

# A Study on the New Education and Training Scheme for Developing Seafarers in Seafarer 4.0 - Focusing on the MASS -

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## 선원 4.0시대에 적합한 새로운 선원교육훈련 체계에 대한 연구 - 자율운항선박을 중심으로 -

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**Abstract :** *The current maritime industry is expected to have a significant impact on the role of maritime-related technologies and systems, especially seafarers, in the rapidly changing Fourth Industrial Revolution. The Maritime Autonomous Surface Ship (MASS) aims to reduce the number of safety accidents and improve seafarers' working environment. With regard to MASS, the International Maritime Organization has been trying to minimize unexpected impact in the maritime education and training sector by establishing international conventions such as the Standards of Training, Certification and Watchkeeping for Seafarers. However, domestic designated educational institutions have not yet established an education and training scheme to develop seafarers who will be on board for MASS. Therefore, this paper reviews the technology of MASS, analyzes the changes in education and training in order to upgrade the qualifications, and suggests the competencies of smart seafarers equipped with the integrated management ability required for Artificial Intelligence, Big Data, Cybersecurity, and the Digital System Revolution through education and training. In addition, this study provides basic information for the education and training of seafarers who are optimized for the rapidly changing technological environment.*

**Key Words :** *Seafarers, MASS, IMO, STCW, Education and Training*

**요 약 :** 4차 산업 혁명으로 해양산업은 해사 관련 기술 및 시스템, 특히 선원의 역할에 상당한 변화가 생길 것으로 예상됩니다. 특히, 자율운항선박(MASS)은 인적과실에 의한 안전사고의 예방과 해상 작업 환경의 개선을 위하여 개발되고 있습니다. IMO는 교육 및 훈련 분야를 포함한 모든 분야에서 MASS의 도입에 대한 준비작업을 하고 있습니다. 이에 반해 국내지정교육기관은 아직 MASS에 탑승할 선원을 육성하기 위한 자격기준이나 교육훈련에 대한 계획을 수립하지 못하고 있는 상황입니다. 따라서 본 논문은 MASS의 특성과 적용기술을 검토하고, AI, 빅 데이터, 사이버 보안 등 급변하는 기술 환경에 최적화될 수 있는 스마트 선원의 능력 및 교육 훈련에 대한 필요성을 제시하고자 한다.

**핵심용어 :** 선원, 자율운항선박, 국제해사기구, STCW 협약, 교육 및 훈련

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## 1. Introduction

### 1.1 Background and Purpose

Since the first introduction of the concept of E-Nav by the International Maritime Organization (IMO) in December 2005, the new type of ship has been subject to change electronic navigation, integrated control systems and advanced technology. In other words, new building ship has been applied with systems and technologies that are environmentally friendly, ergonomic, and can navigate safely, compared to the past steam ship and sailing boat. Since the fourth industrial revolution was presented as a hot topic through the World Economic Forum in 2016, technology trends related to shipping are rapidly changing (Lee, 2018). Also, unexpected maritime technologies such as electronic B/L based on the block-chain and smart maritime traffic monitoring system based on AI (Artificial Intelligence), which are representative of the fourth industrial revolution, have a significant impact on the shipping industry, and are presented in terms of the reduction in operating costs of ships. And AI and deep learning technology which are based on the ship building and operation as applied to European and Japanese shipping companies and shipyards intend to apply for an autonomous surface ship of law and system. In the meantime, the core of the IMO 99th MSC meeting in 2018 is the definition of autonomous surface ships, MASS, and the discussion of what is real autonomy. A working group considered during the session and terms of reference were agreed for an interim working group to continue the work in September 2019 (Song et al., 2019). The first step is underway - identifying, in the relevant IMO conventions, codes, rules, provisions which are applied to MASS. It needs to be amended or clarified, and/or may bridge the gaps. Therefore, the study aims to provide a basic concepts to establish a new education and training scheme for cultivating seafarer which the nation's maritime education university and institute are likely to become a reality in the future.

### 1.2 Literature review

As a result of searching the doctor thesis and paper related to autonomous ships published in Korea as of 2018~2019, which has been discussed in IMO, the results are shown in Table 1, Table 2 below. It is listed mainly on system integration, telecommunication, liability, human resource. In the case of the paper tendency of a thesis, various technical requirements for the safe operation of autonomous ships, communication system between shore and ship,

the legal system of autonomous ships, and verification of crew capability through questionnaire analysis is listed. However, there is still a lack of discussion on the creation of new opportunities through job transitions for managers who can control autonomous ships before they become commercially available, as well as crew on board in the existing vessels. Despite a lot of existing technical and legal studies, research on proper education and training scheme is essential for the safe operation of MASS.

Table 1. Analysis for Doctor thesis

No.	Author/ Adopted Year	Title of paper	Remark
1	Lee (2019)	“A Study on The liability of Maritime Autonomous Surface Ships”	maritime law
2	Jo (2019)	“A Study on the Change in the Size and the Structure of Korean Maritime Manpower followed by Technological Development of MASS utilizing System Dynamics”	maritime-management
3	Kim (2019)	“A Study on the control of motion for the ship apply for MASS”	maritime science
4	Zhao (2019)	“Simulation Method to Support Autonomous Navigation and Installation Operation of an Offshore Support Vessel”	maritime science

Table 2. Analysis for the paper

No.	Author/ Adopted Year	Title of paper	Remark
1	Kim (2019)	“International Trends on the Regulatory Regime of Maritime Autonomous Ships”	maritime-management
2	Yoo et al. (2019)	“A Study on the Ordinary Practice of Seamen as a Controlling Principle of MASS and its Revision of Maritime Laws”	maritime law
3	Chae et al. (2019)	“A Study on Technology Development of Maritime Autonomous Surface Ship and Required Competences for Seafarers”	maritime education

No.	Author/ Adopted Year	Title of paper	Remark
4	Nam et al. (2019)	“Design of Information Exchange Handling System for Safe Navigation of Autonomous Ship”	maritime science
5	Song et al. (2019)	“Trend of Autonomous Navigation Technology for Unmanned Ship”	maritime science
6	Lim and Lee (2018)	“Issues of IMO Convention on 「Maritime Autonomous Surface Ship」 and Its Implications on the Application of Maritime Law”	maritime law
7	Choi et al. (2018)	“Roles and Legal Status of the Remote Operator in a Maritime Autonomous Surface Ship: Focusing on the Concept of a Crew and a Master”	maritime law
8	Jeon (2018)	“Legal Consideration on the Liability Regime of Autonomous Ships”	maritime law
9	Lee (2018)	“Remote Control Management System for Autonomous Ship”	maritime law

## 2. Overview of MASS

### 2.1 Definition

We faces a lot of challenges such as the increasing of tremendous cargo volume in maritime sector, growing environmental standard and a chronic lack of seafarers. The concept of the autonomous ship brings along the potential to overcome these challenges. The IMO has continuously been paying attention to make a convention, code, rule to cover the technology of MASS through MSC 99/INF.3 and IMO LEG 105/1 respectively. As a matter of fact, what is the real role to control the MASS? or who is final in charge to make a decision? So, IMO makes a concept the key word which is 'operator' other than the existing source and expands the various discussions necessary for the related credentials to easy understand (Kim, 2019). After all, the automatic and autonomous definitions for IMO are Autonomous ships take advantage of using automation to support duty officer and engineer decision making, control traditional tasks and response to the emergency situation. According to IMO, the definition of MASS is the vessel which, to a varying degree, can operate independently of human directional or non-directional

interaction. After all, it is important to discuss the right of control or the program of decision which will be monitoring and permitting by shore-based operators.

### 2.2 Category

Basically, seafarer should be understood as people to be responsible for the designated ships. But ship with automated processes and several stages of strategy support, wirelessly controlled share with seafarer on board, remotely controlled share on board, the fully automatic share will make a big change of traditional definition.

Shipowner and shipyard want to understand autonomous ships that are able to operate with varying levels of operation. So, this study compares the degree of MASS defined by the IMO and LR. As shown in Table 3, Table 4 below, IMO and LR have described and delivered the levels required to make decisions enabling the design, construction and operation of autonomous ships to easy understand for all stakeholders. The levels provide a step to explain the safety, technical possibility, which is required to satisfy the international convention, rule, code, regulation classification.

Table 3. The degree of MASS by IMO

No.	Degree of Technology	Detail of definition
1	Degree 1	Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control.
2	Degree 2	Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions.
3	Degree 3	Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.
4	Degree 4	Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.
Summary & Implication		Each degree of MASS depends on the scope of interaction between seafarer and digitalized ship.

Table 4. The degree of MASS by LR

No.	Level of Technology	Detail of definition
1	autonomy level 0	Manual steering. Steering controls or set points for course, etc. are operated manually.
2	autonomy level 1	Decision-support on board. Automatic steering of course and speed in accordance with the references and route plan given. The course and speed are measured by sensors on board.
3	autonomy level 2	On-board or shore-based decision support. Steering of route through a sequence of desired positions. The route is calculated so as to observe a wanted plan. An external system is capable of up-loading a new route plan.
4	autonomy level 3	Execution with human being who monitors and approves. Navigation decisions are proposed by the system based on sensor information from the vessel and its surroundings.
5	autonomy level 4	Execution with human being who monitors and can intervene. Decisions on navigation and operational actions are calculated by the system which executes what has been calculated according to the operator's approval.
6	autonomy level 5	Monitored autonomy. Overall decisions on navigation and operation are calculated by the system. The consequences and risks are countered insofar as possible. Sensors detect relevant elements in the surroundings and the system interprets the situation. The system calculates its own actions and performs these. The operator is contacted in case of uncertainty about the interpretation of the situation.
7	autonomy level 6	Full autonomy. Overall decisions on navigation and operation are calculated by the system. Consequences and risks are calculated. The system acts based on its analyses and calculations of its own capability and the surroundings' reaction. Knowledge about the surroundings and previous and typical events are included at a "machine intelligent" level.
Summary & Implication		Each level of MASS is prescribed in more detail than IMO degree. The reason why is that the level takes the user from identifying the initial 'business need for the shipowner' to a 'systems classed for the shipyard and vendor'.

### 2.3 The principal party

#### 1) Operation side: shipowner & management company

Both shipowners and ship management companies are always focused on the IMO convention to save operation costs and protect the marine environment. Especially shipowners want to keep the existing regulatory framework without additional finance input, however, sometimes they try to consider well-equipped vessel to save the operation costs. Such as, shipowners should be kept at a minimum international standard and only apply for the extent such changes are required by IMO. Eventually, the function and role for key stakeholder including shipowner and ship management company will remain unchanged. Basically, the position of shipowners is ready to accept new technology with never experienced but still consider that the responsibility for the reliability of equipment and that the role and function of both in terms of obligations and liability exposure by themselves.

While automation without crew and system digitalization of the shipping industry remain to be on the key issues, shipowner and ship management company considered that MASS will be introduced and be commercialized. As a result, shipowners are try to revise the IMO convention which is included SOLAS, COLREG, Load Lines, STCW, STCW-F, SAR, Tonnage Convention, STP (Special Trade Passenger Ships Agreement) and ready to observe the regulatory requirements and use the general need for proof of concept (Choi et al., 2018).

#### 2) Design · Building side: Shipyard and vendor

Total Integrated system, automation, two-way exchange of big data and monitoring for the ship is expected to bring the greatest challenge to shipyard and supplier to make a creative project. It means that the technology level of MASS will increase significantly compared to what we know for conventional ships. Simply except for the manufacture and supply of ship's equipment, it is expected that both shipyard and vendor will change their own role to more challenge for whom to operate, maintain, equipment. In particular, in relation to both shipyard and vendor are prepared to move towards for after services market and try to expand their working scope from fabrication to digitalization such as the lifetime service for the condition-based/preventive maintenance solutions. The reason why both shipyard and vendor know key in reducing risks in MASS which is able to operate with well-designed remote situation. It is concluded as follows that the technology of MASS will lead to shipyard and supplier developing shore-based control tower; for example, digital twin centers where

continuously monitor and support the MASS fleet.

### 3) Support side: Classification and Marine Insurance

Both classification societies and marine insurance believe that there will be increased support for shipowner assurance of MASS technology and scheme. In this regard, both classification societies and marine insurance are considered to assume a key role in relation to verification and coverage scope of MASS. Classification society is deeply considered that the verification process of MASS will shift from accessories of navigation equipment to an integrated system. It means that complexity in navigation and engine control systems increases. So, Classification society tries to develop a new type verification system that the verification system of MASS will be included to expand not only the traditional perspective for navigation, engine, cargo, operational side but also cyber security, network, etc. Namely, the most important point is the interface and decision-making without the hacking process between the MASS and the remote operator and the network communication between MASS and shore (Jeon, 2018).

Still, there is no perfect ground to make sure ship's safety such as the look out as duty officer can take to avoid risk to a collision. Even human error is the most frequently reported root cause of marine casualties. If the insurers agree on the mutual co-relation that human error causes marine casualties, the main thing is what is the best way to invest MASS or to waste insurance premiums. As a result, the role of a seafarer cannot disappeared even MASS. It means that the role of seafarer will shift from bridge and engine room to remote control tower, where the remote operator exists and updating takes place in real time. Therefore, although the role of seafarer still exists even may be a shift the marine risk is rated, much more important is the human control in related sea worthiness not yet-to-be-seen direction of the shift.

## 3. Characteristic of MASS and Seafarer 4.0

### 3.1 Characteristic of MASS

#### 1) Requirement

The recent interest of ship owners and shipbuilders is to reduce operating costs applied to ships by using an automation system. A typical project related to this is 'MASS' and a total of the six key items necessary to succeed are as follows. First, the vessel needs high-end technology to ensure ship operating and implement cargo-enabled functions through a ship with four crew members.

Second, a mock evaluation technique is required through the construction of a start-up center for the performance evaluation and certification of autonomous ships. In other words, as a precautionary measure, technologies on various types of launch the automatic system testing, ocean-going navigation and related cyber terrorism are needed. Third, a platform development technology for meta data transmission security management, and control based on high-speed communication between a ship that is a dynamic situation and a ground-based control center that is static is required. Fourth, it is necessary to develop technologies for an integrated automation system between the dynamic subject vessel and another type of static entity, port (Kim, 2019). In other words, we need a situation-recognition-based operating system for incoming and outgoing vessels within the ship fleet, automatic control of logistics flows. We need technologies related to separate operational control rooms that can support functionality similar to existing VTS control rooms. Sixth, we have to prepare the long-term road map and programs for the international standardization response.

#### 2) Difference

For the merchant ship which are installed in electronic navigation and engine control system that informs about ECDIS, RADAR, GPS, RT-flex Engine are used. Such as ULCC (Ultra Large Container Carrier) is navigated by electronic chart and auto-steered by the programmed track. But master and chief engineer want to control the rudder and main engine is used for maneuvering or for controlling in emergency situations or accidents.

Existed ship means that seafarer inputs the order for the selected course and speed, as an engine alarm monitoring system for setting the ship's main engine. So, the officer and engineer have electronic system to avoid accident without human error to ensures the condition, problem, etc. Autonomy ship means that the ship has systems for assessing the emergency situation as well as the subsequent flow and supporting the right decision for seafarer what to do (Choi et al., 2018).

To summarize between existed ship and autonomy ship, seafarer is no more necessarily present on board. and then new type of seafarer who is supported by AI, AR, VR, big data processing system is perceived and assessed and a decision which takes place on board or in the shore control tower without any intervention by human beings.

### 3.2 The definition of Seafarer 4.0

The role of seafarer should be changed continuously with the developing of industry. Seafarer of the sailing ship age which is defined as seafarer 1.0 used the moon, stars, and the sun to get the ships position. Seafarer 2.0 which appeared after the industrial revolution added a new job group called marine engineer. And the seafarer of automated ship age which is defined as seafarer 3.0 should be able to operate by electronic equipment such as RADAR, ECDIS, AIS, ME-GI Engine, LNG FGSS (Fuel Gas Supply System). In this study, the seafarer of the autonomous ship age which is defined as seafarer 4.0 means a person who has the ability to understand and manage not only digitalized ships but also related ports 4.0, logistics 4.0 and shipping 4.0 based on the background of sailing experience.

Rolls-Royce, ABB, Google had already begun developing unmanned aerial vehicles and is planning to start pilot operations in 2020 and commercialize autonomous passenger vessels starting from 2035 in the future. In other words, if the introduction of autonomous ships, which were only considered state of art function, becomes a reality, what level of seafarer could be watching on the bridge or engine room? And the autonomous fleet reduces the quality of future seafarer's jobs. At this point, the reviewer will try to take a new approach to the scheme of the education and training system by presenting an agenda of 'Seafarer 4.0'. In other words, it is not just key words placed on the same lines as Shipping 4.0, Port 4.0, Logistic 4.0, and Marine 4.0. It is a new core 'Seafarer' with the hardware required for MASS. Seafarer 4.0, therefore refers to one-point with integrated operational capabilities that can optimize, streamline and manage the new system of a ship with ICT technology combined with the maritime capabilities of existing.

## 4. Education and training of seafarer 4.0

### 4.1 Job competence of seafarer 4.0

Until now, there are a lot of merchant ships which received with a wide range of sensor and automated control for specific positions, such as specific port, ocean route monitoring. Total integration with sensors, navigation methods, information and communication technologies were applied to ocean-going areas and expanded in scope. In order to specify requirements, for example seafarer's qualification and training matrix, ship owner or management company want to prepare to correspond to develop special rules, codes, guidance, regulations, training plans and

curriculum, procedures for MASS. Also, relevant personnel is to receive pre-post training, obtain a qualification, and be familiarized with the autonomy system.

The best shipping companies in the world predicts that it would be cheaper to operate the MASS when comparing the cost of a ship from building stage to dismantling stage and the cost of carrying a few seafarers aboard as manned. However, the final stage of the MASS is expected to have difficulty responding immediately as there are no seafarer on board to cope with the emergency situation for example blackout, grounding, collision, fire, flooding. In addition, more sensors and cameras are needed for monitoring the conditions in real time than manned ships and the big data is expected to increase dramatically. It is expected that many shipping companies and ship management companies will focus on their roles for maintenance, and shipyards and vendors will be able to predict various situations in advance through big data technology by sharing their roles such as analyzing them using data (Hong et al., 2018).

In reality, relative to past technological changes, the demand for technologies such as artificial intelligence, deep learning, machine learning, etc. With the introduction of the MASS system, training for existing seafarer and training for enhancing job competence, there are limitations to adapting to new technology environment with existing experience. In other words, it is clear that there will be fewer jobs for officer and engineers with is oriented by simple skill. On the other hand, ship in related to autonomy is expected to be associated with the system, alongside, loading/unloading. To prepare for this, a new approach to the existing seafarer education and training scheme is needed desperately. As a matter of fact, the training scheme of seafarer for MASS requires many hours, discussion to establish the official IMO model course. Currently, the nation's educational institutions are not moving yet to change their education and training scheme, but they are closely watching for future changes. So, seafarer education will eventually be changed last, as it has features that the cluster of domestic designated education institutions has changed sequentially when technology has changed significantly in law and institution (Lim and Lee, 2018).

### 4.2 Education and training targets

The biggest changes associated with the MASS have been a serious impact to maintain the ability to navigate, engine control, cargo working. However, with the introduction of MASS, 'Dual Qualified Operator' needs more advanced qualification and training

than past seafarer with both navigation and engine management capabilities (Song et al., 2019).

Especially for shore-based remote operators, which is currently being discussed in IMO, the primary concern is whether the scope of sources defined and applicable in the IMO and STCW agreements. The existing ship was operated by a seafarer who was licensed by STCW. But MASS is expected to disappear and be transformed into a degree 4 phase by IMO and AL6 phase by LR (no man on board) in which can be controlled and managed by the shore control tower. As the role of an existing seafarer is expected to be reduced and the role of the remote operator is expected to expand (Lim and Lee, 2018). Therefore, domestic designated education institutions need to revise their education policies to assist existing navigation technologies by applying convergence technology based on the fourth industrial revolution rather than conventional navigation and institutional management technology.

After all, it is now understandable that the scope of sources applied in the STCW is increasingly necessary to revise the scope to a new concept based on shore, not only for the safety but also reliability. Thus, instead of simply the term 'Operator', the term 'Remote Operator' is more reasonable to manage operations closely related to the ship.

### 4.3 Suggestion

The core of education and training for seafarer related to seafarer 4.0 oriented by STCW convention. Furthermore, considering Chapter 7 (Chapter VII: Alternative certification) of STCW Convention specifies that an algorithmic certification is possible. In other words, the existing method of dividing into navigational and trainees allows for an education and license system that can be included under the condition of receiving the same standards of instruction and training. Therefore, it is necessary to revise the training curriculum, present and future technical based on the content of Chapter 7 (Chapter VII: Alternative certification) of the STCW Convention (Chae et al., 2019). It is true that the current education and training scheme of seafarer training is the risk of significantly shrinking the volume of jobs (Kim and Jeong, 2017).

Traditional shipping, shipbuilding, and logistics companies must integrate with other industries in cooperation with ICT companies, minimizing the need for integration with other industries. We need to develop an Open Course Scheme (OCS) through cooperation with each stakeholder. In the end, designated education institutions that are trained in the officer and engineer should provide new

education based on IMO standards in the short term and various legal standard and requirement (Lee et al., 2015).

Standard of designated education institution covered that it aims to establish the standards necessary for the designated educational institutions in accordance with the provisions of Article 3 of the Enforcement Rules of the Ship Officer Act. So, we can consider in terms of training new seafarer for the following items which are proposed in more detail.

- ① According to Article 4 paragraph 4, the Head of designated educational institutions, as defined in the Annex to this Standard, can establish and operate a separate and appropriate curriculum.
- ② According to Article 4 paragraphs 3 and 4, "University (including trainees for train drivers at the College of Fisheries), the navigation and engineer curriculum shall be 80 courses of credits (more than 90 credits for the integration of trainers and electronic engineers). However, if a professional college wants to operate only the convergent class curriculum of seafarer to adapt the technology of MASS, it is necessary for students to take a diverse credit, which will provide students with more than 64 credits. In addition, the education and training scheme for seafarer should be revised to the existing scheme of trainees to improve the mix of functional capabilities and ICT technologies, especially based on human-machine interaction.
- ③ The Article 5 (course unit) should be included to the contents of MASS, remote operator.

Eventually, the role of seafarer should be changed according to the demand and supply of the international labor market for seafarers' market. The next thing we consider is job exchange education for existed seafarer. The government should support for the existed seafarer to adapt for digitalizing ships and related systems. The introduction of MASS is, after all, the key to minimizing human error, seafarer risk avoiding the unbalance both supply and demand, efficient ship operation, and reducing energy consumption. Particular in order to maintain its status as a seafaring nation with state-of-the-art technology, we should prepare a job exchange curriculum based on sea technology, experience and knowledge, network maintenance, cyber security, artificial intelligence, and big data management. for the existed seafarer to be a special operator in the shore control tower. Such an education and training scheme should be distinguished between the seafarer who shall be on board and the remote operator who controls the vessel on shore from the vessel. Especially remote operators should be subject to stricter IMO model courses.

## 5. Conclusion

The purpose of the existence and development of the MASS is to minimize human error, which can be made by human beings through new technologies, eco-friendly technologies and safety-supporting technologies. Currently, domestic shipping companies face strong challenges in terms of environmental regulations related to emissions control such as Nox and Sox and digitalization based on global networks. In other words, there is a traditional conflict between European-centered shipbuilders and the crew suppliers in the Asia-Pacific region. In connection with the consequences of such conflicts, the introduction of MASS is essential to establishing social consensus and cooperation by providing a complete education and training scheme for the seafarer who can operate it along with technological development and providing opportunities for job exchange.

As a matter of fact, the exclusion of the philosophy of human-centered management should be made to address the concerns of job reduction for the seafarer. However, there may be a risk that domestic shipping companies which not ready to prepare to adapt new technology and system. Therefore, it is necessary to revise the education & training scheme for the seafarer who engaged in MASS for the ensure ship's safety navigation. It may be at risk of losing competitiveness compared to European and Japanese shipping companies. Therefore, the government needs to support the R&D for the domestic shipyards, vendors, laboratories, shipping companies concerning the MASS as well as improve the education and training scheme that is suitable for the concept of Seafarer 4.0 for shipping companies that operate MASS.

## 사 사

이 논문 2018년 ICMASS에서 발표된 논문의 내용을 수정·보완하여 제출하였습니다.

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Received : 2019. 09. 18.

Revised : 2019. 10. 24.

Accepted : 2019. 10. 28.