Exploring Potential Job Profiles in MASS Operations:

A description of tasks, skills, and experience.

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Master's Degree Thesis

Novia University of Applied Sciences - Master's in Engineering

Autonomous Maritime Operations

Turku, November 2022

MASTER'S THESIS

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Autonomous Maritime Operations/ Aboa mare
Specialization: Master's in engineering
Supervisor(s): Ph.D. Thomas Finne

Title: Exploring Potential Job Profile in MASS Operations. A description of tasks, skills, and experience.

Date: 1 November 2022 Number of pages: 65 Appendices:

Abstract

The transition towards digitalization and automation of processes and operations to enhance efficiency, increase competitiveness, and spur industries towards the decarbonization path of net-zero emissions have initiated the emergence of the Maritime Autonomous Surface Ship (MASS) in shipping operations. The rapid pace of digital transformation and technological advancement requires training and re-training of seafarers for adaptability. A Series of research and regulatory discussions are ongoing to accommodate this changing phase of the application of digital technologies in maritime operations. This research aims to explore and identify potential competency requirements and necessary learning and training for seafarers to stay updated in the changing norm. A qualitative approach combined with desk reviews was adopted to develop a proposed competency framework, including technical and non-technical skills (soft skills) that are considered vital for MASS operations. The competency matrix summarily presented in (Figure 10), in (Chapter 5.1), could be adopted for formulating and developing training and learning for seafarers in MASS operations.

Language: English
Key Words: Maritime Operations, Autonomous, Remote Operation Centre (ROC), Remote Control Centre (RCC), Maritime Autonomous Surface Ship (MASS), Competency, Digitalization.

ACKNOWLEDGEMENT

I want to express my gratitude to everyone that supported me in one way or the other throughout the course program and while conducting this research work. I want to thank my supervisor, Ph.D. Thomas Finne for his guidance, patience, and understanding in meeting deadlines and suggesting contacts for interviews. I also thank Johanna Salokannel for providing useful sources and insights for this research and Katarina Sandstrom for her structural reviews. I equally appreciate Mr. Markku Mylly's support and suggestions, especially at the early stage of the research. I want to thank Bjorn Pundars for availing time for the interview and helping add to the thesis structure. I thank Pastor Billi Jimoh for his moral support and encouragement throughout the course program and research work. Engineer Godson Elekwuwa and Mr. Babawale Akinloye are equally not left out for lending their time and consent to be interviewed and providing valuable insights for this research work. I also express my gratitude to everyone who participated in the interview and supported me in one way or another. Finally, I appreciate my opponent Mika Irla for his constructive reviews and broader insights into this research work.

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1 Introduction

The global community is evolving; industries, markets, processes, products, social norms, and education are equally evolving in response to or as drivers of this change, including the maritime industry. One can observe the imminent changes following topical trends in the digitalization of marine operations, fostered by the new industrial revolution: industry 4.0.

Industry 4.0 represents a fourth industrial revolution that embraces intelligent complex digital technologies for the efficient interconnectivity of processes and operations (Pereira & Romero, 2017, pp. 1–2). This paradigm is predominantly shaped by the technical integration of Cyber-Physical Systems (CPS), the Internet of Things (IoT), the Internet of Services (IoS), Artificial Intelligence (AI), Robotics, Big Data, Cloud computing, and Augmented Reality (Kagermann & Wahlster, 2022). The industry 4.0 process uses devices and products that can independently exchange information, trigger actions and control each other, enabling an intelligent, holistic and better-connected system process or operation (Weyer et al., 2015, p. 2).

A significant portion of global trade is transported by sea, thus presenting the maritime industry as a critical agent of globalization. The industry, therefore, faces an inevitable but systematic change to meet global digital trends, hence the introduction of the Maritime Autonomous Surface Ship (MASS) concept, enabling a change from conventional shipping to digital shipping. The advancement of autonomous ships aims to make shipping safer, more efficient, and environmentally friendly, and responses to this change require an integrated and comprehensive approach by all stakeholders.

One primary concern vis-a-vis MASS operations is the uncertainty regarding continuous human involvement. One begins to contemplate the possibilities of job loss or human replacement in MASS operations. MASS development combines automation and considerable human involvement at varying stages of operation. In the context of vessel operations, MASS does not necessarily mean an uncrewed ship. (Chang & Huynh, 2016, pp. 1–2). Therefore, autonomy does not necessarily lead to job loss. Nonetheless, some jobs will be lost, but new job profiles requiring skill adaptation and highly skilled seafarers will be introduced.

The technology for MASS is rapidly developing, though not mainstream yet; however, more responsiveness must equally be given to skill adaptation and modification of traditional work profiles required in MASS operations. It is vital to ascertain the roles, responsibilities, learning, and competencies required in transitioning to MASS operations to ensure human-centred design for safe shipping operations. Oviatt and Rothblum opines (according to Kristoffersen, 2020, p. 1–3) that "while developing new technology, it is common to neglect the user's needs and limits". The idea that the user would adapt to the new system or design, also known as technology-driven design, can be catastrophic, especially for complex systems like ships. The "user adapts" mentality has made systems complex, and it becomes challenging for users to utilize them, often resulting in accidents attributed to human error (Endsley, Bolte & Jones, 2012). A human-centred approach is necessary to consider human involvement in the design process, given the definition and degrees of MASS and the effects on the sociotechnical system in shipping (Hynnekleiv et al., 2019).

Therefore, the purpose of this thesis is to explore possible tasks or job roles, skills and experience required in MASS operations, however, with a limitation to International Maritime Organization (IMO) definition and degrees of autonomy adopted during its regulatory scoping exercise (RSE). IMO defines MASS as "a ship which, to a varying degree, can operate independently of human interaction" with a projected four degrees of autonomy (IMO, 2018). The four degrees of autonomy will be highlighted in (chapter 2.2).

1.1 Background

The maritime industry faces an inevitable but systematic change from conventional shipping to digital shipping with the introduction of MASS. Responses to this change require an integrated and comprehensive approach involving all stakeholders. This technological evolution will essentially alter the entire shipping operations. The term shipping or maritime operations in this context includes.

i. all vessels (i.e., containers, tankers, tugs, PSVs, RO-RO, Passengers, and so on),
ii. port operations, and
iii. related activities involving the use of ships as means of transporting passengers, cargo or offshore activities.

The significant capital investments in ships and cargoes and the risks involved in transporting cargoes by sea and other marine operations have necessitated high regulations and procedures to ensure the safety and protection of lives these huge investments. This is considered to make the industry conservative and slowly receptive to rapid changes. However, the industry has evolved over the centuries from mechanically powered ship designs and propulsions, using sails, coal, and heavy fuel oils, to computerized control in the 1970s and now digital ships, emphasizing MASS (Kristoffersen, 2020, p. 3). A new era in shipping is beginning; the era of “Shipping 4.0”, where autonomous ships can be game changers, providing potentially substantial financial, sustainable, and safety benefits. (Rødseth & Nordahl, 2018, pp. 8–9).

IMO and its committees, notably the Maritime Safety Committee (MSC), are paying attention to the development of autonomous vessels, which is seen in the agenda of the MSC 98th session for a regulatory scoping exercise on MASS. Its focus was primarily on the safe, secure, and environmentally friendly operation of MASS (IMO 2018). IMO defines MASS as a ship "which, to a varying degree, can operate independently of human interaction." Highlighting the phrase 'to a varying degree' from IMO's adopted definition suggests that a considerable human interface is required at some points of the ship's operations, thus, negating the complete exclusion of humans in the operational loop. The phrase can be further understood as the ship requiring certain stages of human involvement in its operational manning or the independency of humans at complete autonomy levels (Ringbom, 2019, p. 1). This sort of clarification by IMO and other stakeholders is necessary for the standardization and taxonomy of the MASS, as it is often used to mean different concepts and contexts (Wennersberg et al., 2021, pp. 33–35).

The autonomous ship is actively being developed following research such as the Maritime Unmanned Navigation through Intelligence in Networks (MUNIN), Advanced Autonomous Waterborne Applications Initiative (AAWA) projects, Autonomous Ship Initiative for European Waters - AUTOSHIP Reference Architecture (AURA), ReVolt, and other projects. These projects have compelled the support of IMO for the realization of MASS. Some of these projects will be discussed in (chapter 2.3). It is also worth noting that autonomous ships are a developing section of maritime operations, making it a part of the whole logistics chain and technical system, even though the term autonomous ships is used in many contexts (Pundars, 2020, p. 2). However, for this research, autonomous ship (MASS) will be used to mean the ship and its support systems (the support system includes the crew, onboard and shore systems) unless otherwise stated.

One common feature of the maritime industry's evolvement over the years has been the presence of crew (seafarers) on board. They have indeed been present in their manning complements to operate these vessels with a professional and internationally approved level of competency under the IMO regulatory competency structure of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarer (STCW) (IMO, n.d.-b). These crew are awarded an internationally accepted certification, a certificate of competence, or a certificate of proficiency (COC/COP), i.e., a certificate issued after a course of study that generally leads to a new career or enhances a person's skill set in this domain. Considerably, these crew can work on various ships, in some cases with additional training such as Electronic Chart Display and Information System (ECDIS), dangerous cargo handling certification, and tanker familiarization, to list a few.

The development of MASS presents an uncertain paradigm shift from the traditional feature of a certain number of crew complements on board ships to fewer crew complements or none. This development will redesign operations and operational roles. MASS will certainly alter shipping operations, beginning with ship designs, training and competency requirements, modes of shipping cargoes, regulations, insurance, port and shore operations. The extent of benefits of autonomous ships from research is projected to reduce risks and accidents related to human error, as statistics show that human-related errors cause about 75% of most marine accidents, with fatigue and attention deficit being the leading causes (Allianz Global Corporate & Specialty [AGCS], 2019; Rothblum, 2000). MASS is also projected to provide cost-effective shipping from a commercial point of view with optimized shipping operations on capital expenditure and operational expenditure including crew cost structure (Ziajka-Poznańska & Montewka, 2021). Other benefits include spurring the industry along the decarbonization path to achieving a net-zero emissions goal by 2050 and improving reliability and efficiency for competitiveness (One Sea, 2021; Ziajka-Poznańska & Montewka, 2021). These projections are considered to set new standards and influence regulatory works to limit the industry's current challenges.

MASS is seen as a new technology in its early stages of development with an existing rational application leveraging on other industries applications such as the automotive industry with self-driving cars, the military and defense systems, and navigational aids and sensors already in use. However, it still requires a proper risk assessment, especially in safety assurance. While MASS is developing fast, much focus is being given to its technologies, but less attention is given to the human functional task or job roles and competencies required to interact with these technologies, which supports the claim of a technology-driven design made in multiple studies by Endsley et al., Kristoffersen, Oviatt, and Rothblum (Endsley et al., 2012; Kristoffersen, 2020; Oviatt, 2006; Rothblum, 2000).

MASS is not a far-fetched future concept; it is a reality, and all players in the maritime industry need to adapt to this changing norm. Therefore, how will the introduction of MASS consolidate the existing job roles and skill competencies on conventional ships? What potential roles, skills, and experiences are required? These confronting questions validate my research interest by recalling the highlighted phrase - 'to a varying degree' in IMO's adopted definition of MASS, which indicates that human involvement is required at varying operations.

1.2 Research Problem

The development of MASS is advancing faster than the user's ability to interact or utilize these technologies or systems, recalling the need for a human-centred design approach to consider human involvement in the design process, thus creating a gap in the intended definition of MASS operation. To bridge this gap, equal or active attention is necessary to develop the human competence required to interact with these systems for a comprehensive and expansive benefit of MASS and to prevent further human error.

1.3 Aim and delimitation

This research aims to narrow or eliminate the uncertainties regarding the continuous human involvement in MASS operations and propose potential job profiles (i.e., task descriptions, skills, and experiences). However, the ongoing development of MASS may limit the research scope given that some recommendations are hypothetical rather than having been tried and tested severally. Therefore, all areas of this study may not be expansively covered.

1.4 Research Questions

The following research questions are outlined and answered with supporting literature and interviews to eliminate the uncertainties regarding continuous human involvement in MASS operations and propose potential job profiles.

1. Will MASS operations require human involvement?
2. What are the required prospective job profiles (i.e., task description, skills, and experience)?

2 Theories, Definitions and Literature Reviews

This chapter discusses relevant concepts, definitions, justification, and the impact the introduction of MASS will have on the maritime industry, along with supporting literature and functionalities.

2.1 The Maritime Sector and the emergence of autonomous ships

Since historical times, the maritime sector and trade have thrived and supported social and economic development. Despite its long history, it still plays a vital role in global trade. Its activities have continued to expand efficiently with growing technologies and human resources, thus benefiting people worldwide and creating employment and career opportunities that are directly and indirectly related to the sector globally. (Wind Rose Network, n.d.). The industry is growing exponentially, and it is difficult to quantify its total value and economic relevance. However, it is necessary to carefully pay attention to its innovative demands and management structures to ensure sustainability and implement regulations and instruments to address the industry's challenges, such as climate change, marine environment protection, labor, and safety. (Wind Rose Network, n.d.).

The maritime industry comprises institutions and authorities that engage in activities ranging from transportation of humans and cargo, cruise and leisure, naval engineering, and shipbuilding. It also includes commercial fishing, port operations, maritime training, legal entities, professional services and associations, trade unions, and organizations that protect the rights and interests of seafarers and maritime professionals. The nature of the industry exposes all personnel involved to physical or commercial risks, which can result in the loss of lives, investments, cargo, equipment, and the ship, all of which are worth millions of dollars. The environment is also not left out with tons of pollution and peril to marine life. These risks have warranted an uncompromising commitment to safety across all spheres of the industry, as shipping is amongst the first industries to adopt widely implemented international safety standards because of its inherently international nature. (International Chambers of Shipping (ICS), n.d.).

IMO "is the United Nations specialized agency responsible for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships." (IMO, n.d.-c). IMO is the body of authority that sets a global regulatory standard in shipping, especially as it concerns the safety, security, and environmental performance of international shipping. Its scope includes regulations on ship design and construction, equipment, manning, disposal of vessel consumables and waste products, disposal of vessel parts, and the entire ship itself (IMO, n.d.-c). The body has since been committed to fostering and implementing sustainable shipping trends in green energy, maritime education and training, development of marine infrastructure, and technological innovation, such as MASS. Hence,

> IMO seeks to integrate new and advancing technologies with safety and security, environmental concerns, international trade facilitation, and impact on personnel into its regulatory frameworks to balance the benefits derived from new technologies. It, therefore, ensures that the regulatory frameworks for MASS keep pace with rapidly evolving technological developments. (IMO, n.d.-a).

Several conventions under the auspices of IMO regulate shipping operations. These conventions are categorized mainly into safety, prevention of marine pollution, and liability and compensation (IMO, n.d.-d). These conventions are being adapted and adopted to determine the operability of MASS. Progressively, IMO recently completed a regulatory scoping exercise (RSE) on MASS, adopting a series of its conventions as instruments for this exercise (IMO, 2021). The RSE for safety concerns on MASS was finalized at the 103rd session of the Maritime Safety Committee (MSC) in May 2021, and for legal concerns, in July 2021 (IMO, n.d.-a). The table below shows a limited categorized list of conventions adopted by IMO for the RSE.

Table 1: A Limited Categorized List of IMO Convention

Categories	Convention	Function
Safety	International Convention for the Safety of Life at Sea (SOLAS)	Specifies minimum standards for ships' construction, equipment, and operation, compatible with their safety.
	International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW)	Establishes basic or minimum requirements relating to training, certification and watchkeeping for seafarers on an international level.
	Convention on the International Regulations for Preventing Collisions at Sea (COLREG).	Guides collision avoidance (determining safe speed, the risk of collision, and the conduct of vessels operating in or near traffic separation schemes).
	International Convention on Maritime Search and Rescue (SAR).	Develop an international SAR plan for the search and rescue operation of persons in distress at any location.
	Safety of Fishing Vessels (SFV)	Concerned with safety requirements for equipment and construction of seagoing fishing vessels of over 24 metres, including vessels processing their catch, while recognising the differences in design and operation from other ships.
Prevention of marine pollution	International Convention for the Prevention of Pollution from Ships (MARPOL)	Deals with the prevention of pollution of the marine environment by ships from operational or accidental causes.
Liability and compensation	Convention on Limitation of Liability for Maritime Claims (LLMC).	Addresses claims for loss of life or personnel injury, damage to other ships, property, or harbour works.

(IMO, n.d.-a)

2.2 The Autonomous Ship Concept and Definition

The concept of autonomy concerning shipping is the performance of a task(s) or the operations of shipboard equipment, which, under certain conditions, are designed and verified to operate without human control. The process is controlled by automation. (International Organization for Standardization [ISO], 2022). IMO equally adopts an interim definition of (MASS), as a ship which, to a varying degree, can operate independently of human interaction (IMO, 2018). MASS encapsulates fully or partly crewed and uncrewed ships. There is a need for a consistent definition of the MASS concept, especially in processes and designs, even as the concept is developing. It is credible to say that the increased application of smart technologies such as artificial intelligence (AI), machine learning, virtual reality (VR), cloud computing, augmented reality, robotics, and real-time data capabilities has significantly aided the reality of MASS concept. IMO further illustrates that, during a single voyage, the ship could operate at one or various degrees of autonomy, as categorized in the table below.

Table 2: The Four Degrees of MASS

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

(IMO, n.d.-a)

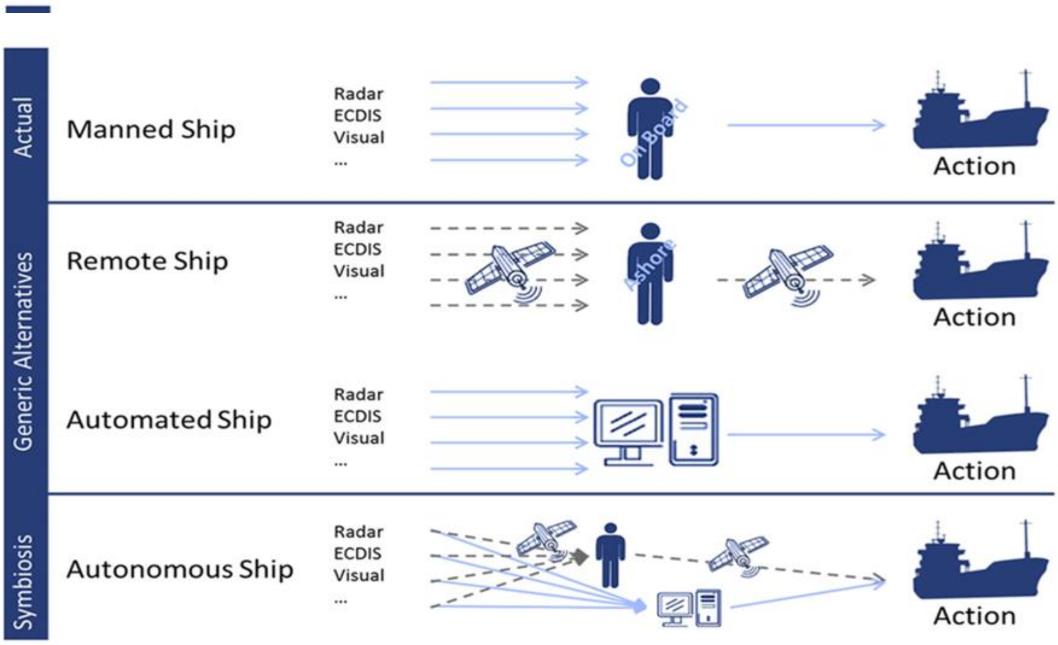


Figure 1:Illustration Supporting IMO's Operational Concept of MASS (MUNIN, 2016c)

According to Batalden, Leikanger & Wide (2017), the concept of MASS according to IMO scoping exercise illustrates that MASS can be manned from a command centre (i.e., monitored and navigated by a trained onshore operator or crew). Models like audio and visual technology can aid the operator in receiving situational awareness of the ship's surroundings. They also suggest that the ship can be completely autonomous in low-traffic areas and controlled from a command centre in high-traffic areas. Complete autonomy would then allow the ship to sail without human interference. (Batalden et al., 2017, pp. 2–3). In this case, the ship system will gather and transmit information from its internal and external surroundings through sensors, cameras, lidars, radar, etc., for decision-making either by the ship itself or from the command centre. It could send and receive navigational and positional data from other autonomous ships, thus allowing it to take safe action when necessary. (Batalden et al., 2017, pp. 2–3). Broek, Griffioen & Drift (2020) opines that the proposed series of MASS categorization is integral in the development and operation of MASS due to its complexity in various manning situations and function re-allocation from manned execution (onboard or ashore) to complete autonomy (p.1).

2.3 Remote Control Centre/ Remote Operation Centre (RCC/ ROC)

Encapsulated in the MASS definition is the concept of a shore command centre which is an essential solution to control and monitor all functions aboard the ship with more shoreside management for safe operations (Batalden et al., 2017; Quick, 2016). The shore command centre allows an operator (e.g., a captain or a skilled crew in a conventional ship) to operate MASS remotely, which can be described as a captain on the land concept (Batalden et al., 2017, p. 3).

Remote operations have been applicable for decades in the marine environment for specific functions with the Autonomous Underwater Vehicle (AUV) for underwater survey missions, such as detecting and mapping wrecks, rocks, and submerged obstructions. Another is a Remotely Operated Vehicle (ROV) used in offshore oil, gas, and renewables industries to inspect, maintain, and repair infrastructures. Safety, connectivity, and cost considerations, to list a few, have been limiting factors for a complete application to commercial shipping. However, the norm is changing following developments in autonomous maritime operations. Necessary regulations also support these efforts to implement interoperability and harmonize information between ships and shore (Quick, 2016).

According to Batalden, Leikanger & Wide (2017), an operation centre can include the following interactions with the vessel (MASS): 1) Operational support, monitoring, and navigation, 2) Operational prediction and optimization of systems, 3) Path tracking, planning, decision making, 4) System maintenance, 5) Risks assessment, 6) System management and communication, and 7) A host server system, all which will be operated and overseen by humans (crew) (p.4). Potentially, some ship traffic could be controlled remotely from land-based virtual bridges, with one ship master overseeing several vessels simultaneously (Batalden et al., 2017, p. 4). Pierre Sames, Group Research and Development Director, DNV, opines that the most likely scenario of MASS operations is that it will be an additional option for ship operations. It can be applied without entirely replacing conventional crewed operations, thereby supporting the crew in steering the vessel, increasing safety, and optimizing operational efficiency. (DNV GL, 2018).

2.4 Research in Autonomous Ship

The autonomous ship development is based on the "Industry 4.0" concept described in the introductory (chapter 1). Some research projects have contributed to the development and awareness of the MASS concept. Amongst many are the Advanced Autonomous Waterborne Applications Initiative (AAWA), Maritime Unmanned Navigation through Intelligence in Networks (MUNIN), Autonomous Ship Initiative for European Waters - AUTOSHIP Reference Architecture (AURA), ReVolt, Designing the Future of Full Autonomous Ship (DFFAS) consortium, and Sea for Value (S4V). This research tries to remedy challenges of emission, safety, increased transport volumes, and crew shortage (MUNIN, 2016b). It is uncertain to predict the extent and consequences of MASS application given the unique nature of the industry's environment and global dynamics. However, Captain Quick suggests that it will be better to approach this development in stages. Each stage will require evaluation, even though MASS is projected to be an essential element for competitiveness and sustainability (Quick, 2016).

The AAWA project is research funded by the Finnish Funding Agency for Technology and Innovation between 2015 and 2017 to develop proposed designs, concepts, and operability of remote and autonomous ships. The project is conducted with ship designers, equipment manufacturers, class societies, universities, ship owners, and other stakeholders within the maritime cluster. Its activities detail technologies for navigation and communication, legal implication, technical requirements, safety and security concerns, and the commerciality of making remote and autonomous ships a reality. (Jokioinen et al., 2016).

The MUNIN project is also collaborative research co-funded by the European Commission to develop and verify concepts for an autonomous ship within a defined scope of a vessel guided by an automated onboard decision system but controlled at a shore control station (MUNIN, 2016a).

The ReVolt is a 3000-kWh battery-powered crewless autonomous ship development concept by DNV GL for an uncrewed, zero-emission short-sea vessel with an average speed of 6 knots. It faces less water resistance than other ships and has a battery range of 100 nautical miles before battery recharge (DNV GL, 2014). Its aim, like other research, is to mitigate or proffer solutions to the growing transport capacity needs, especially on land-based logistic networks, by creating a cost-efficient, greener, more intelligent, and safer alternative through short sea shipping (DNV GL, 2014).

The Designing the Future of Full Autonomous Ship (DFFAS) project is a successful demonstration test project of an operating system developed by the DFFAS Consortium, comprised of 30 companies from various fields using an open innovation framework. It aims to address the challenges of the aging crew and crew shortages, safety and security from marine-related accidents, and ecological concerns facing the coastal shipping industry. (The Nippon Foundation, 2022). The DFFAS project is sponsored by Japan's Joint Technological Development Program (JTDP) for the Nippon Foundation's demonstration of uncrewed ships. It includes shipping companies like NYK and Kinkai Yusen Kaisha, as well as tech providers such as SKY Perfect JSAT, Furuno, JRC, Tokyo Keiki, Weather news, etc. (The Nippon Foundation, 2022).

A test vessel (SUZAKU: 95 meters, 749 gross tons) was used for this project. It navigated a 790-kilometer round-trip route to and from Tokyo Bay by way of Ise Bay in the Chiba area using a complete, fully autonomous navigation system, which included three principal components: (1) a ship navigation system that controls autonomous functions from the ship; (2) a land system that oversees and supports the ship from the land; and (3) an information and communications system that provides reliable communication between the ship and land. (The Nippon Foundation, 2022).

According to the Nippon foundation, about 500 ships pass through Tokyo Bay daily compared to about 40 and 320 passing through the Panama Canal and the Straits of Malacca and Singapore, respectively. The successful demonstration of this project in a densely congested area confirms a high level of technological development with a significant step toward practical implementation. The implementation will mitigate the challenging issues of accident occurrence and crew shortage. The remote operation from land will introduces preferable work pattern that can attract more workforce.

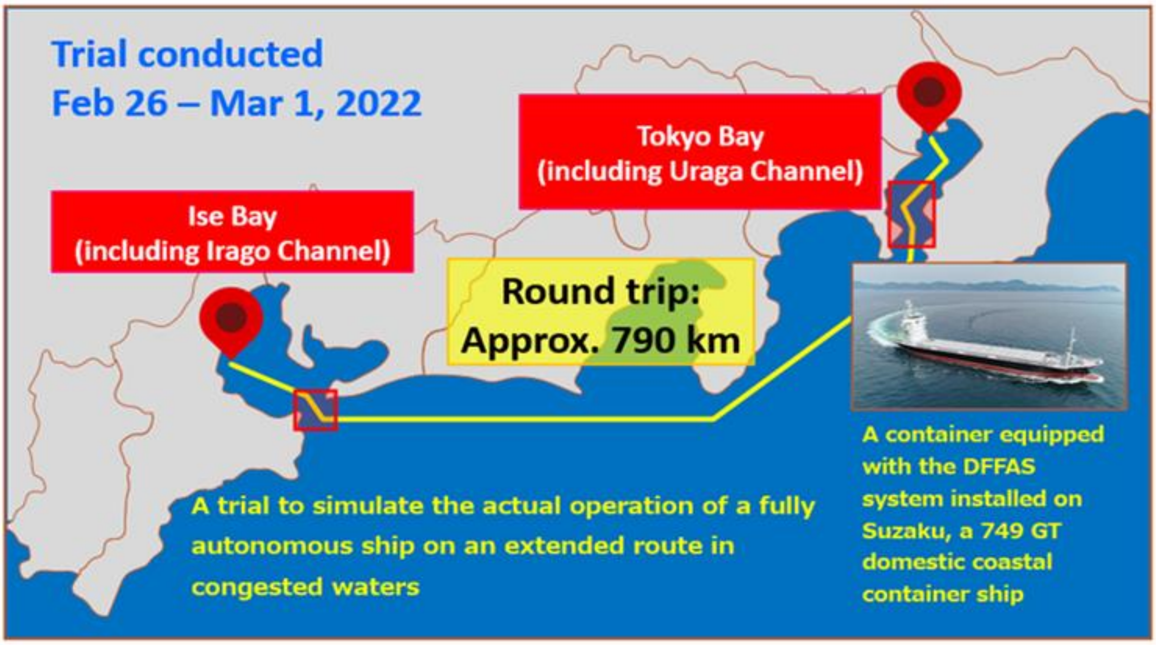


Figure 2: Illustration showing autonomous demonstration trial of Suzaku; 749 GT, 95m ship (The Nippon Foundation, 2022)

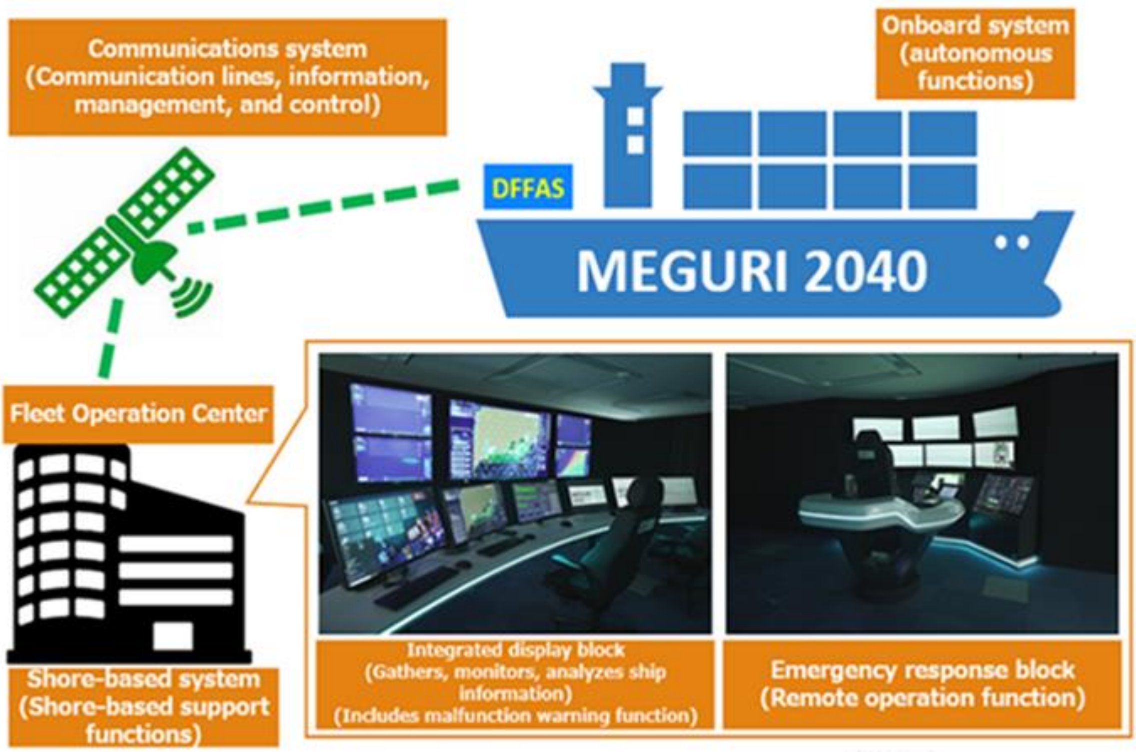


Figure 3: Illustration showing the three principal components of the Suzaku trial - a ship navigation system that controls autonomous functions, a land monitoring and supports system, and an information and communications system (The Nippon Foundation, 2022)

2.5 System Architecture and Operational Structure of MASS

The "AUTOSHIP deliverable D3.1: Autonomous ship design standards", Revision 1.1" is a major reference in this section. The system architecture of MASS consists of a physical and wireless component that enables monitoring and control of MASS operations. Characteristically, a ship consists of two primary sections - the deck and the engine. The deck comprises the bridge and other superstructures consisting of components for navigation, while the engine consists of mechanical components for the ship's propulsion and other related functions. The proper integration of these components enables the safe operation and navigation of the ship. The same characteristics apply to MASS but require a more complex integrating system design. MASS is a cyber-physical system of systems with both physical and ICT components for interaction between humans and the systems, both on water and land (Wennersberg et al., 2021, p. 20).

MASS operating systems must have enabling technologies that are capable of collecting, process, and storing information co-occurring, inside and outside the ship's environment, then relaying them to humans for safe decisions or actions (Höyhtyä et al., 2017; Im et al., 2018, p. 96). The enabling technologies for the deck components depend on autonomous navigation systems or artificial intelligence for situational awareness, collision avoidance, routing, positioning, reliable interconnectivity, cyber security, and remote or operator control station capabilities (Wennersberg et al., 2021, p. 18). While the engine components depend on an autonomous machinery system with intelligent management capabilities for energy management, alarm or alert systems, predictive and preventive condition monitoring, and maintenance (Wennersberg et al., 2021, pp. 18–19).

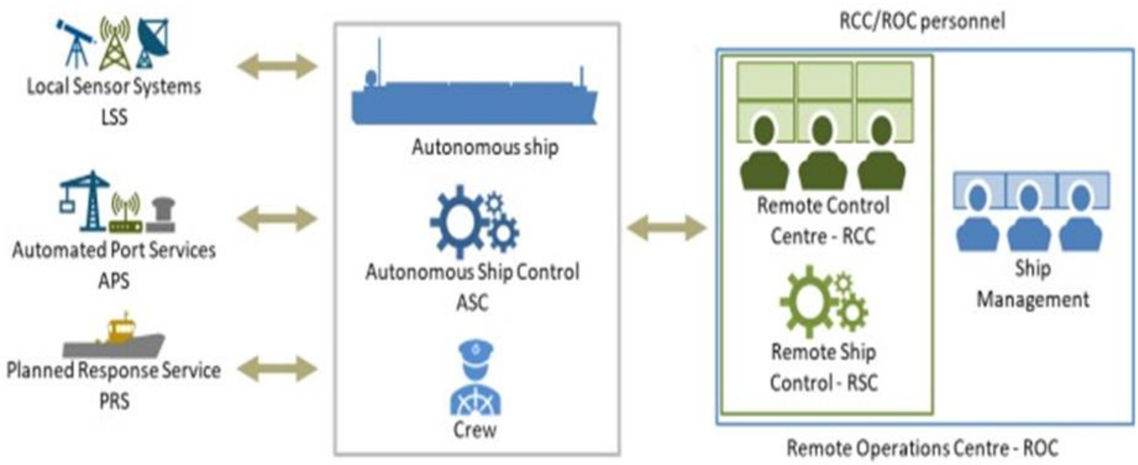


Figure 4: Illustration showing some general component of an autonomous ship system (Wennersberg et al., 2021)

The table below shows a brief explanation of the components in (figure 4) above.

Table 3: Table explaining operational components of MASS (Wennersberg et al., 2021)

Components of an Autonomous Ship	**Details**
Local Sensor Systems (LSS)	These highly effective sensors can be placed ashore instead of onboard ships for high transitive data reception, mainly where several autonomous ships operate.
Automated Port Services (APS)	These are general facilities implemented in ports to facilitate automated ship operations. They may include automated mooring systems, automated cargo handling, berthing aids, etc.
Planned Response Service (PRS)	This refers to some planned assistance (manually or automated) service deployed on or proximal to an autonomous ship in the event of system failure, fire, etc., e.g., towage, etc.
Autonomous Ship (AS)	Refers to the ship and its onboard systems.
Autonomous Ship Control (ASC)	The onboard control and monitoring system provide the interface between the onboard operators (Crew) and the lower-level control systems. The ASC and RSC are together in the overall automation system for the ship.
Crew	Presence of some crew onboard.

Remote Control Centre (RCC)	A remote location from which control or monitoring can be performed.
Remote Ship Control (RSC)	It can be the control and automation functions in the RCC from which the ship system is controlled remotely.
Ship Management	This might include some technical and operational management functions besides the RCC, such as voyage plans and orders, etc.
Remote Operations Centre (ROC)	Houses all remote operation functions and facilities, including crew/ personnel.

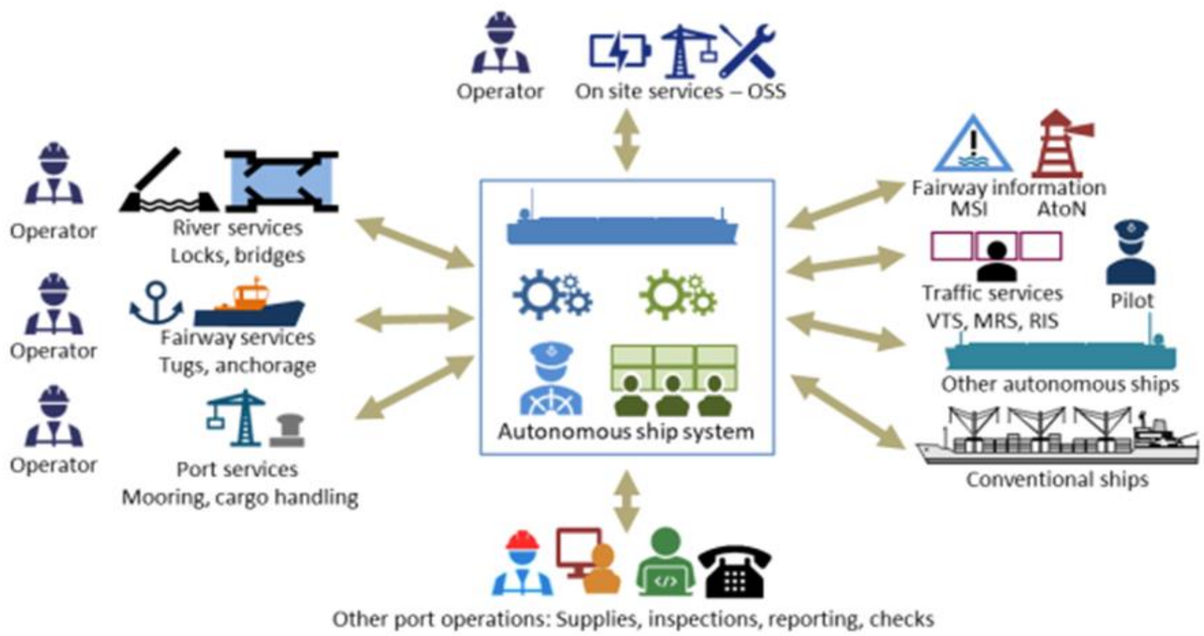


Figure 5: Illustration showing an autonomous ship operational context. (Wennersberg et al., 2021).

2.6 Justification of MASS

The era of digitalization presents an inevitably salient pressure for the shipping sector to conform and harness the vast technological possibilities, bearing in mind that shipping provides a significant share of global trade and is a critical agent of globalization (Habdank, 2019, p. 16). However, the drive for the development of MASS is not solely technological but also directional toward launching the United Nations (UN) Sustainable Development Goal agenda by 2030 (IMO, n.d.-c; United Nations [(UN], 2022).

IMO Secretary-General, Kitack Lim in summary convey the sector's future trajectory -

> Technology and the use of data hold the key to a safer and more sustainable future for shipping. Shipping is entering a new era, the digital revolution, which avails the opportunities afforded by developing energy and fuel consumption, automation and ship management, and ship construction technologies. We must ensure that the opportunities presented by these technologies are incorporated effectively into the body's regulatory framework to improve efficiency in shipping and lead to a new generation of ships that bring significant developments in all the areas that IMO regulates. (United Nations Conference on Trade and Development [UNCTAD], 2018, pp. 37–38).

Proponents of MASS often point out an array of the possible impact of MASS on maritime operations, amongst which are the benefits of increased safety, reduced operational costs by reducing manning and energy consumption, and increased operational time. Other benefits are improved lifestyles and work environment for seafarers, more shore assistance, enhanced skill and competencies if harnessed, increased maritime shipping capacity, and ecological benefit towards net zero emission (Benson, Sumanth & Colling, 2018; Habdank, 2019; Lehtinen, 2020). However, the potential for increased safety comes as a strong drive and top benefit. The safety concern of MASS is discussed further in (chapter 2.5.1) below.

David Appleton, Professional and Technical Officer at Nautilus International, points out that the intelligent ship revolution brings myriad challenges yet to be resolved besides technological hurdles, such as resolving the issue of reliable navigation, protection from cyber-attacks, and immediate social impact. Another concern is ship owners' profit, as shipowners will typically expect to achieve 15 to 25 years of profitable service from the ship (Offshore Energy, 2017). According to Tsvetkova and Hellström (2022), MASS has the potential to transform and create value for the whole shipping supply and logistics chain beyond cost reduction and business cases for ship owners. However, this transformation will depend on the degree to which it disrupts logistics (p. 256).

2.6.1 Safety

Numerous statistics show that about 70% to 85% of most marine accidents are caused by human error, which is expected to increase with the growing maritime sector if things remain the same (AGCS 2019; Rothblum, 2000). MASS advocates often point out that minimal human input or interference in ship operations will reduce these statistics. This may not be the case, argues Appleton in an interview with World Maritime News. He states that there are no adequate records of the number or percentages of accidents at sea that might have been prevented by quick human intervention. He also opined that one major safety factor to consider in MASS operation is that the consequences of fewer or no crew onboard to take swift action might be catastrophic in the event of an accident. (Offshore Energy, 2017).

Rothblum (2000, pp. 1–8) points out that the maritime accident rate is still high even as the industry has evolved over the decades by improving ship structure and systems (e.g., hull design, stability, propulsion systems, and navigational equipment). Now it is adopting technologically driven ships that are presumed to be reliable. Rothblum proposes that one area to pay attention to is the cause and types of human errors, noting that the ship's structure and system are a relatively small part of the safety equation. It requires significant human involvement to balance the operational structure or process, thus making it impossible to eliminate humans from the entire process. Hence, we must study marine accidents and determine how they occur. (Rothblum, 2000, pp. 2–8).

"The maritime system is people-centred (Offshore Energy, 2017; Rothblum, 2000, p. 8)". According to Appleton, if humans are moved from sea to shore, the associated human risk is not necessarily removed but transferred, which introduces the possibility of new types of risk. He also stated that increased automation of systems could lead to skill degradation and impairment of human performance in emergencies, especially when optimal performance is needed. (Offshore Energy, 2017). Appleton and Rothblum believe that most human errors occur due to technologies, work environments, or organizational factors that do not sufficiently consider the abilities and limitations of individuals, thus setting up humans for failure (Offshore Energy, 2017; Rothblum, 2000).

Appleton opines that human errors can be significantly reduced or controlled through human-centred designed technology and better work environment that support humans for improved safety and performance. Suppose the crew or operator does not receive sufficient training or is overworked, or the equipment they use is poorly designed. In that case, the likelihood of accidents occurring is the same or higher as in a crewed ship. Even automated systems are still designed by humans capable of making mistakes. (Offshore Energy, 2017). Also, MASS will still need to co-exist with other manned vessels, which may be another big challenge.

2.6.2 Cyber Security

As new IT technologies emerge, malicious IT activity will grow to create new security challenges, and the suitable protection of these systems or networks in cyberspace will be crucial. Due to the high reliance on software and connectivity of MASS, cyber-attacks are far more likely than on conventional vessels since MASS depends on information technology systems onboard and onshore for operations. The more dependent a ship's operation is on software and connectivity, the more vulnerable it is to cyber threats. Cyber terrorists could hack the remote-control function to directly control communication links and other functions. (M. Kim et al., 2020, pp. 20–22).

MASS may change the patterns of pirate, terrorist, and criminal activities. Cases of human loss, including hostage situations and kidnapping by pirates, and armed robberies, may be decreased. However, the absence of ship crews can lead to increased attempts to hijack vessels for valuable cargo. There is also the risk that MASS can be abused for crimes such as illegal cargo transport, including arms and drugs. (M. Kim et al., 2020, pp. 22–23). "Technical and institutional considerations should strengthen port security by developing new inspection mechanisms or changing the place of inspection if needed. (M. Kim et al., 2020, p. 23)". It is crucial to protect against the potential of cyberattacks considering the current trends of increasingly connected ships. Such protection must be prioritized as ship autonomy increases. (Crespo, Gomez & Arias 2019, p. 22).

IMO officially recognized the importance of cybersecurity, stating that security gaps have the potential to significantly compromise the safety and security of ships, ports, and marine facilities. (IMO, n.d.-e). IMO identified several critical vessel components that are susceptible to cyber-related risks. They include bridge systems, communication systems, management systems, propulsion and machinery management, power control systems, access and control systems, and personnel (IMO, n.d.-e). Consequently, IMO issued a temporary risk management guideline; (MSC.1/Circ.1526), superseded by a formal guideline; (MSC-FAL.1/Circ.322) on maritime cyber risk management. (IMO, n.d.-e). In 2017, IMO adopted Resolution MSC.428(98), requiring member states to apply a cybersecurity risk management approach to the safety management systems of ships. These documents only provide high-level principles without detailed information on securing and protecting ships, but they are significant progress towards achieving and improving Cybersecurity in the marine sector. (IMO, n.d.-e).

The European Union (EU) Directive, 2016/1148 on the security of network and information systems (the NIS Directive) recognized the importance of maritime cybersecurity. It identified maritime operators, including passenger and freight water transport companies, and the managing bodies of ports and operators of vessel traffic services as 'Operators of Essential Services (OES) and invited them to beef up the level of their cybersecurity. (Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 Concerning Measures for a High Common Level of Security of Network and Information Systems across the Union, 2016). In 2011, the EU published the first EU report on cybersecurity challenges in the maritime sector and, in 2019, a second with a detailed list of potential threats, security recommendations, and risk management guidelines for port authorities and terminal operators (Dr. Drougkas et al., 2019). There is no doubt that MASS has safety benefits; however, it comes with risks of an increasing interdependencies on IT technology, making it vulnerable to cyber-attacks if proper risk management is not considered (Finne, 2021, pp. 1–2). Cyber threats will drive the need for a digital maritime workforce.

2.7 Potential Job Redesign (Job Loss/ Job gained)

The emergence of MASS, from general opinion, is assumed logically to lead to a reduction in crew size or elimination of crew, thus, raising concerns of job loss. The assumption might not be valid for some sectors of the maritime industry, such as the cruise industry and ships carrying dangerous cargo. Establishing a business or safety case and automating complex tasks on these vessels is challenging. It is easier for machines to automate a linear task than complex tasks, thus, requiring adequate or retention of the same crew size. (Chaal et al., 2020; Offshore Energy, 2017). The number of jobs for seafarers is expected to increase with more shore-redesignated jobs. However, these new job redesign will have different skill sets and qualifications (Alfultis, 2018, pp. 90–91). We need not fear automation.

Seafarers' shortage is estimated to increase by 2025 following a predicted increase in volumes of shipping traffic associated with an increase in the world's Gross Domestic Product (GDP). Therefore, there is anticipated to be no shortage of jobs for seafarers, especially for officers, within the next two decades, given that the number of autonomous ships operational between 2025 to 2030 will offset the predicted labor deficit. (ICS 2018).

Seaborne trade is projected to double by 2030 (DNV GL, 2018). Appleton opines that "while there may be fewer seafarers per ship, it is not sure that the overall number of seafarers will decline, as the range of automation applications will increase while technology advances. (Offshore Energy, 2017)". As the size of the crew onboard evolves, there will be substantial additional jobs redesignated ashore that require highly skilled seafarers or operators and new kinds of pilots (ICS 2018). "MASS is more likely to alter jobs than eliminate them," opines Kevin Tester, Maritime IT & Electronics Editor, (The Manufacturer, 2018). The ongoing transition from traditional to autonomous ship systems will result in increasingly complex and more integrated cyber systems requiring cyber resiliency against malicious or inadvertent attacks. This resilience will be required across all maritime industry sectors, e.g., ship and terminal operations, brokering, chartering, protection and indemnity (P&I), ship registry, and supply chain management, thus, demanding more cyber security workforce. (Deloitte LLP, 2015).

Most seafarers already work in extreme conditions with irregular hours and mundane tasks. The introduction of stiffer regulations and compliance on emission, monitoring, reporting, ballast water system, just-in-time arrival information, etc., overwhelms the administrative burden on seagoing staff. However, developing digital technologies will ease seafarers' workload and create a better work-life balance, given that digital technologies will support routine requirements from ships with real-time connectivity and advanced satellite communication. This will enable ships to become an extension of shore operations, opines Capt. Eero Lehtovaara, Chairman, One Sea. (One Sea, n.d., p. 2).

The Vice President at Klaveness Ship Management, Torbjorn Eide, explains that some older generations of seafarers are technologically challenged and might be scared of losing their jobs. However, proper communication of the rationale for technology application will make them understand that the application of technology is to make work-life more manageable. Then they will see and anticipate the benefit. "Everything we do in technology and the digital world is not to replace the people, but to enhance jobs and work-life." (Seatrade Maritime News, 2018b). Appleton further clarifies that "it is essential to use these technologies to improve the quality of life and work onboard the ship and not add to the workload" (Offshore Energy, 2017).

Digital technologies can change the future of work in digital entrepreneurship, freelancing, and offshore services. Additionally, trends toward "green jobs" will affect future digital skills requirements for improving environmental performance. (International Telecommunication Union [ITU], 2020). The opportunity for new businesses and job creation resulting from MASS will require highly skilled crew and operators, especially those with expertise in technology and IT systems. A Deloitte study of job automation by U.K. industries found that over 15 years, 3.5 million new jobs were created in contrast to 800,000 low-skilled jobs that were eliminated due to artificial intelligence (AI) and other automation technologies (Deloitte LLP, 2015). The above study is expected to be a similar case to MASS operations. Therefore, job loss is more of an imagined threat. Remote and autonomous operations will transfer many seafaring jobs to land-based SCC/ROC, opening the industry to a new set of people who will find a maritime career onshore more attractive. It is also anticipated that autonomous ships will enhance seafarers' quality of life.

2.8 MASS and Maritime Education and Training (MET)

The rapid pace of digital transformation demands a catch-up in maritime education and training and anticipation of further modifications to roles onboard ships and onshore (Seatrade Maritime News, 2018a). It would be near-sighted to assume that the initially acquired education and training will serve the demands of this rapidly changing workplace. Maritime institutions must assess their current program or curriculum to adjust to or anticipate this transition to ensure skills remain relevant in the industry. (Alfultis, 2018, p. 87). Though, the uncertainty of the future makes it challenging to detail the exact training curriculum at the moment. However, basic training in STEM (i.e., science, technology, engineering, and math) is considered vital given that digital systems require a certain understanding of STEM competency, opines Alexander Avant, Future Education Specialist, Dare Disrupt. (Seatrade Maritime News, 2018a).

While being skeptical about setting up exact programs or certification for autonomous mariner licenses due to ongoing development, though not ruled out of possibilities, it is necessary to infuse new technologies and digital fluency across maritime institutions' curricula (Alfultis, 2018, p. 91). Institutions or faculties should integrate digital technologies into the classrooms, have close partnerships with industry for applied learning and internships that introduce students to the latest technology, create more opportunities for industry interactions, and increase research focus learning. According to Glenys Jackson OBE, Manager, Merchant Navy Board, integrating digital technologies into learning is necessary given that the modes of ship operations will not necessarily be about driving the ship but rather about controlling the systems that drive the ship, either onboard or remotely, and whether it is navigation, engineering, or electro-technical (Seatrade Maritime News, 2018a). "This approach will keep students updated on developments in the industry and enable easy integration into autonomous shipping operations. (Alfultis, 2018, p. 91)".

Maritime institutions should incorporate into their curriculum advanced or intermediate levels programs in computer engineering and programming, software development, data science and analytics, automation engineering, and integrated logistics and network management, also with the inclusion of other programs like artificial intelligence (AI), big data, cybersecurity, digital entrepreneurship, and virtual reality (VR) to aid the development of digital technology skills. (ITU, 2018, pp. 5–6). According to Stephen Cotton, General Secretary, ITF, and Yuzuru Goto, Managing Director, K Line LNG Shipping UK, the application of more 3D simulation, gamification, and computer-based training and practice, even onboard ships, will significantly aid digital learning (Seatrade Maritime News, 2018a).

As the changing demands of work are significantly increasing, the need for upskilling and re-skilling is more certain than speculative. Given the predicted continuous transformation of the industry's trends, there is a need to emphasize continuous learning across all maritime institutions. Continuous learning is a process of learning or acquiring new skills and knowledge on an ongoing basis, which can be formally (e.g., institutions and organizations) or informally (socially), involving self-initiative and taking on challenges. (Valamis, 2022). The continuous learning concept will require a comprehensive approach to improving education and learning. Educational institutions should be able to provide this learning in corporations with relevant policy sectors like regulatory bodies, the private sector, civil society, etc. (Ministry of Education and Culture, Finland, 2019). Each maritime institution should plan its curriculum by applying the continuous learning concept with learning styles that support building intellectual capacity, agility, and adaptability to evolving trends. However, the STCW must be specified.

The ability of institutions to provide different and high-level digital learning may vary significantly between institutions and countries due to varying levels of technological development in different countries. For example, the levels of requirements for digital skills, as well as the processes for assessment and acquisition in developing countries, will differ from those in developed countries, being that the level of technological development in each country potentially influences its digital skills requirements and level. (International Telecommunication Union [ITU], 2020, pp. 1–2; Skillsea, 2020, p. 3). Each country will be affected by the ongoing changes in different ways. With this variation, a uniform response to MET changes might be challenging, as this will depend on the scope of education required, the capacities and expertise available at the institution, and the financial incentives provided in each region. (Skillsea, 2020, p. 3). Nations seeking to understand future skills needs in autonomous ship operations should be aware of several overriding technological developments, such as artificial intelligence (AI), big-data analytics, cloud computing, the Internet of Things (IoT), and robotics. Technology requires sharpening hard and soft skills, suggesting that education and training are critical to enhancing the seafaring workforce and experience.

2.9 The STCW Convention and Digital Competency

The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), under the auspices of IMO, was introduced to set the standards of competence for seafarers internationally. The Convention specifies the core competencies that all seafarers must demonstrate for the specific needs of a ship (e.g., bulk carrier, LPG tanker, cruise ship, container ship, etc.) and its operations, and familiarization with shipboard equipment and operating procedures for the safe operations (Hopcraft, 2021, p. 13; IMO, n.d.-f). The STCW specifies the requirements for education, training, and experience (sea time) for persons working on board vessels (IMO, n.d.-f). IMO developed a series of model courses for maritime training institutions globally that provide a detailed teaching syllabus and learning objectives to assist instructors in developing training programs to meet the STCW convention standards for seafarers (IMO, n.d.-f). However, these model courses do not keep up with the pace of technological changes.

The Convention has undergone two essential revisions since its inception: in 1995 and 2010. The version, which was initially created in 1978, was almost entirely knowledge focused. 1995 changed the focus to practical skills and abilities backed by academic knowledge. However, digital abilities were not mentioned in the STCW Convention, even though computer literacy is presented as an optional tool for acquiring core professional skills. (Skillsea, 2020, p. 21). Due to the ongoing integration of digital systems on ships and the threat of cyberattacks, IMO added a scope to include digital competencies as part of cyber risk management, and all seafarers have a responsibility to ensure they do not jeopardize the safety or security of these systems. (Hopcraft, 2021, pp. 2–3).

IMO introduced the International Safety Management (ISM) code as a guide for both ship and shore operations, especially at the management level but did not include digital skills and other competencies needed to manage sophisticated ships (e.g., MASS) and SCC (Skillsea, 2020, pp. 29, 74). However, this should be substantially improved with ongoing regulatory reforms on the STCW to accommodate MASS. Therefore, shipping should shift towards essential skills for the future, including general IT knowledge and cyber security, system-specific training, revised curriculum, soft skills acquisition, and multidisciplined seafarers. Education and training institutions should equally include subjects or curricula beyond STCW requirements, as mentioned in (chapter 2.7), either in the form of upgrading courses or as part of regular education (Skillsea, 2020, pp. 29–30). Although, the existing STCW requirements for conventional vessels would be highly relevant to be adopted into the ongoing reforms of MASS and SCC operations due to the similarities. (Skillsea, 2020, p. 30).

2.10 Skill Management (Job Requirement and Proposed Competence)

Technological advancement is transforming the way jobs are being performed. As a result, skills and qualifications that were once sufficient are increasingly becoming obsolete or insubstantial, thus requiring skill management. Skill management is the practice of developing and deploying people and their skills. A well-implemented skills management identifies the skills that job roles require, the current skills of individuals, the skills that are lacking, gap(s) between both, and attempts to supplement the gap(s). This is usually achievable through a defined skills framework, also known as a competency framework or skills matrix, which consists of a list of skills and a marking. (Wikipedia, 2021). The skill management practice is achieved by combining basic or interdisciplinary knowledge, education, training, and practical experience of a person (Bachari-Lafteh & Harati-Mokhtari, 2021; T. Kim & Mallam, 2020).

According to Dybvik, Veitch & Steinert (2020, p. 847), until the technology for MASS is proven reliable, research in job requirements and competencies remains speculative and suggestive. However, proposed potential skill sets are developed in addition to existing shipboard competencies and the STCW. MASS operations will require skill balance in three key areas (i) ship digital system understanding and technical knowledge, (ii) classical maritime competence, and (iii) soft skills. (Cicek, Akyuz & Celik 2019, p. 273; Saha, 2021, pp. 10–13; Skillsea, 2020, p. 3). These skills are developed to accommodate the 4 degrees of MASS adopted by IMO in its RSC. However, much focus from ongoing research has been on the Shore Control Centre (SCC) or Remote Operations Centre (ROC).

According to a study by Dybvik et al., a semi-structured interview with members of the research and business communities was examined to assess the difficulties in designing and developing SCCs. The research discussed the expected tasks, interactions, and functionalities in the SCC and the unidentified skill needs of SCC operators. They indicated that little is known about the operator's competence requirements; however, research is being done to create SCC curricula. Therefore, instead of creating a tried-and-true curriculum, they emphasized a learning framework hypothesis more. The skills required for SCC operators will differ mainly from traditional seafarers. However, classical maritime competencies will still be relevant and necessary for a smooth transition to MASS operations to improve situational awareness and prevent technology-assisted accidents in the early introduction phases. Therefore, two persons primarily are earmarked for professional operations and handling in the RCC with additional skills and knowledge acquired from training and familiarization on MASS and the RCC. One is a navigation operator who is an experienced shipmaster or ship officer of a conventional ship. The other is an engine operator who is an experienced engineer in charge of monitoring and controlling the operation of a conventional ship's engine. Though, in the future, the necessary qualifications and competence for being an RCC operator may evolve, one of which might require less or no sea time. One option may be that SCC operators should spend a specific time on that type of MASS vessel before operating them from SCCs. (Dybvik et al., 2020, p. 852).

The results from the study above further outlined the required capabilities for person(s) at the RCC.

1. An individual at the RCC must be capable of proper ship navigation and understanding of basic engineering knowledge of ships for better decision-making at the RCC.

2. The individual should be capable of communicating navigational information to units, including ports control, Port State Control (PSC), VTS, and other units involved.
3. The individual must be proficient with the principles of electronic navigation with the use of GPS & DGPS, automatic identification system (AIS), integrated navigation system (INS), and Integrated Bridge Systems (IBS), knowledge of passage planning with ECDIS, and other replicated shipboard equipment in the RCC.
4. The operator should be familiar with maritime laws, regulations, and several maritime conventions, e.g., COLREG, SOLAS, MARPOL, etc., and maritime security.
5. The operator must thoroughly understand the most common types of goods with knowledge of essential stowage, loading, and unloading principles.
6. The individual should possess other supportive knowledge required of an RCC operator and knowledge of ship construction and stability, automation and control systems, marine communications, environmental science, computer science, and basic cyber security principles.

While MASS is advancing, a detailed requirement to attain an RCC operator qualification should be structured under a revised STCW after undergoing several trials, reviews, and modification phases (Saha, 2021, pp. 12–13). Skill management must be an ongoing process where an individual's skill set is regularly assessed and updated. The diagram below illustrates a suggested approach for acquiring shore-based competencies in light of the evaluations and analysis above.

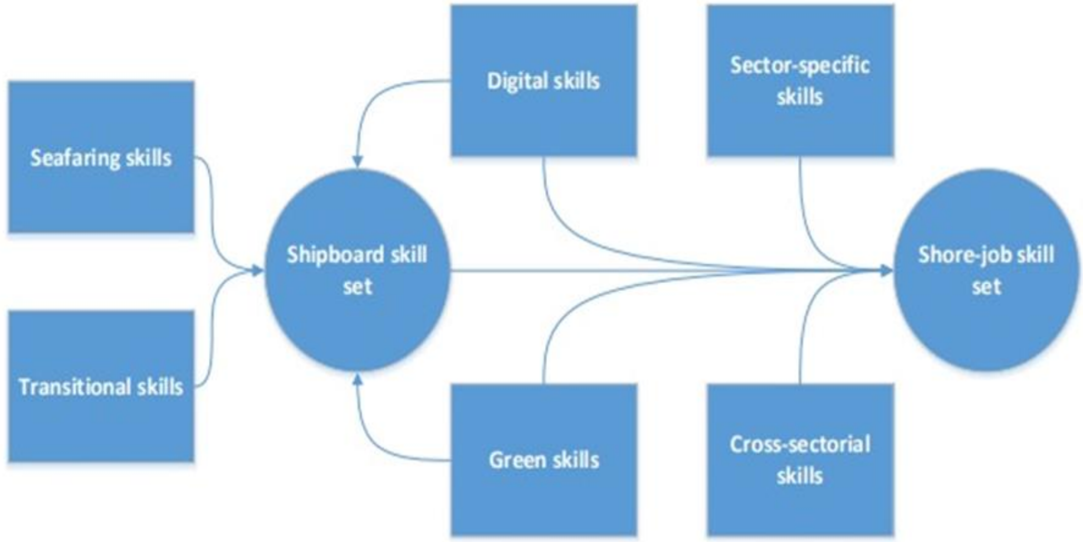


Figure 6: An illustration of a proposed model for the process of acquiring skills for shore-based jobs where the seafaring background is considered essential (Skillsea, 2020, p. 8).

In essence, Bogusawski et al. (2022, p. 338) recommend the following essential propositions for achieving and managing the potential MASS and RCC job profile:

1. Increase the future workforce's understanding of the need to familiarize themselves with growing technologies in automation. The institution's curriculum should be changed, and there should be a more vital collaboration with business partners and R&D organizations.

2. Change training and employment-related policies to accommodate the fact that the maritime industry is losing its seafaring workforce. The current lack of experienced seafarers may deepen depending on the rate of shortage and the long-term outcomes of increasing autonomy in shipping, which must be addressed to secure the industry's sustainability. On the other hand, such an effect may provide more arguments for developing MASS to compensate for the lack of workforce.

3. Redesign curricula and assist the future workforce in developing skills (including soft skills) functional outside sea-going operations rather than teaching hard technical subjects alone. The curriculum redesign should be applied to maritime training, which is currently done to a limited extent since about 41% of seafarers, according to reports, have minimal knowledge of the

potentially disruptive technology of autonomous shipping. The framework for training future navigators and engineers should be based on the STCW, and its related codes with documents that describe the required IT technical skills for MASS and RCC operations, as IT skills would gradually become critical in shipping with technology advancement.

4. Also, governance frameworks should be developed to help societies anticipate and shape the impact of emerging technologies. (2016, p. 26).

An adapted competency matrix showing a comparison of traditional seafaring competencies, function allocation and competencies required for MASS and RCC operations is presented in (Chapter 5).

2.11 Legislations and Regulations - IMO's role in defining future rules and regulations on MASS.

The rapid development of MASS technologies requires immediate regulatory attention. A standard term of reference or collective understanding is necessary for MASS development and prospect for shore support functionalities for ship owners, operators, designers, insurers, the public, and regulators. Digital experts and seafarer welfare groups recommend that IMO establish priorities to support efficient and safe ship operation given the increased application of digital technologies in shipping and also proffer roadmaps towards actualizing MASS. (One Sea, n.d., pp. 2–3). IMO is taking active steps in developing and accommodating necessary regulatory requirements for MASS operations, as seen in its regulatory scoping exercise (RSE) (IMO, n.d.-a). Hence a change in existing regulation is anticipated to accommodate MASS operations. However, it is uncertain to determine the time frame, but it is expected that these changes will be gradual and in phases.

3 Research Methodology and Procedures

Research methodology is a practical process used in conducting research. According to Jansen (2020), a research methodology is a systematic approach a researcher deploys to obtain valid and credible results that address the research's purpose. It elucidates the motives and research techniques utilized. Therefore, this chapter describes how the research study was carried out, including the choice of method for data collection and selection, data analysis, and the ethics and limitations encountered.

3.1 Research Approach

The inductive and deductive research methodologies are both possible in this research. According to Anderson et al. (2015), a deductive approach focuses on utilizing literature to identify theories and propositions by using a procedure designed to test them with hypotheses. The deductive technique enables the researcher to formulate their goals and questions using theory, connect them to the framework, and gather data using a survey strategy to test and explain the fundamental connections between variables and offer appropriate responses to their goals and questions (Anderson et al., 2015). The deductive research technique uses theoretical hypothesis evidence to add to or disprove an existing theory. The researcher begins at the top and works his way down. (Soiferman, 2010). However, the inductive approach is chosen for this study. In the inductive technique, the researcher progresses from research questions through analysis to a hypothesis. It operates from the bottom up, utilizing the participants' replies to establish and develop a theory that connects the study issues (Soiferman, 2010). The decision to use the inductive technique is based on objectivity in examining diverse viewpoints, as opposed to the deductive, which is based on subjectivity in evaluating views to support study conclusions.

3.2 Research Design

When attempting to find an answer to a question or solve an issue, researchers turn to a research design which is a framework that enables the researcher narrow or focus his/ her attention on the research methods that are suitable for the subject matter

(Research and Research Methods: Research Design [AMO21MI02-3002] (AMO21HP-Å); (Soiferman, 2010).

3.2.1 Choice of Method

The study is exploratory research deploying a qualitative research approach to narrow or eliminate the uncertainties regarding the continuous human involvement in MASS operations and propose potential job profiles (i.e., task descriptions, skills, and experiences). The analysis and findings may offer a partial answer or conclusion to the perceived problem given that research is still ongoing, and some recommendations are hypothetical rather than tried and tested. Therefore, all areas of this study may not be expansively covered. However, it will narrow the uncertainties and provide room for further research.

Qualitative research involves collecting and analyzing non-numerical data (e.g., text, video, or audio) to understand opinions, concepts, events, and experiences. It receives information on the participant's views and opinions of their reality. It enables the researcher to gather in-depth insights into a problem or generate new ideas for research, thus creating an overall understanding of the quality, characteristics, and meanings of the object or topic of research rather than brief and superficial knowledge. (Research and Research Methods: Qualitative data analysis [AMO21MI02-3002] (AMO21HP-Å); Introduction to research method). One strong advantage of the qualitative method according to Rahman (2016, p. 3) is that it produces detailed descriptions of participants' opinions, experiences, and feelings. However, selecting a sample is crucial to provide the data needed to answer the research questions, often deploying some research philosophy or hypothesis (Edwards & Holland, 2013, p. 5). Also, conducting this research using the qualitative method was inexpensive and still received accurate findings. A proper data analysis is crucial to credible qualitative research, and one helpful approach pointed out is the thematic analysis which involves identifying patterns or themes (Maguire & Delahunt, 2017, p. 2). One clear disadvantages is the generalizability of the whole population given the small sample size and subjectiveness of participants (Bryman, 2016, p. 10; Maguire & Delahunt, 2017, p. 4).

3.2.2 Method of Data Collection

The data for this research was collected through interviews and relevant scientific materials sourced from public records (e.g., the internet, previous studies, reports, and the library).

3.2.3 Study Population

According to Sahay (2016), a population is the group of people or things the researcher wants to look into using his subset, sometimes referred to as a sample. The study's population comprises professionals operating in the marine sector and related industries.

3.2.4 Sample and Sampling Technique

The purposive sampling method was used to select participants to narrow the sample to the research focus area. This method is also known as selective or subjective sampling (Research and Research Methods [AMO21MI02-3002] (AMO21HP-Å)). The convenient and snowball sampling techniques were equally adopted from which nine (9) participants were selected representing the maritime business and education sector primarily. Participants were selected from my little contact network. My supervisor, PhD. Thomas Finne made suggestions for other potential candidates, who responded positively.

The convenient sampling method implies that only available respondents and those who consent to the research would be part of the study. The convenient sampling technique allows the researcher to enjoy a certain amount of flexibility, as the researcher only administers the instrument to respondents who stated they are interested in the study (Sahay, 2016). However, the sampling technique may not be representative of the entire study population as it is highly dependent on the people available and accessible to the researcher. For the snowball sampling, the selected participants were kindly asked to nominate other known persons within the maritime or related domain that could be relevant to this research scope. The methods chosen were specifically targeted to individuals, which characterized maritime professionals, persons involved in independent ship research projects and education, ship officers, and crewing agencies. These methods were selected to achieve an informed result because the MASS concept is novel, developing, and not mainstream or widely familiar to many.

3.3 Data Analysis Method

The data gathered using the qualitative methodology was analyzed using thematic analysis. Conducting thematic analysis on any data set involves detecting patterns or themes within a qualitative dataset (Maguire & Delahunt, 2017, p. 3352). Thematic analysis was chosen because of its immense benefits for early career researchers, as it provides some freedom in selecting the appropriate theoretical and thematic framework (Bryman, 2016). Conducting a thematic analysis would require the researcher to acquaint oneself with the data, define the codes, search for themes, examine the themes, and define and label the themes before finally composing the report. According to Bryman (2016), the choice of thematic analysis is based on three factors: 1) its suitability for inexperienced researchers; 2) its incorporation of a degree of interpretation; and 3) its simplicity and straightforwardness.

3.4 Ethical Considerations

Ethical considerations in research are a set of conducts and principles researchers must adhere to while conducting research, some of which include authorship and plagiarism (Bhandari, 2021). According to Bhandari (2021), authorship signifies the name of the individual or entity that made a significant contribution to research work. It becomes unethical when someone else who has not contributed to the research work claims authorship or adds his/her name. Plagiarism is presenting another author's ideas, language, or context (verbatim) as one's own without permission or proper reference. Some software has been developed to check the originality of research works. Meanwhile, NOVIA UAS uses " Urkund " software to check for plagiarism to ensure that students comply with this ethical standard. Before and while conducting interviews for this research work, participants' consent was given for name unanimity and recording of the interview session because it was practically impossible to retain by memory or write down everything discussed during the session. The records were used only for this research and kept securely. All the participants respected any confidential agreement they had with their organization.

3.5 Limitation and Challenges

Conducting research work, such as a master's degree thesis, is quite tasking, especially for the first time. The researcher must be willing to dedicate adequate time and apply all necessary guides made available by the institution. Also, conducting interviews as part of the research process requires some skill and objectivity to meet the purpose of the research. According to Bryman (2016), some challenges with interviews are that the researcher can misunderstand or misinterpret what is said, in some cases, miss the entire information. However, recording the discussion made it possible to go back for references while analyzing and interpreting the interviews. However, it took much work to document and interpret the interview discussions because it can take hours to get all words accurately, especially for multiple participants. It was also challenging to coordinate schedules with the participants due to their busy schedules and time zones in different regions. These mismatching schedules led to missing out on two participants. The number of participants is seven, which is a small sample size and does not represent the whole population. It is equally necessary to begin the research process in time to meet up with timelines.

4 Empirical Analysis

While conducting research, it is essential to present verifiable and well-distributed data for accurate insight analysis rather than theory or logic. Therefore, this chapter presents the participants' details, demographic information, and the interview results (i.e., each question and response).

4.1 Participant's information

1. **Bjorn Pundars:** Lecturer, Head of Department, Kalmar Maritime Academy, Faculty of Technology, Linnaeus University (LNU). LNU is a state university in south-eastern Sweden. Bjorn Pundars has a Master's Degree in Autonomous Maritime Operations from Novia UAS, Finland. His thesis research is titled *Autonomous Shipping in changing the structures, Future implications on Maritime Education and Training.*

2. **Markku Mylly**: Senior Advisor, Safety and Security, SeaFocus International. SeaFocus is a group of experienced, highly professional logistics, supply chain management, and maritime experts with global track records. The company aims to find synergies, share innovations and best practices, and match future talents, experienced professionals, companies, and industries.). Markku Mylly is a Master Mariner with working experience in the maritime and shipping sector for 47 years in Finland and abroad. He has vast and comprehensive experience in the shipping and maritime sector, both public and commercial. He has developed national and international VTS systems, icebreaking fleets and operations, maritime safety, maritime security, environmental protection, and international collaboration. He has experience in the maritime and shipping regulatory framework concerning safety, security, environmental protection, and maritime emissions. His experience also focuses on the port sector, port technological development, digitalization, logistics, and markets.

3. **Johanna Salokannel:** Project Manager, R&D Maritime Simulations, AboaMare, Novia University of Applied Sciences (UAS). Novia UAS, an institution of higher professional education in Finland, also offers bachelor's and master's degree programs in maritime studies.

4. **Engr. Godson Elekwuwa:** General Manager, Technical and Operations Starzs Investments Company Ltd (SICL). SICL is an indigenous Nigerian marine logistics provider, ship management, and maritime security company providing services in the oil and gas sector. Godson is an experienced Manager of Offshore Support Vessel Operations with a demonstrated history of working in the West African Region and over 20 years of work experience in the maritime industry.

5. **Babawale Akinloye:** Technical Superintendent, Technical and Operations, Starzs Investments Company Ltd. Babawale is skilled and experienced in the Marine industry with proficiency in leadership and engineering capacity and over 15 years of working experience in the maritime industry.

6. **Bonipamo Kalaiti:** Site Project Manager, Lekki Freeport Terminal, Lagos, Nigeria. The Lekki deep seaport is a modern multi-purpose seaport at the Lagos free trade zone, offering support and commercial operations across West Africa. Bonipamo is the Site Project Manager in the Lekki Deep Sea Port Construction Project.

7. **Sunday Ekeh:** Business Development Specialist, a ship broker, chattering agent, and crewing manager.

4.2 Demography of Participants

The participants have ample years of experience in the maritime sector. They are located in the Nordic countries in Northern Europe (mainly Finland and Sweden) and West Africa (mainly Nigeria). Some have acquired fairly international experience or work with companies that engage in international business relations. The term international contextually means operations or business relations outside their locality.

4.3 Interviewing

According to (Kvale & Brinkmann, 2009, p. 82), interviewing is an active process where the interviewer and interviewee produce knowledge through a discussion. The interview questions were open-ended and semi-structured, seeking answers to 'how,' 'why,' 'what,' and 'when.' A semi-structured interview is used when the questions are pre-defined in advance, and the questions may usually start from a more general one, followed by detailed questions (Bryman, 2016; Kvale & Brinkmann, 2009). The interview questions were planned to follow a pre-defined sequence. However, there were cases of leading discussions that altered the sequence, and interestingly, this allowed an easy flow and a more narrative approach to the interview process. It also allowed the participant to feel more comfortable enthusiastically sharing their relevant experiences and perspectives. It is equally pertinent for the researcher to obtain some basic skills and experience with this procedure to determine which discussions are relevant to the research (Kvale & Brinkmann, 2009, pp. 82–83).

The advantage of this method is that it uncovers in-depth information from respondents at a low cost. However, the limitation is that few respondents are used, which is unlikely to represent the entire population. However, according to Bryman (2016), one has to have a grip on the candidate's knowledge and experience for objectivity and to maximize the small sample size. Also, results from findings could be difficult to interpret due to the respondent's subjectivity.

The interview involved seven participants and was conducted virtually through the Microsoft Teams platform. A formal written invitation was sent separately to the participant's email between 25th – 30th April 2022. The invitation contained the research topic, scope, research question, time limit of the interview (60 – 90 minutes), and a few preliminary questions to prepare the participants. All the interviews were scheduled and conducted between 6th May and 18th July 2022. The interviews were scheduled at the participant's convenience which was necessary for an engaging and productive discussion and recorded with the participant's consent. The recording was necessary for reference purposes, as one may be unable to take accurate notes or remember all discussions.

4.3.1 Interview questions and response.

This chapter presents a catalog of the homogenous interview questions and a categorized summary of the participant's responses. The questions are connected and range from a general understanding of MASS, safety, environment, and the social aspect of MASS. The individual responses are summarized and grouped into the same or similar ideas or opinions to establish a pattern or relationship. Please note that the summarized responses are grouped randomly and not in any particular. (Q1....Q13) represents questions (1-13) accordingly.

Q1: What is your understanding of MASS?

(Homogenous responses)

i. The understanding of autonomous ships is quite vast. However, depending on the choice of definition, MASS could mean ships operating with less crew or no crew onboard, which could be remotely controlled or self-driven.

ii. MASS is an intelligent ship that can operate partially or entirely autonomously, i.e., within a given voyage with less or no crew onboard.

iii. MASS is a digitalized ship.

iv. MASS are ships that can operate without necessarily physical human interaction.

(Homogenous responses)

i. MASS are ships that can operate with less human interaction, but it is impossible to have no crew onboard, especially for safety reasons.

Q2: Is MASS achievable, and what possible time frame?

(Homogenous responses)

i. It is achievable but will be adopted faster in some regions than others. However, no one is sure of how far and fast technology will continue to develop, as there is an immediate circle of change with future uncertainties. The central focus of technical development is on remote operations with a possible time frame of 5-10 years, but fully autonomous ships will take a very long time.

ii. It is achievable but will take an extended period, possibly over ten years, to be fully adopted due to legislation, government policies, and safety and security concerns.

(Homogenous responses)

i. Complete MASS autonomy is not achievable, especially in some areas of the maritime industry, like the cruise industry, which will require lots of human interaction with passengers onboard the ship. Ships used for offshore support operations cannot be completely autonomous because of constant operations changes and interaction with several objects or equipment. Also, MASS cannot be completely autonomous when pilotage service is required to guarantee safety within the channel.

Q3: What is the justification and value of MASS

(Homogenous responses)

i. Some values include operational efficiency and reduced environmental impact through equipment optimization. Increased safety because of the machine's reliability for a routine task, as routine tasks can lead to complacency in humans, which can cause an error.

ii. MASS would benefit ship owners because it will reduce human cost elements (e.g., removal of accommodation spaces that can be used for more cargo, energy consumption onboard ships, salary cost, and accidents related to human errors. However, this is debatable because the cost of a new ship exceeds the crew's cost.

iii. MASS is a product of technological advancement and investment (i.e., the philosophical drive for technological advancement).

iv. The introduction of MASS would offset the shortage of seafaring workforce, which is predicted to increase.

(Homogenous responses)

i. There is not much value because accidents can be more catastrophic if there is no adequate crew to take emergency actions. Security concerns will also remain (e.g., these ships have higher rerouting and hijacking tendencies). There might be an increase in freight rate.

Q4: Would seafarers lose their jobs?

(Homogenous responses)

i. Not all seafarers will lose their jobs. New jobs will be created for those likely to lose their jobs. I would rather say jobs will evolve and not necessarily be lost. New emerging work profiles will replace partly or wholly traditional profiles, and more jobs will move to shore.

ii. The shortage of seafaring workforce will counter any job loss if there is any.

iii. Humans will still handle complex jobs because it is easier for machines to automate tasks that are clear and linear.

iv. Jobs will not be lost in the cruise sector because passengers will require lots of interaction with the crew. It is uncertain how passengers will respond or react when no crew is on board.

(Homogenous responses)

i. Jobs will be lost with complete autonomy, especially in predominantly seafaring nations.

Q5: What new potential jobs will be created?

(Homogenous responses)

i. Major ongoing research concerning layout, roles, and concepts focuses more on remotely operating the ship. Some potential jobs are a remote operator who monitors the operation of one or more ships, a control engineer in charge of the maintenance plan and assistance on technical issues, a team that could take over the direct remote control in certain situations, persons in charge of transmission of visual monitoring and radar picture so that the operation center has sufficient information of the ship's surroundings, and possible additional VTS functions for traffic management within the port or an area of high traffic density. However, these jobs will require highly skilled workers, which might not be equivalent to the number of jobs lost in regions with a predominantly seafaring workforce.

ii. Some other jobs include a data management team ashore and cyber security specialist.

iii. Teams for automated systems inspections and testing during port calls and docking.

iv. Most roles onboard ships will be maintained but with updated skills.

Q6 – Who becomes the Operator in the ROC/ RCC?

(Homogenous responses)

i. The captain or officer of a conventional ship is probably an excellent candidate to operate remotely in this transition phase. However, if necessary, this might necessitate a remote operator exam and attendant license while taking a master mariner competency course. It is essential and safer with persons with real-time experience on the sea. It might be catastrophic to initially put some novice who probably have just virtual or play station games experience. However, things might change in the future.

ii. Possibly, the captain or officer at the ROC or onboard the MASS would not be operating around the clock. Some work rotations may be transferred to other qualified persons at the remote station.

iii. The crew in the higher cadre (officers) can be remote Operators just as the role of a Dynamic Positioning Officer (DPO) faded with officers being trained to operate DP vessels. The lower-skilled or job cadre (ratings) might not fit into this category because of a lack of high technical knowledge or competency.

Q7 – What educational Structure and new competency are required for MASS? (Homogenous responses)

- <u>For education:</u>

i. Research on education and training is currently limited, and no strong or detailed recommendations are available. This is understandable as the regulations on which education depends are undergoing several investigations on which the new technology is dependent. However, the content of the training will change with a need to develop education in two lanes of the transition phase: one supporting MASS and the other supporting conventional ship.

ii. Educational institutions should also be able to provide learning for digital competencies and increased IT literacy (e.g., digital operations of physical systems, software and computer engineering, coding and computer programming, cyber security, data fluency, and analytics). Institutions should still maintain classical maritime competencies with the STCW as a minimum requirement but include into their curriculum other advanced programs like automation engineering, maritime law in the area of autonomous operations, maritime economics, and logistics with an understating of how global trends impact businesses and business models, and environmental sustainability on evolving technologies.

iii. Education should incorporate and emphasize a continuous learning approach (i.e., a voluntary and self-motivated pursuit of knowledge, upskilling, and re-skilling to ensure up-to-date skills). Some enablers for this kind of learning include adaptability, agility, innovativeness, intellectual capacity, and stress tolerance.

<u>- Skills and Competency:</u>

iv. Soft skills like leadership, teamwork, cultural awareness, analytical skill and reasoning, critical thinking, information literacy, and creative problem-solving are required.

v. Competency in standardization of communication in autonomous ships and legal competency in autonomous operations is required. Also, understanding of complex systems, operational safety, and management of autonomous ships (e.g., alarm systems), familiarization with new concepts, computer-aided operations and applications for ship operations (e.g., how to move from one phase of computer operation to another), remote operator license with more simulation-based training, a combined deck/engine/electrical qualification are also considered as required competencies.
vi. A remote operator may not need to be a master mariner.

Q8 – Will legislation support the development and implementation of MASS?
(Homogenous responses)
i. Legislative support is ongoing but slower than the technology advancement. However, in the meantime, legislation might not support full autonomy but partial or more automated functions for safety concerns and security (e.g., piracy and terrorism).
ii. there are many undefined risks involved with complete autonomy. However, a comprehensive risk analysis must be conducted to ensure safety, security, and social concerns.

(Homogenous responses)
i. The legislation will not support full autonomy.

Q9 - Is an RCC seen as being onboard?
(Homogenous responses)
i. This question is also being debated, given that many factors are involved. However, ongoing development research seeks to replicate the bridge structure in the RCC/ROC. In this case and according to legislation, it might be seen as being onboard.

(Homogenous responses)
i. The RCC is seen as a bridge extension or shore support, not onboard.

Q10 – Would MASS negatively impact jobs for predominant seafaring nations?

(Homogenous responses)

i. Not necessarily, because an officer in these regions can also be a remote operator and mann MASS; however, he/she would require additional skills in training and education.

(Homogenous responses)

i. Initially, yes, but a new line of trade or vocation will develop in this area for people to adapt. However, resistance to change from seafarers, business owners, institutions, etc., might impede a smooth transition and the possibility of establishing a learning infrastructure to acquire relevant competencies.

Q11 – Is MASS infrastructure sustainable across continents and countries?

(Homogenous responses)

i. It is sustainable but will require considerable investments in ROCs, automated harbors, smart fairways, etc. However, stepwise is the easiest way to achieve it; this is usually how development is done in pieces until the entire process works. A good example is the auto mooring docks which is a step to a more extensive process.

(Homogenous responses)

i. In the meantime, MASS infrastructure is not sustainable across continents and countries if targeting full autonomy because this will require the entire process to be automated and not just operate the ship remotely; if not, the benefit of efficiency and salary costs will not be fully achieved. E.g., the cargo loading for the cargo ship, for instance, and the harbor process has to be automated, which is quite a big task.

ii. It is not sustainable because local and international legislations might enforce restrictions in busy channels for safety reasons.

Q12 – Will it be better to focus on RCC instead of complete autonomy in the nearest future?

(Homogenous responses)

i. It is both ways, but it will depend on the environment, scenario, operations, and the size of the ships. A small ferry going from point A to B without any other boat traffic will be easy to have complete autonomy.

ii. In a cargo ship, you might need to do it stepwise, with some crew onboard, then operate remotely. Afterward, the crew can be removed. However, one must have all the technology and process in place, factoring in all possible and conceivable scenarios, because the ship will require maintenance. It should be figured out if the technology onboard can automate and manage itself until the ship arrives at the harbor for maintenance.

(Homogenous responses)

i. Focusing on partial autonomy and remote operations will be better.

Q13 – How will maintenance be carried out?

(Homogenous responses)

i. Proper maintenance of systems at some point will have to be carried out, both for complete autonomy and remote operations, which will need some maintenance crew in the team or hired personnel from a company, and maintenance can be done at the harbor.

ii. More standardization of equipment will enable an easy maintenance process. The classification society can champion this.

iii. Modularization of equipment for easy replacement (i.e., dividing equipment, products, or system into interchangeable modules).

iv. Incorporating a more preventive maintenance approach (i.e., live time or live circle monitoring and maintenance) and conditioning monitoring (real-time).

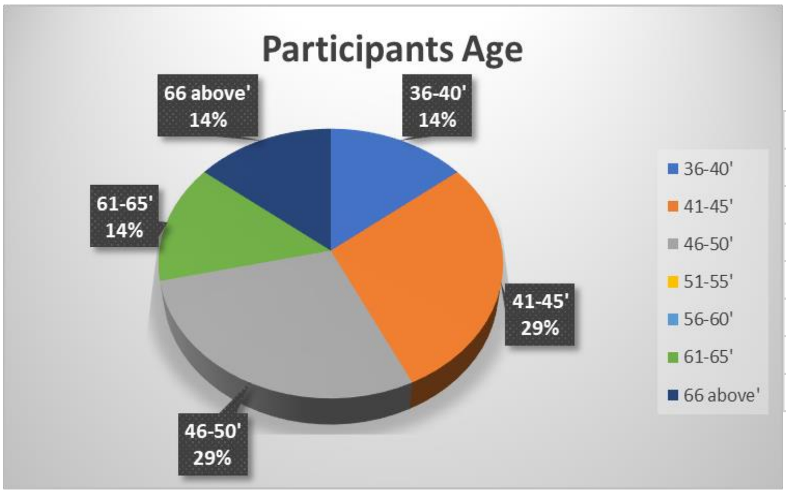
v. Higher redundancy of equipment (i.e., a reliable engineering technique that enables systems to perform without interruption even when a piece of equipment fails. Two identical machines working simultaneously and sharing the load with both machines capable of taking over the complete load or operation in the event the other fails)

4.3.2 Gender Distribution

A total of seven individuals representing a sample of the population participated in the interview, six of whom were males (86%) and one female (14%). However, the gender disparity does not directly affect the participant's responses or research results. The maritime industry is often seen as male-dominated, possibly due to its socially unattractive nature in terms of social disconnect from long voyages at sea, irregular work hours, mundane tasks, and harsh environments. The introduction of MASS and

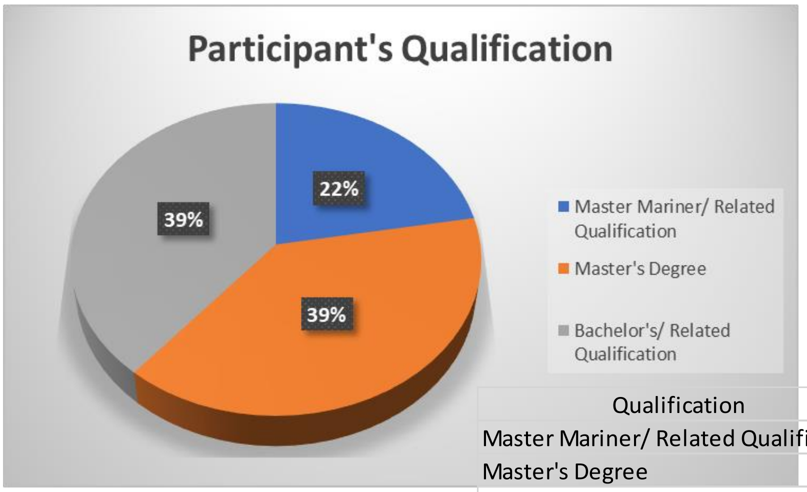
SCC would counter this norm by introducing alternative ways to seafaring. Operation centres on shore can function as a bridge from which the crew can remotely control and monitor the vessel and, at the end of the workday, spend time with family and friends or live an active social life. Also, more automated onboard ships can reduce mundane tasks and irregular work hours, thus creating a better work-life balance. This balance being achieved could improve female gender inclusion and diversity to counter the growing shortage concern of seafarers. This view also aligns with the MUNIN project (MUNIN, 2016c).

4.3.3 Age, Competence/ Qualifications, Years of Work Experience and Location



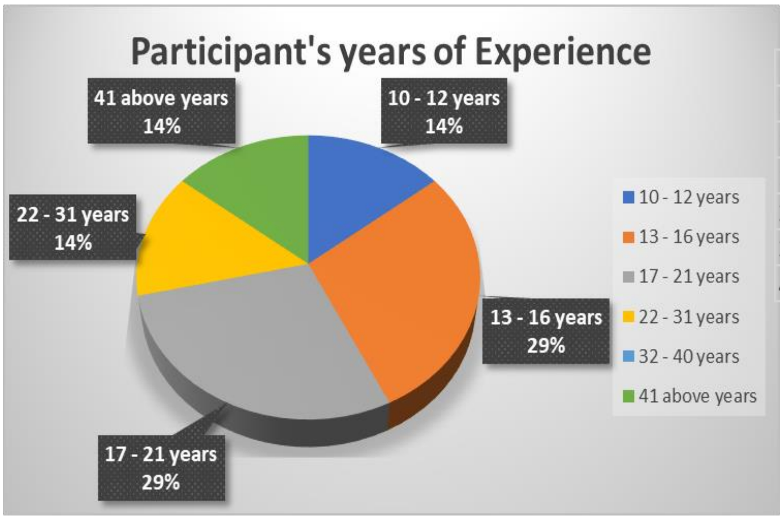
Age	P'
36-40'	1
41-45'	2
46-50'	2
51-55'	
56-60'	
61-65'	1
66 above'	1

Figure 7: Age distribution of Participant



Qualification	Number
Master Mariner/ Related Qualification	4
Master's Degree	7
Bachelor's/ Related Qualification	7

Figure 8: Distribution of Participants Qualification
N.B. (Some participants have more than one qualification).



Work Experience	Number 'P'
10 - 12 years	1
13 - 16 years	2
17 - 21 years	2
22 - 31 years	1
32 - 40 years	
41 above years	1

Figure 9: Participants years of work experience

The distribution figures above show that 57% of the participant are above the average age of 45years, assuming that the starting work age is 25years and retirement age is 65years. Each participant has acquired at least ten years of work experience and relevant qualifications. Thus, participants have ample work experience in the maritime and related sectors.

For the purpose of this study, sector is categorized into business & operations and education & institution. Business & operations represents companies operating, producing or rendering products and services in the maritime industry, while education & institutions represents establishments providing educations, training, research and certifications in the maritime industry.

Sector	**No. of 'P'**	**Country**	**No. of 'P'**
		Sweden	1
Business and Operations	5	Finland	2
Education and Training	2	Nigeria	4

Table 4: Sector in the Maritime Industry and Country

5 Critical review and discussion of results.

This chapter presents a juxtaposition of the literature used with a discussion of the interviews conducted and a reflection of my opinion to answer the centric research questions. Despite the uncertainties of technological development, it is encouraging to find out how much information and knowledge of many skilled people working in the maritime sector are available on the novel concept of autonomous ships. History has proven that change is constant, given the rapid evolution of digitalization. We expect to see further development and realization of MASS in no distant future.

5.1 Analysis

The literature review in (Chapter 2.1) shows that the maritime sector is a crucial area of the transport industry that supports globalization. The industry, therefore, is expected to keep up with emerging global trends (especially in digitalization) to stay competitive and sustainable, which has necessitated the concept of the autonomous ship (MASS). (Chapter 2.2) further expounded the concept and design of MASS with a related vocabulary from ISO and definition and levels of autonomy by IMO for harmonization of the concept. ISO defines *ship autonomy* as the performance of a task(s) or the operations of ship equipment that, under certain conditions, are designed and verified to operate without human control. The process is controlled by automation. (ISO 2022). IMO defines MASS as a ship that, to a varying degree, can operate independently of human interaction (IMO, 2018). These levels of autonomy are presented in (Table 2). The bone of contention in the MASS concept is the speculation that MASS will replace human involvement in ship operations. This speculation has prompted the first research question – (i) Will MASS operations require human involvement?

A leading answer is drawn from the highlighted phrases 'under certain conditions' and 'to a varying degree' in ISO and IMO's definitions, which implies that considerable human involvement is required at varying levels of MASS operations. Similarly, the summary of participants' responses in (interview Q1) further supports and aligns with IMO and ISO's definitions, negating the exclusion or replacement of humans in MASS operations. Furthermore, the research series described in (Chapters 2.3 and 2.4) incorporates humans at varying phases of MASS operations, including the ROC. The benefit of safety in (Chapter 2.5.1) presents humans as crucial during an emergency for quick action, either onboard or at the ROC. Humans are also presented as a cybersecurity workforce to monitor cyberspace for inadvertent attacks, given that MASS operations rely on digital connectivity. Therefore, human involvement is required; however, with adaptive job roles to suit MASS operations. The above analysis provides the answer to the first research question. The answer to the first research question leads to the second research question – (ii) What prospective job profiles (i.e., job description, skills, and experience) are required? In an attempt to answer the second research question, a wide range of factors and functionalities are considered.

Encapsulated in IMO's degrees of MASS operations is the description of a remotely controlled ship outlined in (Degrees 2, 3, and degree 4 in some cases). This concept presents a vital aspect of MASS: ROC/ RCC. Interview (Question 2) also generates a leading response to the concept of the ROC/RCC. Participants' responses (i) for (Question 2) opine that the central focus in technical development currently is on remote operations since degree 4 of MASS is envisaged to take a longer time for actualization due to a series of regulatory considerations(Pundars, 2020, p. 24).

The ROC offers the possibility for a skilled crew in a conventional ship to be an operator but with enhanced competencies and familiarization that suit the MASS model and operations. The job description in a ROC, as listed below, integrates interview (Question 4), response (i, ii, iii, iv), (Question 5), response (i, ii, iii, iv), (Question 6), response (i, ii, iii), which further provides answers to the first research question. It indicates that jobs will evolve and adapt to the MASS operations. The concept is equally presented in (chapter 2.2.1.) where the possibility of the captain and other skilled crew of a conventional ship operating from the shore center is considered (Batalden et al., 2017, pp. 2–3). The table below shows a limited summary of task descriptions onboard MASS, especially the ROC.

Table 5: Task Description in MASS Operations

S/N	Task	Description
1	Operational support, monitoring, and navigation	Control all MASS systems, maintain safety at all times, and operate MASS based on regulatory requirements.
2	Operational prediction and optimization of systems	Planning the most efficient route and choice of action.
3	Path tracking, mission planning, and decision-making	Conduct mission planning for MASS operations according to the area, type, and vessel.
4	System maintenance	Servicing and repair (including fault finding), maintenance, pre-launch checks, and overhaul of components of the system.
5	Risks assessment	Conduct a general risk assessment for MASS operations, including deployment, intervention, and recovery.
6	System management and communication	Understand and manage all vessel control and interactions and awareness of the specifics of remote operations.
7	Hosting of server systems	Hosting and managing host server systems.

The evolving pace of the maritime industry requires training and qualification in both core and soft skills to meet the complexity of MASS operations. (Chapters 2.6, 2.7) and interview (Questions 7) response (i, ii, iii, iv, v, vi) further expound on the required skills and experience for MASS operations. Below is a table showing some of these necessary competencies and skills.

Table 6: Core Competencies and Soft Skills for MASS Operations

S/N	Core Competencies	Soft Skills
1	Digital competency (e.g., digital operations of physical systems, software and computer engineering, coding and computer programming, cyber security, data analytics)	Leadership.
2	Classical maritime competencies	Teamwork and communication
3	Automation engineering	Critical thinking, analytical skill and reasoning
4	Maritime law in autonomous maritime operations	Creative problem-solving
5	Maritime economics and logistics (i.e., how global trends impact businesses and business models	Adaptability and agility
6	Remote monitoring operations	Innovativeness
7	Environmental sustainability on evolving technologies	Continuous learning ability

The listed task description and competencies further gives a complete answer to the research question (ii). Technology is a double-edged sword which can provide great benefit and can also introduce threats to industries, states and economies. The threat is arguably at the human element (Parker, 2015). While much focus is on the technologies for MASS development, there are also manning issues and emphasis on changes in required skill sets and competencies for seafarers. The required skill set, competency, and certification are essential and regulatory bodies must set minimum qualification standards for seafarers. The shift in the competency pool will require highly skilled seafarers or professionals. New skills mostly linked to data management and analysis, software engineering, data grid engineering, remote automation engineering, onboard support technician, shore support specialist, and cyber-attack specialist are considered vital (Parker, 2015). The literature reviews and interviews support the development of the listed competencies. A proposed competency matrix is presented in addition to answering the research question (ii) and reference to (Chapter

2.8), which explains the necessity of skill management to supplement the gap(s) between the skills set that job roles require and the skills that the individual lacks.

Table 7: Limited Summary of Specific Training Needs in MASS Operations.

Key Training areas	Explanation
Principles of Autonomous Systems	Understanding of the levels of automation and specifically the level of operator's interaction with the MASS
MASS Regulations, permissions, notifications, requirements	Understand and produce the required notifications, permissions and requirements for the operation of MASS in the given area
MASS Safety Principles including Machine Application of Regulations	Understand the safe operation of the MASS and any limitations in the application of regulations within the system
MASS Command Control and Communications to include Security	Operate and control communications with the MASS, awareness of security aspects (e.g. cyber) and responses when communications are lost
MASS Deployment and Recovery	Control the launch and Recovery of vessels from land or other vessels
MASS Responsibilities (Owner, operator, insurer, accreditor, certifier)	Understand the responsibilities of all parties involved with a MASS operation
MASS Operations Risk Assessment	Conduct Risk assessment for MASS operations including deployment and recovery
MASS Vessel Specifics	Control the specific MASS and understand all operational requirements according to the MASS vessel in operation.
System Maintenance & Checks	Training on the servicing, repair to (including fault finding), maintenance, pre-launch checks & overhaul of all appropriate components of the whole system
Operator Facilities and interactions	Understand all vessel controls and interactions available to the operator and awareness of the specifics of operating a vessel at distance
Limits of Operation	Understand the limitations of the vessel
Sea Awareness and Handling	Demonstrate awareness of the performance of the MASS under different conditions and any specific handling limitations
Operations	Control all MASS system operations, maintaining safety at all times and meeting regulatory requirements
Emergencies contingencies and Faults	Control the vessel or take appropriate action in the event of emergencies including loss of communications with the MASS
Mission Planning	Conduct mission planning for the MASS Operation according to the area, type and vessel solutions

(safety4sea; Maritime UK)

Table 8: Adapted competency matrix for MASS and conventional ships

MASS Competency Matrix

Persons	Vessel/ Shore	Ship (MASS) Digital System Understanding and Technical Knowledge	Operations monitoring and analysis (remote operations)	Equipment operations and control	Equipment maintenance and repair	Automation engineering	Trouble shooting	Data engineering (data processing and analytics)	Electrical/ electronics engineering	Autonomous maritime law and regulations	Programming	Cybersecurity	Maritime economics and logistics	Classical Maritime Competency - Deck/ Engine (STCW i - viii)	Navigation/ marine engineering	Cargo handling and stowage/ maintenance and repair	Ship operations/ Electrical, electronics and control engineering	Maritime law and regulations	Security Duties	Good seamanship	Soft Skills	IT and technology affinity	Leadership and teamwork	Good reasoning and decision making	Critical thinking and problem solving	Efficiency orientation	Good communication	Managing complexity	Cognitive ability and analytical skills	Innovativeness	Flexibility and adaptability	Continous learning - motivation to learn, learning & resaerch	Environmental awarenes and sustenability mindset
Traditional Seafareres	Conventional ships		0	0	0	0	2	0	0	0	0	1	1		2	2	2	2	2	2		1	2	2	2	2	2	2	2	2	2	2	2
Seafarers with Advanced Technology Skills	MASS (autonomy levels - 1 & 2); IMO		2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2
Remote Operator	MASS (SCC/ROC - autonomy levels - 3 & 4); IMO		2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2

Definitions:
0 - Not necessary
1 - Should have basic knowledge/skills
2 - Should have good knowledge/skill (theory &practical)

Comments: These competencies and task descriptions are summarily explained in (Chapters 2.8, 2.9, Tables 5 & 6, and figure 10 in chapter 5.1). The matrix is in generalty to seafaring, both traditional and MASS operations.

(Cicek et al., 2019; IMO, n.d.-b; ITF 2017)

6 Conclusion

This study created an overview of human (crew) integration in the emergence of MASS by providing answers to the centric research question –"Will MASS operations require human involvement? Furthermore, the require potential job profiles (i.e., task description, skills, and experience). The introduction of MASS does not mean that there will be no significant human involvement operationally. Active operator involvement will be required invariably. The role of humans in the remote-control centre is similar to the role on the bridge of a crewed ship. Therefore, a user-friendly design of the system interface of the remote-control centre is essential to minimize user errors and maximize safety. The shore-controlled centre operators should possess a combination of maritime and technological competence and basic software skills with wide-ranging knowledge of the remote vessel operational and monitoring system. Also, detailed requirements to attain these competencies and qualifications should be structured by regulatory bodies. Intended requirements should undergo several phases of trial, review, and modification before implementation.

Consequently, MASS will impact future seafarers' educational training across maritime institutions and training centres. However, the competency framework and MASS operations' job roles are still being researched. Exploring potential job roles and attendant competencies for seafarers is an active step toward anticipating and preparing for the maritime industry's future. Through desk research and qualitative analysis of a representative sample from the global shipping industry, a competency matrix is proposed, which could aid the curriculum design in MET institutions to equip the trainees with the updated skillset for advancing technical maritime operations. Future research could explore various job roles in the remote operation centre (ROC), and the specific competence required. Another research interest is the possibility of adaptability and training software engineers as ROC operators.

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