomous, paving the way for the construction of future autonomous fleets.

The International Maritime Organization (IMO) defines an "autonomous ship" as a merchant vessel possessing varying degrees of independent operational capability without human intervention (IMO, 2021). Various international organizations, classification societies, and associations have segmented the levels of autonomy within the Maritime Autonomous Surface Ships (MASS). For most participating companies and stakeholders, the central objective is to achieve elevated safety and efficiency levels, offering potential solutions for maritime industry issues, such as marine accident prevention and work environment improvement. The latest report from the European Maritime Safety Agency (EMSA) underscores that human error was the primary factor in 81.1% of all marine incidents (EMSA, 2022). This highlights the necessity of recruiting specialized and qualified staff.

Comprehensive Maritime Education and Training (MET) on MASS and associated emerging technologies is crucial to equip new and existing seafarers with the necessary skills for safe and efficient operations.Technological innovations and industry developments necessitate a shift in seafarers' career perceptions, from being mere workers to becoming thinkers. By educating, training, and preparing seafarers, MET plays an instrumental role in shaping the safety and sustainability of shipping operations in the forthcoming era of MASS ships (Vujičić, S. et al., 2022).

1.2 Research Objective

As ships gain higher levels of intelligence and autonomy, the roles and environments of seafarers will inevitably evolve. Maritime Autonomous Surface Ships (MASS) promise enhanced crew safety, efficient ship operations, and economic benefits, potentially resolving longstanding issues in the maritime industry (Basak, 2017). This transition will shift from requiring all crew members aboard a vessel to a blend of on-site and shore-based operators, ultimately leading to full land-based crew operations. In contrast to current seafarers, the required knowledge and skill sets for minimal on-board crew members and MASS shore-based operators will change dramatically, rendering current crew training programs obsolete. As a result, maritime regulations concerning MASS shore-based operators will require substantial revisions.

In February 2023, the Human Element, Training and Watchkeeping (HTW) Sub-Committee initiated discussions in its ninth session to comprehensively review the 1978 STCW Convention and Code. Addressing the development of competencies related to maritime MASS operations as part of the STCW Convention and Code's current review will be both timely and beneficial. This will facilitate the establishment of unified international standards for MASS personnel and promote the smooth, safe implementation of autonomous operations.

Given the predicted surge in officer demand (BIMCO and ICS, 2021) and the rapid introduction of technology in the shipping industry, top supplying countries' Maritime Education and Training Institutions (METIs) face the challenge of ensuring a sufficient supply of qualified and competent seafarers to operate the MASS. This research paper tackles cutting-edge issues concerning international maritime safety and future MET, providing a foundation for developing competency training, regulatory rules for MASS operators, and establishing technical standards to guarantee personnel suitability for MASS operations.

Drawing on the aforementioned content, this paper elucidates the principles and future direction of maritime education and training in the MASS era. It offers constructive suggestions aimed at enhancing maritime safety levels and marine environmental protection.

Moreover, the research findings from this project will contribute to boosting shipping efficiency and safety, fostering the sustainable development of the shipping industry, and reaping substantial economic and social benefits.

1.3 Research Programme and Methodology

This dissertation utilizes a mixed methodology approach.

In the literature review, a comprehensive understanding of Maritime Autonomous Surface Ships (MASS), the STCW Convention and Code, and Maritime Education and Training (MET) is developed through extensive reading of relevant papers, journals, books, reports, and other resources. The interplay between these elements is investigated to identify optimal strategies for MET development. Essential competencies for operators in the MASS era are highlighted, and current best practices related to MASS within MET are examined to provide a foundation for further research.

Semi-structured interviews and questionnaire surveys form another significant component of this study. Experts from Maritime Authorities, Maritime Education and Training Institutes (METIs), Shipping Companies, and onboard seafarers are invited to participate in semi-structured interviews. Questionnaires are distributed to stakeholders to ascertain the priority competencies of shore-based MASS operators and the current state of MASS-related maritime education and training.

The mixed-method approach, employing both qualitative and quantitative methods, proves suitable for this research. Qualitative data are collected via semi-structured interviews, providing a nuanced understanding of how MET can adapt to MASS developments and ensure the training of qualified MASS operators for the MASS era. Quantitative data, gathered through survey questionnaires, gauge the prioritization and suitability of skills necessary for MASS remote operators in the industry. The results from both data types are cross-checked for reliability and validity, complementing each other to answer the research questions.

1.4 Dissertation Structure

Chapter 2 of this dissertation provides a comprehensive literature review, analyzing the developmental status of Maritime Autonomous Surface Ships (MASS), the STCW Convention and Code, and Maritime Education and Training (MET). It establishes the interconnectedness of these elements, searching for the optimal path for MET development. The chapter also scrutinizes the essential competencies for future seafarers and shore-based MASS operators, laying the groundwork for subsequent questionnaire surveys and semi-structured interviews. Chapter 3 primarily concerns itself with identifying the challenges that MASS presents to MET, including the evolving careers, roles, and responsibilities of traditional seafarers in the MASS era, as well as the varying impacts of MASS on MET. Chapter 4 presents the research methodology and data analysis, including a summary of notable responses from the semi-structured interviews. Chapter 5 engages in a discussion to develop solutions to the traditional MET challenges arising in the MASS era, with the introduction of two tools developed specifically for this purpose. Chapter 6 delivers policy recommendations to MET stakeholders, including METIs,, seafarers, maritime authorities and shipping companies. The final chapter discusses the conclusion, limitations, and future prospects of the research.

1.5 Scope of the Research

The shipping industry's different organizations and institutions have varied classification schemes for MASS levels based on ship autonomy degrees. For instance, DNV has designed five MASS autonomous navigation levels (DNV, 2018), Lloyd's Register has defined six levels (Lloyds Register, 2016), Thomas Sheridan has listed ten autonomy levels, and the International Maritime Organization (IMO) has outlined four MASS levels (Rolls-Royce, 2016; IMO, 2018). As an inter-governmental organization and a specialized United Nations agency, the IMO has taken steps to promote MASS-related matters effectively. The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), pertinent to seafarer competencies, is one of the four pillars of international maritime law (Bansal, 2006). This dissertation will adopt the IMO's classification standards for autonomy degrees.

Regardless of the vessel type or the presence of seafarers, the establishment of relevant competency and standard requirements is crucial as long as human involvement and control are present. Although MASS operators do not physically work aboard the ship, they effectively control and operate the ship, thus warranting consideration as seafarers in this dissertation. This consideration is devoid of their legal roles and responsibilities and focuses solely on their competency and certification standards from a technical perspective. Thus, the MASS operators referred to in this study are the remote operators of MASS in levels 2-4, as defined by the IMO classification system.

Chapter 2. Literature Review

2.1 Introduction

This chapter offers a literature review focusing on Maritime Education and Training (MET) in relation to Maritime Autonomous Surface Ships (MASS). It will dissect the concepts of each element and the interconnections among them, presenting relevant background and concepts in a logically sequenced manner.

Section 2.1 lays out the framework for this chapter. Section 2.2 scrutinizes various aspects of MASS, including its definition, classification criteria, and regulatory frameworks. In Section 2.3, the discussion pivots from MASS to an International Maritime Organization (IMO) legal instrument impacting MET, specifically the STCW Convention and Code. This section evaluates the impact of two major amendments to the STCW on MET, along with the new comprehensive review triggered by innovative technologies like MASS. By undertaking an in-depth review of the latest round of STCW Convention and regulations, the section also illuminates the link between technological innovation and the competencies of industry workers. This examination aids in identifying how the STCW convention content might affect MET in the MASS context. Section 2.4 reviews the definition, origin, and developmental progression of MET. The current research status of MET concerning MASS is the key focus of this section, and the practice of MET related to MASS in some countries also comes under consideration. Section 2.5 encapsulates the content of this chapter, highlighting the gaps in research on the countermeasures to MET in the MASS era and the areas warranting further enhancement.

2.2 MASS

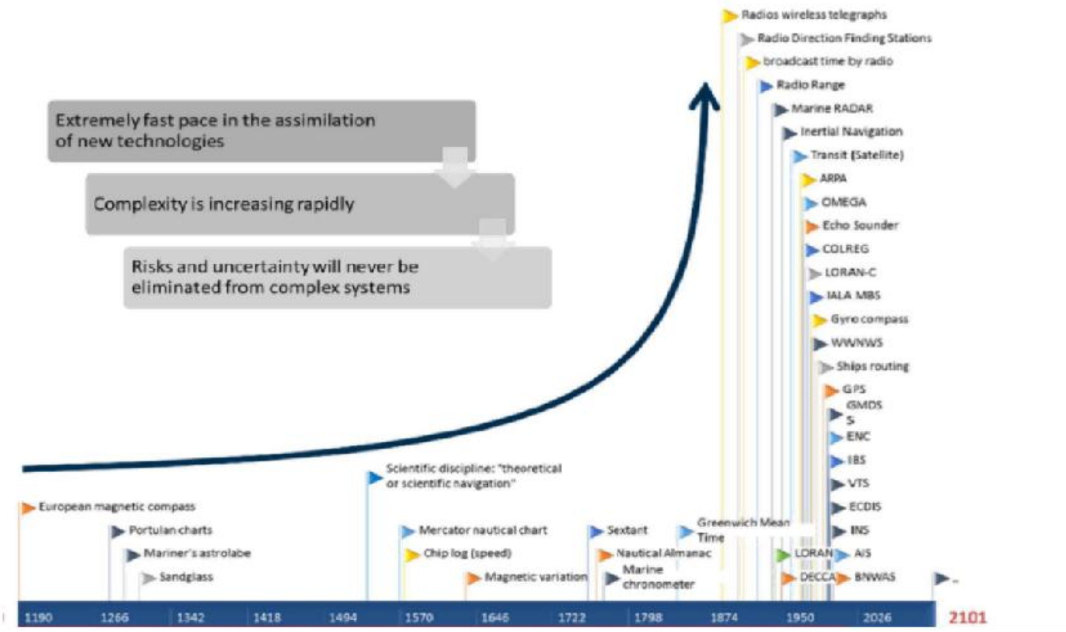
2.2.1 Emergence of MASS

Technological innovations comprise new products and processes and significant technological changes of products and processes (Nakazawa, 2022). Moreover, technological innovation has transformed traditional processes and optimized elements to maximize social efficiency and sustain economic growth (Kogabayev & Maziliauskas, 2017). Technological innovation can not be separated from the rapid design and development of new technological methods (Ivanova et al., 2019), and technological innovation is the driving force of industry development and improvement of business activities (Pomaquero et al., 2019).

The fourth industrial revolution represents the amalgamation of digital technology and physical systems, leading to the formation of what is known as cyber-physical systems. The progress of this revolution has coincided with significant advances and developments in communication-related technologies, as depicted in Figure 1. For instance, ship navigation technology has seen rapid emergence of new technologies since the industrial revolution, greatly propelling the shipping industry towards the phase of Shipping 4.0 (Primi & Toselli, 2020).

Figure 1

Timeline of maritime navigation technology innovation



Note. From "The Geography of Transport Systems FIFTH EDITION," by Jean-Paul Rodrigue, (2020), *New York: Routledge*, 456 pages. ISBN 978-0-367-36463-2. doi.org/10.4324/9780429346323

A notable characteristic of Shipping 4.0 is the digital transformation of shipping, enabling digitalization across all shipping aspects (Shahbakhsh et. al., 2022). Shipping 4.0 can be defined as the digitalization in shipping, illustrated in Figure 4, akin to other land-based industries impacted by Industry 4.0 (Kavallieratos et. al., 2020).

Figure 2

Shipping 4.0

Note. From Rødseth, Ø. J.(2017). Towards Shipping 4.0. Proceedings of Smart Ship Technology. *Royal Institution of Naval Architects 2017 ISBN* 978-1-909024-63-2.

This ongoing digital transformation is already bringing significant changes to the design, construction, operation, maintenance, and manning of ships, consequently reshaping the modus operandi of the shipping industry. The bedrock for the sustainable development of the shipping industry is the assurance of shipping safety and security, along with the prevention of marine and atmospheric pollution by ships. As an integral component of Shipping 4.0, the emergence of MASS is moving the shipping industry towards a novel paradigm centered around cyber-physical systems and autonomy (Issa et al., 2022).

2.2.2 Definition, classification of MASS

During the 99th Session of the Maritime Safety Committee (MSC), MASS was officially defined as a ship that can operate with varying degrees of independence from human-machine interaction. This definition was ratified during the 100th session of the MSC (Wu et al., 2019). The same session also categorized the degree of autonomy of MASS into four levels (IMO, 2018).

The regulatory scoping exercise (RSE) was completed in 2021 with the outcome document MSC.1/ Circ.1638. The Circular provided additional clarity on the Autonomy Degree and Description of the MASS, shown in the Table 1.
In 2021, the regulatory scoping exercise (RSE) concluded with the outcome document MSC.1/Circ.1638. This circular further elucidated the autonomy degree and description of MASS, as shown in Table 1.

Table 1

Four Degree of MASS

Level	Autonomy Degree	Description
L1	Ship with automated processes and decision support	Seafarers are board to operate and control shipboard systems and functions while some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
L2	Remotely controlled ship with seafarers onboard	The ship is controlled and operated from another location. Seafarers are onboard to take control and to operate the shipboard systems and functions.
L3	Remotely controlled ship without seafarers on board	The ship is controlled and operated from another location. There are no seafarers onboard.
L4	Fully autonomous ship	The operating system of the ship is able to make decisions and determine actions by itself.

Note. Created by author according MSC.1/Circ.1638

Apart from the IMO, major global shipping nations and relevant organizations have shown considerable interest in the development of MASS, each devising their classification based on different degrees of automation and the presence or absence of seafarers on board. Det Norske Veritas (DNV) established several scales for describing the degree of autonomy in ship navigation, constituting 5 levels of autonomy (DNV GL, 2018); The American Bureau of Shipping (ABS) in 2021 demarcated the level of autonomy into 4 levels, contingent on the level of human-computer interaction (ABS, 2021); Bureau Veritas (BV) classified MASS into 5 levels in 2017, according to the confidence coefficient and degree of autonomy in the technology utilized in the MASS system (BV, 2017); Korean Register (KR) divided the level of MASS into 5 levels, based on the process of Data acquisition/analysis, Decision-making, and Action (KR, 2022). Sheridan categorized MASS into 10 levels, depending on the type, size, operational area, and conditions of the ship (Rolls-Royce, 2016). Table 3 provides detailed information regarding the number and content of classifications for autonomy levels.

Table 2

Autonomy levels delivered by classification societies

Classified by IMO	Classified by DNV	Classified by LR	Classified by Sheridan	Classified by ABS	Classified by BV	Classified by KR
4 - Fully autonomous ship: the operating system of the ship is able to make decisions and determine actions itself	A - Autonomous function (the system will execute the function, normally without the possibility for a human to intervene on the functional level)	AL6 - Fully autonomous (& with no supervision)	10 - The computer does everything autonomously, ignores human	Autonomous - Without human intervention, the system makes decisions and executes instructions autonomously.	4 - Personnel will be notified only in emergency situations.	AL5 - All functions are performed by the system and the operator monitors the emergency situation. System responses to abnormal operating scenarios are possible.
3 - Remotely controlled ship without seafarers on board: the ship is controlled and operated from another location. There are no pseafarers on board	DS - Self controlled function (the system will execute the operation, but the human is able to override the action. Sometimes referred to as human on the loop	AL5 - Fully autonomous (& rarely supervised)	9 - The computer informs human only if it (the computer) decides so	Semi-Autonomous - Navigation tasks can be carried out according to pre-set procedures, some actions can be completely active, and can also be operated remotely from the shore.	3 - The system can call the function without waiting for manual authorization	AL4 - Data acquisition/analysis, decision-making and action are performed by the system. The operator always monitors the information about the decision-making and action by the system. System responses to abnormal operating scenarios are possible.
			8 - The computer informs human only if asked			
			7 - The computer executes automatically, informing human when necessary			
		AL4 - Human on the loop – operator/supervisory	6 - The computer allows human a restricted time to veto before automatic execution			
2 - Remotely controlled board: the ship is controlled and operated from another location, but seafarers are on board	DSE - System decision supported function with conditional system execution capabilities (human in the loop, required acknowledgement by human before execution)	AL3 - 'Active' human in the loop	5 - The computer executes the suggested action if human approves		2 - System decisions, but manual authorization is required to execute them. Within a certain period of time, manual intervention can be carried out.	AL3 - Data acquisition/analysis, decision-making and action are performed through system or off-board remote operation. However, the operator's confirmation of the decision-making by the system is required, and if the operator confirmation is not preceded, the decision-making is withdrawn. In case of system failure or remote operation is not working
		AL2 - On and off-ship decision support	4 - Computer suggests single alternative			
			3 - Computer narrows alternatives down to few			
			2 - Computer offers a complete set of decision alternatives			
1 - Ship with automated process and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated	SC - System decision supported function	AL1 - On-ship decision support	1 - Computer offers no assistance, human is in charge of all decisions and actions	Smart - The system assists personnel in ship maneuvering and provides decision support	1 - The system provides decision support, and human beings make decisions and take actions	AL2 - Data is collected/analyzed through system or off-board remote operation and decision-making and action are performed by the operator. The system supports operator' s decision-making. The operator's decision-making is supported through system or off-board remote operation
	M - Manually operated function	AL0 - Manual- no autonomous function		Manual - The system provides only simple assistance and leaves it entirely up to the personnel to make decisions and execute instructions.	0 - People make all decisions and operate all things onboard	AL1 - Data acquisition/analysis can be performed by the operator and the system, but decision-making and action based on the collected information are performed by the operator.

Note. Created by auothor according the guideline issused by classification societies

2.2.3 Development progress of MASS

The advent of MASS marks a paradigm shift in the shipping industry. By revolutionizing various aspects of shipping, it's positioning itself as a powerful driver for the industry's future development. The evolution of MASS has transpired in stages. It began with the automation of system controls in the engine room, followed by autonomous navigation and avoidance facilitated by integrated sensors, and finally, the achievement of automated control and energy efficiency management across the entire ship. Table 3 elucidates the development process and future trajectory of MASS.

Table 3

Representative Vessel or Project in the development progress of MASS

Year	Country / Region	Vessels	Features
1964	Japan	"SELEM DAM 65", tanker	Engine room centralized control, engine remote controlled on the navigation bridge.
1970	Japan	"Starlight Maru", tanker	The control and management of the entire vessel is achieved through various subroutines and interfaces.
1985	China	"Berlin Express", container vessel	Automatic steering system, automatic navigation system, vessel management center, comprehensive management of the whole vessel was achieved through the computer system.
2008	China	"Tianxiang No. 1", offshore exploration vessel	Intelligent navigation, radar search, satellite applications, image processing and transmission
2012	EU	MUNIN	Unmanned vessel
2012	China	Automatic unmanned sampling vessel	Robot control technology, automatic navigation technology, ultrasonic intelligent wall protection barrier technology, 3G network / GPRS real-time communication technology. With autonomous navigation, automatic obstacle avoidance, network management and other advantages
2014	UK	"Mayflower", marine autonomous vessel	Unmanned trimaran sailing boat
2016	USA	"Sea Hunter"	Unmanned vessel
2016	China	Unmanned Vehicle	All-weather automatic cruise and risk aversion, remote reconnaissance operations, professional equipment load piggyback, 360-degree video transmission, voice intercom
2016	Norway	"Hronn" light marine vessel	Unmanned vessel
2017	China	"Da Zhi"	Intelligent navigation, intelligent engine room, intelligent energy efficiency management, etc.
2018	Norway	Yara Birkeland	Unmanned, electric, container
2020	Europe	One Sea	Independent control of marine ecosystem by enterprises, completely remotely controlled
2020	UK	Rolls-Royce	Remotely controlled unmanned vessel
2025	Europe	One Sea	Autonomous commercial operation
2035	UK	Rolls-Royce	Unmanned ocean-going merchant vessel

Note. Deling, W., Dongkui, W., Changhai, H., & Changyue, W. (2020). Marine Autonomous Surface Ship - A Great Challenge to Maritime Education and Training. American Journal of Water Science and Engineering, 6(1), 10. https://doi.org/10.11648/j.ajwse.20200601.12

2.2.4 Regulating of the MASS

For the adoption of autonomy-related technology to advance, corresponding regulations must be developed in tandem with technological progression. The incorporation of novel and evolving technologies into the regulatory framework is a key strategic direction the IMO (IMO, 2017).

The 98th Session of MSC, held in June 2017, introduced autonomous ships as an agenda item and kick-started the methodology for the RSE. In May 2018, the 99th Session of MSC discussed the objectives, definitions, scope, methods, and work plans of the MASS RSE. The 100th Session of MSC deliberated on the principles for drafting interim guidelines for MASS trials in December 2018, marking the official commencement of the RSE. The interim guidelines for MASS trials (MSC.1/Circ.1604) were approved at the 101st Session of MSC in June 2019, summarizing key policies to be considered during autonomous ship operations (IMO, 2019). The RSE for safety treaties was concluded with the document MSC.1/Circ.1638 at the 103rd Session of the MSC in May 2021. It identified potential gaps between current IMO instruments and MASS requirements, leading to the decision to develop an independent MASS instrument.

Following the work of the 105th Session of the MSC and the completion of the RSE, the 106th Session of the MSC in November 2022 approved the development of a MASS instrument through the goal-based method. The aim is to implement a non-mandatory MASS Code by 2025 and a mandatory MASS Code by 1st January 2028. A Joint Working Group (JWG) comprising MSC, LEG, and FAL was established to address issues identified by the RSE and is playing a significant role in developing the MASS Code.

STCW Convention and Code, as amendments, related to the competencies and skills of seafarers, was identified as a high-priority area during the RSE process.

2.3 STCW Convention and Code

2.3.1 The impact of the STCW Convention and Code amendments on the MET

The STCW Convention and Code, which feature prominently in the IMO RSE process, constitute a crucial convention, known as one of the four pillars of the shipping industry (Ahmed, 2022). STCW ensures global uniformity in the training of seafarers, enhancing their professional competence and guaranteeing the international credibility of their qualification certificates. The 1978 STCW Convention was the first to establish basic global requirements for the training, certification, and watchkeeping of seafarers (USCG, 2020).

The 1978 STCW Convention came into effect on 28th April 1984, with subsequent amendments adopted in 1991, 1994, 1995, 1997, 1998, 2004, 2006, 2010, 2014, 2015, 2016, 2017, and 2018. Significant amendments were adopted in 1995 (coinciding with the introduction of the STCW Code) and in 2010.

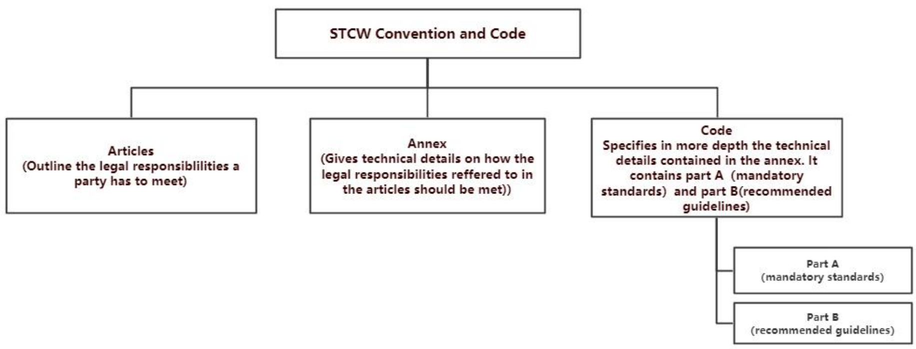
The first big revision of the STCW Convention was the 1995 amendment. The 1995 amendments to the STCW Convention significantly changed the way of training and certification of the seafarers serving modern ocean-going vessels. While the STCW 1978 emphasized almost exclusively the acquisition of specialized knowledge, the

1995 amendment shifted the focus to practical skills and competencies supported by the theory of knowledge (ITF, 2002). It placed significant importance on the quality of training institutions and implemented measures to ensure compliance with the convention (Hanzu-Pazara et al., 2008). STCW 1995, as amended, divided the ship's complex work items into seven functions, and the ship's personnel into three levels of responsibility, namely management level, operational level and support level. Within this framework, standards of knowledge, understanding and proficiency(KUP) required to perform each function at different levels have been developed, and a clear structure of convention suitability criteria has been established.

The second significant amendment came in 2010. The Manila Amendment, adopted in June 2010 during the Conference of Parties to the STCW Convention held in the Philippines, made significant changes to the Convention and the Code. The structure of the STCW Convention and Code is depicted in Figure 3.

Figure 3

Structure of the STCW Convention and Code



This amendment impacted MET in numerous ways, including the introduction of revised content to accommodate modern shipping technology like Electronic Chart Display and Information Systems (ECDIS). Key new training requirements and detailed content can be found in Table 4.

Table 4

Manila Amendment's key new training requirements

Key New Training Requirements	Detailed Requirement Content
Changes to Competence Tables	Various changes to the STCW Competence Tables are included in the Manila Amendments. Important examples include the need for deck officers to be competent in the use of ECDIS and for engineer officers to be able to operate pollution prevention equipment.
Leadership and Teamwork	For deck and engine officers, substantial new competence requirements related to leadership, teamwork and managerial skills have been added. Assertiveness training for all seafarers has also been included, given its importance not only for those who have to direct operations but also for those in lower grades who may have to communicate on safety matters with senior officers, the master and/or shore personnel.
Training Record Books	It will be mandatory for all deck and engine rating trainees to demonstrate competence through the use of on board training record books, with completion to be supervised by officers responsible for on board training (in addition to the existing requirements applicable to officer trainees).
Mandatory Security Training	As well as specific training and certification requirements for Ship Security Officers, new security familiarisation and training requirements have been introduced for all grades of shipboard personnel. Seafarers may already comply with these new security requirements through seagoing service or previous training.
Refresher Training	An important feature of the Manila amendments is the additional emphasis given to the need for seafarers' standards of competence to be maintained throughout their careers. All seafarers are now required to provide evidence of appropriate levels of competence in basic safety training (including survival, fire-fighting, first aid, and personal safety) every five years.
Tanker Training	New, comprehensive Competence Tables for training in oil, chemical and gas tanker operations, at both basic and advanced levels. (New guidance has also been developed for crew on offshore support vessels and all ships in polar waters.)
New Seafarer Grades and Certification	STCW 2010 introduces extensive training and certification requirements for the new grades of 'Able Seafarer Deck' and 'Able Seafarer Engine'. These are in addition to the current navigational and engine watch rating requirements which are otherwise unchanged. New competence standards and certification for the position of 'Electro-Technical Officer' and 'Electro-Technical Rating' have also been established, in recognition of a position already widely established, particularly in the passenger ship industry.
Medical Standards	Additional medical fitness standards and requirements for certification have been introduced.
Prevention of Unsafe Alcohol Use	These include a specific limit of 0.05% blood alcohol level or 0.25mg/l alcohol in the breath.

The Manila Amendment established minimum competency standards for seafarers and set related standards for MET facilities, equipment, and instructors. Parties to the Convention are responsible for ensuring that these personnel possess appropriate qualifications relative to the type and level of training and assessment they offer. The STCW Regulations I/6 (Training and assessment) and I/8 (Quality standards) focus on the qualification requirements for instructors and assessors within METIs. Sections A-I/6 and A-I/8 of the STCW Code Part A detail mandatory training and assessment requirements and quality standards (IMO, 2017). For instance, training and assessment should also be monitored, evaluated, and supported by qualified personnel (Fisher & Muirhead, 2005; Cross, 2013). Part B of the STCW Code, sections B-I/6 and B-I/8, contain non-mandatory provisions offering guidance to member states on how to comply with the specified requirements.

2.3.2 Latest round of STCW Convention and Code comprehensive review

In order to ensure the STCW Convention keeps pace with technological advancements and avoids frequent revisions, the 2010 Diplomatic Conference in Manila adopted a General Assembly Resolution, Resolution 15. This resolution urged State Parties to maintain, where possible, a five-year cycle for significant revisions of the Convention and a ten-year cycle for a comprehensive review of the Convention to address any identified gaps. Adjustments were made based on the inappropriateness identified and to keep abreast with emerging technologies and growing demands on seafarers (IMO, 2021).

Several issues such as the conflict between larger ships, including container ships and crew manning, the expansion of onboard internet and addressing cyber-security incidents, the transition towards paperless shipping, the declining allure of sea work, and the sustainability of the seafarer workforce have been surfacing. Employers have observed that certified seafarers are struggling to adapt to new technology and meet new industry requirements for their roles, necessitating additional training before placement. Consequently, the International Chamber of Shipping (ICS) submitted a proposal at the 6th Session of Sub-Committee on Human Element, Training and Watchkeeping (HTW6) in 2019, suggesting another comprehensive review of the

STCW Convention (ICS, 2019). The International Association of Maritime Universities (IAMU), as a provider of Maritime Education and Training (MET), understands the challenges faced by the STCW Convention in achieving its objectives. IAMU believes that the STCW standards represent an observable, controllable, effective, and stable system, and that the STCW comprehensive review should harmonize with other IMO instruments (IAMU, 2019).

During the 104th Session of the MSC, several countries and organizations put forth proposals for a comprehensive review and revision of the STCW Convention and Code. Countries including Australia emphasized the need for the review to focus on current technological developments and digitalization processes, such as electronic certificates and education and training related to MASS. Japan proposed that the current STCW Code's concept of Knowledge, Understanding, and Proficiency (KUP) is applicable for METIs and should be retained. In addition, the comprehensive review of the STCW Convention and Code needs to address emerging technologies such as ships using alternative fuels, MASS, and cyber-security. ICS underscored the need for the comprehensive review of the STCW Convention to adapt to technological, regulatory, and operational developments (IMO, 2021).

During the 105th Session of the MSC, the meeting considered the proposal for a comprehensive review of the 1978 STCW Convention and Code and approved the inclusion of the new output in the 2022-2023 biennial agenda of the HTW Sub-Committee and the provisional agenda of HTW 9, targeting a completion year of 2026 (IMO, 2022).

At the 9th Session of the HTW, the member states showed great interest and concern for the comprehensive review of STCW Convention and Code. Approximately 30%

of all proposals for this session, 16 related proposals, were received by the HTW Secretariat. The emergence of MASS requiring new standards of competence, functions, and levels of responsibility was a point of consensus. HTW9 also established a Correspondence Group to facilitate the comprehensive review progress (IMO, 2023).

In conclusion, the IMO legal framework, although in its preliminary stages, is prepared for the future. This suggests that Member States and METIs need to pay greater attention and respond positively to MASS.

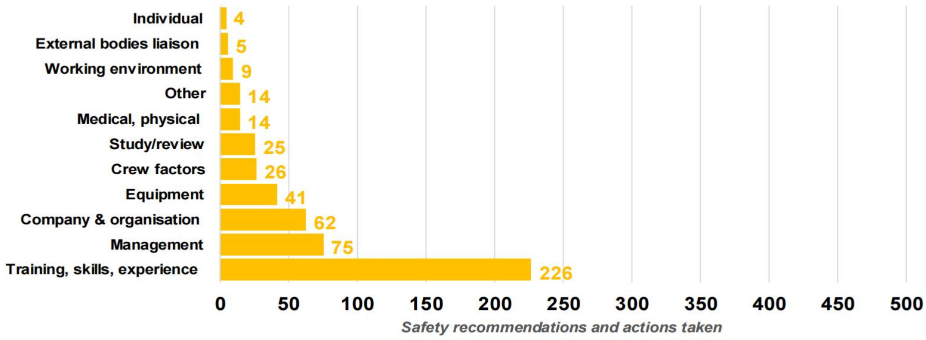
2.4 MET

2.4.1 Overview of the MET

Human resources serve as the connection between organizations, businesses, industries, and economies (Wikipedia contributors, 2023). In the shipping industry, the human factor is fundamental. As per the Annual Overview of Marine Casualties and Incidents 2022, Training, Skills, and Experience account for 45.1% of the recommended actions to be taken concerning Human Factors (EMSA, 2022). MET plays a critical role in mitigating the negative impacts of human factors and ensuring the continual supply of qualified personnel for the merchant marine and professionals for all related maritime industries. This aligns with the introduction of MET frameworks such as the STCW Convention and Code (Toresano et al., 2022).

Figure 4

Safety recommendations and actions taken for human factors focus area



Note. From EMSA, Annual Overview of Marine Casualties and incidents 2022, available at: https://www.emsa.europa.eu/newsroom/latest-news/download/7362/4867/23.html

It has been long held that Infante Henry founded the first MET school in 1419. Since then, MET has steadily evolved, generating a plethora of talent for the shipping industry (Wikipedia contributors, 2023b). As Dong (2014) highlighted, MET's initial purpose was to train crew and officers for naval and merchant ships. However, as the shipping industry developed, the demand emerged for MET to train higher quality maritime talents at all levels. The industry requires not only qualified seafarers with superior ship operation skills but also exceptional talents equipped with a sound theoretical foundation, adaptability, potential, team spirit, leadership ability, and research skills. Today's shipping industry extends beyond transportation and management, encompassing maritime finance, brokerage, law, insurance, and more. Therefore, it is imperative to broaden the concept of MET to meet the talent needs of the shipping industry.

2.4.2 Status of research on MET relating MASS

Safety remains paramount in the shipping industry. As noted by Kitada et al. (2018), the shipping industry has become digitized and automated. Though fully automated systems require minimal or no human intervention, human cognition, skills, and knowledge are critical for safe operations in partially automated or digital systems. Bartuseviciene (2020) emphasized that safety is the purpose and an essential consideration during the implementation of MET. The STCW impacts the majority of MET aspects, and only through the collective effort of all stakeholders in developing regulations can MET enhance the safety of the shipping industry.

The evolution of MASS and Remote Control Centers (RCC) relies heavily on the direct application of artificial intelligence (AI), development of new communication and data transmission systems, optimization of sensors, and control of ship routes (Smith, 2020). With regard to new skills or competencies required in the MASS era, the abilities necessitated by new technologies should be considered. As highlighted by Toresano et al. (2022), the evolution of MASS will alter seafarers' work environments and promote the development of new teaching and training methods. The new training and education will be built upon existing knowledge of navigation, safety, planning, navigation equipment, positioning, meteorology, and emergency procedures, with additions like artificial intelligence, remote operations, data transmission, and communications (Toresano et al., 2022). In terms of maritime cyber-security, students should be trained to develop awareness and ability to address cyber-security issues (Chirea-Ungureanu, 2021). These considerations should be taken into account during the revision of the STCW Convention and IMO Model Courses (Belev et al., 2021).

The techniques and instruments of maritime education and training are also under scrutiny. Considering the complexity of MASS, Mogensen (2018) suggested cross-disciplinary teaching as a suitable approach. The STCW Convention and Code require revisions to introduce a new standard for remote control abilities and skills. Simulators and interactive evaluation tools are deemed the primary options. Simulators, particularly those equipped with AR technology, are seen as beneficial training tools that can substitute for certain work experiences, providing participants with the knowledge and confidence needed to handle critical incidents in remote control daily operations (Lokuketagoda et al., 2017).

The advent of MASS has led to concerns about potential job losses and reductions in the number of seafarers (Schröder-Hinrichs et al., 2019). However, many experts anticipate the creation of new job opportunities (Ramos et al., 2019). Ahvenjärvi (2017) noted that the new maritime education and training will need to cater not only to future seafarers or operators, but also other workgroups such as port workers, VTS operators, network engineers, lawyers, and authorities, all of whom will require new skills.

Qualified instructors with MASS knowledge are crucial. The IMO document MSC.1/Circ.1638 already suggests that the STCW should be revised. Skills and competencies beyond those provided by traditional maritime education will be needed, prompting a significant transformation in maritime institution curricula, including instructor training. The Maritime Insights Database (MarTID, 2018) survey identified a lack of qualified maritime instructors as a shared challenge, which in turn impacts the quality of maritime education and training (Vujičić et al., 2022b).

2.4.3 MET practice relating to MASS of sample countries

2.4.3.1 United Kingdom

In collaboration with SeaBot XR and with the support of the UK Maritime and Coastguard Agency, Fugro initiated an International Training Standards Working Group centered on MASS, titled MASSPeople. This training course aims to enhance the skills of existing qualified seafarers, facilitating their transition from sea to shore and ensuring they gain the necessary skills for the safe and effective operation of MASS. The training encompasses key areas such as mission analysis, situational awareness, cyber-security, and resource management.

The training employs experiential learning, equipping trainees with comprehensive theoretical knowledge before introducing them to command and control processes in stages. This approach allows trainees to directly apply their newly acquired skills in the work environment, preparing them to handle challenges posed by emerging technologies.

2.4.3.2 Finland

Novia University in Turku, Finland, has established a new Master's degree program dedicated to autonomous maritime operations. This program is open to individuals who hold a Bachelor's degree from a university or an equivalent higher education degree, and have at least 24 months of work experience in a related field. The Master's degree program focuses on the digitization of offshore operations, imparting advanced skills and knowledge in the realm of autonomous offshore operations. The subjects covered are displayed in Table 5.

Table 5

The full curriculum of the Autonomous Maritime Operations(AMO), 2023

ADVANCED PROFESSIONAL STUDIES
Master Studies - Introduction
Cyber Security and Connectivity
Artificial Intelligence, Machine Learning, Human - Machine Interaction
Autonomous Vessels - Automation
Remote Operations
Classification, Qualification and Safety Perspectives
MASTER'S THESIS
Master's Thesis

Note. Master of Engineering, Autonomous Maritime Operations. (n.d.). novia.fi. https://www.novia.fi/en/study/study/technology-and-seafaring/master-of-engineering-autonomous-maritime-operations/

2.4.3.3 Republic of Korea

Between 2021 and 2022, Korea conducted six sessions of remote operation simulation training for MASS, primarily aimed at increasing awareness about remote operations of MASS. Using MASS remote control simulators, hands-on training was provided to 48 participants, some of whom held seafarer's certificates of competency (CoC). Of these, 34 were shipyard trial seafarers with operational level or higher CoC, and the remaining 14 were instructors and researchers from various METIs.

2.4.3.4 China

Chinese METIs have begun exploring how to adjust training programs and curriculum for students to meet the needs of future MASS development. Table 6 presents the MASS-related curriculum and methods developed by METIs.

Table 6

Chinese METIs' practice relating to MASS

METIs	Curriculum or Method
Dalian Maritime University	Overview of Modern Navigation Technology Artificial Intelligence Integration Engine Modeling and Simulation
Wuhan University of Technology	Intelligent Navigation Algorithm Design Artificial Intelligence and Ship Collision Avoidance
Shanghai Maritime University	Fundamentals and Applications of Intelligent Ship Technology
Jimei University	Set up a class of intelligent navigation
Ningbo University	Maritime Intelligent Transportation

2.5 Chapter Summary

Shipping 4.0 is an application of Industry 4.0 principles to the shipping industry, encompassing all the characteristics of Industry 4.0. MASS vessels are one of the outputs of Shipping 4.0 and pose a disruptive potential to the shipping industry. The IMO has categorized the autonomy levels of MASS into four degrees, with degrees 1 and 2 requiring crew onboard, while degrees 2 and 3 necessitate a role for MASS operators. The highest level of autonomy, degree 4, is managed by systems, but will invariably need MASS operators to oversee the system and address emergency situations.

As a UN specialized agency, the IMO has been vigilant of changes in the shipping industry and has implemented several measures in response. The STCW plays an essential role in assuring the quality of global seafarers. In the course of RSEs, the STCW was identified as one of the IMO instruments requiring high-priority discussion. The STCW is intricately linked with MET, setting minimum standards for MET training crew, playing a crucial role in standardizing global MET standards, and enhancing MET quality. The STCW Convention also outlines requirements for MET facilities, equipment, instructors, and other resources. Therefore, any changes to the STCW Convention will inevitably result in changes to MET.

The literature review reveals considerable interest in MASS within the shipping industry, with several academic studies focusing on MET related to MASS. Certain countries have even implemented relevant practices through their METIs. While the theories and concepts concerning MET and MASS have been well-established in previous studies, current research lacks specificity and depth regarding the competency standards for future seafarers. Moreover, suggestions for future MET remain relatively rudimentary, highlighting the need for further research in these areas.

Chapter 3. Identification of Challenges of MASS on MET

3.1 The changing career, roles and responsibilities of traditional seafarers in the MASS Era

Traditional seafarers are those who have received MET in accordance with the STCW Convention and Code, mastering the knowledge, skills, and competencies required for the operation, maintenance, and repair of ships' equipment and systems, as well as for managing ship operations.

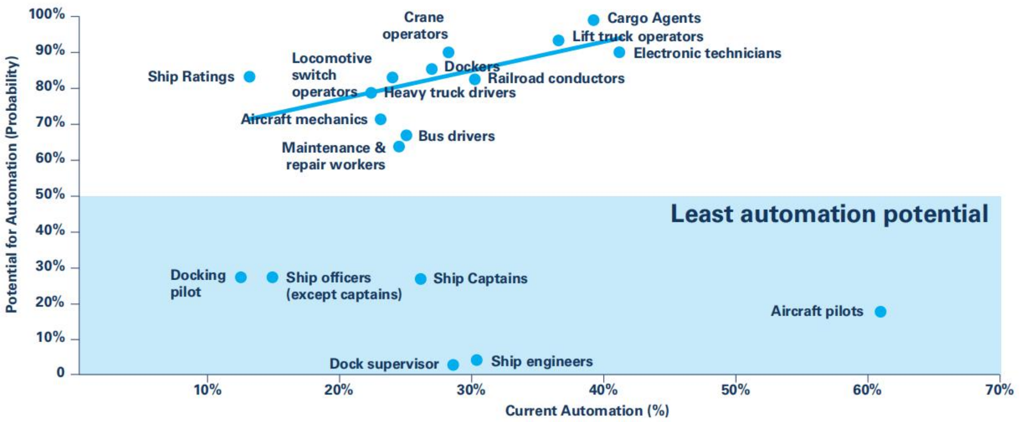
With the advancement of ship automation technology, ships will increasingly rely on shore-based remote control operations or autonomous ship operations. Consequently, the demand for traditional seafaring skills will gradually decrease, while the requirements for comprehensive quality will increase. Talents proficient in intelligent ship control technology will be in greater demand.

Certain functions of traditional seafarers may diminish or disappear, with fewer seafarers onboard to perform corresponding duties. Some functions will shift to shore-based operators. Although the nature of the activities performed by seafarers will largely remain the same, MASS special sensors distributed throughout the ship will cause a significant shift in how these activities are carried out. Consequently, MASS operators or seafarers at the operational level may need to manage one or two additional functional units, dealing with a vast amount of specialized communications knowledge beyond the current Global Maritime Distress Safety System (GMDSS) requirements, as well as knowledge pertaining to the new sensors on MASS. Given that sensors provide RCCs with the only means of attaining situational awareness of the ship and its environment, monitoring sensor operation and performance is critically important.

Historically, support-level seafarers perform specific tasks under the supervision of operational or management-level seafarers. In the MASS era, the duties and responsibilities of support-level seafarers will undergo significant changes. Many current support-level tasks will migrate to RCCs, while others will be entirely eliminated through automation. For instance, in the case of deck seafarers at the support level, robotic systems are likely to assume the routine maintenance of deck equipment, especially as automated mooring and berthing systems become more stable and technologically mature. This trend is depicted in a joint WMU and ITF report (2019), illustrated in Figure 5.

Figure 5

Automation potential for job profiles in transport



Note. From Frey and Osborne. Tech. Forecast. Soc. Change. 114 (2017), Occupational Information Network (O*Net), WMU analysis

The ICS forecast report predicts that by 2025, there will be approximately 3,000 fully and semi-automatic ships, potentially reducing the demand for seafarers by 30,000 to 50,000 (ICS, 2021). While some roles will be diminished or transformed, new roles will emerge, such as remote automation engineers, ship data engineers, cyber-security engineers, shore-based technical support personnel, and other logistical support staff. Marine careers will become more specialized, with a clearer division of roles. Besides the gradual transition of traditional seafarers to RCCs, they may also move into newly emerging roles related to shipping. For instance, after reaching their safe operation period, ships require maintenance, and intelligent ships necessitate maintenance bases for their onboard systems and equipment. This will generate related jobs and introduce a new category to the shipping service industry.

Based on the above analysis of the changing roles and responsibilities of traditional seafarers, the functional levels of future MASS operators will be confined to the management and operational levels, excluding the support level, as depicted in Figure 6.

Figure 6

The change of the levels of responsibility for seafarers onboard

3.2 Impact of MASS on MET in different level

The introduction of technologies in Shipping 4.0 and their requirements by MASS means different levels of MASS will have varying impacts on future MET.

3.2.1 Impact of the Level 1 MASS on MET

Level 1 MASS involves process automation and decision support. Ships with this level of automation are equipped with systems or devices that assist seafarers by providing support for navigational tasks. Navigational decisions are made solely by the seafarers, and information obtained from the system merely complements these decisions.

3.2.2 Impact of the Level 2 MASS on MET

Level 2 MASS involves seafarers onboard but also relies on support and control from RCCs. Compared to traditional ships, the crewing of remote-control ships will undergo significant changes. This level introduces the need for shore-based remote control personnel. Onboard personnel will be reduced, and the work mode and content will drastically change.

The structure of the knowledge required by seafarers onboard remote-control ships has significantly evolved. In addition to relevant traditional maritime knowledge, new knowledge and technologies linked to autonomous surface ships are necessary, including information regarding automation, information physical systems, big data, autonomous navigation, and remote control, among others. These changes will have a profound impact on MET in the MASS era. Future MET will be required to integrate these new knowledge and technologies alongside traditional maritime knowledge. At this stage, the communication and teamwork abilities of the seafarers onboard will have heightened demands to ensure seamless communication and cooperation between the ship and the RCC.

3.2.3 Impact of the Level 3 MASS on MET

Level 3 MASS involves ships without seafarers onboard, entirely operated by on-shore RCCs. Ships at this level are equipped with remote control systems or facilities that can assist shore-based personnel in performing navigation tasks. Decisions will primarily be made by onshore personnel, and the ship will be unmanned.

In contrast to level 2 MASS, level 3 MASS is entirely dependent on the operation of qualified onshore personnel. As such, these personnel need to have a profound understanding of network information technology and automation technology. In addition, they must possess a wide-ranging knowledge base to deal with the remote and complex maritime navigation environment.

3.2.4 Impact of the Level 4 MASS on MET

Level 4 MASS involves systems or equipment that can perform navigation tasks autonomously. The decision-making operation is carried out autonomously, without seafarers onboard. Remote operators primarily monitor the ship's navigational performance and participate in the control of the ship when necessary. These remote operators require high levels of specialization and technical knowledge. These personnel are expected to be familiar with the ship's systems and equipment, not only with the knowledge mentioned in Section 3.2.3, but also with the ability to troubleshoot and maintain the ship's systems. They should be able to quickly respond to emergencies. MET must optimize its curriculum and training methods to ensure that operators have the necessary knowledge and skills for remote operation and autonomous navigation systems.

3.2.5 Chapter summary

This chapter analyzes the challenges that may be faced by MET according to the different levels of autonomy of MASS. The changing career, roles and responsibilities of traditional seafarers in the MASS Era are also included.

Chapter 4. Methodology and Data analysis

4.1 Research approaches

This study employs a variety of research approaches, defined as the methods and procedures employed in academic research. These range from overarching hypotheses to meticulous data collection, analysis, and interpretation procedures. As the research progresses, decisions about epistemology, theory, and methodology are made and reflected in the research design. There are primarily two types of research methods: qualitative and quantitative, along with a third category known as mixed methods, which blends elements from the other two (Creswell & Creswell, 2017).

4.1.1 Qualitative Research

Qualitative research is utilized to comprehend social phenomena. Although many approaches to qualitative research exist, they tend to emphasize flexibility and the preservation of intricate meanings during data interpretation. Research findings are typically conveyed in narrative and descriptive formats. Research begins with questions, seeks answers in the real world, and forms chunks of knowledge (Merriam, 2009). A variety of data collection methods are employed to understand behavior in social, cultural, and physical environments. Qualitative research involves the gathering and analysis of non-digital data, such as text, audio, or video, to comprehend concepts, viewpoints, or experiences. It can be used to gain insights into issues or to generate novel research ideas. Qualitative research contrasts with quantitative research, which involves the collection and analysis of numerical data for statistical analysis (Bhandari, 2023).

4.1.2 Quantitative Research

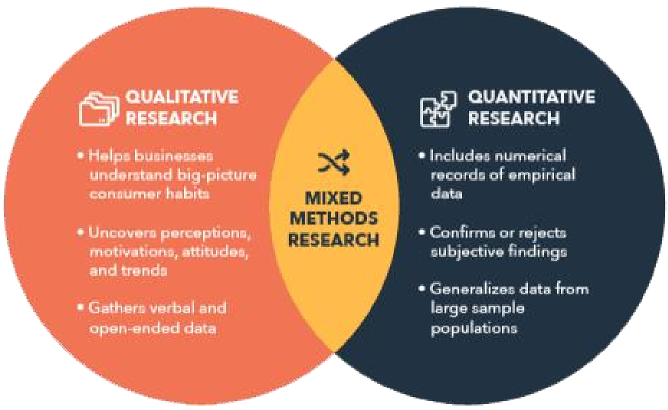
Quantitative research involves collecting information from participants in digital form, often through surveys. The resulting data is statistically analyzed to reveal trends and responses. Specific questions are posed in surveys, and data is measured using rating scales. Quantitative research emphasizes breadth, statistical description, and generality. Research employing quantitative methods seeks to achieve objectivity, control, and precise measurement (Creswell, 2000).

4.1.3 Mixed methodology

This study utilizes a mixed methodology as it integrates both qualitative and quantitative methods, providing a comprehensive and persuasive body of evidence (as illustrated in Figure 7). Mixed methodology constitutes an integrated approach to devising a comprehensive research design (Creswell & Plano Clark, 2007; Dörnyei, 2007).

Figure 7

Research approaches



Note. Amaresan, S. (2023). 5 Qualitative Research Methods Every UX Researcher Should Know. Hubspot. Retrieved May 24, 2023, from https://blog.hubspot.com/service/qualitative-research-methods

4.2 Research Tools

4.2.1 Literature Review

Literature reviews form the primary source of qualitative data collection in this study. Given the scarcity of articles on MET in the MASS era, the study involves reviewing literature on several key elements relevant to this topic. As MASS-related regulations have not been fully established by the IMO, we have expanded our understanding of this topic through examining the development of MASS, the latest comprehensive review of STCW, and the evolution of MET.

Literature reviews provide an overview that informs the reader about known and unknown aspects of a topic (Denney & Tewksbury, 2013). As stated by Ridley (2012), the literature review is where you establish the theoretical and empirical status of your chosen research topic and the methodology you will use.

4.2.2 Questionnaire

A web-based questionnaire was designed for this study, with data collected via the WJX platform (www.wjx.cn). The questionnaire was distributed to potential stakeholders related to MET in the MASS era, including but not limited to maritime authorities, METIs, IGOs or NGOs, and shipping companies.

This method provides a broad understanding of the perspectives of various stakeholders. Data is collected through the questionnaire approach and interpreted logically using appropriate scales to ensure clarity, coherence, and accuracy. The questionnaire provides clear contexts and explanations. Additionally, the inclusion of both open-ended and closed questions enhances the likelihood of collecting valid information (MERRIAM, 2009).

4.2.3 Likert Scale

Likert Scale is one of the most common types of rating summing scale. The general form of Likert Scale is five or seven points, which is used to indicate the degree of agreement or emotional intensity of the participants. Each point can reflect the intensity of positive or negative feelings towards related issues (Mcleod, 2023).

Likert Scale as one of the tools used in this study, played an important role in measuring stakeholders' acceptance of the key competency of MASS operators.The 5 point Likert Scale Questionnaire is used in this study, as shown in Table 7.

Table 7

The Classic 5 point Likert Scale Questionnaire for Survey

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
(1)	(2)	(3)	(4)	(5)

Note. Mcleod, S., PhD. (2023). Likert Scale Definition, Examples and Analysis. Simply Psychology. https://www.simplypsychology.org/likert-scale.html

4.2.4 Semi-structured Interview

The semi-structured interview is a type of exploratory interview most often used for qualitative research purposes or data collection and is one of the methods used in qualitative research. It usually follows a prior guide or outline designed to the interview and focuses on a core topic to provide an overall structure, but semi-structured interviews also allow for the discovery that this exchange of information is mutual as the conversation unfolds. One of the characteristics of a semi-structured interview is that the interviewer could have ability to change and explore different directions, including interview flexibility, while maintaining the pre-determined outline points of the interview (Hill et al., 2005; Burkard, 2014).

The author is looking for the challenges MET faced in the MASS era and how to deal with them, and it is necessary to ask directly who is involved with the MET. Taking into account research needs, interviews will be conducted with different categories of stakeholders, including METIs, seafarers, maritime authorities and shipping companies. Interviews are very helpful for the completion of the study, helping to understand the attitudes and positions of different stakeholders on this issue, as well as their concerns.

4.3 Data Presentation and Analysis

4.3.1 Questionnaire

The data of the questionnaire(Appendix 1) was collected through the WJX platform, which powered by www.wjx.cn, and sent to potential stakeholders to know their opinions and attitude. The questionnaire was divide in to three main parts. The first part is about the background information. This part is to understand the level of knowledge of MASS among those who completed the questionnaire. The second part is regarding the skills and competencies are required by MASS operators. This part is to understand the level of recognition of the relevant key competencies and skills of MASS operators. The third part is about the MET in the MASS era. This part includes the evaluation of whether the current MET can meet the requirement of MASS development and the outlook of future MET.

The questionnaire is approved by World Maritime University (WMU) Research and Ethics Committee(REC) unanimously. As the figure 9 shows, a total of 212 questionnaires were received, and all of them were aware of the use and confidentiality of the personal data filled in.

Fugure 8

Note of the Confidentiality

【Questionnaire】Maritime Education and Training (MET) in the Era of MASS

1.Whether or not you consent to the use of personal data, as outlined above, being used for this study. Are you understand that all personal data relating to the participant is held and processed in the strictest confidence and will be deleted at the end of the researcher's enrolment?

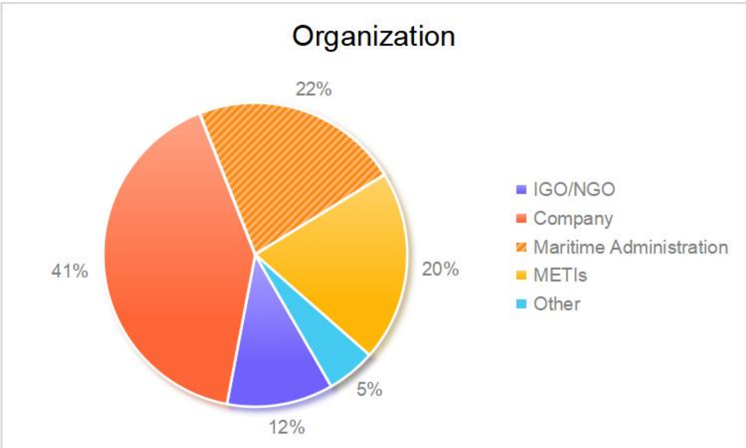
Options	Subtotals	Proportion
a. YES	212	100%
b. No	0	0%
Grand totals	212	

4.3.1.1 Profile of participants

Based on the statistics, 95% of all participants are directly related to MET, as shown in figure 10. None of the participants are without work experience. It's worth noting that the proportion of companies is large, mainly because many seafarers opted to list the shipowner's company and the ship's seafarer management company.

Figure 9

Percentage of participants' organizations



4.3.1.2 Section 1 - Background Information

This section was designed to know the participants' basic knowledge of MASS.

Figure 10 shows how participants familiar are you with Maritime Autonomous Surface Ships (MASS), with 1 point being not familiar at all and 5 point being expert.

Figure 10

Familiarity of participants with the MASS

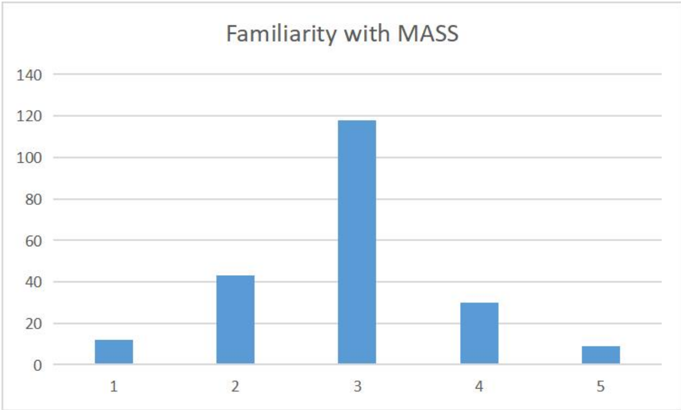


Figure 11 shows how will the MASS affect shipping in the future, with 1 point being no impact at all and 5 points being completely revolutionize shipping.

Figure 11

Most people believe that MASS will greatly affect the future of shipping

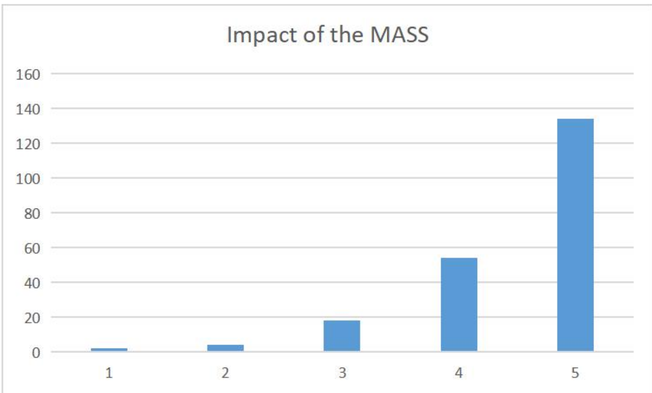


Figure 12 shows how will the MASS affect shipping in the future, with 1 point being no impact at all and 5 point being completely revolutionize shipping.

Figure 12

The importance of MET in the future of MASS

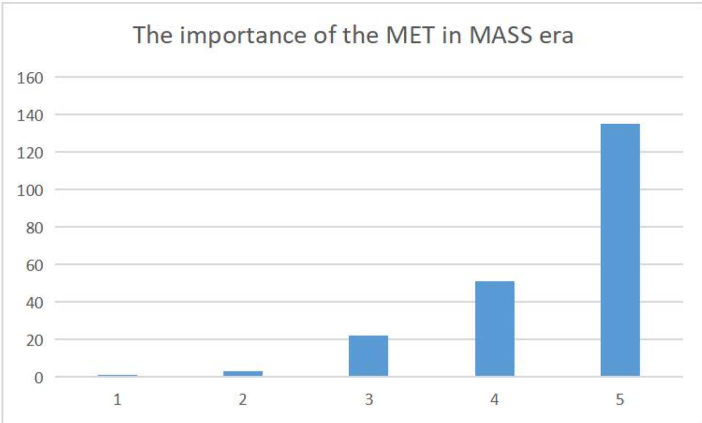


Table 8 shows impacts of MASS on the roles of seafarers.

Table 8

The support rate of the different options on the impact factors of MASS on the role of the seafarers

What do you think are the impacts of MASS on the roles of crew members?	
Options	Support Rate
a. Reduction in the number of onboard crew members	87.7%
b. Shift in responsibilities from manual to remote monitoring and control	87.7%
c. Increased emphasis on technical knowledge and skills related to autonomous systems	90.0%
d. Greater focus on cyber-security and data management	91.0%
e. Change in crew composition to include more specialized roles for MASS operations	91.0%
f. Potential for increased remote collaboration between crew members and shore-based support teams	91.0%
g. Enhanced safety due to reduced human error in ship operations	58.1%
h. Other (please specify)	3.3%

The statistical analysis of this section reveals that most respondents are aware of MASS. Likely, this is because MASS is still in its development phase, with many aspects yet to be defined, making it not widely publicized in the media and not formally included in MET. The vast majority of participants believe that MASS will significantly impact the future shipping industry. Among the options for how MASS might affect crews, technical knowledge and skills in cyber-security and autonomous systems, ship-shore interaction, and changes in crew roles had the highest levels of agreement. The prospect of reduced manning and a significant shift in responsibility from manual operations to shore-based monitoring also garnered significant support.

4.3.1.3 Section 2 - Skills and Competencies are required for MASS operators

MET's vital function is to develop competent personnel suited for the shipping industry's development, following the STCW Convention, which prescribes the minimum standards that member states and METIs must adhere to.

Regarding the future division of MASS operators, participants provided clear options, as shown in table 9.

Table 9

The traditional ship departments' future division

Do you think that future MASS operators will still be divided into traditional ship departments such as Deck and Engine?

Options	Support Rate
a. Yes, the division will remain the same	7.14%
b. Yes, but with some adjustments to accommodate MASS technology	52.68%
c. No, the roles will be more integrated and multidisciplinary	29.46%
d. No, entirely new departments and roles will emerge	6.25%
e. Unsure	4.46%

This questionnaire offered several key competencies and skills for MASS operators, based on a literature review, in the form of a Likert Scale. The participants were asked to give their opinions. The statistical results are presented in Table 10.

Table 10

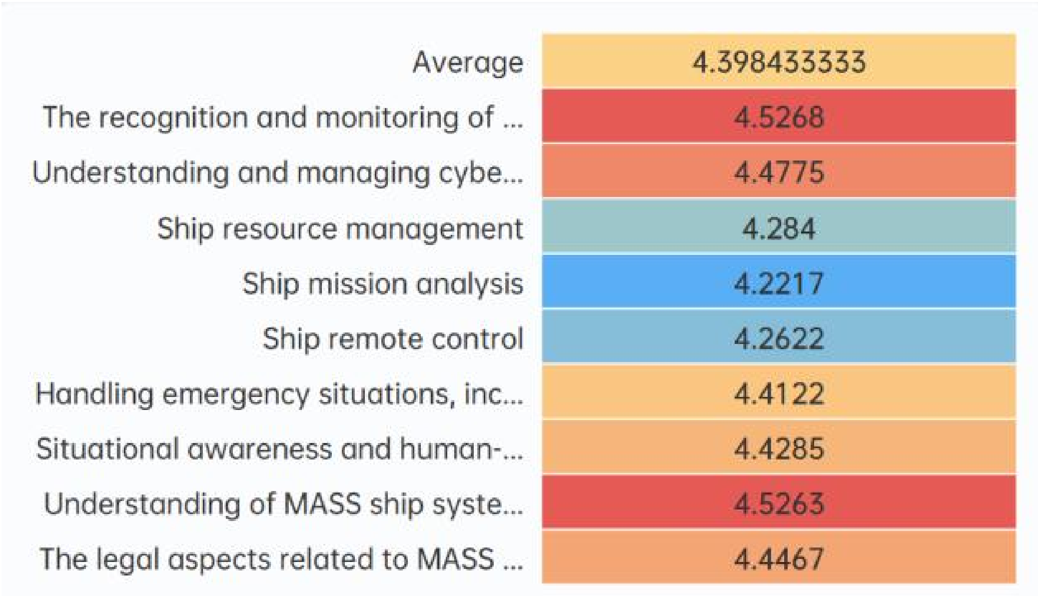
The key competencies and skills are required of MASS operators, compared with the traditional seafarers

The key competencies and skills are required of MASS operators, compared with the traditional seafarers.					
No.	Options	Sub-Options	Likert Scale (5 point)	Support Rate	Weighted Composite Value
1	The legal aspects related to MASS operations	Unnecessary	1	0.00%	4.4467
		Not need	2	1.79%	
		Neutrality	3	11.61%	
		Need	4	26.79%	
		Essential	5	59.82%	
2	Understanding of MASS ship systems for a MASS operator	Unnecessary	1	0.00%	4.5263
		Not need	2	0.86%	
		Neutrality	3	9.82%	
		Need	4	25%	
		Essential	5	64.29%	
3	Situational awareness and human-machine interaction	Unnecessary	1	0.00%	4.4285
		Not need	2	1.79%	
		Neutrality	3	10.71%	
		Need	4	30.36%	
		Essential	5	57.14%	
4	Handling emergency situations, including digital communication failures, fires and flooding, collisions, and grounding	Unnecessary	1	0.89%	4.4122
		Not need	2	0.89%	
		Neutrality	3	8.93%	
		Need	4	19.64%	
		Essential	5	66.64%	
5	Ship remote control	Unnecessary	1	0.00%	4.2622
		Not need	2	0.89%	
		Neutrality	3	20.71%	
		Need	4	29.64%	
		Essential	5	48.75%	
6	Ship mission analysis	Unnecessary	1	0.00%	4.2217
		Not need	2	1.79%	
		Neutrality	3	24.29%	
		Need	4	23.93%	
		Essential	5	50%	
7	Ship resource management	Unnecessary	1	0.00%	4.284
		Not need	2	0.89%	
		Neutrality	3	22.50%	
		Need	4	23.93%	
		Essential	5	52.68%	
8	Understanding and managing cyber-security	Unnecessary	1	0.00%	4.4775
		Not need	2	0.89%	
		Neutrality	3	10.29%	
		Need	4	29%	
		Essential	5	59.82%	
9	The recognition and monitoring of MASS status	Unnecessary	1	0.00%	4.5268
		Not need	2	0.89%	
		Neutrality	3	11.61%	
		Need	4	21.43%	
		Essential	5	66.07%	

The Figure 13 shows the average value and the weighted composite value of different options. The average value is 4.398. There are three options' scores are lower than the average: ship remote control, ship resource analysis and ship mission analysis. This result has a direct reference value for the follow-up study.

Figure 13

Weighted Composite Value Comparison



Opinions of the participants on the functional positioning of MASS operators are as the Table 10.

Table 10

The functional positioning of the MASS operators

What is your opinion on the functional positioning of MASS operators?

Options	Support Rate
a. MASS operators should primarily focus on remote monitoring and control	69. 64%
b. MASS operators should be able to perform both traditional and MASS-specific tasks	69. 64%
c. MASS operators should specialize in one area (e.g., navigation, engineering) but have a basic understanding of all areas	75. 00%
d. MASS operators should have a multidisciplinary skill set that covers all aspects of ship operations	76. 79%
e. MASS operators should work closely with other maritime professionals, such as traditional ship crew members, to ensure smooth operations	75. 00%
f. Other	0. 00%

Suggestions from the participants regarding competency for MASS operators are as the Table 11.

Table 11

The suggestions on the competency for MASS operator

What suggestions do you have regarding competency for MASS operators?	
Options	**Support Rate**
a. Strong technical knowledge of MASS systems	80. 36%
b. Extensive maritime experience in both traditional and autonomous ships	90. 18%
c. Proficiency in cyber-security and data analysis	77. 78%
d. In-depth understanding of maritime regulations and safety protocols	76. 79%
e. Ability to adapt and learn new technologies quickly	76. 79%
f. Strong communication and teamwork skills for remote collaboration	83. 04%
g. Ability to handle high-pressure situations and make decisions under uncertainty	69. 64%
h. Other (please specify)	0. 00%

This section is one of the core parts of this questionnaire, with quantitative research on the competencies and skills MASS operators should have. It provides support for formulating MET strategies and solutions in the future.

4.3.1.4 Section 3 - Maritime Education and Training (MET)

When asked to what extent MET resolves technical issues in MASS operations, approximately 60% responded negatively, and an additional 20% were unfamiliar with it. The three main challenges identified by respondents were outdated curricula, lack of training for instructors, and limited resources. Resistance to change received the least amount of support, indicating a willingness within the shipping industry to actively adapt and respond to technological innovations.

This questionnaire also queried the implementation of new technologies in MET to better support the advent of MASS. The results are displayed in Table 12.

Table 12

The use of new technologies in MET to better support the arrival of MASS

Which emerging technologies do you think will be utilized in MET to better support the arrival of the MASS era?

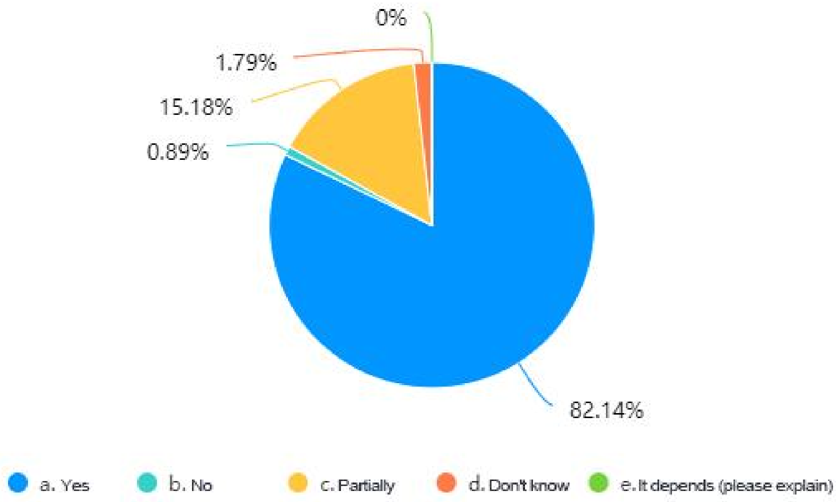
Options	Number	Support Rate
a. Virtual reality (VR) and augmented reality (AR) in training simulations	208	98.11%
b. Artificial intelligence (AI) and machine learning for personalized training	176	83.02%
c. Remote and online training platforms	108	50.94%
d. Advanced data analytics for performance assessment	94	44.34%
e. Collaborative robots (cobots) for hands-on training	38	17.92%
f. Other (please specify)	0	0.00%

Advanced navigation systems, AI and machine learning, and cyber-security are the top three areas that should be incorporated in MET for better MASS operations.

Simulators are widely recognized tools to enhance MET in the MASS era, but certain considerations must be made in their usage. Industrial partners should collaborate in the development of MET projects. Over 70% of participants agreed that the competency of MASS operators could be evaluated through the use of simulators, on-the-job performance, and continuous assessment. Notably, over 80% of participants concurred on the need to harmonize training standards for MASS operators across the shipping industry, as shown in Figure 14.

Figure 14

Support rate to standardizing the approach to MASS operator training.



This section represents another core part of this questionnaire, conducting qualitative research on MET issues in the MASS era, understanding the current alignment between MET and MASS, and identifying specific challenges in current MET development. Valuable information regarding future improvement measures was also garnered through the questionnaire.

4.3.2 Semi-structured interview

The semi-structured interview is the primary qualitative research method used in this study. To gain a more comprehensive understanding of MET stakeholders' views on MET in the MASS era, semi-structured interviews were designed with a common yet differentiated outline for METIs, seafarers, maritime authorities, and shipping companies, as displayed in Appendix 2-1, 2-2, 2-3 and 2-4. The WMU REC unanimously approved the semi-structured interview outline. A summary of representative responses will follow.

4.3.2.1 Semi-structured interview to the METI

Ten METI members were selected, including professors, teachers, and instructors, with an average working tenure of 8 years, ensuring the high reliability and validity of the interview results.

In the eyes of METI members, it's time for change in MIT. MASS implementation will occur, but it won't happen overnight. It will be a protracted process where ships are managed by both on-board and onshore operators as their autonomous navigation capabilities gradually increase. The absence of clear standards is a challenge in the current MET development. Furthermore, the shipping industry needs greater public visibility to attract younger individuals and increase their interest in the industry. The societal needs and mental health of MASS operators should also be considered in MET development. METIs must conduct more research on the impact of MASS on MET and develop long-term strategic plans. Facilities and equipment for education and training need to be upgraded in line with MASS. A MASS-themed MET alliance should be established.

Attention should be paid to the training, qualifications, competency, and watch-keeping standards of MASS operators. For on-board MASS operators, understanding the principles and limitations of autonomous navigation, mastering operational technology, enhancing communication abilities with shore-based personnel, and managing their physical and mental health are necessary. For onshore operators, mastering laws and regulations related to MASS, mastering remote ship operation technology, developing abilities to perceive on-site environments, and improving communication with ship personnel are critical.

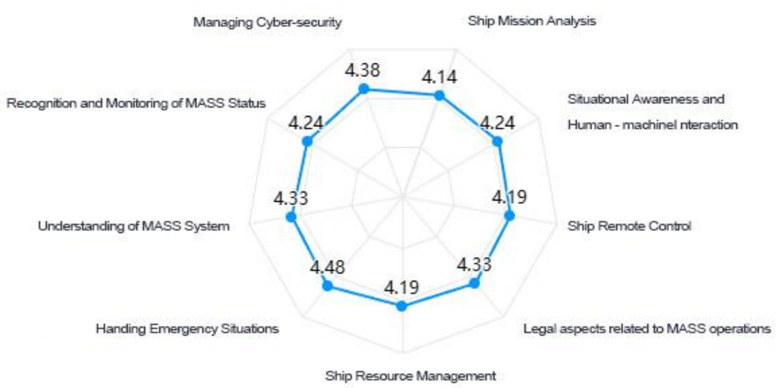
4.3.2.2 Semi-structured interview to the seafarer

Ten seafarers were selected, including masters, officers, and ratings, with an average onboard tenure of 16 years, ensuring high reliability and validity of the interview results.

The advent of new technologies has significantly impacted the work style and living conditions of seafarers on board. These technologies have improved work efficiency, reducing the workload and work-related stress for seafarers. The availability of high-speed internet has made work on board resemble onshore work more closely. Enhanced autopilot safety reduces mental stress for seafarers during watchkeeping and avoidance maneuvers. The results are shown in Figure 15.

Figure 15

Radar map of the weighted composite value of the the key competencies and skills are required.



The seafaring profession will undergo substantial changes. Automation technology and remote control will drastically reduce crew workloads, but this will necessitate greater abilities and standards from seafarers. As seafarers are progressively relocated to shore, acquiring advanced knowledge and skills becomes paramount. The advent of MASS is likely to attract more women to the shipping industry, resulting in significant changes in the gender, age, and knowledge structure of seafarers. During the interviews, some expressed concerns about future career development.

4.3.2.3 Semi-structured interview to the shipping company

Three respondents were selected, two from China (including one from Hong Kong) and one from Denmark. The interview results maintain relatively high reliability and validity.

Despite the growing acceptance of MASS in commercial operations, traditional seafarers currently operate the majority of fleets. The international maritime industry is focusing intensely on timely ship schedules and strict international carbon emission requirements. Port state control officers place significant emphasis on personnel-related inspections. The introduction of MASS could address these challenges. Cybersecurity has become increasingly important, with companies investing heavily in this area. Shipping companies are eager to cooperate and communicate with METIs and maritime authorities, and express their industry opinions during the development of MASS regulations.

4.3.2.4 Semi-structured interview to the maritime authority

Five respondents form different agencies of China MSA were selected, with an average working life of 9 years. The respondents are working in the field regarding smart ship or seafarers management. The interview result has relatively high reliability and validity.

The emergence of MASS puts forward new requirements on the knowledge and skill structure of sailors. In the future, sailors should master the knowledge of computer, communication, network security, etc., and have strong fault identification and judgment ability. MASS will bring changes to the original MET system, which was based on crew position responsibilities and competency requirements. At present, China Maritime Safety Administration has issued Interim Rules for Autonomous Navigation Test Technology and Inspection of Ships (2023) to supervise the trial voyage and inspection of MASS. The IMO instruments related to MASS are still under formulation, so it is still in the research stage in many aspects. At present, the UK, France, Russia, Japan, South Korea and other countries are active in the IMO. China maritime safety Administration should pay close attention and learn from each other. To better serve the development of MET and MASS trials in precondition of the safety. In the short term, the shipping industry, including the operation of MASS ships, relies on traditional seafarers. In the long term, it is inevitable that MASS shore-based operators will replace traditional seafarers.

4.4 Chapter summary

This chapter reviews the methods and tools used in this study, focusing on the process, data, and analysis of questionnaires and semi-structured interviews used. The two dimensions of reliability and validity are ensured that the information obtained could contribute to the study and recommendation.

Chapter 5. Developing Solutions for MET in the Era of MASS

Through the questionnaire survey and semi-structured interviews, it became apparent that the STCW Convention and Code serve as a guiding beacon for traditional MET. The IMO RSE has prioritized discussing the STCW Convention and Code. As the STCW Convention and Code enter a new round of comprehensive review, the roles and competencies for MASS operators remain unaddressed in the current version.

Currently, a non-mandatory MASS Code is under discussion in a joint working group. However, a clear path for MET development cannot be directly extracted from existing IMO instruments. This chapter, building upon the insights from Chapters 2, 3, and 4, will aim to define the functions of MASS operators in line with the STCW Convention, and attempt to develop a new competency module. This new standard of competence is likely to provide useful reference for the development of MET in the era of MASS.

5.1 Role of duty and competency requirements of MASS operators

As MASS continues to evolve, the shipping industry's expectations regarding seafarers' skill sets and knowledge structures will increase. Given the IMO's classification of varying degrees of MASS autonomy, MASS development is a progressive process, and different levels of autonomy demand varied comprehensive competencies from seafarers, as illustrated in Table 13.

Table 13

Responsibilities and competencies required for different stages of development of MASS

Autonomy Level	Role of Duty	Responsibilities	Key competency requirements
L1	Traditional seafarers	Responsibilities of the traditional seafarers	The competency of seafarers under the STCW Conventions and Code.
L2	Ship-based MASS Operators	The routine maintenance, emergency repairs, and emergency operations of ships	The competency of ship navigation management, maintenance and repair, cargo stowage and management, etc. They should know both routine maintenance and emergency repair of machinery and knowledge of ship navigation to achieve the competency required by STCW Convention and Code.
L2/L3/L4	Shore-based MASS operators	Responsible for the remote operation of the vessel	Proficiency in professional maritime knowledge and a thorough understanding of sensors, IoT, and related technologies are essential for individuals to remotely operate ships using computer technology, automatic control systems, and big data analysis. The competency of leveraging information and data acquired from these technologies to effectively remote control and navigate the vessel.
		Responsible for quick maintenance and repair of the vessel	Proficiency in ship propulsion systems, auxiliary machinery, electronic equipment, communication and navigation devices, as well as knowledge of network and information security, while ensuring compliance with established safety protocols.

5.1.1 Level 1 - Ship with Automated Processes and Decision Support

At the initial stage of MASS development, ships are equipped with automated processes and decision support, yet seafarers remain necessary. These ships are capable of autonomous navigation under seafarers' supervision and can be overridden by seafarers at any time. Consequently, the basic knowledge and skills of seafarers align with the current requirements of the STCW Convention and Code.

5.1.2 Level 2 - Remotely Controlled Ships with Seafarers on board

At the second stage of MASS development, shore-based intelligent sensing and remote communication systems can monitor the ship's marine environment and operate its navigation. While crew numbers will decrease, seafarers necessary for safety in the event of system failure remain crucial. The roles of traditional seafarers will split into on-board support and on-shore control, each demanding distinct knowledge and skill requirements.

- Ship-based MASS Operator: At this stage, ship-based MASS operators must meet the knowledge and performance standards of the seafarers from the first stage. They should possess an in-depth understanding of foundational theoretical knowledge in areas such as artificial intelligence, IoT, intelligent sensing, and control theory. They should also be proficient in operating intelligent devices on board and possess skills to troubleshoot intelligent system faults. With these competencies, they can effectively contribute to the operation and maintenance of intelligent equipment on board.

- Shore-based MASS Operator: At this stage, shore-based MASS operators should master not only the basic professional knowledge of navigation but also have a deeper understanding and application ability of intelligent technology. They should especially understand the MASS system, data communication, security and environmental protection, human perception and human-machine interaction, and emergency handling.

5.1.3 Level 3 - Remotely Controlled Ships without Seafarers on board

In this stage, ships operate without seafarers on board, achieving a high degree of ship-shore information integration, covering areas such as ship navigation, berthing, cargo handling, and port management. Traditional seafarers are entirely transferred to shore roles, and on-board auxiliary and security tasks are performed by robots. In addition to traditional navigation knowledge and skills, seafarers at this stage also need to master computer application knowledge, control theory, control engineering, AI, and other skills related to remote control operation. They need a deep understanding of IoT, AI, control, and other disciplines to correctly identify system operations, troubleshoot early, and ensure navigation safety.

5.1.4 Level 4 - Fully Autonomous Ships

This level represents the final form and objective of MASS. Intelligent systems on these ships possess autonomous learning abilities comparable to the human brain, enabling completely autonomous navigation, berthing, and port operations without the need for personnel control. At this stage, operators may take the following forms:

- The Pilot: These individuals are on board during new ship sea trials and when MASS requires manual operation at certain ports where independent sailing is not possible. They possess the same knowledge and skills as traditional navigation pilots and must meet the STCW Convention and Code requirements for corresponding positions.
- Shore-based Support Staff: There may be various types of such personnel, such as emergency remote maintenance and repair engineers, cargo stowage and cargo management operators, marine accident management experts, etc. The determination and specific requirements for these roles should be based on the development and operation of MASS, along with a comprehensive consideration of the development of the shipping industry.

5.2 The standard of competence the shore-based MASS operators

For MASS shore-based operators, in addition to the competency required for masters and officers by existing conventions and regulations, they must also possess specific knowledge, understanding, and demonstrated skills. They must have proficiency required to properly perform MASS operation functions. This forms the standard of competence for MASS operators.

5.2.1 Mandatory standards of STCW Conventions and Code

Section A of the STCW Code contains mandatory provisions specifically referenced in the annexes to the amended STCW Convention. These provisions require parties to maintain minimum standards for full and complete implementation of the Convention. They also establish the competency standards that applicants must demonstrate for issuing Certificates of Competency (CoC) under the STCW Convention and for revalidation of the CoC.

To clarify the link between the standards for alternative certification in Chapter VII of the STCW Code and the certification requirements in Chapters II, III, and IV, the STCW Code categorizes the abilities specified in the standard of competence into seven functions:

・Navigation

・Cargo handing and stowage

・Controlling the operation of the ship and care for person on board

・Marine engineering

・Electrical, electronic and control engineering

・Maintenance and repair

・Radiocommunication

Simultaneously, the STCW Code classifies seafarers into three levels according to their responsibilities:

・Management level

・Operational level

・Support level

Under the present and predicted circumstances, shore-based MASS operators are expected to hold roles equivalent to masters or officers in charge of watchkeeping. Consequently, the minimum standard of competence for officers in charge of a navigational watch serving on ships of 500 gross tonnage or more, as well as for masters and chief mates on similar vessels, outlined in Section A-II/1 and A-II/2 of the STCW Code, should be encompassed within the competency standards for shore-based MASS operators.

Upon reviewing Section A-II/1 and A-II/2 of the STCW Code, it is found that the functional categories of the minimum competency standards for both management level and operational level outlined in Table A-II/1 and Table A-II/2 are identical. They encompass navigation, cargo handling and stowage, and controlling the operation of the ship and care for persons on board. Under these three functions, a total of 20 competencies are covered at the management level and 19 at the operational level, as shown in Table 14.

Table 14

The function and competence at the operational level and management level

Function	Competence	
	Operational Level	Management Level
Navigation	Plan and conduct a passage and determine position	Plan a voyage and conduct navigation
	Maintain a safe navigational watch	Determine position and the accuracy of resultant position fix by any means
	Use of radar and ARPA to maintain safety of navigation	Determine and allow for compass errors
	Use of ECDIS to maintain the safety of navigation	Coordinate search and rescue operations
	Respond to emergencies	Establish watchkeeping arrangement and procedures
	Respond to a distress signal at sea	Maintain safe navigation through the use of information from navigation equipment and system to assist command decision making
	Use the IMO Standard Marine Communication Phrases and use English in written and oral form	Maintain the safety of navigation through the use of ECDIS and associated navigation systems to assist command decision making.
	Transmit and receive information by visual signalling	Forecast weather and oceanographic conditions
	Manoeuvre the ship	Respond to navigational emergencies
		Manoeuvre and handle a ship in all conditions
		Operate remote controls of propulsion plant and engineering systems and services
Cargo handing and stowage	Monitor the loading, stowage,securing, care during the voyage and unloading of cargoes	Plan and ensure safe loading, stowage, securing, care during the voyage and unloading of cargoes
	Inspect and report defects and damage to cargo spaces, hatch covers and ballast tanks	Assess reported defects and damages to cargo spaces, hatch covers and ballast tank and take appropriate action
		Carriage of dangerous goods
Controlling the operation of the ship and care for persons on board	Ensure compliance with pollution prevention requirements	Control trim, stability and stress
	Maintain seaworthiness of the ship	Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea, security and the protection of the marine environment
	Prevent, control and fight fires on board	Maintain safety and security of the ship's crew and passengers and the operational condition of life saving, fire-fighting and other safety system
	Operate life-saving appliances	Develop emergency and damage control plans and handle emergency situations
	Apply medical first aid on board ship	Use of leadership and managerial skill
	Monitor compliance with legislative requirements	Organize and manage the provision of medical care on board
	Application of leadership and team-working skills	
	Contribute to the safety of personnel and ship	

For each competency, a corresponding minimum level of KUPs required for certification is defined. These KUPs reflect the knowledge level necessary for seafarers to carry out their duties. For example, for an officer at the operational level responsible for a navigational watch, 66 KUPs are included within the 19 competencies.

5.2.2 Development of new function and corresponding standards of competence for shore-based MASS operators

As automation within MASS escalates, navigational risks such as collisions and groundings are likely to decrease. Meanwhile, non-navigational risks such as fire and flooding will potentially increase. Moreover, heightened on-board automation and digitization bring with them vulnerabilities, increasing the risk of cyber-attacks on MASS. Therefore, the ability of shore-based MASS operators to understand systems and their interactions comprehensively and systematically becomes critical. They need to comprehend the complexity of systems, assess the interrelationships between subsystems, and form the most effective decision and action plan.

Compared to traditional seafarers, shore-based MASS operators should not only meet the competency requirements for a master and officer as outlined in the previous section but also possess the standard or level of MASS-specific KUPs necessary to appropriately perform the functions of operating and monitoring MASS.

To develop new competency standards for shore-based MASS operators, this study utilizes a mix of tools, including literature review, questionnaire survey, and semi-structured interview. Based on the findings from the literature review, questionnaire survey, and expert interviews, the author identified the need to add a new function module within the existing competency standards outlined in the STCW Code. This addition ensures consistency and relevance to the STCW Convention and Code. The 8th function module, tentatively named "Remote Control Engineering," augments the original seven functions to eight. Considering that the primary responsibilities of the

"Remote Control Engineering" function are fulfilled by shore-based MASS operators, it is recommended that this function be applicable only to management-level and operational-level positions. The standard of competence includes knowledge of conventions and regulations related to MASS, understanding of MASS systems, recognition and monitoring of MASS status, managing cybersecurity, situation awareness and human-machine interaction, and emergency situation handling, as detailed in Appendix 3.

5.2.3 Training for the shore-based MASS operators

Any shift in industry inevitably leads to a transformation in the education model. Developments in MASS technology and operational models will undeniably impact MET. Current MET models and content are insufficient for meeting the training needs of shore-based MASS operators. These operators must undergo thorough theoretical and practical training to acquire the necessary knowledge and skills to perform their duties effectively.

5.2.3.1 Current stage shore-based MASS operators entry qualifications

Most MASS projects are still in the pre-testing phase, with a significant distance from commercial operation. However, the MASS industry has been gradually shifting from a technology- and policy-oriented focus to a market-oriented one in recent years. MASS projects represented by the European container ship "Yara Birkeland" and China's container ship "ZHI FEI" have started exploring commercial applications. These projects are expected to establish a unique market operation mechanism for MASS in the future. In light of this, there is an urgent need to determine the entry qualifications for MASS operators at this stage.

The China Classification Society (CCS) (2018) explicitly states in its GUIDELINES FOR AUTONOMOUS CARGO SHIPS 2018 that ship remote operators should hold master or deck officer certificates, be familiar with the ship's performance and operation, and be verified through practical operation. Given that seafarers possess most of the necessary skills and experience for ship operation, the ABS suggests that experienced masters and deck officers could be prioritized as the first shore-based operators during the initial phase of MASS. DNV also clearly stated that Remote Control Center (RCC) operators need to have seagoing ship crew qualification certificates. From a semi-structured interview, it was learned that the shore-based MASS operator of the "ZHI FEI" was a master.

It is generally believed in the shipping industry that currently and for a long period of time in the future, the shore-based MASS operators will be the in-service seafarers who hold the CoC for master or officer. The object of study in this section is limited to the master or officer who are transferred to shore-based MASS operators.

After the broad application of MASS, shore-based MASS operators may come from three primary sources: First, graduates of maritime colleges and universities who, after completing relevant courses and training, obtain a bachelor's degree and a second/third officer certification. Second, college graduates with engineering degrees but no crew certification, who have received undergraduate postgraduate education and earned corresponding degrees in MASS-related majors. Third, serving seafarers holding various CoCs, who may or may not have a bachelor's degree. After completing specialized training related to the operation and management of MASS, they meet the requirements of the corresponding functions.

5.2.3.2 Training program and curriculum for shore-based MASS operators

In light of the existing traditional MET curriculum's deficiency in covering the new knowledge and technology associated with MASS, the developmental needs of MASS cannot be fully met (Deling et al., 2020). Given that shore-based MASS operators are currently selected from the ranks of masters or officers, the focus of training for these operators should be on acquiring additional competencies. This necessitates the creation of a new curriculum, incorporating subjects such as MASS regulations, an overview of MASS systems, recognition and monitoring of MASS status, automation systems, mechatronics integration, human-machine interaction, and fundamentals of cyber-security.

Moreover, it is imperative to augment the training hours dedicated to MASS simulators. This training should be primarily centered on the remote operation of MASS, firefighting protocols, and strategies to tackle unexpected events. Driven by these factors, the author has endeavored to create a training course outline, exclusively designed for remote MASS operators at this stage. Detailed information about this course outline can be found in Appendix 4.

5.2.3.3 Training and internship records for shore-based MASS operators

Every trainee enrolled in shore-based MASS operation training should adhere to a standard format for maintaining training and internship records. The training records, at a minimum, should comprise the subjects of training, course content, location of training, dates of training, and instructors' signatures.

Internship records pertinent to shore-based MASS operations should at least encompass internship certification, details such as date, vessel, location, operation, duration or voyage in the internship record, as well as the trainee's internship experience and supervisor's assessment.

5.2.3.4 Examination and assessment of MASS operators

Owing to the diverse operational modes that can be utilized by MASS, assessments of shore-based MASS operators must be administered separately for each operational mode to ensure they possess the requisite knowledge and skills for their duties. The examination should predominantly include objective questions, supplemented by subjective ones, and should employ computer-based testing to preclude the need for paper. Evaluations should be conducted using simulators, in accordance with the respective assessment procedures. For a comprehensive evaluation of the shore-based MASS operators, the operations of MASS should be broken down into multiple components, and the handling and operations of each part should be evaluated. This systematic assessment process of the shore-based MASS operators guarantees a thorough evaluation of their knowledge and ability to execute specific tasks in various modes of operation, aiding in determining their aptitude to operate and manage the MASS effectively under diverse circumstances.

5.2.3.5 Chapter summary

Based on the literature review in Chapter 2, the identification of challenges faced by MET in the MASS era in Chapter 3, the method introduction and data display analysis in Chapter 4, this chapter attempts to provide development methods for MET in the MASS era. Considering the inseparable relationship between the STCW Convention and MET, this chapter takes the STCW Convention as the starting point, attempts to develop suitability standards of competences for MASS remote operators, and tries to develop a corresponding course outline. It is hoped that these two tools can provide useful references for MET to deal with the challenges brought by MASS.

Chapter 6. Policy Recommendation

As per the research and analysis, the evolution of MET calls for collaborative efforts from all stakeholders to foster cooperation, thereby ensuring a sustainable supply of competent maritime talents for the shipping industry in the MASS era. The recommendations from the study are as follows.

6.1 Recommendation to the METI

In order to meet the evolving needs of MASS development, the incorporation of new knowledge and technology related to MASS into the MET curriculum is essential (Deling et al., 2020). There is a need for a shift in the current teaching paradigm at METIs. Future maritime talents will not only serve as seafarers or MASS operators, but also occupy a variety of new roles arising from the evolution of MASS and the emergence of new business models. METIs are tasked with the responsibility of educating highly qualified individuals for these prospective roles. This necessitates an educational paradigm shift to adapt to the intricacies of emerging maritime occupations. Subjects such as data analysis, artificial intelligence, cyber-security, and Internet of Things should be incorporated into the curriculum. Current instructors need to possess an understanding of MASS to impart relevant skills and knowledge effectively. METIs will play a crucial role in shaping a new generation of maritime professionals proficient in leveraging technology to enhance operational efficiency and safety in the maritime sector.

A significant change is also required in the facilities and equipment used for MASS training, particularly in the development of new simulators or upgrading of existing ones. Incorporation of technological concepts such as augmented reality (AR), virtual reality (VR), and the metaverse can significantly enhance training outcomes. It is noteworthy that the progression of MASS is gradual and traditional MET teaching facilities and equipment continue to be beneficial, especially for enhancing students' practical abilities and perception of the maritime environment.

METIs should study the trajectory of MET development in the MASS era, adhering to the relevant provisions of the STCW Convention and Code, and based on the IMO Model Course. They should also actively participate in international organizations such as the IAMU and the International Maritime Lecturers Association (IMLA). Engaging with these global platforms allows METIs to learn from advanced practices and experiences, thereby better serving the development of their respective national MET.

6.2 Recommendation to the seafarer

As the primary human resource in the shipping industry, seafarers need to adapt to the changing landscape in the MASS era. Technological innovations and industry developments necessitate a shift in seafarers' career perceptions, from being mere workers to becoming thinkers. Seafarers must adopt a forward-thinking approach and prepare for potential career changes. They need to embrace the concept of lifelong learning, continually updating their knowledge and skills in line with technological advancements (Dehmel, 2006). Emphasis should be placed on enhancing comprehensive skills, particularly interdisciplinary learning abilities and communication skills. A strong safety consciousness and adherence to international conventions and national legislation are imperative. Seafarers must professionally operate MASS ships and be prepared to respond to emergencies.

6.3 Recommendation to the Maritime Authority

The advent of MASS has brought transformative changes to the maritime sector, with both challenges and opportunities arising for the entire shipping industry. Maritime authorities should fulfill their responsibilities to ensure this transition happens smoothly, safely, and for the benefit of all stakeholders.

Authorities need to establish a comprehensive regulatory framework for the implementation of MASS, addressing safety and maritime environmental protection concerns. These regulations should retain flexibility to accommodate technological advancements while guaranteeing compliance with established standards. There should be a focus on bolstering international cooperation, actively participating in the IMO process of formulating legal instruments pertaining to MASS, and sharing best practices and insights. Communication with METIs, seafarers' unions, and shipping companies should be strengthened to build a platform for all stakeholders to exchange information, promoting the development of MASS standards and MET. Maritime authorities also need to draft long-term strategies to guide the industry's growth. In allocating resources, the needs of METIs should be fully considered, along with the potential impact of key MASS technologies on seafarers' career progression and the maritime labor market.

6.4 Recommendation to the shipping company

As direct beneficiaries of MASS, shipping companies are acutely responsive to technological innovation. During the evolution of MET, shipping companies should adopt a cooperative role, vigilantly identifying and documenting shortcomings and issues needing resolution. Active communication with maritime authorities and METIs is crucial to ensure MET aligns with the needs of the shipping industry. Problems encountered in actual operations should be studied and addressed through MET to derive appropriate solutions. Shipping companies should collaborate with METIs to provide trainees with internships in the RCC.

6.5 Chapter summary

Based on the qualitative research content in the semi-open interviews and questionnaire surveys, this chapter provides policy suggestions for METIs, seafarers, maritime authorities, and shipping companies. MET is not only a tool but also an ecosystem. In the development of MET, all stakeholders need to play their respective advantages to maximize the role of MET in cultivating suitable human resources for the shipping industry. This not only concerns the future of MET and seafarers but also concerns the future of the shipping industry.

Chapter 7 Conclusion

7.1 Research summary

The maritime sector, a unique industry that underpins and stimulates development across all societal domains, stands to be significantly impacted by Shipping 4.0, a byproduct of the fourth industrial revolution, with MASS being one of the most substantial outcomes. MASS also serves as a critical driver for future growth in the shipping industry. MET, providing skilled and professional human resources to the shipping industry, is an essential yet distinct component in this equation.

This paper has reviewed several key aspects of MET in the era of MASS through literature review, including MASS's definition, classification, and regulation. It has examined revisions to the STCW Convention directly impacting MET and has explored the influence of MASS on MET. It assessed the current state of MET research in relation to MASS and selected best practices already adopted in MASS-related MET by certain countries. An analysis was carried out based on MASS autonomy levels, addressing the challenges MET faces at each stage.

Through questionnaire surveys and semi-structured interviews, this paper has sought to develop a function module and its standard of competence for shore-based operators in the MASS era, providing a course outline as a friendly reference for the future development of MET. Recommendations have been made for the four main stakeholders of MET - MET Institutions, seafarers, maritime authorities, and shipping companies - encouraging them to fulfill their roles, leverage their strengths, enhance cooperation, and collectively advance the development of MET in the era of

MASS.

7.2 Shortcoming and prospects

This paper delivers a comprehensive review of three integral elements: MASS, STCW, and MET, as well as their interrelationships. It is primarily focused on scrutinizing the challenges MET encounters in the era of MASS. Tools for MET development are offered from the perspective of the STCW, and specific recommendations are put forth from the viewpoint of MET's stakeholders.

Nevertheless, due to constraints in available information and individual capabilities, the quantity of samples and range of occupations included in the questionnaire survey may not be exhaustive, potentially leading to a less thorough analysis. The concluded key competencies may lack comprehensive and systematic representation, which could limit the formulation of competency standards for shore-based MASS operators and their course outlines. This also poses restrictions on the completeness of the recommendations. Acknowledging these limitations, the author intends to continue focusing on this area in subsequent work and research, aiming to contribute more valuable findings and outcomes.

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Appendices

Appendix 1 Questionnaire on the Maritime Education and Training (MET) in the Era of MASS

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is A Comprehensive Analysis: Confronting Challenges and Developing Solutions for Maritime Education and Training (MET) in the Era of Maritime Autonomous Surface Ships (MASS)

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will later be published online in WMU's digital repository (maritime commons) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student's name JIN Lei
Specialization Maritime Safety and Environment Management (MSEM)
Email address jinlei_msa@163.com

* * *

1.Whether or not you consent to the use of personal data, as outlined above, being used for this study. Are you understand that all personal data relating to the participant is held and processed in the strictest confidence and will be deleted at the end of the researcher's enrolment? *

○a. YES

○b. No

2. The name of your organization: *

____

3.Organization: *

○a.IGO/NGO

○b.Company

○c.Maritime Administration

○d.Maritime Education and Training Institution / Maritime University

○e.Other

Please describe in detail (If I choose option **e**, this question will come up) *

____

4.What is your position in your organization ? *

____

5.How long have you worked in your working/research field ? *

____

6.E-mail address: *

____

Section 1: Background Information

Q1. How familiar are you with Maritime Autonomous Surface Ships (MASS)? Please rate on a scale of 1-5, with 1 being not familiar at all and 5 being expert. *

○1 ○2 ○3 ○4 ○5

Q2. How do you think MASS will affect shipping in the future? Please rate on a scale of 1-5, with 1 being no impact at all and 5 being completely revolutionize shipping. *

○1 ○2 ○3 ○4 ○5

Q3. How do you think the importance of Maritime Education and Training (MET) in the future of the shipping industry in the MASS era? Please rate on a scale of 1-5, with 1 being not important at all and 5 being absolutely essential. *

○1 ○2 ○3 ○4 ○5

Q4.What do you think are the impacts of MASS on the roles of crew members? *

□a. Reduction in the number of onboard crew members

□b. Shift in responsibilities from manual to remote monitoring and control

□c. Increased emphasis on technical knowledge and skills related to autonomous systems

□d. Greater focus on cybersecurity and data management

□e. Change in crew composition to include more specialized roles for MASS operations

□f. Potential for increased remote collaboration between crew members and shore-based support teams

□g. Enhanced safety due to reduced human error in ship operations

□h. Other (please specify)

specify your description(If I choose option **h**, this question will come up) *

____

Section2：Skills and Competencies are required for MASS operators

Q1. Do you think that future MASS operators will still be divided into traditional ship departments such as engineering and navigation? *

○a. Yes, the division will remain the same

○b. Yes, but with some adjustments to accommodate MASS technology

○c. No, the roles will be more integrated and multidisciplinary

○d. No, entirely new departments and roles will emerge

○e. Unsure

Q2. Rate the significance of a MASS operator's understanding of the legal aspects related to MASS operations. Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q3. How important is the understanding of MASS ship systems for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○3

Q4. How important is the recognition and monitoring of MASS status for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q5. How important is situational awareness and human-machine interaction for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q6. How important is understanding and managing cybersecurity for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q7. How important is handling emergency situations, including digital communication failures, fires and flooding, collisions, and grounding, for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q8. How important is ship remote control as a competency for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q9. How important is ship mission analysis as a competency for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q10. How important is ship resource management as a competency for a MASS operator? Please rate on a scale of 1-10, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q11. What is your opinion on the functional positioning of MASS operators? *
(multiple choice)

□a. MASS operators should primarily focus on remote monitoring and control

□b. MASS operators should be able to perform both traditional and MASS-specific tasks

○b. Yes, but with some adjustments to accommodate MASS technology

○c. No, the roles will be more integrated and multidisciplinary

○d. No, entirely new departments and roles will emerge

○e. Unsure

Q2. Rate the significance of a MASS operator's understanding of the legal aspects related to MASS operations. Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q3. How important is the understanding of MASS ship systems for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○3

Q4. How important is the recognition and monitoring of MASS status for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q5. How important is situational awareness and human-machine interaction for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q6. How important is understanding and managing cybersecurity for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q7. How important is handling emergency situations, including digital communication failures, fires and flooding, collisions, and grounding, for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q8. How important is ship remote control as a competency for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q9. How important is ship mission analysis as a competency for a MASS operator? Please rate on a scale of 1-5, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q10. How important is ship resource management as a competency for a MASS operator? Please rate on a scale of 1-10, with 1 being not important at all and 5 being extremely important. *

○1 ○2 ○3 ○4 ○5

Q11. What is your opinion on the functional positioning of MASS operators? *
(multiple choice)

□a. MASS operators should primarily focus on remote monitoring and control

□b. MASS operators should be able to perform both traditional and MASS-specific tasks

□c. MASS operators should specialize in one area (e.g., navigation, engineering) but have a basic understanding of all areas
□d. MASS operators should have a multidisciplinary skill set that covers all aspects of ship operations
□e. MASS operators should work closely with other maritime professionals, such as traditional ship crew members, to ensure smooth operations
□f. Other (please specify)

specify describe your answer (If I choose option **f**, this question will come up) *

____

Q12. What suggestions do you have regarding competency for MASS operators? *
(multiple choice)

□a. Strong technical knowledge of MASS systems

□b. Extensive maritime experience in both traditional and autonomous ships

□c. Proficiency in cybersecurity and data analysis

□d. In-depth understanding of maritime regulations and safety protocols

□e. Ability to adapt and learn new technologies quickly

□f. Strong communication and teamwork skills for remote collaboration

□g. Ability to handle high-pressure situations and make decisions under uncertainty

□h. Other (please specify)

specify describe your answer (If I choose option **h**, this question will come up) *

____

Section 3：Maritime Education and Training(MET)

Q1. How well do you think current MET programs are adapting to the MASS? Please rate on a scale of 1-5, with 1 being not adapting at all and 5 being fully adapted. *

○1 ○2 ○3 ○4 ○5

Q2 To what extent do you believe current MET programs address the technical aspects of MASS operations? *

○a. Not at all

○b. Partially

○c. Adequately

○d. Completely

○e. Don't know

Q3. What do you think are the top 3 challenges faced by Maritime Education and Training (MET) in the MASS era? *

(Choose 3)

□a. Updating curricula

□b. Adapting teaching methods

□c. Training instructors

□d. Limited resources

□e. Resistance to change

□f. Regulatory constraints

□g. Other (please specify)

specify your description *

____

Q4. Which emerging technologies do you think will be utilized in MET to better support the arrival of the MASS era? *

(Choose 3)

□a. Virtual reality (VR) and augmented reality (AR) in training simulations

□b. Artificial intelligence (AI) and machine learning for personalized training

□c. Remote and online training platforms

□d. Advanced data analytics for performance assessment

□e. Collaborative robots (cobots) for hands-on training

□f. Other (please specify)

specify your description *

____

Q5. What additional topics should be covered in MET programs to better prepare MASS operation? *

(Choose 3)

□a. Advanced navigation systems

□b. Artificial intelligence and machine learning

□c. Cybersecurity

□d. Remote monitoring and control

□e. Ethical considerations

□f. International regulations

□g. Other (please specify)

specify your description (If I choose option **g**, this question will come up) *

____

Q6. How should MET programs be updated to accommodate MASS-related simulation exercises? *

(multiple choice)

□a. Integration of MASS-specific scenarios

□b. Upgrade simulators to include MASS functionalities

□c. Development of dedicated MASS simulation facilities

□d. Collaboration with industry partners for simulations

□e. Other (please specify)

specify your description (If I choose option **g**, this question will come up) *

____

Q7. What role should industry partners play in developing MET programs for MASS operators? *

○a. No role

○b. Advisory role

○c. Collaborative role

○d. Leading role

○e. Other (please specify)

specify your description (If I choose option **e**, this question will come up) *

____

Q8. In your opinion, how should MASS operator competency be evaluated? *

(multiple choice)

□a. Written examinations

□b. Simulation exercises

□c. On-the-job performance

□d. Continuous assessment

□e. Other (please specify)

specify your description (If I choose option **g**, this question will come up) *

____

Q9. How can international collaboration enhance MET programs for MASS operators? *

(multiple choice)

□a. Sharing best practices

□b. Joint training programs

□c. Standardizing training requirements

□d. Coordinating research efforts

□e. Other (please specify)

specify your description (If I choose option **e**, this question will come up) *

____

Q10. Should there be a standardized approach to MASS operator training across the maritime industry? *

○a. Yes

○b. No

○c. Partially

○d. Don't know

○e. It depends (please explain)

specify your description (If I choose option **e**, this question will come up) *

____

Appendix 2-1 Semi-structured Interview Outline for the METIs

WORLD MARITIME UNIVERSITY

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is A Comprehensive Analysis: Confronting Challenges and Developing Solutions for Maritime Education and Training (MET) in the Era of Maritime Autonomous Surface Ships (MASS)

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will later be published online in WMU's digital repository (maritime commons) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student's name JIN Lei
Specialization Maritime Safety and Environment Management (MSEM)
Email address jinlei_msa@163.com

* * *

Part I Background Section

What is the name of your institution? *

____

What is your position in the institution? *

____

How long have you been in this position? *

____

Part II Questionnaire Section

Q1. What do you think are the impacts of MASS on maritime education and training (MET)? *

____

Q2. What has your institution adapted to the rise of MASS technology? *

____

Q3. What new courses or training programs have been introduced to address MASS-related skills and competencies? *

____

Q4. How do you ensure that your graduates are prepared for the challenges of MASS operations? *

____

Q5. What are the key challenges your institution faces in training future MASS operators? *

____

Q6. How do you collaborate with industry partners, such as shipping companies and maritime authorities, to ensure relevant and up-to-date training? *

____

Q7. How do you assess the effectiveness of your MASS-related training programs? *

____

Q8. What are the most important skills and competences that future MASS operators should have? *

____

Q9. How do you ensure that your instructors stay updated with the latest MASS technologies and developments? [填空题] *

____

Q10. What is your predictions on the future of MET in the MASS era? *

____

Appendix 2-2 Semi-structured Interview Outline for Seafarers

WORLD MARITIME UNIVERSITY

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is A Comprehensive Analysis: Confronting Challenges and Developing Solutions for Maritime Education and Training (MET) in the Era of Maritime Autonomous Surface Ships (MASS)

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will later be published online in WMU's digital repository (maritime commons) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student's name JIN Lei

Specialization Maritime Safety and Environment Management (MSEM)

Email address jinlei_msa@163.com

* * *

Part I. Background Information Section

What is your position onboard? *

____

How long have you been onboard throughout your maritime career? *

____

How has the use of new technologies on ships changed the work and living condition of seafarers onboard? *

____

Part II. Questionnaire Section

Q1. What do you think will be the impact of MASS on seafarer careers? Please share your thoughts on both positive and negative effects. *

____

Q2. In your opinion, on a scale of 1-5, how do you rate the necessity of the following competencies for MASS operators? (where 1 is the lowest and 5 is the highest) *

	1	2	3	4	5
Understanding of the	○	○	○	○	○

Legal Aspects related to MASS Operations					
Understanding of MASS Systems	○	○	○	○	○
Recognition and Monitoring of MASS Status	○	○	○	○	○
Situational Awareness and Human-machine Interaction	○	○	○	○	○
Understanding and Managing Cybersecurity	○	○	○	○	○
Handing Emergency Situations	○	○	○	○	○
Ship Remote Control	○	○	○	○	○
Ship Mission Analysis	○	○	○	○	○
Ship Resource Management	○	○	○	○	○

Q3. What addition skills or competencies should the MASS operators have to develop to work with MASS? *

____

Q4. What suggestions or opinions do you have for MET in the era of MASS？ *

____

Appendix 2-3 Semi-structured Interview Outline for Maritime Authorities

WORLD MARITIME UNIVERSITY

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is A Comprehensive Analysis: Confronting Challenges and Developing Solutions for Maritime Education and Training (MET) in the Era of Maritime Autonomous Surface Ships (MASS)

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will later be published online in WMU's digital repository (maritime commons) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student's name JIN Lei

Specialization Maritime Safety and Environment Management (MSEM)

Email address jinlei_msa@163.com

* * *

Part I. Background Information Section

1. What is the name of your administration? *

____

2. What is your position in the administration? *

____

3. How long have you been in this position? *

____

Part II. Questionnaire Section

4. What do you think are the impacts of MASS on shipping industry, especially on the maritime training and education (MET) and crew members? *

____

5. What regulations or guidelines have been established to address MASS operations? *

____

6. How do you ensure that MASS operators and ships are in compliance with these regulations? *

____

7. What are the main challenges in regulating MASS operations? *

____

8. How do you collaborate with other maritime authorities internationally to address common MASS-related issues? *

____

9. How do you ensure that seafarers are adequately prepared for the changing job market due to MASS adoption? *

____

10. What's your prediction on the evolution of maritime regulations as MASS technology advances? *

____

11. What role do you see for maritime authorities in supporting the growth and development of the MET regarding the MASS? *

____

Appendix 2-4 Semi-structured Interview Outline for Shipping Companies

WORLD MARITIME UNIVERSITY

Dear Participant,

Thank you for agreeing to participate in this research survey, which is carried out in connection with a Dissertation which will be written by the interviewer, in partial fulfilment of the requirements for the degree of Master of Science in Maritime Affairs at the World Maritime University in Malmo, Sweden.

The topic of the Dissertation is A Comprehensive Analysis: Confronting Challenges and Developing Solutions for Maritime Education and Training (MET) in the Era of Maritime Autonomous Surface Ships (MASS)

The information provided by you in this interview will be used for research purposes and the results will form part of a dissertation, which will later be published online in WMU's digital repository (maritime commons) subject to final approval of the University and made available to the public. Your personal information will not be published. You may withdraw from the research at any time, and your personal data will be immediately deleted.

Anonymised research data will be archived on a secure virtual drive linked to a World Maritime University email address. All the data will be deleted as soon as the degree is awarded.

Your participation in the interview is highly appreciated.

Student's name JIN Lei

Specialization Maritime Safety and Environment Management (MSEM)

Email address jinlei_msa@163.com

* * *

Part 1. Background Information Section

1.What is the name of your company? *

____

2.What is your position in the company? *

____

3.How long have you been in this position? *

____

Part II. Questionnaire Section

4.How has your company adapted its operations to incorporate MASS technology? *

____

5.What are the key challenges you have faced in transitioning to MASS operations? *

____

6.How do you ensure that your MASS operators are adequately trained and prepared for their roles? *

____

7.How has MASS technology impacted the roles and responsibilities of traditional crew members? *

____

8.What are your future plans for expanding the use of MASS technology? *

____

9.How do you evaluate the cost-effectiveness and efficiency gains of using MASS technology in your operations? *

____

10.How do you collaborate with MET institutions to ensure a pipeline of skilled MASS operators? *

____

11.What strategies do you employ to address the cybersecurity risks associated with MASS technology? *

____

12.How do you maintain strong communication and collaboration between onshore and offshore teams in MASS operations? *

Appendix 3 Specification of minimum standard of competence for shore-based MASS operators in charge of remote-control engineering

Function：Remote control engineering

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
Conventions and regulations related MASS	Understand the changes in international maritime conventions and national legislation concerning the operation of autonomous vessels Familiar with the international and domestic classification of the MASS Familiar with the regulatory and legal system of MASS operations Familiar with the legislative specification and legal liability limits of the crew on the MASS of different autonomous levels Be familiar with the relationship between owners and crew of different autonomous levels	Examination and assessment of evidence obtained from one or more of the following: .1 approved in-service experience .2 approved training experience	Correctly construe conventions and regulations related to MASS
MASS system appreciating	*Composition of MASS system*	Examination and assessment of evidence obtained from one or	Correctly interpret and analyze the information obtained by the MASS

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	Explain the components and functions of the MASS system Outline the control, monitoring and safety systems of the ship and the RCC The operating procedures of functional units of ships with different degrees of autonomy are summarized List the ship and the systems RCCS use to control autonomous, remotely operated ships and their levels of autonomy Explain the performance and limitations of equipment used to avoid collisions and monitor the environment around autonomous, remotely operated ships Identify the ship's condition to minimize the risk of operating an autonomous vessel in all navigational conditions	more of the following: .1 approved in-service experience .2 approved training ship experience .3 approved simulator training， where appropriate .4 approve laboratory equipment training	system
	System integration and automatic control		Correctly interpret and analyze the information obtained from the sensor,

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	Understand the combination of sensors for automatic navigation Describe the ship's mechanical equipment, sensors, instrumentation, and control systems for autonomous or remotely operated ships and RCCS and their limitations Understand the basic terms and definitions of automatic control theory Understand the principle of automatic control Familiar with classification of automatic control tasks in navigation		and correctly interpret the principle of automatic control
	Data communication procedures and influencing factors		Correctly explain the quality and influencing factors of data

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	List the data communication carriers used between RCCS and autonomous, remote operations, and explain data communication redundancy Assess the quality (accuracy) and reliability (integrity) of data received from autonomous, remotely operated vessels Explain the consequences of not having enough bandwidth and latency List the steps taken to restore adequate data communication		communication, and take action to restore data communication
	Knowledge of engine room operations and electronic equipment Identify alarms and understand the conditions that trigger these alarms Know how different alarms are related Lists the measures to restore device functions Describes the functions of the engine room control panel		Correctly identify and interpret alarms to quickly restore equipment function
MASS status identification and monitoring	*MASS status recognition* Understand the general	Examination and assessment of evidence obtained from one or	Correctly identify the status of MASS

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	requirements of offshore ship automation systems and autonomous control Understand the problems, tasks and technical solutions of autonomous ship management Understand the principles of autonomous ship management Understand the structure and operation of Marine automatic systems Understand the limitations of automated ship systems	more of the following: .1 approved in-service experience .2 approved training ship experience .3 approved simulator training, where appropriate	
	MASS status monitoring and control Understand the task of continuous automatic monitoring and control of the status of MASS Master the technology of automatic monitoring and diagnosis of MASS status Understand the factors		Correctly carry out MASS status monitoring and control

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	that have the greatest impact on the safety of MASS Understand the automatic control technology for the structural and functional integrity of MASS Understand the automatic control of structural and functional integrity of MASS Understand the control parameters of MASS Master the technology to automatically monitor and control the movement of ships along pre-planned routes in case of adverse environmental effects Understand the possibilities and limitations of using AI elements in the field of collision avoidance Understand navigation information collection and automatic processing procedures Understand the modern communication channels and their limitations Understand the parameters used to monitor the navigational readiness of autonomous vessels		
	Interaction with VTS Master procedures for		Accurately describe the procedure for interacting with the VTS

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	interacting with VTS and search and rescue centers in daily and emergency situations Knowledge of the organization and existing international regulations on interaction with coastal State administrations in emergency situations		
Human perception and human-machine interaction	*Remote situational awareness* Explain how automation adversely affects real-time situational awareness Explain what remote situational awareness is and what is involved Explain how to establish remote situational awareness using the tools available in RCC Determine what is sufficient situational awareness to provide a solid basis for analyzing the status of autonomous, remotely operated vessels and for planning and executing operations	Examination and assessment of evidence obtained from one or more of the following: .1 approved in-service experience .2 approved training ship experience .3 approved simulator training， where appropriate .4 approve laboratory equipment training	Always maintain good situational awareness
	Resource management Explain the elements of		Make full and rational use of available resources

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	resource management in terms of RCC and autonomous, remotely operated ship operations Implement effective resource management for RCC and autonomous, remotely operated vessels		
	Human-machine interaction An overview of the differences in state perception when monitoring and steering a ship on board versus monitoring an autonomous, remotely operated ship from the RCC Explain automation awareness and trust in automation Identify the impact of data transmission on the decision-making process		Maintain a good feeling with the equipment
	IT and AI Understand the working		Ability to operate a computer at any time, understanding the

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	principle of computer, master the basic computer operation Understand the basics of AI Understand the mathematical models and hardware and software of AI Understand the implementation of AI systems Learn about examples of using neural networks to solve autonomous navigation problems Familiar with the main tasks of AI prediction and decision making Identify the various inputs used in AI and machine learning		principles of artificial intelligence
Cyber-security	*Cyber-security* Interpret ISPS rules and	Examination and assessment of evidence obtained from one or	Be able to determine the level of cyber risk in MASS operations and

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	other applicable regulations regarding the security of autonomous and remotely operated vessels Understand the company's network security policy, safety management system and ship safety plan Master the issues and basic principles of protecting ship information Understand the cyber-security awareness requirements on board Understand the source of cyber-security risk for MASS Understand the main types of network security threats Identify cyber threats and potential consequences for companies and ships	more of the following: .1 approved in-service experience .2 approved training ship experience .3 approved simulator training， where appropriate .4 approve laboratory equipment training	understand the source of cyber security risks
	Cyber attack Explain the capabilities		It can explain the main types of network attacks and countermeasures

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	and vulnerabilities of autonomous, remotely operated ship systems to prevent cyber attacks Explain how a network attacker can break into the connecting systems/lines used to communicate between an RCC and an autonomous, remotely operated ship Explain the alerts representing cyber attacks in the RCC List the various signs of a cyber attack Distinguish between true and false cyber attacks / threats Explain the measures and steps to deal with cyber attacks		
Emergency situations handling	*Safety and environmental protection*	Examination and assessment of evidence obtained from one or	Quickly identify the ship, ship risk assessment, and control measures

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	Familiar with autonomous, remote operating ship SMS Interpret safety-related information received from autonomous, remotely operated vessels, including video streams Understand the risk concept of ship safety and environmental protection Familiar with safety and environmental risk assessment methods of autonomous vessels Be familiar with the risk assessment and management requirements of ISM rules Control risk measures to ensure that risk is at an acceptable level in decision making Understand the consequences of wrong actions or wrong events	more of the following: .1 approved in-service experience .2 approved training ship experience .3 approved simulator training, where appropriate .4 approve laboratory equipment training	
	Communication failure Explain the limitations of		Quickly determine the question, the type and, scope, action, in line with

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	communication and connectivity outside coastal areas This describes the safety status of the remotely operated ship after communication interruption Evaluate the consequences of communication delay and bandwidth degradation between the Rescue Coordination Center (RCC) and autonomous, remotely operated vessels Describes the procedures and measures for re-establishing communication links between RCC and autonomous, remotely operated vessels		the situation at that time
	Fire and flooding Describes sensors and		Promptly identify possible causes and damage conditions and

Column 1	Column 2	Column 3	Column 4
Competence	Knowledge, understanding and proficiency	Methods for demonstrating competence	Criteria for evaluating competence
	other means for verifying and locating fire or water flooding on autonomous, remotely operated ships Describes the layout of the fire protection system on an autonomous, remotely operated ship Describes the procedure for initiating a fire operation List water prevention devices and startup procedures		take measures to minimize losses

Appendix 4 Course outline for shore-based MASS operators in charge of remote-control engineering

Function：Remote control engineering

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
1.1Conventions and regulations related MASS	.1 International maritime conventions and national legislation concerning the operation of autonomous ships .2 International and domestic classification of the MASS .3 International and domestic classification of MASS .4 The English translation would be: "Legal norms and limits of liability for crew members on MASS at different levels of autonomy			4	0
1.2 MASS system appreciating	*.1 Composition of MASS system* .1.1 Explain the components and functions of the MASS system . 1.2 Overview of the control, monitoring and safety systems of	Be able to perform the following on board (internship) or in the laboratory (simulator) : 1. Summarize the operating procedures of functional units of ships with different	Correctly interpret and analyze the information obtained by the MASS system	10	4

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	ships and RCC	degrees of autonomy 2. Proficient in computer operation 3. Understand the meaning of signals from the engine room control panel 4. Able to master the program of device function recovery 5. Test the communication bandwidth between the RCC and the autonomous, remotely piloted vessel 6. Master the procedures for restoring data communication			
	.1.3 List ships and RCCS used to control autonomous, remote operations The system of a ship and its level of autonomy .1.4 Explain the performance and limitations of the equipment used to avoid collisions and monitor the environment surrounding autonomous, remotely operated ships				
	.2 System integration and automatic control .2.1 Understand the sensor combination for automatic navigation .2.2 Describe the ship's mechanical equipment, sensors, instrumentation and control systems for autonomous or remotely operated ships and RCCS and their limitations		Correctly interpret and analyze the information obtained from the sensor, and correctly interpret the principle of automatic control		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	.2.3 Basic terms and definitions of automatic control theory .2.4 Principle of automatic control .2.5 Classification of automatic control tasks in navigation				
	.3 Data communication procedures and influencing factors .3.1 Data used between RCCS and autonomous and remote operations Communication operators, and explain data communication redundancy .3.2 The quality (accuracy) and reliability (integrity) of data received from autonomous, remotely operated vessels .3.3 Data links between RCCS and autonomous, remotely operated vessels (bandwidth and latency)		Correctly explain the quality and influencing factors of data communication, and take action to restore data communication		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	.3.4 Consequences of insufficient bandwidth and latency .3.5 Steps taken to restore adequate data communication *.4 Knowledge of engine room and electronic equipment* .4.1 Identify alarms and understand the conditions that trigger these alarms .4.2 Understand the relationship between different alarms .4.3 This section describes how to restore device functions .4.4 Describe the functions of the engine room control panel		Correctly identify and interpret alarms to quickly restore equipment function		
1.3 MASS status identification and monitoring	*.1 MASS status recognition* .1.1 offshore ship automation systems and autonomous control .1.2 Problems, tasks and technical	Be able to perform the following on board (internship) or in the laboratory (simulator) : 1. Outline the different autonomous ship states	Correctly identify the status of MASS	12	8

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	solutions of autonomous ship management .1.3 principles of autonomous ship management .1.4 Structure and operation of Marine automatic systems .1.5 Limitations of automated ship systems *.2 MASS status monitoring and control* .2.1 Task of continuous automatic monitoring and control of the status of MASS .2.2 Technology for automatic monitoring and diagnosis of MASS status .2.3 Factors that have the greatest impact on the safety of MASS .2.4 Automatic control technology for structural and functional integrity of autonomous ships .2.5 Control parameters of	2. Master autonomous ship status monitoring technology 3. Master the control technology of autonomous ship status 4. Master the control technology of autonomous ship status	 Correctly carry out MASS status monitoring and control		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	autonomous vessel .2.6 Technology for automatically monitoring and controlling the movement of ships along pre-planned routes in the event of adverse environmental impacts .2.7 Possibilities and limitations of the use of artificial intelligence elements in the field of collision avoidance of ships .2.8 Navigation information collection and automatic processing program .2.9 Modern communication channels and their limitations .2.10 Parameters for monitoring the navigational readiness of autonomous vessels				
	.3 Interaction with VTS .3.1 Procedures for interaction with VTS and search and rescue centers		Correctly state the procedures for interacting with VTS		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	in routine and emergency situations 3.2 The organizations and current international regulations for interacting with the administrative authorities of coastal states in emergency situations				
1.4 Human perception and human-machine interaction	*.1 Remote situational awareness* .1.1 Explain how automation adversely affects real-time situational awareness .1.2 Explain what is remote situational awareness, what is included and how to establish remote situational awareness using the means available in RCC .1.3 Determine what is sufficient situational awareness to analyze the status of autonomous, remotely operated vessels and to plan	Be able to perform the following on board (internship) or in the laboratory (simulator) : 1. Ability to implement effective resource management 2. Good remote situational awareness 3. Maintain good interaction with machines and equipment 4. Can explain the role of artificial intelligence in autonomous ships	Always maintain good situational awareness	10	2

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	and execute rows Movement provides a solid foundation				
	.2 Resource management .2.1 Explain the elements of resource management in terms of RCC and autonomous, remotely operated ship operations .2.2 Implement effective resource management for RCC and autonomous, remotely operated vessels		Make full and rational use of available resources		
	.3 Human-machine interaction .3.1 Outline the difference in state perception when monitoring and operating a ship on board versus autonomous, remote operation of a ship from the RCC .3.2 Explain automation awareness and trust in automation .3.3 Identify the		Maintain a good feeling with the equipment		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	impact of data transmission on the decision-making process				
	4. IT and AI .4.1 Principle of computer operation .4.2 Basic computer operations .4.3 Basic knowledge of AI .4.4 Mathematical models, software and hardware of AI .4.5 Implementation of AI system .4.6 Using neural networks to solve autonomous navigation problems .4.7 The main task of AI for prediction and decision-making .4.8 Various inputs used in AI and machine learning		Operate a computer at any time and understand the principles of artificial intelligence		
1.5 Cyber-security	*.1 Cyber-security* .1.1 ISPS rules and other applicable regulations relating to the	Be able to perform the following on board (internship) or in the laboratory (simulator) :	Quickly identify possible causes and types and take measures to reduce losses	4	2

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	security of autonomous and remotely operated ships .1.2 Corporate Cyber-security policy, safety management system and ship safety plan .1.3 Problems and basic principles of protecting ship information .1.4 Requirements for cyber-security awareness on board .1.5 Sources of network security risks of MASS .1.6 Main types of network security threats .1.7 Potential consequences of cyber threats on companies and ships *.2 Cyber attacks* .2.1 Capabilities and vulnerabilities of autonomous and remotely operated ship systems in preventing cyber attacks .2.2 How does a cyber attacker	1. Summarize the cyber risk dentification methods of ships with different degrees of autonomy 2. Master the measures and steps to deal with cyber attacks			

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	penetrate the connecting systems/lines used to communicate between an RCC and an autonomous, remotely operated vessel .2.3 Alarm of cyber attack in RCC .2.4 Various signs of cyber attack .2.5 Real and fake cyber attacks/threats .2.6 Measures for responding to cyber attacks measures and steps				
1.6 Emergency situations handling	*.1 Safety and environmental protection* .1.1 SMS for autonomous, remotely operated ships .1.2 Safety-related information received from autonomous, remotely operated vessels, including video streams .1.3 Concept of risk in terms of ship safety and environmental protection	Be able to perform the following on board (internship) or in the laboratory (simulator) : 1. Master the risk control measures of autonomous and remote control ships 2. RCCS re-establish communication links with autonomous, remotely controlled ships	Promptly confirm ship risk assessment and control measures	8	4

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	.1.4 Methods for safety and environmental risk assessment of autonomous vessels .1.5 Requirements of ISM rules on risk assessment and management .1.6 Measures to control risks to ensure that risks are at an acceptable level in decision-making .1.7 Consequences of wrongful acts or events				
	2.Communication failure .2.1 Explain the limitations of communication and connectivity outside coastal areas .2.2 Describe the full state of an autonomous, remotely operated ship after communication interruption .2.3 Assess the consequences of communication delays and bandwidth degradation		Quickly identify the type and scope of the problem and act in accordance with the circumstances		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	between RCCS and autonomous, remotely operated vessels				
	.2.4 Describe the procedures and measures for re-establishing communication links between the RCC and autonomous, remotely operated vessels				
	.3 Fire and flooding .3.1 Describes sensors and other means for verifying and locating fire or water flooding on autonomous, remotely operated ships .3.2 Describes the layout of the fire protection system on an autonomous, remotely operated ship .3.3 Describes the procedures for remotely startup fire operations .3.4 List the devices and startup procedures to prevent water flooding		Promptly identify possible causes and damage conditions and take measures to minimize damage		

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	.4 Collision and grounding .4.1 Indicates the systems, sensors and other sources of information that autonomous, remotely operated vessels support for collision or grounding detection .4.2 Explain the alarms in the RCC that point to collision or grounding 4.3 Describe the measures to be taken in the event of a collision or grounding .4.4 Describe the autonomous, remotely operated ship systems, sensors and other sources of information available for assessing damage to the ship and other ships or objects in the event of a collision or grounding		Promptly identify possible causes and damage conditions and take measures to minimize damage		
	.4.5 Describe the sensors and information sources available to assess environmental damage in the				

Competency requirements	Theoretical knowledge and requirements	Practical skills and requirements	Evaluation standard	Total hours	
				Lecture	Practicals
	event of a collision or stranding				