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Development of maritime education and training methods with technological innovation : Japan as a case study focusing on MASS

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DEVELOPMENT OF MARITIME EDUCATION AND TRAINING METHODS WITH TECHNOLOGICAL INNOVATION

Japan as a case study focusing on MASS

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Declaration

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

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

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Abstract

Title of Dissertation: **DEVELOPMENT OF MARITIME EDUCATION AND TRAINING METHODS WITH TECHNOLOGICAL INNOVATION: Japan as a case study focusing on MASS**

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In contemporary society, technological innovations such as AI and automation are being promoted. These innovations can affect human life, work and social structure. This research is focused specifically on Maritime Education and Training (MET). It was investigated how technological innovation has influenced to provide effective MET. Maritime Autonomous Surface ship (MASS) is the centre of technological innovation in current maritime industry, and how it affects the competence required of maritime professionals, who are the main target of MET.

Currently, the maritime professionals, who are required a certificate, are only seafarers working on board. As MASS development progresses, not only onboard workers but also new workers to control from land remotely will emerge. The challenge of MET institution (METI) is how to train maritime professionals including this new role, which will be appeared by technological innovation. This research was investigated how METI would respond to technological innovation.

In this research, the analysis is made based on the Training Record Book (TRB) used by the Japan Agency of Maritime Education and Training for Seafarers (JMETS), which is one of the Japanese METI. The competence, which was required by onboard, land, both and neither workers, was color-coded for each MASS autonomy level defined by International Maritime Organization (IMO). From this result, it will be considered how future MET will change and what METI should do.

KEYWORDS: Maritime Autonomous Surface Ship (MASS), Future maritime education and training, Japanese Training Record Books for seafarers

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AI	Artificial Intelligence
AIS	Automatic Identification System
AUV	Autonomous Underwater Vehicle
CBM	Condition Based Maintenance
CoC	Certificate of Competence
COLREG	International Regulations for Preventing Collisions at Sea, 1972 as amended
EPIRB	Emergency Position Indicating Radio Beacon
GMDSS	Global Maritime Distress and Safety System
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IC	Integrated Circuit
ICT	Information and Communication Technology
IMO	International Maritime Organization
INS	Information Service
IoT	Internet of Things
IT	Information Technology
JMETS	Japan agency of Maritime Education and Training for Seafarers
NBDP	Narrow Band Direct Printing
NYK	Nippon Yusen Kaisha Line
MASS	Maritime Autonomous Surface Ships
MET	Maritime Education and Training
METI	Maritime Education and Training Institution
MLIT	Ministry of Land, Infrastructure, Transport and Tourism
NAS	Navigational Assistance Service
PB	Practice Based
RFID	Radio Frequency Identification
SDGs	Sustainable Development Goals
SNS	Social Networking Service
SOLAS	International Convention for the Safety of Life at Sea, 1974 as amended
STCW	International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended
TBM	Time Based Maintenance
TOS	Traffic Organization Service
TRB	Training Record Book
UAV	Unmanned Aerial Vehicle
VTS	Vessel Traffic Service
WEF	World Economic Forum
WMS	Warehouse Management System

Chapter 1 Introduction and background

With recent advances in technology such as artificial intelligence (AI) and automation, it will soon be possible to reduce the amount of labour needed in some of the existing work that is currently carried out by humans, and the profession itself will be replaced by new technology in some cases (Bessen, 2018). On the other hand, new technology will create new jobs or require them to change, so many people must adapt to these occupational changes (Acemoglu & Restrepo, 2019). The wave of technological innovation is advancing in various industries. For example, unmanned delivery by unmanned aerial vehicles (UAV) have been tried through trial and error. If UAV delivery is realized, the human labour force for delivering and storing items will be reduced or eliminated. At the same time, the task of manipulating and managing the delivery of UAV may be newly created, or existing work may be replaced.

There is also a trend towards the Fourth Industrial Revolution in the maritime transport industry. It facilitates the digital transformation of ship operations with the potential to reach full automation (Kobyliński, 2016). The advent of Maritime Autonomous Surface Ships (MASS) will have a significant impact on the maritime industry (Pribyl & Weigel, 2018). MASS, which is operated remotely or autonomously manoeuvrable ships, is influenced by technological advances in various fields within the maritime industry. For example, there are developments in automatic collision prevention (Ramos et al., 2019), which is the device used to select the optimum route in taking into account the weather (Perera & Soares, 2017), and ports to enable automatic berthing and cargo handling (Kooij et al., 2018). Moreover, preparations for new risks, such as pirates and cyber attacks targeting cargo and ships themselves, from technological developments are also considered in international discussions (Kavallieratos, et al. 2018). Even if only focusing on the introduction of the automatic collision prevention device, it requires the development of high-performance sensors that can detect any object, and AI must be able to determine whether it is necessary to avoid the detected object or not at the same time (Wright, 2019). In addition, safety regulations such as the current International

Convention for the Safety of Life at Sea (SOLAS) are not considered to apply without any changes to this new technology. However, the International Maritime Organization (IMO) started to discuss the rules for the introduction of MASS in parallel with the development of technology (Komianos, 2018).

While the development of new equipment and mechanical technologies seems to be impactful, the user's perspective must be considered. In other words, necessary qualifications, skills and knowledge for those who operate and manage MASS must be considered along with the improvement of technology. The IMO's scoping exercise does not fully cover potential changes in operators that affect the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978, as amended (STCW). In this research, surveys will be administered to investigate the education and training requirements and methods necessary for future maritime experts who operate MASS.

1.1 Problem statement

With the advent of MASS, the qualifications that are related to ship operators are expected to become more complex. Because the operational personnel such as seafarers and remote operators differ in each autonomy level, it is necessary to define them in each situation as well as the qualifications (IMO, 2018). Incidentally, there are various definitions of autonomy levels, but the level of autonomy by the IMO used in this research is as follows:

Degree 1: Ship with automated processes and decision support

Degree 2: Remotely controlled ship with seafarers on board

Degree 3: Remotely controlled ship without seafarers on board

Degree 4: Fully autonomous ship

At first, qualified MASS operators in different autonomy levels must be defined in order to clarify the targets of this research. Potential operators will include traditional seafarers such as navigators and engineers, as well as shore-based remote operators. Moreover, as the level of automation advances, the duties of these workers may change and should be considered accordingly.

1.1.1 Navigation officers and ratings

A qualified navigation officers or ratings must be assigned on the bridge during sailing, but new technologies are trying to develop unmanned navigation. However, there are many other tasks that the navigator and rating must conduct for ship operations, which include berthing/leaving, ballast operations, cargo management, cargo hold cleaning and maintenance of cargo handling equipment and fire extinguishing equipment. Since the required level of Maritime Education and Training (MET) may vary depending on the level of automation, the change of MET needs to be considered.

1.1.2 Engine officers and ratings

Some vessels are already been equipped with operating systems for unattended machinery space and these can switch to remote control without qualified watch keepers in the engine room. However, Figure 1 shows while current automation is around 30%, the automation potential for ship engineers is below 5%. MET must change in response to more advanced automation in engine rooms.

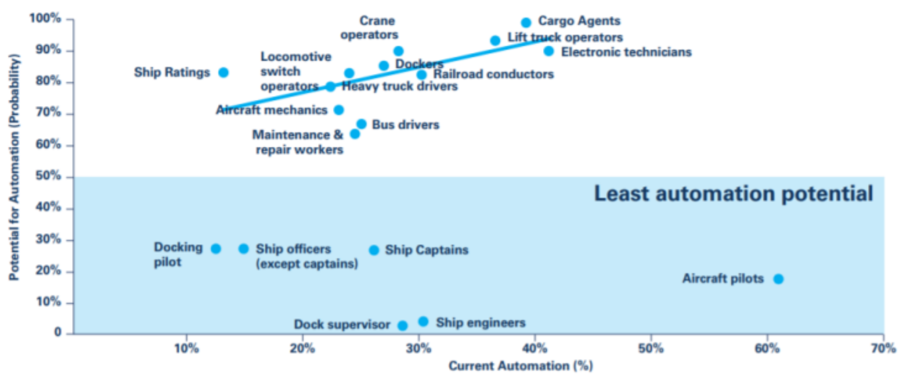

Figure 1. Automation potential for job profiles in transport (WMU, 2019)

1.1.3 Shore-based remote operators

At present, there is no qualification required for those working remote operators. Mechanics, maintains the equipment without certification, and are only onboard for periods of time with the sole purposes of maintenance even on fully autonomous ships; however, it also needs to consider whether the mechanics are required to have qualifications as seafarers. As a result of autonomy, the MET is required to change significantly due to the emergence of new shore and marine workers as well as varying the type of work done by navigators and marine engineers.

1.2 Research aim and objective

The aim of this research is to examine how innovation, especially MASS development in the maritime industry, affects the competence required of seafarers. The impact of technological innovation on humans and society will be investigated historically to examine how it applies now and how it will in the future.

1.3 Research questions

The purpose is to clarify the necessary competence for maritime professionals like MASS operators, and to find a practicable MET systems for them; moreover, the research will answer the following questions.

1. How does innovation affect workers?
2. How did innovation impact workers in the maritime industry?
3. How does innovation impact workers in the maritime industry?

Chapter 2 Literature Review on innovation

This chapter provides a literature review of how technological innovation have affected people and their work and how it may change the transportation and maritime industries. There are similar but different terms for technological innovation, which are technological development and technological advancement. Technological innovation is a product, a process, or a service; moreover, the main idea of it is to speed up the processes to achieve the goals, which are to maximize the profit, social project efficiency and sustainable economic growth (Kogabayev & Maziliauskas, 2017). On the other hand, technology development focuses on the rapid design and development of new technical methods (Ivanova et al., 2019), and technological advancement is synonymous with international prosperity and efficiency, which improves the manner in which business is conducted (Pomaquero et al., 2019). In short, technological innovation includes both of them.

In addition, to illustrate the technological innovation that is progressing in the shipping industry, selected cases of tested MASS are presented. Further, the implications of technological innovation affecting the maritime industry will be discussed with a particular focus on workers engaged in the operation of ships.

2.1 Previous Industrial Revolutions

Technological innovation has dramatically changed humans' lives. There was the First Industrial Revolution in England in the latter half of the 18th century, and it was the development of production technology accompanying technological innovation and a major revolution in industry, economy and society (Tomory, 2016). The Industrial Revolution created the foundation of modern society by changing the way people lived, how they worked and how they spent their leisure time (Santagiustina, 2013). Technological innovation through the Industrial Revolutions historically resulted in leaving a considerable impact on people.

Technological innovations in spinning machines, steam engines and steelmaking have become the driving force of the First Industrial Revolution (Gráda, 2016). In particular, technological innovations in the cotton textile industry have had various effects. Technological innovation made it possible to mechanize the factory (Barham, 2013). Further, it replaced mass-produced spinning machines, which were widely used in rural areas because they were capable of mass production and there were no restrictions on location. Furthermore, this required the use of hundreds of workers to utilize the machines, which in turn eliminated the need for skilled workers (Hirschi, 2018). Even if there is technological innovation, the labour force is still needed; however, the skills of those required workers will change.

Technological innovations in steam engines and steelmaking not only contributed to the development of mechanization, but also to changes working conditions in the factories (Adeniran, 2016). Unlike the income generation mechanisms seen in rural areas, employment was based on hourly wages and it came into common (Rota & Weisdorf, 2019). As a result, workers have come to distinguish between working hours and daily hours, and enjoy leisure activities such as travel during non-working hours. In this way, technological innovation has greatly changed people's lives and values in societies. However, it did not only led to such positive changes.

While the mechanization of the factory through technological innovation eliminated the need for skilled workers, in some areas, it began to exploit low-waged workers, including women and children who may even be forced to overwork (Mohajan, 2019). Further, in urban areas where the population increased rapidly, the development of infrastructure such as water and sewerage was not under developed, and it led to an unsanitary environment (Yahya, 2018). As a result, infectious diseases such as cholera spread. In addition, poverty and crime became major issues (Thachduryany, 2017). It must be taken into consideration that industrialization with technological innovation has had various effects on people and society. In short, people not only benefit from it, but they also suffer disadvantages.

The Second Industrial Revolution refers to the revolution from the late 1800s to the early 1900s. A shift from light industry to heavy industry took place mainly in the United States and Germany. In addition to steel, non-ferrous metals such as aluminium and nickel were mass-produced by the new technology (McInnis, 2005). Moreover, chemically synthesized substances such as dyes, fertilizers, rubber and fibres were produced. Furthermore, internal combustion engines, electric motors, electric lamps, telephones, radios, automobiles were put into practical use, and economic activities and daily life have changed drastically.

The imperialist powers had huge productivity against the background of these technological innovations. They established military superiority, and expanded overseas to secure colonies and spheres of influence. The subordinated areas were not only positioned as the supply of raw materials such as agricultural products and mineral resources and the sales market of products, but also as the target areas for capital exports and were incorporated into the framework of the world system of capitalism (Parthasarathy,2013).

During this period, trade, transportation, and communication methods were highly developed, and the traffic of people, goods, information, and culture became active. In the changes that accompany these innovations, three ideal models of vocational systems have emerged (Agrawal, 2013). One was a market-driven system, which characterized that a labour market provided much of the vocational training. The other is a school model where most vocational trainings are done in schools. And the third is a dual model with an apprenticeship system (Nilsson, 2010). These models are also used in current vocational training.

The Third Industrial Revolution began in the late 1900s and is also known as the digital revolution. Computers could be used to replace tasks related to human intelligence. For example, it has become possible to automate production lines at the direction of humans (Han, 2018). The impetus for the revolution was the end of the Cold War and the conversion of American military technology into private industry (Lungu, 2005). During the war, companies with advanced technologies such as GPS and image processing were under the control of the Defence Ministry. With the entry of national companies into the private industry, the somewhat stagnant American industry revived and a new revolution began. In particular, IT companies such as apple, Google and Facebook have grown. With the introduction of IT in the manufacturing and distribution industries, the world has rapidly become digital. In addition to IT, there were technological innovations such as renewable energy technology, environmentally friendly construction, nanotechnology, sustainable chemistry, fuel cell development, power management using digital technology, hybrid electricity and hydrogen driven transportation. As in the previous Industrial Revolution, extensive vocational training was needed for workers using these new technologies (Rifkin, 2012).

As mentioned above, the Industrial Revolution accompanied by technological innovation has required new education and training for workers while it changes human life, society, structure and relationships. The new Industrial Revolution we face is called the Fourth Industrial Revolution, in which its impacts remains unknown.

2.2 Fourth Industrial Revolution

The Fourth Industrial Revolution was featured at the World Economic Forum (WEF) held in Switzerland in January 2016 (WEF, 2016). Although the Industrial Revolution is closely related to technological innovation, the development of Information and Communication Technology (ICT) is the key to the Fourth Industrial Revolution. In particular, the three pillars of the Fourth Industrial Revolution are the Internet of Things (IoT), AI, and big data (Hyun Park et al., 2017). In the past, only Information Technology (IT) communication devices such as personal computers and mobile phones were connected to the network. However, with IoT technology, everything from household appliances to social infrastructure will be connected to servers and cloud environments via the Internet. Not only are they connected by a network, but they also exchange data with each other, so the IoT has made automatic control possible and mutual control of various things (Di et al., 2020).

AI is a technological innovation that makes computers perform cognition and reasoning that humans can do. It consists of a learning process in which a computer analyses a huge amount of data and an inference process in which a judgment is made based on the learning results (Sun & Vasarhelyi, 2017). Furthermore, the evolution of learning methods such as machine learning and in depth learning has made it possible to make sophisticated judgments like humans in recent years. For example, it is possible to make advanced work autonomous by combining AI with robot technology. It is expected that AI will assist or replace the work that humans have been doing so far (Wilsonet al., 2017).

Big data includes customer's browsing and purchasing history collected from shopping sites, sensor data such as location information and temperature collected from Radio Frequency Identification (RFID) and Integrated Circuit (IC) cards, and user comments and profile fields collected from Social Networking Service (SNS).

Big data demonstrates its value when combined with AI and IoT. By collecting large amounts of data from IoT devices and letting AI analyse big data, it becomes possible to make decisions and work with a higher level of accuracy (Karelberg, 2018). It will be mentioned how these three technological innovations of the Fourth Industrial Revolution will affect human and what challenges they will face as a result of using them.

The Fourth Industrial Revolution will have a major impact on the industrial structure and the working style. It is expected that the fusion of real space and cyber space will be realized by utilizing IoT, AI, and big data (Yao et al., 2017). By connecting people and things in real time, detailed services will be provided. Further, new ways of working may emerge as in the past with the Industrial Revolution while the substitution of labour performed by humans has progressed. In other words, advanced AI and robots can not only reduce labour demand for some jobs but also create new labour demands. For example, substitutable jobs that can be done by sensors and IoT devices would be replaced by them. On the contrary, jobs that require human communication and intellectual jobs that need to use and develop AI and IoT devices would require new human labour (Afza & Kumar, 2018). It is important to forecast labour demands and provide appropriate vocational training to workers by developing human resources and reviewing work styles (Ivanova & Ivanov, 2020). The next section refers to technological innovation and its impact on logistics.

2.3 Relationship between technological innovation and workers in transportation

Technological innovation has greatly affected the lives, working styles, and society for a range of people. In this section, the impact of technological innovation on transportation, especially on workers on ships, will be discussed.

Logistics refers to unified management of the flow from the production of goods to the delivery to consumers, including raw material procurement to production, storage, packing, and sales (Gen et al., 2008). In short, it is a series of systems for managing physical distribution. In logistics, innovation was brought along with technological innovation as in the Industrial Revolution. There are stages from Logistics 1.0 to Logistics 4.0, and it is currently in the stage of Logistics 4.0.

Since ancient times, ships have played a key role in mass transportation. Meanwhile, Logistics 1.0 developed new land transportation by mechanization. With the advent of railways, the amount of land transportation has improved dramatically. Practical use of steam engines on ships has also dramatically improved the punctuality compared to sailing ships. The use of these means of transportation has made it possible to accurately and efficiently carry large quantities of goods to remote areas (Wang, 2016).

Logistics 2.0 is mechanization of cargo handling. The automation of cargo handling operations such as loading and unloading advanced in this step (Wang, 2016). Above all, freight containers had a great impact on the efficiency of cargo handling work because it was enough to stack standardized containers on board (Talley, 2000). Huge gantry cranes capable of hoisting these containers were installed at the port, and containers were used in seaborne trade and reduced the transport costs (Cho, 2014). Moreover, the use of freight containers made it easier to tranship from container ships to trailers. In areas where the containers used at sea and on land were shared, it was possible to combine sea and land transportation using container ships, railroads, and trailers.

Logistics 3.0 is a mechanization of logistics management. The movement to systemise the management and processing of logistics began. The development of the Warehouse Management System (WMS), which is a system for managing the quantity of inventory in warehouses, and the digitization of various procedures for international transportation advanced (Wang, 2016).

Logistics 4.0 is said to be manpower saving and standardized by IoT and AI (Szymańska et al., 2017). Manpower saving makes it possible to greatly reduce the processes that require human operations and decision-making in each area of physical distribution (Barreto et al., 2017). For example, if automated driving becomes practical, luggage can be delivered without a driver. Unmanned Aerial Vehicles may also deliver small parcels. As robots improve in performance, the task of unpacking and packing packages in the warehouse will no longer be a human task. In other words, manpower saving means that the subject of the logistics operation is replaced from humans to machines or systems.

Further, it becomes possible to share information in real time by connecting objects and the Internet. Therefore, the standardization of decision making and business instructions will progress (Sun, 2020). If transportation vehicles and product inventory are connected to the Internet, the flow and movement of goods will be accumulated as digital information. By repeating machine learning and analysis of such big data with AI, it becomes possible to flexibly rearrange the optimal transportation means and routes. If the part of human thinking can be entrusted to digital, there will be no variation in the quality of decisions and business instructions, and it will be possible to aim for standardization. The innovations in logistics as described above are progressing in the shipping industry. The next section will introduce the technological innovations that are actually underway in the maritime industry.

2.4 MASS trials as maritime innovation

This section discusses selected cases on autonomous vessels currently in progress in the maritime industry. As stated in Chapter 1, autonomous vessels are categorized into four levels by IMO. The following cases are regarded as level 3, which is controlled by remote operator without onboard workers, and level 4, which is operated autonomously.

2.4.1 The trial of fully autonomous and remote control (IMO levels 3 and 4)

In December 2018, the Falco, which is a fully autonomous ferry carrier, autonomously operated the route between Parainen and Nauvo in Finland, and succeeded in remotely controlling the return route (Zinchenko et al., 2019). All of the operations were carried out without any human intervention by the onboard crew. Therefore, it is equivalent to IMO levels 3 and 4. The ship avoided collisions using sensor fusion and AI, which are able to detect obstacles; moreover, it demonstrated berthing by an automatic navigation system (Reddy et al., 2019). Falco was equipped with a variety of high-precision sensors, and it was possible to accurately grasp the detailed surrounding conditions in real time. The fusion of the sensor data creates a situational awareness image that is relayed to Finferries remote control centre located in the centre of Turku city, which is approximately 50 kilometers away (Zinchenko et al., 2019). The trial was conducted in such a way that the captain could monitor the autonomous operation and control the ship if necessary.

Figure 2. A Falco’s picture (helsinkitimes.fi, 2018 December 28)

2.4.2 Remote control trial in the English Channel (IMO level 3)

In May 2019, a remote control test was conducted under actual traffic conditions. The test vessel crossed the English Channel from Tollesbury in Great Britain to Ostend in Belgium. The vessel used for this trial is the SEA-KIT Maxlimer, which was not built for the purpose of autonomous navigation, but for a project that investigates the topography of the seabed together with another Autonomous Underwater Vehicle (AUV) (Zwolak et al. 2020). However, the operation was done in the autopilot mode and the remote operator, and the ship was unmanned. The system for determining the position of the ship and managing the communication and power must consider the decision making algorithm. Regarding the position information, the reliability could be improved by considering cyber security such as jamming and using a plurality of types of position information determination devices (Felski & Zwolak, 2020).

Figure 3. A Picture of SEA-KIT Maxlimer (sea-kit.com, n.d.)

2.4.3 The trial of autonomous operation with seafarers (IMO levels 1)

In September 2019, Nippon Yusen Kaisha Line (NYK) succeeded in a trial experiment toward the realization of a manned autonomous vessel for safe operation and labour load reduction (NYK, 2019). NYK aimed to be a manned autonomous vessel, which supports the manoeuvring operations of the crew on board with advanced technology and remote support from the shore office, enabling safer and more efficient operations. This experiment was the world's first trial experiment based on the IMO's Interim Guidelines for MASS trials (Fan et al., 2020). The IRIS LEADER, which is a large car carrier equipped with an optimal navigation program, sailed using the program intermittently day and night while maintaining a normal watchkeeping system. The optimum navigation program was for collision avoidance manoeuvring, and it was developed by incorporating the experience and sensory values of captains and navigation officers with abundant experience in manoeuvring in a traffic simulation program. The trial was conducted in the test area excluding the bay, from Xinsha (China) to Nagoya (Japan) and from Nagoya to Yokohama. In the trial, the program grasped the surrounding conditions based on the data from the navigation instrument, the ship autonomously calculated the collision risk, determined the optimum course, and carried out a series of operations in the actual sea.

Figure 4. A Picture of IRIS LEADER (NYK.com, 2019)

2.5 Upcoming MASS trials

Yara Birkeland is scheduled to be assembled in 2020 and aims to be fully autonomous in 2022. The vessel is expected to be the world's first zero emissions fully electric propulsion and autonomously operated container vessel (Reddy et al., 2019). The success of this vessel could potentially save 40,000 diesel trucks each year, which would help to reduce carbon dioxide and NOx emissions (Othman et al., 2019). In short, it shows that efficient and environmentally friendly transportation is required by switching from land transportation to sea transportation. Furthermore, this vessel autonomy is not only for navigation, but also for cargo handling such as cranes. Moreover, berthing and unberthing by an automatic mooring system is also possible without humans (Guerra, 2017). These will greatly affect the existing supply chain.

Figure 5. A Picture of Yara Birkeland (worldcargonews.com, 2020 March 17)

Chapter 3 Literature review on competence requirements

This chapter discusses how the competence of maritime professionals has over time and will possibly change their future requirements. The following sections are organized as competence required in the past, present, and future.

3.1 Competence required by past maritime professionals

Large sailing boats have been built with various means in order to cross the sea further and more safely. It was 500 years ago that Columbus crossed the Atlantic Ocean to the Americas, but the ship used at this time was a small sailing boat of less than 100 tons.

Figure 6. A Picture of Columbus fleet (history.com, 2019 October 10)

Until the invention of the steam engine, sailboats using wind power were the mainstream of power for ships, and the only nautical instruments were compass and astronomical surveys to determine the position by the sun or stars. In other words, only the knowledge and skills of a navigator who could handle navigation instruments and sail were necessary at that time except for the captain.

When steam engines were put to practical use in ships, a job classification called a marine engineer with the knowledge and skills to use the machine emerged (Bruyns, 2007).

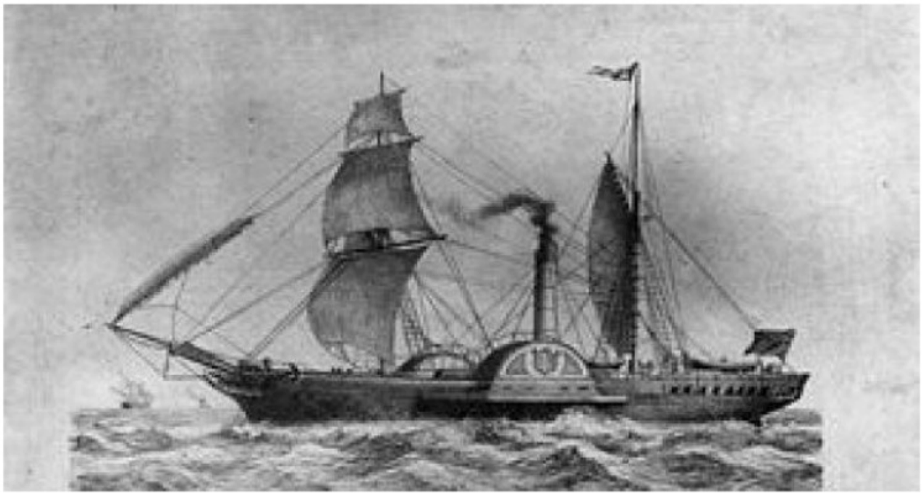

Figure 7. A Picture of steam ship (irishtimes.com, 2018 July 22)

The marine engineer adapted to the change from the steam engine to the diesel engine due to the technological innovation of the propulsion engine, and came to be in charge of new machines necessary for life on board such as generators and refrigerators. Further, a marine radio operator who was familiar with Morse communications, also appeared due to technological innovations in wireless technology. According to international treaties, these onboard workers engaged in the operation of the vessels were required to have qualifications corresponding to the captain, chief engineer, and so on (Leong, 2012). International standards for the qualification of seafarers are specified in the STCW.

In the past, the systems for seafarers' training qualifications differed greatly from state to state, and little effort was made to set international standards. However, the Torrey Canyon tanker accident occurred in the English Channel in 1967, and public opinion that the quality of seafarers must be improved in order to prevent such accidents increasing worldwide (Schröder-Hinrichs et al., 2013). Then, work to review the standards of seafarers' skills and knowledge started by the IMO. As a result, the STCW was adopted in July 1978 and came into effect from April 1984, establishing international standards for training, certificates and duty for seafarers. The STCW has been amended with several revisions up to the present. Above all, a comprehensive review was conducted in 1995 due to the increasing human factors in recent marine accidents, as well as in 2020 to include new requirements such as leadership and teamwork skills (Uğurlu et al., 2015).

The STCW requires seafarers to meet a minimum standard of competence. On that basis, the flag states supervise the education and training institutions of seafarers, certify their skills and knowledge, and issue a certificate of competence (CoC)s. Further, the countries recognized by the IMO as meeting international standards based on the STCW are listed on the White List. As of July 2019, 130 countries are on the White List. On the other hand, even if listed on the White List, the monitoring responsibility of flag states are not sufficient; therefore, the process to acquire CoC, which is carried out by White List states, cannot be trusted (Nautilus Federation, 2020).

3.2 Competence required of recent maritime professionals

Due to technological innovation, the certificates required for seafarers has been changing. A marine radio operator is one example. In the 1980s, satellite communications and Narrow Band Direct Printing (NBDP) were introduced along with the modernization of ships. Moreover, Global Maritime Distress and Safety System (GMDSS) was introduced in the early 90's, and distress signals were automatically digitally transmitted by Emergency Position Indicating Radio Beacon (EPIRB). As a result, Morse communications and its personnel were removed from the international requirements of ships, and the qualifications of radio operators for the new system were also established (Grigore-Valentin & Cristian, 2015). Furthermore, the seafarers in other departments also began to serve concurrently as one of the radio department, and captains and navigation officers on large ships were required to oblige to possess the radio certificate. Therefore, exclusive marine radio operators were not in demand and they disappeared from most commercial vessels (Pocock, 1995). In short, technological innovation has changed the competence required of seafarers, and changed their work styles.

In some cases, technological innovation and international economic conditions have changed the way seafarers work. Vessels are normally operated by certified navigators and marine engineers. However, there were attempts by a small number of seafarers, who have dual certificates for both navigation and marine engineering, to operate a ship in order to save labour costs (Mathews, 2004). Therefore, maritime education and training programs to train dual certified seafarers have been developed in Denmark, Germany, Japan, and others. At that time, labour saving progressed, but the operation of ships by dual certificated seafarers did not become a major trend. The reason is that overwork due to the reduction of operating personnel and capital investment exceed personnel costs. That is why the vessels are still operated by seafarers, who have each certificate as navigator and marine engineer; however, as technological innovation progresses, it becomes possible to realize dual purposed seafarers, and increase the demand for them again.

3.3 Competence required by future maritime professionals

One of the goals of MET for seafarers is to assure the competence set by STCW. It should be noted that STCW is the minimum standard for seafarers. Moreover, STCW only regulates seafarers who work on board, not land-based workers. Therefore, it is necessary for future competence to be discussed not only for on board personnel but also the shore-based personnel in considering the appearance of remote operators or similar in the future (Pundars, 2020). In the following section, the issues relating to competence required for future maritime professionals will be discussed from three perspectives: Digitalisation, Transportation, and Sustainability, which appear to be the key for facilitating technological innovation in determining future competence.

3.3.1 Digitalisation

Similar to other industries, digital transformation and disruptive innovation have been observed in the shipping industry. MASS has a self-governing function that allows it to make decisions without the presence of humans. This autonomy function includes the selection of the optimum route in consideration of the weather and the collision prevention algorithm (Oksavik et al., 2020). These autonomy functions reduce the number of existing seafarers or allow them to operate from land-based centres. The ship will not be completely unmanned in the next two to three decades, but technological innovations in ship autonomy and advanced support systems will continue. In other words, it is possible that both unmanned and manned vessels will be present during the transition to MASS (Aro & Heiskari, 2018). Therefore, maritime professionals must have a deep understanding of all the complicating systems to ensure maritime safety.

Further, this digitalisation will require maritime professionals, including seafarers, to have the ability to analyse and utilize the data (Oksavik et al., 2020). For example, ship locations, speed, fuel consumption, and even freight status will be monitored at the control centre. Fleet managers must be able to understand and analyse this data and provide the captains and crew with the best advice if necessary. For unmanned ships, the fleet manager must make the final decision and operate them correctly. This ability to understand and analyse the data is needed by maritime professionals to reduce the risk of maritime accidents due to human error and cost effectiveness.

Data transmission is one of the foundations of this digitalisation. Maritime professionals must have a deep understanding of communication systems and be able to respond appropriately in an emergency (Felski & Zwolak, 2020). In particular, it would be more important for the unmanned MASS operators. When the remote operators want to change the course of MASS because of stormy weather, they must know how to properly communicate and operate with the MASS system in case of emergency. Furthermore, the response to crime must be considered. It is possible that the unmanned MASS will encounter a cyber attack. Therefore, maritime professionals involved in navigation are also required to have knowledge of cyber security (Blagovest, 2019).

This digitalisation is expected to change the roles of existing seafarers and the birth of new remote operators. Each role will be subdivided and specialized, and maritime professionals will be required to have the competence according to that.

3.3.2 Transportation

The environment for the logistics business can change significantly and maritime professionals will be required to have knowledge of the logistics. For example, Amazon, which is an online retailer, plans to use its own ship to handle all logistics from start to finish as digitalisation advances. In short, there is a possibility that retail companies like Amazon will be able to control logistics by itself without shipping companies that was one of the existing specialized logistics companies (Altuna, 2020). With the increase in the number of retailers providing such logistics, maritime professionals are required to understand and operate the logistics environment. In other words, they do not only need safe navigation at sea, but also financial knowledge and abilities as a member of the logistics operation (Kitada et al., 2018).

In addition, maritime professionals are required to have knowledge of the changing international laws and regulations. Depending on the area the fleet is operating in, it is required to be familiar with not only international law but also the national laws of the area in which it operates. Besides, it will be necessary for maritime professionals to actively learn and adapt to their lives, according to the changing technology and environment. This can be linked to lifelong learning.

3.3.3 Sustainability

Sustainability is the core agenda for today's maritime industry. While the IMO identifies how their work is relevant to all the 17 UN Sustainable Development Goals (SDGs) (IMO, 2017), in shipping and ports, a larger emphasis tends to be made on environmental sustainability, with regard to SDG 7 (energy efficiency), SDG 13 (climate action), and SDG 14 (clean ocean). Regarding the environment, carbon dioxide and sulphur emissions are being regulated by the IMO in the maritime sector. Specifically, a goal was agreed to bring carbon dioxide emissions to 50% by 2050 in the shipping sector. Taking into account the increase in international logistics, more than 50% of emissions will have to be reduced compared to today (Oksavik et al., 2020). These trends have increased the demand for more effective and efficient ship operations. In the operation of ships, carbon dioxide and sulphur gas are produced by the combustion of fuel in propulsion engines, power generation engines and so on. One of the current countermeasures is to reduce fuel consumption and the release of those gases by deceleration operation, which is called slow steaming. Furthermore, maritime specialists are required to have the ability to carry out optimal operations such as the use of canals like the Panama and Suez canals, and the history of waiting times at ports (Park & Suh, 2019). Naturally, the ability to forecast the weather such as existing winds and tidal currents is also included in this optimal operation competence.

Technological innovations are also reducing the emission of these gases. Regarding sulphur content, emission control was enforced from January, 2020, and some ships have introduced a new machine called scrubbers (Smith et al., 2014). This is a device that is attached to an exhaust pipe and removes sulphur in exhaust gas. As the regulation of sulphur emission is regulated as an international rule, it is necessary to familiarize maritime specialists with appropriate methods of monitoring sulphur and maintenance of related equipment. In addition to the correct use of the scrubber, it is necessary to familiarize the maritime expert with proper ballast water management because the new equipment is attached to the upper part of the hull and affects trim optimization, which balances the ship (Panasiuk et al., 2018).

Other technological innovations include changing specifications of fuel oil used and propulsion engines. Regarding the use of new fuel oil, it is necessary to learn how to load, store and use the alternative fuel oil. In the case of a new propulsion machinery, the person in charge must be familiar with its structure, principle, usage and maintenance method (Smith et al., 2014).

As mentioned above, international environmental regulations for sustainable development change existing operating methods and technologies used; therefore, maritime professionals need new education and training to respond to the changes (Oksavik et al., 2020). Maritime professionals are required to have the knowledge to properly operate, support and manage the hull to maximize sustainability both at sea and on land.

In the next chapter, research methods are explained.

Chapter 4 Research method

4.1 Research approach

It is apparent that more research is necessary to understand the way in which new technologies and ship operational practices are adopted in the maritime industry. However, many studies discuss future MET in comparison with the STCW, which provides the minimum standard of seafarer training. This may potentially limits the understanding to what people say that they do. This study therefore takes a different approach which focuses on what people actually do, in other words, what is actually practised in the site of training. It is important to focus on what MET does rather than the image the MET portrays. In order to cope with this challenge, the analytical framework used in this research is based on a practice based (PB) approach. Schultze and Boland (2000) argue that when designing and implementing technology, it is essential to take a PB approach and grasp what people actually do, not what they say or should do. In short, research is focused on what is more practically used, not on the ideal STCW.

4.2 Research method

In this research, the analysis is made based on the Training Record Book (TRB) used by the Japan Agency of Maritime Education and Training for Seafarers (JMETS), which is one of the Japanese MET institutions (METI). In other words, this is also a case study of the impact of innovation on the competence of maritime professionals. The reasons for using TRB in this research are as follows:

The seafarer's competence is set both internationally and nationally. In the international treaty, it is defined by STCW as described in Chapter 3. The STCW stipulated a minimum competence, and it was not credible in some cases even if the state was whitelisted. In short, it is ideal, but it may not be suitable as the one actually used domestically. On the other hand, competence in each state is defined by each national law. Furthermore, unlike international treaties, domestic law is more flexible and quicker to respond and adjust to various changes. Therefore, this study uses a TRB created to obtain competence by national law, not STCW. Next, it will mention why the focus was on Japan.

4.3 Japan as a case study

The reasons why Japan was chosen for research include the historical background as a shipping country and the social conditions of modern Japan. MET in Japan was started in 1871 on navigation and marine engineering teaching before the STCW was enacted. In 1875, the government granted subsidies to a private company, and founded a merchant marine school, which is now the Tokyo University of Marine Science and Technology, and began training Japan's first full-scale shipping personnel (MLIT, n.d.). In 1876, the maritime qualification system and certificate for onboard workers were established in detail, and the national examination for seafarers was started. Since then, it has been forbidden to engage as a captain, navigator and marine engineer unless they are certified. In 1881, the maritime qualification system was improved and subdivided into certificates for seafarers on ocean-going and coastal ships. In this way, Japan has a history of MET for seafarers and the competent certificate; moreover, it still occupies a large proportion of the international shipping volume. Furthermore, Japan proactively suggests MASS proposals as Norway and Denmark do at the IMO.

Further, social conditions may drive technological innovation although Japan is said to have slow penetration of Industrial Revolution 4.0. In addition, Japan has technological potential, as some companies have already begun trials of MASS. Japan has problems with the declining birth rate and aging population; moreover, the working population is predicted to decline. Japan's Ministry of Health, Labour and Welfare estimates that the working-age population of about 12 million people will decrease by 2040, which means a decrease of about 20% (Fleming, 2019). The substitution of labour by AI and robots can be expected to have a positive effect as a solution to the expected workforce shortage problem in Japan even if people are simply deprived of work. The Cabinet Office of Japan announced a social concept of a super-smart society, which connects all people and things, in the 5th Science and

Technology Basic Plan in January 2016. The goal of a super-smart society is to provide the necessary goods and services to the people who need them when the people need them, and to meet the various demands of society in a finely tuned manner. Furthermore, all people are enabled to receive high-quality services, overcome various differences such as age, gender, religion and language, and live comfortably and vividly in the society (Nakajima, 2016). To realize such a society, the introduction of technological innovation will be promoted. For this reason, Japanese TRB, which defines competence criteria, is used for the research in this paper. Specific research methods will be described in the next section.

4.4 Research method

Using a Japanese TRB that meets the STCW, the study examines at each MASS autonomy level whether the stated competence is still necessary to be trained. Further, it is expected that the positions requiring competence will change in the future, and each competence will be colour-coded with four types of classification (Table 1). Specifically, a table will be created in which the competence required for onboard personnel is red, those required for onboard personnel and land staff are yellow, those required for land staff are green, and those not needed are blue. These are classified based on the literature, and future MET will be discussed from the created table.

Table 1. *Example of colour-coded TRB (Source: Author)*

Navigation at the operational level

No	Competence		Knowledge, understanding and proficiency	The degrees of autonomy			
				1	2	3	4
1	Plan and conduct a passage and determine position 航海の計画・航行及び船位の決定	1.1	Ability to use celestial bodies to determine the ship's position 船位を測定するための天体観測方法		1	1	1, Nav. Mgmt. 2.1
		1.2	Knowledge and ability to use nautical charts, and publications 水路図誌に関する知識及び利用する能力		2, Nav. Mgmt. 7, 8.4	31	2, Nav. Mgmt. 7, 8.4
		1.3	Knowledge and proficiency to determine the ship's position 船位測定に関する知識と技能		1, Nav. Mgmt. 2	9	1, Nav. Mgmt. 2
		1.4	Knowledge of operational procedures and optimal adjustment of steering control systems 操舵制御装置の取扱方法、最適な制御調整方法		3, Nav. Mgmt. 9	32	3, Nav. Mgmt. 9
		1.5	Knowledge to use and interpret information obtained from meteorological instruments 気象測器から得られる情報の利用及び解釈に関する知識		4, Nav. Mgmt. 8	33	4, Nav. Mgmt. 8
		1.6	Knowledge of the characteristics of the various weather systems, reporting procedures and recording systems 気象システムの特徴、通報手順及び記録方式に関する知識		13	13	5, 13

Chapter 5 Finding

In this chapter, the TRB for oceangoing seafarers are used in JMETS, which is one of the Japanese METIs, it is used to analyse the need for competence acquisition at each level of autonomy on MASS. The TRBs are for navigators and engineers, which are further classified into operational levels and management levels as with the STCW.

5.1 Relationship between Japanese TRB and STCW

First, the relationship between Japanese TRB and STCW is analysed above and they are classified by colour. As shown in Table 2, it is clear that Japanese TRBs use 100% identical items for competence. Regarding the knowledge, understanding and proficiency, which are a further division of competence, were described in the Japanese TRB, but not in the STCW. Overall, all 52 competence was the same as in the STCW, with the exception of duplicated navigation and marine engineers on operational levels. Regarding knowledge, understanding and proficiency, only 7 out of 117 items had additional elements that STCW did not have, and the similarity was 94%. Therefore, it can be concluded that the TRB actually used in Japan has almost the same contents as the STCW.

Table 2. *Similarities between the STCW and the Japanese TRB (Source: Author)*

	Same item as STCW	Additional items not found in STCW	Similarity (%)
The number of competences	52	0	100
The number of knowledge, understanding and proficiency	117	7	94

5.2 Analysis by colour coding

Appendix A shows the result of color-coding each item using the Japanese TRB for each autonomy level for MASS. In the table, *red* is categorized to be required only for onboard workers, *yellow* is onboard and land workers, *green* is only for land workers, and *blue* is no longer required. Incidentally, there is another references for Appendix A separately from ones for the main text. Moreover, the tables and figures below show the relationship between the competence required of maritime professionals and the autonomy levels of MASS, which are excerpts of the results of Appendix A.

As mentioned above, the autonomy levels used in IMO are as follows:

Degree 1: Ship with automated processes and decision support

Degree 2: Remotely controlled ship with seafarers on board

Degree 3: Remotely controlled ship without seafarers on board

Degree 4: Fully autonomous ship

In particular, this analysis focused on degree 4, which enables to operate autonomously with a drastic reduction in human involvement. In other words, degrees 1 to 3 are controlled by humans, but degree 4 is basically operated autonomously by the ship itself. Therefore, the overlapped competence is shown blue in the operational level when the content overlaps between the operational and the management level at degree 4. Moreover, some competence in degree 2 is shown in green similar to degree 4, because remote operators are the ones who mainly operate a ship at this stage and it will result in reduction of seafarers on board.

Tables 3 to 7 are excerpts of the results of Appendix A. Further, figures 8 to 12 are graphs of Tables 3 to 7.

Table 3. *Competence for navigation at the operational level (Source: Author)*

Competence for	Degree 1		Degree 2		Degree 3		Degree 4	
	n	%	n	%	n	%	n	%
Onboard	46	100	0	0	0	0	0	0
Onboard & land	0	0	15	33	0	0	0	0
Land	0	0	29	63	39	85	6	13
Unnecessary	0	0	2	4	7	15	40	87

Table 4. *Competence for navigation at the management level (Source: Author)*

Competence for	Degree 1		Degree 2		Degree 3		Degree 4	
	n	%	n	%	n	%	n	%
Onboard	30	100	2	7	0	0	0	0
Onboard & land	0	0	28	93	0	0	0	0
Land	0	0	0	0	26	87	22	73
Unnecessary	0	0	0	0	4	13	8	27

Table 5. *Competence for marine engineer at the operational level (Source: Author)*

Competence for	Degree 1		Degree 2		Degree 3		Degree 4	
	n	%	n	%	n	%	n	%
Onboard	36	100	3	8	0	0	0	0
Onboard & land	0	0	8	22	0	0	0	0
Land	0	0	25	70	26	72	2	6
Unnecessary	0	0	0	0	10	28	34	94

Table 6. *Competence for marine engineer at the management level (Source: Author)*

Competence for	Degree 1		Degree 2		Degree 3		Degree 4	
	n	%	n	%	n	%	n	%
Onboard	19	100	0	0	0	0	0	0
Onboard & land	0	0	19	100	0	0	0	0
Land	0	0	0	0	16	84	16	84
Unnecessary	0	0	0	0	3	16	3	16

Table 7. *Competence for navigation & marine engineer at the operational & management level (Source: Author)*

Competence for	Degree 1		Degree 2		Degree 3		Degree 4	
	n	%	n	%	n	%	n	%
Onboard	117	100	5	4	0	0	0	0
Onboard & land	0	0	65	56	0	0	0	0
Land	0	0	45	38	98	84	45	38
Unnecessary	0	0	2	2	19	16	72	62

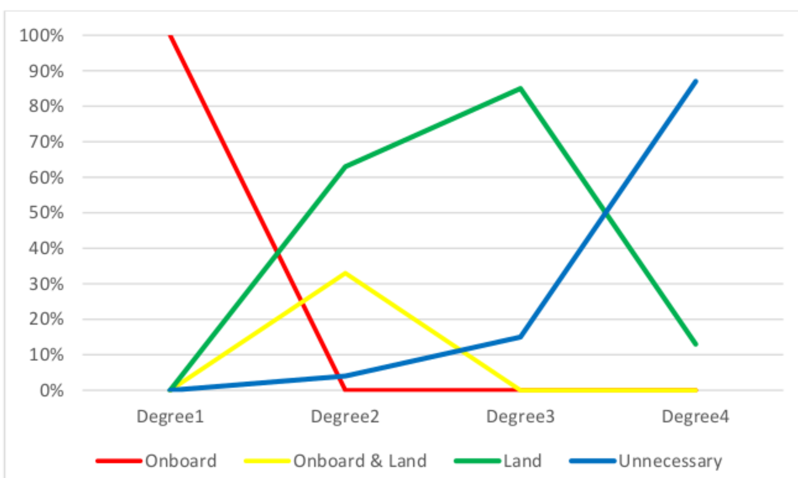

Figure 8. Competence for navigation at the operational level (Source: Author)

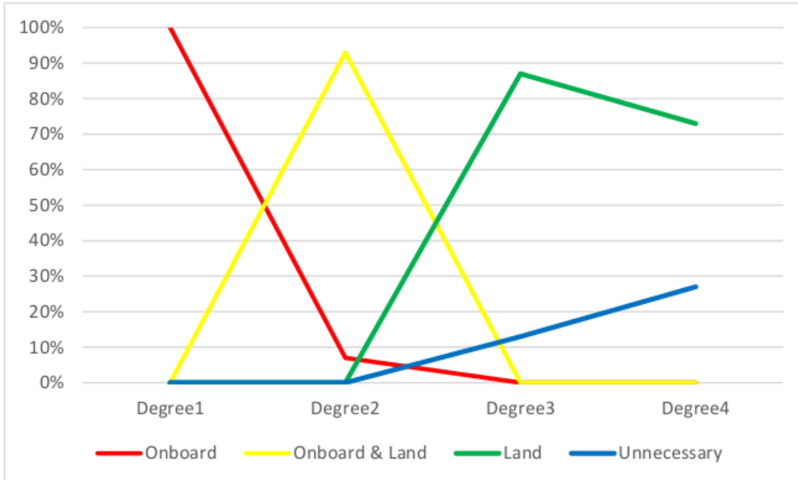

Figure 9. Competence for navigation at the management level (Source: Author)

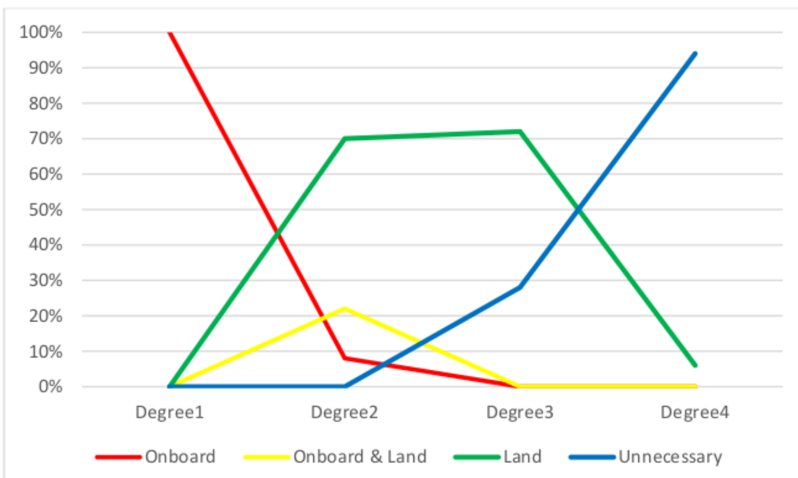

Figure 10. Competence for marine engineer at the operational level (Source: Author)

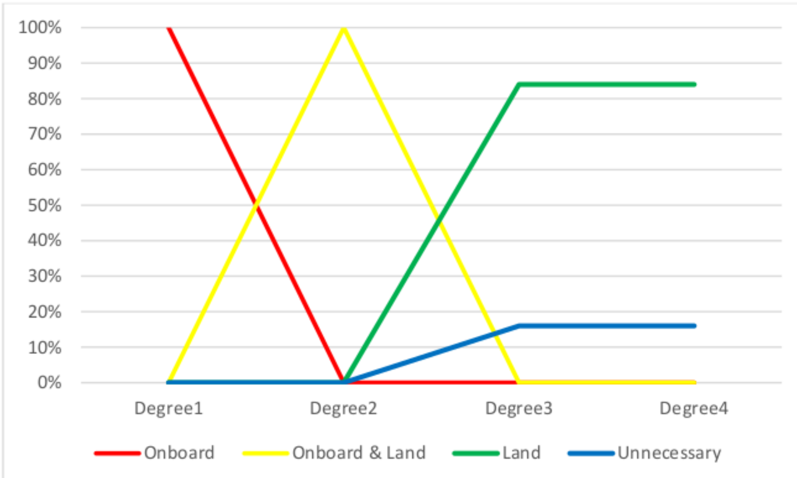

Figure 11. Competence for marine engineer at the management level (Source: Author)

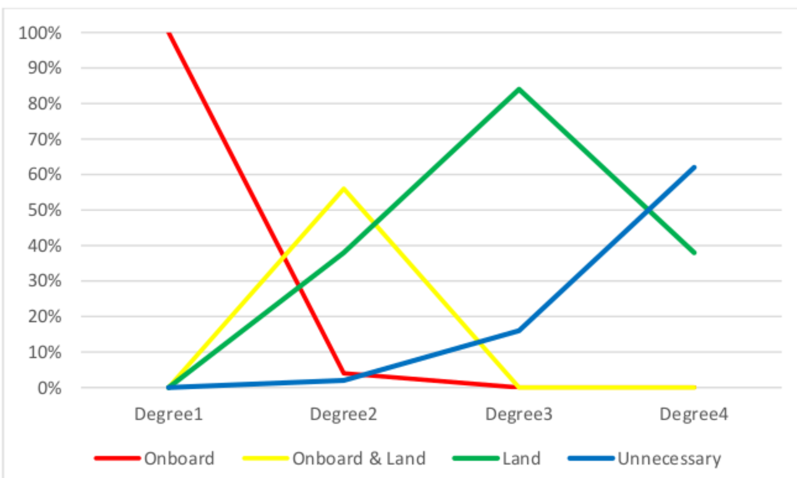

Figure 12. Competence for navigation & marine engineer at the operational & management level (Source: Author)

As Figures 8 to 12 show, all maritime professionals are still required competence at degrees 1 to 3, which involve people in operating ships. On the other hand, there is a difference in the need for competence between the operational and the management level at degree 4. These results indicate that management level personnel are still required to have much competence. Furthermore, focusing only on the management level, marine engineers were required to have more competence than navigators. This is similar to the result shown in Figure 1, which shows the possibility of marine engineers' autonomy is lower than navigators. More specific discussions at each stage are given below.

5.2.1 Degree 1 changes the required competence for seafarers

Even at this stage, ship autonomy is promoted. However, the ship only assists human decision making as the seafarers are on board the ship and the final decision making is left to humans (Wright, 2019). The work load of the onboard workers may be reduced, but they are basically required to have the same competence because they work onboard as seafarers. Therefore, the conventional competence required for navigators and marine engineers in an operation and management level at degree 1. How the vessel supports the decision making of the crew will be confirmed.

One of the decision-making support systems on ships is the lookout support during ship navigation. Incidents caused by insufficient lookouts include serious accidents such as collision, contact, and grounding (EMSA, 2019). Ports and coastal areas account for a large proportion of places that are prone to accidents. Even now, a watch system using Automatic Identification System (AIS) information and a new navigation system utilizing mixed reality, which integrates the real and virtual worlds and interacts in real time, information is being developed (Fossen, 2018). Many causes of collisions in marine accidents are insufficiently watched, and accounts for about 80% of all causes; therefore, these technologies developed to reduce such human error of the ship operators (Fitrawan, 2019). Originally, ships are one form of transportations modes that requires more human expertise, advanced manoeuvring skills, and the actions of vessel operators based on their experience, as compared with other types of transportation such as aircraft, railways, and automobiles.

Therefore, devices that support humans are being innovated daily; however, new competence to the use the technologies is also required. For instance, the installation of ECDIS on ships gradually became mandatory by amending the SOLAS in 2012. ECDIS simplifies nautical chart information management using communication lines and enables safe navigation by monitoring planned routes. In other words, it combines nautical chart information and navigation information to help monitoring when approaching dangerous places such as shallow waters. Even such a very useful device is meaningless unless the user learns how to use it and uses it properly. Therefore, it was added to the required competence at the operation level and management level of navigation in the Japanese TRB and the STCW Code A. In this way, when new equipment is installed due to technological innovation such as digitalization, workers involved in the operations may be required to have new competence.

As above, automation is progressing every day even at this stage; moreover, it is expected that even more advanced operations such as port entrance and leaving will be automated in the future. Specifically, the introduction of a system that simplifies operations in the harbour area by using mixed reality technology and high-precision sensors that can respond to all weather conditions such as rain, wind and waves are considered. Simplifying not only navigation at sea but also manoeuvring in the harbour area may further reduce the burden on the navigator. While the innovation reduces the burden on people and safe operation, MET for those who handle it should also be considered.

5.2.2 Degree 2 changes the way of ship operation

At this stage, the vessel is basically monitored and remotely controlled from land, but there are still sea workers on board. When it is difficult to continue remote control due to a communication failure or some problems, it is necessary for a maritime worker to operate the vessel. Therefore, marine workers are basically required to have the same competence as they do today. The major change at this stage is the advent of remote operator. As mentioned in the previous chapter, STCW only prescribes the competence required for seafarers. However, remote operators need to be educated and trained to gain competence to make final decisions properly and operate optimally when they are in charge of MASS operations in degree 2. Since the remote operators mainly monitor and operate MASS, seafarers will be able to concentrate on the maintenance and management of all equipment, such as deck equipment and propulsion equipment on board, monitoring and management of cargo, and preparation of documents required for port entry and departure.

Because seafarers still work on board, they need to manoeuvre due to narrow waters or congestive areas in some cases. However, technological innovation supports remote operators and seafarers. By displaying the AIS information on the image of the camera installed in front of the ship and displaying the position information of other ships and obstacles using mixed reality, the ship operator can be visually supported. In the harbour with many obstacles and narrow areas, it is very important to grasp the surrounding conditions. Conventionally, the work of berthing a large ship has mostly depended on the master's experience, but more precise manoeuvring is possible if this system operates correctly. In addition, if the system reached the stage of practical use, an automatic port entrance and leaving would also be put into practical use. As remote control and automatic control are put to practical use in this way, the required number of seafarers may decrease.

In the past, there have been attempts to operate modernized ships by seafarers with dual purpose certificates, which include navigation and marine engineering. At that time, the performance of the sensor, the communication capacity and cost were insufficient (Habara, 2019). Therefore, few ocean-going seafarers have both certificates. However, due to technological innovation, the accuracy of the sensor has been dramatically improved, and the communication capacity and its cost have been improved. Moreover, seafarers are aging and there is a shortage of manpower in the case of Japan. Further, the work of seafarers is becoming less attractive to the younger generation due to the harsh working conditions on board (Sason, 2019). In that regard, the new role of remote operators can work at an office where they can return home every day, which can make it more attractive for new maritime professionals.

5.2.3 Degree 3 makes the role of the remote operator more important

At this stage, the vessel is basically monitored and remotely controlled from land, and there are no workers on the vessel. The big change here is that there will be no sailors on board. Since there are no seafarers, there is no need for onboard communication systems or knowledge of seafarer survival techniques (Su et al., 2019). Furthermore, the absence of seafarers eliminates the need for knowledge and skills related to the equipment necessary for humans to live on board, such as refrigerators and air conditioners. The reduction of living space is expected to increase cargo space. However, a higher level of technological innovation is required than in degree 2 due to the disappearance of seafarers. Sensors are installed in various parts of the hull to estimate the external wave force, the stress state and fatigue strength of each part from the data.

Further, this technology is applied not only to navigation but also to engineering equipment. By accumulating and analysing the data obtained from the sensors of various parts of the engine and equipment, it becomes possible to estimate the remaining life of parts and the maintenance timing. These enable Condition Based Maintenance (CBM) instead of Time Based Maintenance (TBM) (Jakovlev et al., 2013). Currently, engineers who are actually onboard vessels have made equipment maintenance plans, and discovered anomalies by monitoring sounds and vibrations of machines. The innovation makes it possible to detect abnormalities in equipment early and deal with them. However, the final decision as to whether or not maintenance is required must be made by a person who is remotely controlling, and the person in charge of operating the ship must have the necessary knowledge and carry out it.

There is a Digital Twin that has advanced the above-mentioned sensor precision, data storage, and analysis technologies. A Digital Twin is a digital copy of an actual ship, integrating all available digital information about the ship and virtualizing the ship's entire system (Höyhtyä, 2019). By using it, it is possible to evaluate the performance of a ship in almost real time. The generated model is positioned as a twin in the digital world of a real ship. The Digital Twin is expected to be a convenient tool for planning and managing vessel maintenance, repairs, modifications and technical updates. While it is expected that the maintenance of ships will change as described above, remote control operation will be mentioned.

Nothing is specified in the STCW in terms of remote operation, but the operator of the Vessel Traffic Service (VTS), which is a maritime transportation centre at an important point of maritime traffic and assists navigation of ships, is recommended that they should have a certificate approved by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). Their work is roughly divided into three services, which are Information Service (INS), Navigational Assistance Service (NAS), and Traffic Organization Service (TOS) (Chong, 2018). INS is a basic operation of VTS. In order for the ship to operate safely and efficiently, information on the movement of other ships, meteorological conditions, abnormal road signs, and other information necessary for the safety of navigation are provided through the VHF.

NAS recommends that the traffic rules should be complied with when there is a risk that a ship navigates ignoring the rules of the sea area or a risk of danger in the navigation of the vessel. It also encourages the vessel to take certain actions to avoid danger. The TOS gives instructions on the scheduled time of entry into the route to keep an appropriate distance between vessels in consideration of the operating characteristics of huge ships and ships carrying dangerous goods. It ensures safety and efficiency of navigating vessels that way. To carry out these tasks, advanced judgment and coping abilities are required to support the ship operator are required, so the VTS operator needs specialized knowledge and experience. There are some differences between VTS and remote operator work, but there is also a common point in terms of monitoring. Therefore, education and training methods for VTS operators may be incorporated into the maritime specialists who operate MASS.

5.2.4 Degree 4 requires new competence for maritime professionals

At this stage, vessels make decisions themselves and operate autonomously. Although various approaches have been taken regarding MASS, the ultimate goal is unmanned. It is an automatic navigation system that implements AI. The above mentioned mixed reality and IoT technologies have been limited to the decision making support of the operator, but the ship can operate by autonomous judgment if advanced AI can be implemented in the system. In short, the system itself judges and operates based on the instructions from the shore operators and the surrounding information. Although there are some parts that require human hands at key points, mass transportation with a smaller number of people will be realized if they are put to practical use at this level. In other words, the competence required of humans may be reduced or changed since the ship is operated autonomously; however, humans who direct it are still necessary.

There may be various problems depending on the sailing area due to the absence of seafarers in degrees 3 and 4. When entering and leaving the port, freight vessels are required to be delicately maneuvered due to positional adjustments with cargo handling equipment. Because of the ship maneuvering, the propulsion equipment is also required to finely adjust the output. Similar operations and power adjustments are also required in areas with a large amount of vessel congestion, such as harbours and coastal areas. On the other hand, there is the possibility of contact with unexpected floating materials like driftwood and drift ice although the volume of navigational ships decreases in the pelagic sea. As for engines, long routes can continue to run for three weeks unlike automobiles and airplanes, and maintenance of equipment during navigation is essential on such routes. However, due to the development of engine monitoring technology, it may be possible to temporarily send maintenance personnel who are not seafarers to ships using helicopters if necessary. Furthermore, what is expected is the emergence of maintenance-free engines.

To reduce engine maintenance as much as possible, it is conceivable to reduce the amount of equipment and the sliding parts of them (Umeda et al., 2018). Battery-powered ships already in practical use on short-distance routes are excellent in terms of maintainability. In order to use a diesel engine, which is the most commonly used propulsion engine in commercial ships, there are various necessary things such as fuel, lubricating oil, cooling water, steam, and electricity. However, battery propulsion vessels can reduce some of those requirements. In short, the need for maintenance can be reduced. Instead, knowledge and skills of battery-powered vessels will be required and the required competence will change. Considering the equipment used that changes with technological innovation, MET required by maritime professionals must be considered.

Chapter 6 Future MET

In the previous chapter, the need to obtain competence at each level of autonomy was discussed. To further narrow down the target, Figure 13 shows the competence required for each of the operational and the management level of navigators and marine engineers, extracted from the colour coding in Chapter 5.

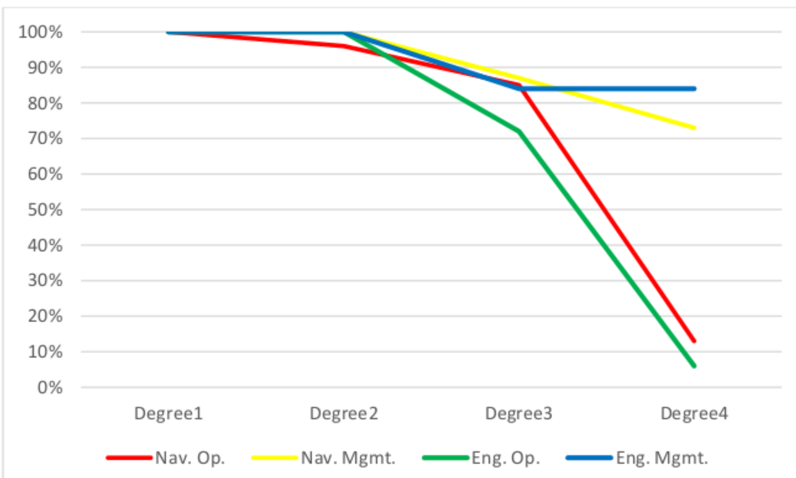

Figure 13. Competence required for each position (Source: Author)

Figure 13 shows that as autonomy progresses, especially at degree 4, MET to the management level becomes more important. Furthermore, in the discussions in all chapters, what has been found at all levels of autonomy is the importance of flexible response to changes due to technological innovation. In other words, those who use them need to continue to learn and adapt to the new ways of operating ships safely and efficiently as changes occur. Even though the current required competence is acquired by maritime professionals, it does not mean that this guarantees the future competence needed. STCW requires that the certificate should be renewed once every five years, but it is permitted based on the experience and period of seafaring. As today's technological development has a greater impact on people and society at a faster pace, those who use them are required to continue learning.

METIs have the role of providing maritime professionals the opportunity to continue learning, such as lifelong learning. Currently, the idea of lifelong learning is spreading to all educational settings. One of the concepts of lifelong learning is that learners can receive education anytime, anywhere (Hu et al., 2017). Another definition of lifelong learning is all learning activities, which will improve learners' knowledge, skills and competencies, from individual, social development and working perspective (EC, 2001). These show that not only students going to school but also working employees need to continue learning to improve their lives. Introducing this concept will significantly change the shape of conventional classroom lectures because not all learners from different backgrounds can be in class at the same time. For example, online lectures may be promoted more without actually gathering at educational institutions. To respond to such changes, it is necessary to keep up with METIs' own technological innovation and learn about new technologies. Various collaborations can be the key elements for METIs to facilitate the learning of technological innovation. In this chapter, how METIs need to change and respond to obtain these ever-changing competence will specifically be discussed.

6.1 MET with academia, industry and legislation

At this stage, seafarers are working on board as final decision makers. As already mentioned, the development of communication technology has eliminated the need for the role of marine radio officers. On the contrary, seafarers are required to have a new competence with the advent of ECDIS. In this way, the role of seafarers and the required competence for them have changed due to technological development. METIs, which educate and train maritime specialists, must quickly respond to these changes and provide the required MET curriculum to the personnel required in the maritime industry. Educational institutions and those who belong to them may be interested in efficient and effective teaching methods, but not in the changes in what they teach. Especially in vocational education and training, the content of teaching may change significantly due to the influence of technological innovation as mentioned above. That is why collaboration with other fields is important for METIs. Collaboration stimulates the content, and transforms it into optimal services.

It is necessary to know where technological innovation is occurring in terms of listed competence of seafarers. Technological innovation occurs mainly through research in several fields such as academic facilities and equipment manufacturers. These new technologies will be put to practical use after repeated trials. By being involved in these processes, METIs will be able to come into contact with technological innovation quickly and provide new knowledge and skills for new technology to maritime experts. In short, collaboration with academia and industry is important. Moreover, obtaining a new competence can be a mandatory requirement with amendments of the STCW. After the amended STCW, it will eventually be reflected in the national law of each state. Therefore, METIs are also required to cooperate with the national legislature. METIs would be able to provide more effective MET to maritime professionals if the MET itself proactively engage in the international community and was involved in legislation within the state.

6.2 MET with employer of maritime professionals

At this stage, the onboard tasks of seafarers will be reduced because remote operators are mainly responsible for the operation of the ship. The MET for remote operators will be similar to degree 3, so it will be mentioned later. The maritime professionals on board are particularly focused on in this section.

As mentioned in paragraph 5.2.2, this stage may facilitate the reduction of crew on board. In that case, there is a possibility that a dual purpose certificate will be required as in the past. This is just one example of a new need, but meeting the demand requires cooperation with shipping companies and crew dispatching agencies. While METIs supply competent maritime professionals, it must match what is required by their employer. Particularly in Japan, where a case study was conducted, most seafarer cadets gain onboard experience and are trained on exclusive training ships without boarding a shipping company's cargo vessel. On the other hand, there are various MET mechanisms and patterns depending on the state or METI, for example, a shipping company has its own METI, or a METI and a shipping company is not related. In any case, it is important for METI to meet the demands of the employer to provide more effective and efficient MET in a sustainable manner.

6.3 MET with educational institutions

At this stage and degree 2, it is assumed that the remote operator will operate the vessel. Therefore, simulator training that makes full use of digital technology is effective as education and training for remote operators who are not actually on board and engaged in ship operations. Technologies such as Digital Twin allow virtual real-time operational data of a ship to be obtained. In other words, remote operators may need to have competence to judge the ship's situation and make a decision as necessary even if they are not actually on board. With simulator training, training tools can be developed based on such actual data. However, actual onboard training is still the main training method currently in MET (Kitada & Baum-Talmor, 2019), and simulator training is not used as a major training tool due to the requirement of onboard experience to obtain a certificate. That is why the cooperation with simulator development companies is important; further, the cooperation with other educational institutions that are already actively adapting these tools for vocational training is also important.

Simulator training has become a major training tool in the aviation industry, and telemedicine training has been put to practical use in the medical industry. Some METIs closely associated with equipment manufacturers have already begun offering new services to replace simulator training with major training tools. METIs, which has not yet introduced simulator training as major training tools, must deepen cooperation with these industries and other educational institutions to provide more effective and efficient MET.

Furthermore, attention must be paid to the decision of international conventions such as STCW as mentioned in degree 1. Especially, the competence required for remote operators which is not currently defined. There will be some form of requirement for them in the near future. While keeping an eye on the development in the IMO and the member States, MET should be provided by cooperating with them in accordance with the situation.

6.4 MET with logistics, economy, environment

At this stage, vessels will be operated according to their own judgement while receiving the operational instructions from the land. What people on land should do is primarily to monitor safe navigation and to realize an economical operation.

For safe vessel navigation, shore personnel as remote operators at other autonomy degrees must be able to judge whether the vessel is operating normally based on the vessel's data. Furthermore, they also need to monitor whether the data itself sent from the ship and the decision made by the ship are accurate. In short, they are required to have the ability to judge whether or not the ship has system problems. This is because the ship's managers have to explain to ships around theirs, and their business partner when something goes wrong with safety navigation. This is an important ability to prevent marine casualties or to minimize damage if they occur. Moreover, this has a major impact on the trust issues of the ship company management, which in turn affects their business. The ship company management must be able to fulfil accountability if the ship is abnormal. This is a collaboration with the economy and the environment.

Even if there is no abnormality in the ship, it is still required to operate in consideration of the environment. Consistent operation of marine transportation makes the ship operation more effective. As a member of the transportation industry, ship managers no longer not only operate ships, but also need to plan ship operations in consideration of air and land transportation. In other words, maritime professionals are required to have knowledge of logistics to realize consistent transportation from raw materials to consumers. In that case, it will be necessary to collaborate with METI and all transportation companies even though they are destroying existing transportation and creating a new models like Amazon. New logistics, which are affected by technological innovation, considering business and environment, could significantly change vocational training and education across the transportation industry.

Chapter 7 Conclusion

In this chapter, the research question and the answer will be reviewed by summarizing the whole chapter. Furthermore, the limitation of this research and the proposal for the future research based on it will be proposed.

7.1 Summary

How technological innovation affects the competence of maritime professionals was researched. In this research, a more practical legal standards of seafarers' competence is used. It is TRB,which is made based on the STCW by each state. This means that TRB is more practical than the STCW. In other words, this research was based on the PB approach. The adopted TRB is used by JMETS, which is one of the Japanese METIs. This is one of the case studies used in Japan. It was selected based on the background of the Japanese MET history and the current declining birthrate and aging society. As for the concrete research method, competence was divided into four colours based on each autonomy level of MASS, and maritime professionals who needed competence was classified. The findings at each level of autonomy are as follows:

Although degree 1 is basically the same as the conventional competence required for seafarers, it was found that METI needs to flexibly respond to the role of seafarers changing due to technological innovation and the required competence. At degree 2, competence is required in the same way as before although the burden on crew on board may be reduced with the advent of remote operators. It means that the work, which was conventionally done by multiple people, has to be done with fewer people. In such a case, the operation of a small number of seafarers with dual purpose certificates of both navigators and marine engineers must be assumed to reduce onboard personnel while it was not realized because the past technology could not catch up to human thoughts. Then, METI will need to prepare and create a new curriculum that suits its purpose. At degree 3, ships will be operated only by land-based remote operators; therefore, data analysis and a deep understanding of communication systems will be required. The curriculum imposed on VTS operators may also be helpful in their education and training. In degree 4, the vessel will operate autonomously based on instructions from the land. To reach this stage, technological innovation beyond the current technology may be necessary, and it may be possible to be operated with a smaller number of personnel. However, people are still required to direct, communicate, monitor and manage the vessels. The competence required of humans are changing as with the occurrence of past technological innovation, and the METI's role is to provide education and training accordingly. What METI should do in the future to respond to the changes caused by these technological innovations was discussed.

The matters that METI should prioritize for each level of MASS autonomy were discussed. Not limited to METI, other educational institutions tend to become closed industries, which just provide learners with educational services for a certain period repeatedly unless they are actively involved in other industries. However, educational institutions must also change the content and methods of services in response to changes due to technological innovations as mentioned before. Collaboration with other industries is necessary to bring about innovation in the education field. Actively touching the technological innovations, which are occurring in other industries, can inspire educational institutions themselves. Therefore, METI must consider the origin of technological innovation and its impact after it occurs, and actively cooperate with industries that are closely related to them. Specifically, the academia, state, manufacturing industry, logistics industry including shipping companies and education institutions were mentioned. By deepening collaboration with these industries, METI can provide effective and efficient services without delaying technological innovation.

7.2 Limitations and future research recommendations

In this research, the discussion focused on MET for maritime professionals operating MASS on the assumption that it will be realized in the future. No consideration was given to how different levels of MASS will be realized by various ship types and sizes. In the near future, large container ships and crude oil tankers may be approved (even partially) due to safety regulations, such as SOLAS and COLREG, which may influence the realisation of MASS. While this research focuses mainly on STCW, consideration for other international treaties (e.g. SOLAS and COLREG) can be reflected in future research. It is the author's hope that this research will be helpful in making further evaluations of implementing MASS and then discuss the vocational education and training of those involved in MASS operations.

Moreover, even if the technology becomes technically feasible, it does not always mean that the technology would actually be used. There are trade-offs where other factors, such as finance and human element, may influence decision-makers. The realisation of MASS is expected to potentially reduce the number of maritime specialists, including seafarers involved in ship operations; further, optimizing operations can reduce fuel consumption, and determine the timing of equipment maintenance to reduce operating costs. On the other hand, some shipping companies may hesitate to completely eliminate seafarers due to ensuring safety, and avoiding damage caused by marine accidents. In addition, the costs saved by reducing the crew has to be compared with the investment costs of the additional equipment that is to be installed in MASS. In short, various factors influence the successful operation of MASS as a business.

Further, this research was colour-coded based on the autonomous level defined by IMO. In the definition of IMO, the change in human factors from degree 3 to degree 4 is very large. On the other hand, there are other models of autonomous levels that define the level of autonomy in more detail such as DNV GL, Lloyd's Register. Future research is can investigate detailed processes of autonomy that could not be found in this analysis by colour-coding based on those definitions. In addition, this research focused on the existing TRB. However, technological innovations will bring about new demands for competence as discovered in this study. Therefore, degree 4 does not simply mean that the competence required for maritime professionals will dramatically decrease.

Furthermore, this research is a case study in Japan where the birth rate is declining and the number of young workers is decreasing. It will be different in the analysis of MET if considering other IMO member States that produce a large number of seafarers. In addition, this research was based on the Japanese TRB and literature review. More empirical research is needed in order to clarify what kind of services METI should provide, and enable METIs to provide timely high quality education and training for future maritime professionals.

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Appendix A: Colour-coded Japanese Training Record Books

<u>Navigation at the operational level</u>

No	Competence		Knowledge, understanding and proficiency	The degrees of autonomy			
				1	2	3	4
1	Plan and conduct a passage and determine position 航海の計画・航行及び船位の決定	1.1	Ability to use celestial bodies to determine the ship's position 船位を測定するための天体観測方法		1	1	1, Nav. Mgmt. 2.1
		1.2	Knowledge and ability to use nautical charts, and publications 水路図誌に関する知識及び利用する能力		2, Nav. Mgmt. 7, 8.4	31	2, Nav. Mgmt. 7, 8.4
		1.3	Knowledge and proficiency to determine the ship's position 船位測定に関する知識と技能		1, Nav. Mgmt. 2	9	1, Nav. Mgmt. 2
		1.4	Knowledge of operational procedures and optimal adjustment of steering control systems 操舵制御装置の取扱方法、最適な制御調整方法		3, Nav. Mgmt. 9	32	3, Nav. Mgmt. 9
		1.5	Knowledge to use and interpret information obtained from meteorological instruments 気象測器から得られる情報の利用及び解釈に関する知識		4, Nav. Mgmt. 8	33	4, Nav. Mgmt. 8
		1.6	Knowledge of the characteristics of the various weather systems, reporting procedures and recording systems 気象システムの特徴、通報手順及び記録方式に関する知識		13	13	5, 13
2	Maintain a safe navigational watch 安全な航海当直の維持	2.1	Understanding and practice of duty in a navigational watch 航海当直業務内容の理解及び実務		34	34	6
		2.2	Understanding and practice of duty on a berth or anchorage 停泊当直業務内容の理解及び実務		35	35	7
		2.3	The use of information from navigational equipment for maintaining a safe navigational watch 安全な航海当直を維持するための航海計器の使用と情報の利用		6, Nav. Mgmt. 6	34	6, Nav. Mgmt. 6
		2.4	Knowledge of blind pilotage techniques 狭視界航行技術についての知識		2, Nav. Mgmt. 1.1, 10	9	2, Nav. Mgmt. 1.1, 10
		2.5	Knowledge of the General Principles for Ship Reporting Systems and VTS procedures 船舶通報制度の一般原則及びVTS通報に関する知識		13	13	8
		2.6	Knowledge of bridge resource management principles ブリッジリソースマネジメントの原則に関する知識		Nav. Mgmt. 16.2	36	Nav. Mgmt. 16.2
3	Use of radar and ARPA to maintain safety of navigation 安全な航海維持のためのレーダ及びARPAの使用	3.1	Knowledge of the fundamentals of radar and automatic radar plotting aids (ARPA) レーダ・ARPAに関する基礎知識		Nav. Mgmt. 6	34	Nav. Mgmt. 6
		3.2	Ability to operate and to interpret and analyse information obtained from radar and ARPA レーダ・ARPAの操作法、情報分析能力		Nav. Mgmt. 6	34	Nav. Mgmt. 6
4	Use of ECDIS to maintain the safety of navigation 安全な航海維持のためのECDISの使用	4.1	Knowledge of the capability and limitations of ECDIS operations ECDIS操作の能力と限界についての知識		9, Nav. Mgmt. 7	9	9, Nav. Mgmt. 7
		4.2	Proficiency in operation, interpretation, and analysis of information obtained from ECDIS ECDISから得られる情報の解釈及び分析の技能		9, Nav. Mgmt. 7	9	9, Nav. Mgmt. 7
5	Respond to emergencies 非常時の対応	5.1	Precautions for the protection and safety of life and of the ship in emergency situations 非常事態における船体、人命の保護及び安全に関する注意事項		10, Nav. Mgmt. 9	37	10, Nav. Mgmt. 9
		5.2	Initial action to be taken following a collision or a grounding, initial damage assessment and control 衝突及び乗揚げ後にとるべき初期動作、損傷の判断及び損傷制御		10, Nav. Mgmt. 9	37	10, Nav. Mgmt. 9
		5.3	The procedures for rescuing persons from the sea, assisting a ship in distress, responding to emergencies which arise in port 遭難者の救助、遭難船への支援及び港内で発生した非常時に対する手順		10, Nav. Mgmt. 9	37	10, Nav. Mgmt. 9
6	Respond to a distress signal at sea 海上における遭難信号への対応	6.1	Knowledge of the contents of the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual 国際航空海上捜索救難マニュアルの内容に関する知識		10, Nav. Mgmt. 4	37	10, Nav. Mgmt. 4
		6.2	GMDSS		9	9	9
7	Use the IMO Standard Marine Communication Phrases and use English in written and oral form IMO標準海事通信用語集の使用及び筆記及び口述による英語の使用	7.1	Ability to understand charts and other nautical publications, meteorological information and messages concerning ship's safety and operation 水路図誌、気象情報並びに船舶の安全及び運航に関する情報を理解する能力		36	36	11
		7.2	Ability to communicate with coast stations and VTS centres using the IMO Standard Marine Communication Phrases (IMO SMCP) IMO標準海事連絡用語集を用いて海岸局及びVTSセンターと通信する能力		36	36	13
8	Transmit and receive information by visual signaling 視覚信号による情報の送信と受信	8.1	Ability to transmit and receive distress signal and visual signalling of single-letter signals as specified in the International Code of Signals 国際信号書に定める遭難信号及び視覚信号の一字信号を送受信する能力		12, Nav. Mgmt. 13	38	12, Nav. Mgmt. 13
9	Manoeuvre the ship 操　船	9.1	Knowledege of ship manoeuvring and handling 操縦性能及び操船法に関する知識		19, Nav. Mgmt. 10	19	19, Nav. Mgmt. 10

10	Monitor the loading,stowage,securing, care during the voyage and the unloading of cargoes 貨物の積込み、積付け、固定、輸送中の状態及び荷揚げの監視	10.1	Knowledge of the effect of cargo on the seaworthiness and stability of the ship 耐航性及び復原性に関する貨物の影響に関する知識		13, Nav. Mgmt. 15	39	13, Nav. Mgmt. 15
		10.2	Knowledge of safe handling, stowage and securing of cargoes, and their effect on the safety of life and of the ship 貨物の安全な取扱い、積付け及び固定並びに人命と船舶の安全に対する貨物の影響に関する知識		13, Nav. Mgmt. 14, 15	39	13, Nav. Mgmt. 14, 15
11	Inspect and report defects and damage to cargo spaces, hatch covers and ballast tanks 貨物艙、ハッチカバー、バラストタンクの検査並びに欠陥及び損傷報告	11.1	Knowledge and ability to explain damage and defects conditions due to loading and unloading operations, corrosion, and severe weather 積み卸し作業、腐食、荒天の場合の損傷及び欠陥の状態を説明する知識及び能力		14	14	14
		11.2	Ability to carry out ship inspection 船舶検査を実施するための能力		10	10	10
		11.3	Knowledge of the causes of corrosion in cargo spaces and ballast tanks and how corrosion can be identified and prevented 貨物室、バラストタンク内の腐食の原因、腐食の確認及び防止法		10	10	10
		11.4	Knowledge of procedures on how the inspections shall be carried out 検査の手順に関する知識		10	10	10
		11.5	Knowledge and ability of maintainance 保存手入		13	13	13
12	Ensure compliance with pollution prevention requirements 汚染防止要件の遵守の確保	12.1	Knowledge of the precautions to be taken to prevent pollution of the marine environment, and importance of proactive measures to protect the marine environment 海洋環境汚染防止処置に関する知識と措置の重要性について		11, Nav. Mgmt. 13	11	11, Nav. Mgmt. 13
13	Maintain seaworthiness of the ship 船舶の耐航性の維持	13.1	Knowledge of stabulity of the ship 船舶の復原性に関する知識		13, Nav. Mgmt. 12	39	13, Nav. Mgmt. 12
		13.2	Knowledge of the principal structural member of a ship 船舶の主要構造部材に関する知識		Nav. Mgmt. 12	3	Nav. Mgmt. 12
14	Prevent, control and fight fires on board 船内における防火、火災制御及び消火	14.1	Ability to organize fire drills, and proficiency in fire-fighting 防火操練を計画する能力と消火活動及び消火に関する技能		10, Nav. Mgmt. 14	10	10, Nav. Mgmt. 14
15	Operate life-saving appliances 救命設備の運用	15.1	Ability to organize abandon ship drills, knowledge and proficiency in life boats, life rafts and rescue boats 退船操練を計画する能力と救命艇、救命いかだ及び救助艇に関する知識と技能		16	16	16
16	Apply medical first aid on board ship 船内における応急手当	16.1	Knowledge and proficiency in medical first aid 応急医療における知識と技能		17	17	17
17	Monitor compliance with legislative requirements 法的要件を遵守するための監視	17.1	Knowledge of the relevant IMO conventions concerning safety of life at sea, security and protection of the marine environment 海上における人命の安全及び海洋環境の保護に関するIMO関連条約の知識		11, Nav. Mgmt. 13	11	11, Nav. Mgmt. 13
18	Application of leadership and teamworking skills リーダーシップとチームワーク技能の適用	18.1	Knowledge of shipboard personnel management 船内要員の管理に関する知識		18, Nav. Mgmt. 16.1	18	18, Nav. Mgmt. 16.1
		18.2	Effective resource management and decision-making techniques 効果的なリソースマネジメントと意志決定技能		Nav. Mgmt. 16.2	15	Nav. Mgmt. 16.2
		18.3	Ability to apply task and workload management 職務及び業務分担の管理ができる能力		19, Nav. Mgmt. 16.3	19	19, Nav. Mgmt. 16.3
19	Contribute to the safety of personnel and ship 人員及び船舶の安全に貢献すること	19.1	Knowledge of personal survival techniques 個々の生存技術に関する知識		16	16	16
		19.2	Knowledge of fire prevention and firefighting 防火に関する知識と消火活動及び消火に関する知識		10, Nav. Mgmt. 14	10	10, Nav. Mgmt. 14
		19.3	Knowledge of elementary first aid 初歩的な救急処置に関する知識		17	17	17
		19.4	Knowledge of personal safety and social responsibilities 個々の安全と社会的責任に関する知識		20	20	20

Navigation at the management level

No	Competence		Knowledge, understanding and proficiency	The degrees of autonomy 1	2	3	4
1	Plan a voyage and conduct navigation 航海計画及び航海の指揮	1.1	Voyage planning and navigation conducting for all conditions あらゆる状況を考慮した航海計画と安全航海の指揮		19, 37, 40	19	19
		1.2	Knowledge of routeing 航路選定に関する知識		19, 37, 40	19	19
2	Determine position and the accuracy of resultant position fix by any means **船位の決定及び各手段によって得られた決定船位の精度**	2.1	Position determination by celestial observations 天体観測による船位測定		1, 37, 40	1	1
		2.2	Position determination by terrestrial observations 地物の観測による船位測定		2, 37, 40	2	2
		2.3	Position determination using satellite navigation systems 衛星航法装置による船位測定		1, 37, 40	1	1
3	Determine and allow for compass errors コンパス誤差の決定と考慮	3.1	Knowledge of the magnetic and gyro-compasses, and abilityto determine and allow for errors of them 磁気コンパス・ジャイロコンパスに関する知識及び誤差を検出する能力		1, 37, 40	1	1
		3.2	Knowledge of the operation and care of the main types of gyro-compass ジャイロコンパスの主な種類の取扱いと運用に関する知識		1, 37, 40	1	1
4	Coordinate search and rescue operations 捜索と救助作業の調整	4.1	Knowledge and procedures of the International Aeronautical and Maritime Search and Rescue (IAMSAR) Manual 国際航空海上捜索救難マニュアルの知識と手順		10, 37, 40	10	10
5	Establish watchkeeping arrangements and procedures **当直体制及び手順の確立**	5.1	Thorough knowledge of content, application and intent of the International Regulations for Preventing Collisions at Sea, 1972, as amended 海上衝突予防規則の内容、適用及び目的に関する十分な知識		10, 37, 40	10	10
		5.2	Thorough knowledge of the content, application and intent of the Principles to be observed in keeping a navigational watch 「航海当直の維持に当たり遵守すべき基本原則」の内容、適用及び目的に関する十分な知識		10, 37, 40	10	10
6	Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision making 意志決定支援のための航海計器及びシステムから得られた情報の使用を通じての安全な航海の維持	6.1	Optimal use of navigational information derived from all sources, including radar and ARPA, in order to make and implement command decisions for collision avoidance and for directing the safe navigation of the ship 衝突防止及び安全航海のためのレーダ・ARPAを含むすべての航海計器から得られた航海情報の最適な利用		2, 37, 40	2	2
7	Maintain the safety of navigation through the use of ECDIS and associated navigation systems to assist command decision making ECDIS及び意志決定支援のための関連航海システムの使用を通じての安全な航海の維持	7.1	Management of operational procedures, system files and data for using ECDIS ECDIS使用に関する操作手順、システム・ファイル及びデータの管理		9, 37, 40	9	9
		7.2	Use ECDIS playback functionality for passage review, route planning and review of system functions 航路の見直し、航路計画及びシステム機能の見直しのための再生機能の使用		9, 37, 40	9	9
8	Forecast weather and oceanographic conditions **気象・海象の予測**	8.1	Abilityto understand and interpret a synoptic chart and to forecast area weather, taking into account local weather conditions and information received by weather fax 天気図を理解し及び解読する能力、局地的な気象状態及び気象ファックス図からの情報を考慮して、地域の天気を予測する能力		4, 37, 40	4	4
		8.2	Knowledge of the characteristics of various weather systems, including tropical revolving storms and avoidance of storm centres and the dangerous quadrants 種々の気象状態の特徴に関する知識(熱帯暴風雨及び暴風雨の中心及び危険半円の回避に関するものを含む)		14, 37, 40	14	14
		8.3	Knowledge of ocean current systems 海流システムに関する知識		21, 37, 40	21	21
		8.4	Abilityto calculate tidal conditions using all appropriate nautical publications on tides and currents 潮汐に関するすべての適切な航海用書誌を使用し潮汐の状態を算出する能力		5, 37, 40	5	5
9	Respond to navigational emergencies 航海に関する緊急時の対応	9.1	Respond to navigational emergencies 航海に関する緊急時の対応		10, 37, 40	10	10
10	Manoeuvre and handle a ship in all conditions あらゆる状態における操船	10.1	Manoeuvre and handle a ship in all conditions あらゆる状態における操船法		19, 37, 40	19	19
11	Operate remote controls of propulsion plant and engineering systems and services 推進機関及び機関システムと運用の遠隔制御の操作	11.1	Knowledge of ships' power plants and auxilary machinery, and general understanding of marine engineering watch 船舶の出力装置と舶用補機に関する知識及び機関室当直の概要の理解		22, 37, 40	22	22
12	Control trim, stability and stress **トリム、復原性及び応力の管理**	12.1	Knowledge of the effect on trim and stability of a ship in the event of damage to and consequent flooding of a compartment and countermeasures to be taken 区画室に損傷が生じ浸水があった場合に浸水が船舶のトリム及び復原性に及ぼす影響並びに当該影響の生じた場合にとるべき措置に関する知識		10, 37, 40	10	10

13	Monitor and control compliance with legislative requirements and measures to ensure safety of life at sea and the protection of the marine environment 海上における人命の安全確保と海洋環境の保護のための法的要件と手段に応じた監視と管理	13.1	Knowledge of international maritime law embodied in international agreements and conventions 国際協定及び条約で定められている国際海事法に関する知識		11, 37, 40	11	11
14	Maintain safety and security of the ship's crew and passengers and the operational condition of life-saving, fire-fighting, and other safety systems 船舶，乗組員及び旅客の安全と保安の維持及び救命、消火及び他の安全システムの作動状態の維持	14.1	Maintaining the safety and security of ships, crew and passengers, and maintenance knowledge of operational condition of life-saving, fire—fighting and other safety 船舶，乗組員及び旅客の安全と保安の維持及び救命、消火及び他の安全システムの作動状態の維持に関する知識		10, 37, 40	10	10
15	Develop emergency and damage control plans and handle emergency situations 非常時及び損傷制御計画の立案及び非常事態への対応	15.1	Understanding of fundamental principles of ship construction and the theories and factors affecting trim and stability and measures necessary to preserve trim and stability 船体構造に関する基本原理、トリム及び復原性に関する理論及び要因並びにトリム及び復元性を保つために必要な措置に関する理解		13, 37, 40	13	13
		15.2	Use of proper equipment in emergency situations 非常事態時における適切な機器の使用		10, 37, 40	10	10
16	Use of leadership and managerial skill リーダーシップと管理技能の適用	16.1	Knowledge of shipboard personnel training 船内要員の訓練に関する知識		18, 37, 40	18	18
		16.2	Effective resource management and decision-making techniques, including risk-assessment 効果的なリソースマネジメントと意志決定能力（リスクアセスメントを含む）		23, 37, 40	23	23
		16.3	Ability to apply task and workload management 職務及び業務分担の管理ができる能力		19, 37, 40	19	19
		16.4	Proficiency in development, implementation, and oversight of standard operating procedures 標準作業手順の策定、実行及び監督する能力		19, 37, 40	19	19
17	Organize and manage the provision of medical care on board 船内医療に関する規定の組織と管理	17.1	Thorough knowledge of the use and contents of the publications of medical care on board 船内医療に関する出版物の利用及び内容に関する十分な知識		17, 37, 40	17	17

Marine engineering at the operational level

No	Competence		Knowledge, understanding and proficiency	The degrees of autonomy			
				1	2	3	4
1	Maintain a safe engineering watch 安全な機関当直の維持	1.1	Duty in an engineering watch 当直業務		41	13	6
		1.2	Engine-room resource management 機関室リソースマネージメント		23	23	6
2	Use English in written and oral form 筆記及び口述による英語の使用	2.1	Basic Maritime English used in engineering duties 機関業務に使用する基礎海事英語		19	19	19
3	Use internal communication systems 船内コミュニケーションシステムの使用	3.1	Operation of all internal communication systems on board 船内通信システムの使用		16	16	16
4	Operate main and auxiliary machinery and associated control systems 主機関，補機及び関連の制御システムの運転操作	4.1	Propulsion plant 推進プラント		25, Eng. Mgmt. 1	25	25, Eng. Mgmt. 1
		4.2	Marine steam turbine 蒸気タービン主機		24, Eng. Mgmt. 1.1	24	24, Eng. Mgmt. 1.1
		4.3	Marine diesel engine ディーゼル主機		25, Eng. Mgmt. 1.2	25	25, Eng. Mgmt. 1.2
		4.4	Steam generator 蒸気発生装置		25, Eng. Mgmt. 1.3	25	25, Eng. Mgmt. 1.3
		4.5	Auxiliaries, including deck machinery 補機器（甲板機器を含む）		25, Eng. Mgmt. 1.4	25	25, Eng. Mgmt. 1.4
5	Operate fuel, lubrication, ballast and other pumping systems and associated control systems 燃料、潤滑油、バラストその他のポンプシステム及び関連の制御システムの運転操作	5.1	Pumps ポンプ		25, Eng. Mgmt. 1.4	25	25, Eng. Mgmt. 1.4
		5.2	Oily-water separators and drainage equipment ビルジ処理装置及び排水装置		25, Eng. Mgmt. 1.4	25	25, Eng. Mgmt. 1.4
6	Operate electrical, electronic and control systems 電気、電子及び制御システムの運用	6.1	Basic configuration and operation principles of electrical equipment 電気装置の構造作動及び操作		25, Eng. Mgmt. 5	25	25, Eng. Mgmt. 5
		6.2	Basic configuration and operation principles of electronic and control system 制御装置の構造作動び操作		26, Eng. Mgmt. 5	26	26, Eng. Mgmt. 5
7	Maintenance and repair of electrical and electronic equipment 電気及び電子機器の保守及び修理	7.1	Procedure for maintenance and repair of electrical equipment and electronic control system 電気装置及び電子式制御装置の修理･点検要領		25, Eng. Mgmt. 5, 6	25	25, Eng. Mgmt. 5, 6
		7.2	Function and performance tests of electrical and electronic control system 電気･電子制御装置の作動試験及び性能試験		25, Eng. Mgmt. 5, 6	25	25, Eng. Mgmt. 5, 6
		7.3	The interpretation of electrical and simple electronic diagrams 電気及び電子回路図の理解		25, Eng. Mgmt. 5, 6	25	25, Eng. Mgmt. 5, 6
8	Appropriate use of hand tools, machine tools and measuring instruments for fabrication and repair on board 船内製作及び修理のための適切な手工具、工作設備及び計測機器の適切な使用	8.1	Knowledge and proficiency required for fabrication and repair on board 船内保守作業に必要な知識及び技能		18	18	18
		8.2	Use of hand tools, machine tools and measuring instruments for fabrication and repair on board 船内保守作業に必要な工具，計測器具の取扱い		18	18	18
9	Maintenance and repair of shipboard machinery and equipment 機関装置及び機器の保守及び修理	9.1	Safety procedures for maintenance, repair, inspection and adjustment of diesel engine ディーゼル機関の主要保守作業及び点検調整要領		25, Eng. Mgmt. 3.2	25	25, Eng. Mgmt. 3.2
		9.2	Safety procedures for maintenance, repair, inspection and adjustment of steam turbine engine 蒸気タービン機関の主要保守作業及び点検調整要領		24, Eng. Mgmt. 3.1	24	24, Eng. Mgmt. 3.1
		9.3	Safety procedures for maintenance, repair, inspection and adjustment of steam generator 蒸気発生装置の主要保守作業及び点検調整要領		25, Eng. Mgmt. 3.3	25	25, Eng. Mgmt. 3.3
		9.4	Safety procedures for maintenance, repair, inspection and adjustment of auxiliaries 補機器の主要保守作業及び点検調整要領		25, Eng. Mgmt. 3.4	25	25, Eng. Mgmt. 3.4
10	Ensure compliance with pollution-prevention requirements 汚染防止要件の遵守の確保	10.1	Knowledge of the precautions to be taken to prevent pollution of the marine environment, and importance of proactive measures to protect the marine environment 海洋環境の汚染防止に関する知識と措置の重要性について		11, Nav. Mgmt. 13	11	11, Nav. Mgmt. 13

11	Maintain the seaworthiness of the ship 船舶の耐航性の維持	11.1	Knowledge of stabulity of the ship 船舶の復原性に関する知識		13, Nav. Mgmt. 12	39	13, Nav. Mgmt. 12
		11.2	Knowledge of the principal structural member of a ship 船舶の主要構造部材に関する知識		Nav. Mgmt. 12	3	Nav. Mgmt. 12
12	Prevent, control and fight fires onboard 船内における防火，火災制御及び消火	12.1	Ability to organize fire drills, and proficiency in fire-fighting 防火操練を計画する能力と消火活動及び消火に関する技能		10, Nav. Mgmt. 14	10	10, Nav. Mgmt. 14
13	Operate life-saving appliances 救命設備の運用	13.1	Ability to organize abandon ship drills, knowledge and proficiency in life boats, life rafts and rescue boats 退船操練を計画する能力と救命艇、救命いかだ及び救助艇に関する知識と技能		16	16	16
14	Apply medical first aid onboard ship 船内における応急手当	14.1	Knowledge and proficiency in medical first aid 応急医療における知識と技能		17	17	17
15	Monitor compliance with legislative requirements 法的要件を遵守するための監視	15.1	Knowledge of the relevant IMO conventions concerning safety of life at sea, security and protection of the marine environment 海上における人命の安全及び海洋環境の保護に関するIMO関連条約の知識		11, Nav. Mgmt. 13	11	11, Nav. Mgmt. 13
16	Application of leadership and teamworking skills リーダーシップとチームワーク技能の適用	16.1	Knowledge of shipboard personnel management 船内要員の管理に関する知識		18, Nav. Mgmt. 16.1	18	18, Nav. Mgmt. 16.1
		16.2	Effective resource management and decision-making techniques 効果的なリソースマネージメントと意志決定能力		Nav. Mgmt. 16.2	15	Nav. Mgmt. 16.2
		16.3	Ability to apply task and workload management 職務及び業務分担の管理ができる能力		19, Nav. Mgmt. 16.3	19	19, Nav. Mgmt. 16.3
17	Contribute to the safety of personnel and ship 人員及び船舶の安全に貢献すること	17.1	Knowledge of personal survival techniques 個々の生存技術に関する知識		16	16	16
		17.2	Knowledge of fire prevention and firefighting 防火に関する知識と消火活動及び消火に関する知識		10, Nav. Mgmt. 14	10	10, Nav. Mgmt. 14
		17.3	Knowledge of elementary first aid 初歩的な救急処置に関する知識		17	17	17
		17.4	Knowledge of personal safety and social responsibilities 個々の安全と社会的責任に関する知識		20	20	20

Marine engineering at the management level

No	Competence		Knowledge, understanding and proficiency	The degrees of autonomy			
				1	2	3	4
1	Manage the operation of propulsion plant machinery 推進機関プラントの運用管理	1.1	Marine steam turbine 蒸気タービン主機		24, 37, 40	24	24
		1.2	Marine diesel engine ディーゼル主機		19, 37, 40	19	19
		1.3	Marine steam generator 蒸気発生装置		19, 37, 40	19	19
		1.4	Auxiliaries 補機器		19, 37, 40	19	19
2	Plan and schedule operations 運転計画	2.1	Significance of ship's seaworthiness, and summary of casualty in marine engineering 船舶の堪航性の意義と機関海難の概要		27, 37, 40	27	27
		2.2	Marine steam turbine 蒸気タービン主機		24, 37, 40	24	24
		2.3	Marine diesel engine ディーゼル主機		19, 37, 40	19	19
3	Operation, surveillance, performance assessment and maintaining safety of propulsion plant and auxiliary machinery 推進プラント及び補機器の運転、監視、性能評価及び安全性維持	3.1	Marine steam turbine 蒸気タービン主機		24, 37, 40	24	24
		3.2	Marine diesel engine ディーゼル主機		19, 37, 40	19	19
		3.3	Marine steam generator 蒸気発生装置		19, 37, 40	19	19
		3.4	Auxiliaries 補機器		19, 37, 40	19	19
4	Manage fuel. lubrication and ballast operations 燃料、潤滑油及びバラスト操作の管理	4.1	Procedure for loading and storing fuel and lubrication 燃料油及び潤滑油の搭載要領と保管方法		13, 37, 40	13	13
5	Manage operation of electrical and electronic control equipment 電気及び電子制御機器の運用管理	5.1	Automatic control equipment and safety devices for main engine, generator, distribution system, and steam boiler 主機、発電機及び蒸気ボイラの自動制御装置及び安全装置		19, 37, 40	19	19
		5.2	Hydraulic and pneumatic control equipment 油圧及び空圧制御機器		19, 37, 40	19	19
		5.3	High-voltage installations 高電圧設備		19, 37, 40	19	19
6	Manage trouble-shooting restoration of electrical and electronic control equipment to operating condition 電気及び電子制御機器の作動状態へのトラブルシューティング修復管理	6.1	Troubleshooting of electrical and electronic control equipment 電気及び電子制御機器のトラブルシューティング		28, 37, 40	28	28
		6.2	Software version control ソフトウェアの管理		29, 37, 40	29	29
7	Manage safe and effective maintenance and repair procedures 安全で効果的な保守及び修理手順の管理	7.1	Plan and implementation of safe maintenance and repair procedures 安全な保守及び修繕手順の計画と実施		30, 37, 40	30	30
		7.2	Preparation for maintenance record book in engineering department 機関整備書類の作成		30, 37, 40	30	30

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