Volume 7 Issue 2

ISSN: 2456-7035

ISF Institution of Research and Education (IIRE)

IIRE JOURNAL
OF
MARITIME RESEARCH AND DEVELOPMENT
(IJMRD)

October 2023

ISF Institute of Research and Education (IIRE)

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Volume 7 Issue 2

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ISSN: 2456-7035

Published by:

ISF INSTITUTE OF RESEARCH AND EDUCATION (IIRE)
410, Gemstar Commercial Complex, Ramchandra Lane Ext, Kachpada,
Off Link Road, Malad West, Mumbai 400 064, India.
Website: www.iire.in, www.inner-search.org, www.isfgroup.in

Link of Publication: - https://ojsiire.com/index.php/IJMRD
Place of Publication: - Mumbai

IIRE Journal of Maritime Research and Development

Maritime sector has always been influencing the global economy. Shipping facilitates the bulk transportation of raw material, oil and gas products, food and manufactured goods across international borders. Shipping is truly global in nature and it can easily be said that without shipping, the intercontinental trade of commodities would come to a standstill.

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SKILLING THE MARITIME SECTOR IN THE WORLD OF DIGITALIZATION

Dr (Capt) Suresh Bhardwaj[1]

Abstract

The transition towards digitalization and automation of processes and operations to enhance efficiency, increase competitiveness, and spur industries towards the decarbonization path of net-zero emissions have initiated the emergence of the Maritime Autonomous Surface Ship (MASS) in shipping operations. The rapid pace of digital transformation and technological advancement requires training and retraining of seafarers for adaptability. To accommodate this changing phase of the application of digital technologies in maritime operations and enable smooth transition, the Company of Master Mariners of India organized a focused group seminar to explore and identify potential competency requirements and necessary learning and training for seafarers to stay updated in the changing norm. This White paper distils the proceedings from the focused group seminar and validates it against the extant literature review from the world-class research documented in high-impact journals and then presents an analysis of relevant issues. Systematically commencing from the identification of 4 levels of MASS operation, analysing the key emerging technologies being used, thence analysing the Tasks and Competencies, to assessing the specific training needs, the paper culminates with defining a competency matrix that could be adopted for formulating and developing training and learning for seafarers in MASS operations. CMMI wishes to acknowledge and express its gratitude to the participating organizations, The Directorate General of Shipping, the Indian Maritime University, Warsash Maritime Academy, UK, and the organizing Seminar Committee of the CMMI.

Keywords: Maritime Autonomous Surface Ship (MASS), Digitalization, Automation, Training, Seafarers, Competency Requirements, Learning, Technological Advancement, Decarbonization, Net-zero Emissions.

1. INTRODUCTION

In December 2018, in the 100th session of Maritime Safety Committee meeting (MSC100), MASS was officially defined from the view of legislation as a ship that can operate independently of human-machine interaction in some extent. According to the automation level, MASS was divided into four levels.

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See figure 1 below "Automation level (AL) of MASS".

Table 1 - Automation levels of MASS (IMO, 2018)

	Level of autonomy	Human presence	Operational control	Human role
Degree 1	Ship with automated processes and decision support	Yes	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	Supervision and operation
Degree 2	Remotely-controlled with seafarers on board	Yes	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	Backup to manoeuvre, supervise the systems
Degree 3	Remotely-controlled without seafarers on board	No	The ship is controlled and operated from another location. There are no seafarers on board	Monitoring and remote control
Degree 4	Fully autonomous	No	The operating system of the ship is able to make decisions and determines actions by itself	Monitoring and emergency management

2. ANALYSIS OF KEY TECHNOLOGIES TO BE USED ON MASS

Based on the features of MASS, MASS involves the integrated application of technologies such as cyber-physical systems, Integrated Bridge Systems, environmental information perception, collision avoidance path planning, track control, internet of things, cloud computing, big data, automation, network information security, remote control, satellite and communication, fault diagnosis technologies for equipment and systems and hull condition monitoring etc.

Analysis of Key technologies for MASS is as below.

1. Cyber-physical Systems

Cyber-physical systems (CPS) are the integration and interaction between computing processes and physical processes. In other words, it can detect and control the physical process through embedded computer and network and realize the influence of physical process on calculation process through feedback loop.

Different from the traditional concepts of computing system and physical system, it combines the information world with the physical world through self-adaptive and feedback closed-loop control, and mainly considers the performance optimization in function. It is an intelligent technology integrating computing, communication, and control technology (3C), which has the characteristics of real time, security, reliability, and high performance.

Autonomous ship is a complex, heterogeneous, and highly reliable application system that meets the requirements of CPS. The realization of intelligent needs the support of multi-source isomerism information, such as the vessel's own navigation status, surrounding environment, equipment status, and inter-vessels, vessel-to-shore interaction.

2. Integrated Bridge System

The Integrated Bridge System IBS is an integrated system, which is reflected in various functions such as perfect navigation, driving control, collision avoidance, information centralized display, alarm monitoring, communication, shore station support, navigation management and control automation.

It is convenient for the driver and shore-based personnel to observe and manipulate and optimize the information of each equipment at the same time, so that the Integrated Bridge System can play a greater role in ensuring the safe navigation of the vessel and reducing the personnel cost than when the equipment is used alone.

The current IBS has entered the stage of artificial intelligence and mobile internet development, and the new generation of IBS will undergo a major change under the guidance of information technology, network technology, communication technology and computer technology.

3. Environmental information perception

At present, information of the fairway, surrounding traffic, other vessels, and own vessel navigation status can be obtained by means of the existing navigation equipment such as radar, AIS, electronic chart and GPS, etc. The water depth, water flow velocity, wind speed and wind direction are obtained by means of hydrological sensors such as depth sounder, ocean current meter and anemometer etc.

For non-vessel obstacles, laser scanners and radar can also be used for fusion recognition. In the process of environmental perception, the information of different sensors or devices may be redundant, conflicting, and missing. It is necessary to realize the reliable identification of the environment by means of information fusion theory.

4. Collision avoidance path planning

When the vessel is sailing, it is necessary to follow the vessel collision avoidance rules. Considering the safety of the collision avoidance path, it is also necessary to consider making the route shorter, more energy efficient and more timesaving. In the early stage, the collision avoidance path planning method based on expert system was widely used.

After the 1990s, with the rapid development of intelligent algorithms, fuzzy control, neural networks, and artificial potential fields have been used in the field of vessel collision avoidance path planning.

However, different intelligent algorithms have their own advantages and disadvantages. The application of multiple intelligent algorithms to avoid collisions has become the development trend of current vessel collision avoidance path planning.

5. Track control

The traditional vessel track control adopts the track automatic rudder method and has experienced four stages: mechanical automatic rudder, PID automatic rudder, adaptive automatic rudder, and intelligent automatic rudder.

In response to these demands, some advanced control algorithms have begun to be applied to vessel track control, such as Line of Sight (LOS) navigation based on state feedback, Model Predictive Control (MPC) based on optimal control theory method, etc.

6. Internet of Things

Based on the communication network such as the internet and mobile communication networks, the Internet of Things uses the intelligent objects with sensing, communication, and computing capabilities to automatically acquire various information of the physical world. It interconnects all physical objects that can be independently addressed, realizes comprehensive sensing, reliable transmission, and intelligent analysis and processing, and constructs an intelligent information service system in which people and things, things and things are interconnected.

In the field of navigation, the application of Global Positioning System (GPS), ARPA (Automatic Radar Plotting Aid) radar, AIS, electronic chart display and information system, integrated bridge system, radio frequency identification (RFID), video surveillance and other technical means has made the vessel develop rapidly in the direction of informatization and intelligence. The emergence of the Internet of Things has provided new ideas for the development of autonomous vessels.

7. Cloud computing

Cloud computing is the development of distributed computing, parallel computing, and grid computing. Real-time and dynamic analysis of the massive amount of information collected by a large number of sensing devices at different times during vessel navigation, and the aggregation, splitting, statistics, and backup of such information require cloud computing with elastic growth storage resources and massive parallel computing capabilities as a support.

8. Big data

The application of big data is the process of using the results of big data analysis to provide users with decision-making and mining potential value. Regional or dedicated data monitoring centres have emerged in the shipping industry.

For example, international shipping companies such as China Ocean shipping Group have realized the operation status of their vessels on a global scale. Europe's information collaboration service concept for supporting inland navigation, traffic management, transportation management and multi-modal transport - Harmonized River Information Services (RIS) provides users with static information such as electronic maps, laws and regulations, and dynamic information such as vessel registration and vessel position, cargo information, and estimated arrival time.

The application of those technologies above on ships is the guarantees to realize the development of different levels of MASS. (Wang Deling, 2020)

3. ANALYSIS OF TASKS & RELATED COMPETENCIES

The table below shows a limited summary of task descriptions onboard MASS, especially the ROC (Remote Operation Control).

Table 2 - Task description for MASS

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

The evolving pace of the maritime industry requires training and qualification in both core and soft skills to meet the complexity of MASS operations. Below is a table showing some of these necessary competencies and skills for MASS Operation: -

Table 3 - Competencies for MASS

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

4. ANALYSES OF KNOWLEDGE AND SKILLS NEEDED TO MANAGE AND OPERATE MASS

The current STCW convention and code stipulates the requirements of the training, certification, watch-keeping, and competence for seafarer. MET in most countries in the world are basically conducted in accordance with the requirements of STCW convention and code. As to the positions on board ships, seafarers are divided in STCW code into three levels: management level, operation level and support level, and the table of KUP (Knowledge, Understanding, Proficiency) in STCW code specifies the competence requirements of the three levels.

The application of new knowledge and new technology on MASS is bound to produce new requirements for the competence of seafarers. The requirements of the current STCW convention and code will not meet the development of MASS in no doubt. In order to further analyse the specific influence of MASS on seafarers' MET, - according to the development trend of MASS, the knowledge and skills needed by navigators in the future to manage and operate MASS is divided into three aspects: Ability, Knowledge and Technology. Each aspect includes several elements (see table 3 below). However, In the existing traditional MET curriculum, the new knowledge and technology related to MASS are not included, which will not meet the needs of MASS development, making it urgent to reform in MET. See Table 2 below "Knowledge and skills needed to manage and operate MASS in the future".

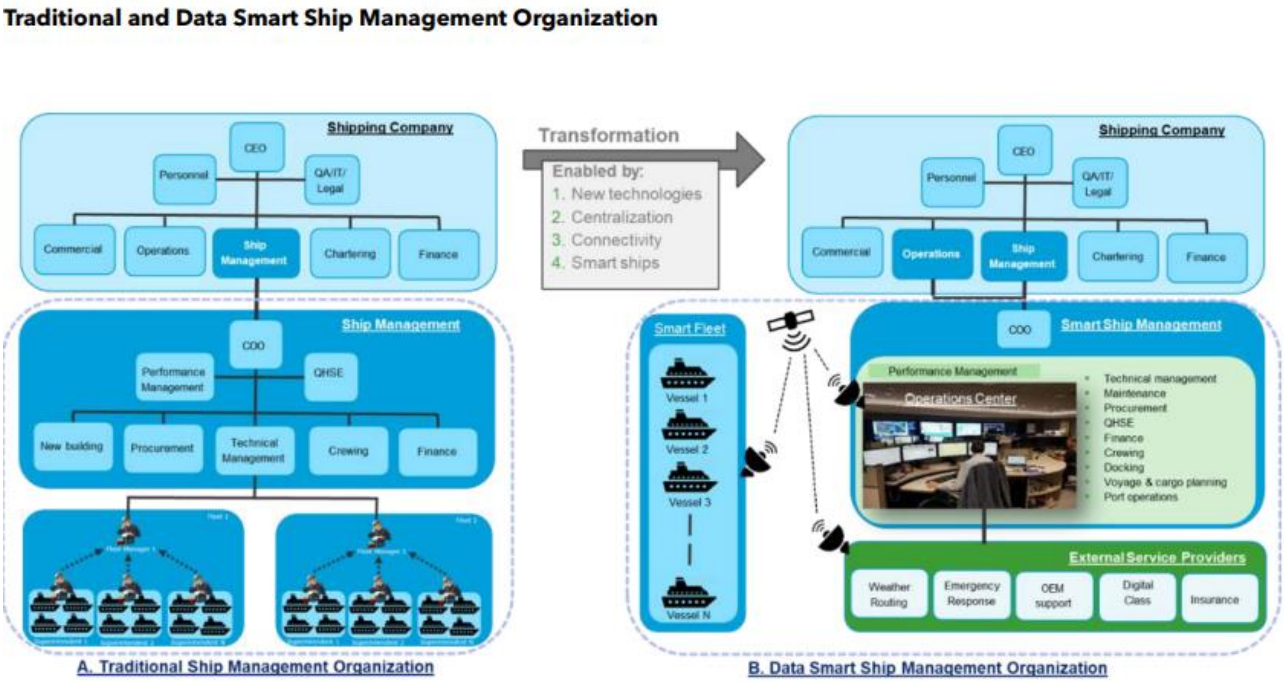
Table 4 - Knowledge and skills for MASS (Onwuamadike, 2022)

Classification of Knowledge and skills in relation to MASS	**Knowledge and skills**	**Whether included in the existing MET curriculum?**
Aspect of ability	Leadership and communication	Yes,
	Obedience and execution	Yes
	Psychological stress resistance	Not exactly, as the number of ship manning decreases, problems of "psychological stress" will become more prominent.
Aspect of knowledge	Traditional nautical knowledge	Yes
	Network communication knowledge	Not exactly, this knowledge is only reflected in GMDSS courses.
	Automatic control knowledge	Not exactly, there are only some automation knowledge in ships' bridge and engine room control in existing MET.
	Data mining knowledge	No
	Artificial intelligence knowledge	No
Aspect of technology	Autonomous navigation	No
	Fault diagnosis	No
	Remote control	No
	Environmental information perception	No
	Internet of Things	No

Note: The word "navigator" is used here instead of "seafarer", because "seafarer" refers to persons manned on board ships to management and navigate the ship. However, when

MASS develops to a certain stage in the future, the ship will no longer be manned, and it would be inappropriate to use the word of "seafarer" while there is no seafarer on board. The transition is well captured the Figure 1 below:

Figure 1 - Traditional and Data Smart Ship Organization



Being more specific, a limited summary of Specific Training Needs in MASS Operations is as below (UK, 2018)

Those knowledge and skills listed in table above are essential and minimum requirements for navigators in future to manage and operate MASS. The mastery degree of the knowledge or skills required by navigators varies according to position of navigator and the level of MASS.

Table 5 - Specific Training Needs for MASS

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

5. IMPACTS OF MASS ON THE SHIP'S MANNING

The division of four levels of autonomy, in essence, is that the ship's navigation behaviour depends on the division of the level of the ship's crew on board, from no longer entirely depending on the shipboard crew to completely getting rid of crew on board ships.

In the first level of MASS, the ships' manning is decreased. In the level of remote-controlled ships, the future "seafarers" will be divided into two types: "shore-based operator" and "seafarers on board ships". In the full autonomous level, the ships will sail autonomously, under which condition there will be no seafarers on board ships. Thus, it can be seen that the reduction of ship manning is a general trend, and the enrolment scale of navigation major will be reduced with the development of MASS.

In terms of horizontal structure, the development of MASS will bring about the adjustment of seafarer type structure. In accordance with the STCW convention and code, seafarers are basically divided into three types: deck crew members in charge of ship navigation and cargo transportation (Major of nautical technology); engine room crew members responsible for ship propulsion and machinery system (Major of marine engineering); and electrical, electronic and control personnel (Major of electrical, electronic and control engineering) responsible for the electrical, electronic installation and control system of the ships. While in higher levels of MASS, the seafarers will not be classified according to the workplaces, and ship control personnel will be divided into two types: "shore-based" personnel and "shipboard crew". The shore-based personnel will be responsible for the navigation of ships by remote control, and the shipboard crew will undertake multiple tasks such as navigation and machine maintenance.

In terms of longitudinal structure, the development of MASS will bring about the adjustment of the hierarchical structure of maritime talents. At present, the cultivation of the maritime talents has three levels: technical secondary, high-vocational education and undergraduate. Whether from view of human capital or from the view of technological development, this occupation requires higher technical conditions, and the society needs more high-quality talents. The development of MASS needs more skilled maritime talents, so the proportion of maritime talents at the levels of technical secondary will continue to shrink, and those of high-vocational and undergraduate level will occupy the mainstream.

6. IMPACTS OF MASS IN DIFFERENT LEVEL ON THE REQUIREMENT OF MET

Through the study on the technologies required by MASS and the content in tables above, different levels of MASS have different impacts on the future maritime education and training.

Impacts of ships with process automation and decision support on MET

Ships with process automation and decision support are equipped with some systems or equipment that can help seafarers to achieve the process automation and decision support of navigation tasks. The navigation decision-making of ships is entirely made by the seafarers themselves, and the information obtained from outside only plays a supplementary role in the decision-making of seafarers. The operation of ship with process automation and decision-support remains largely dependent on the operation and management of seafarers. MASS in this level has limited impacts on modern maritime education and training. However, as the automatic control system and decision support system are widely applied in this type of ship, new requirements will be put forward for the knowledge system and training method of education training.

1. Impacts of Remote-control ships with crew on MET

When the marine autonomous surface ships develop to the second level, i.e. the Remote-control ships with crew, the personnel allocation of the ships will be greatly changed compared with that of traditional ships: shore-based Remote-control personnel will appear, the number of the personnel on board reduced, and the working mode and division of labour will greatly be changed. Marine navigators will need to complete the learning or practice of relevant knowledge and skill in accordance with the requirements in table 2 and meet the corresponding standards of competency. As can be seen from table 2, the knowledge structure required by maritime navigators on Remote-control ships with crew members is changed greatly. In addition to the corresponding traditional maritime knowledge, marine navigators should master new knowledge and technology related to marine autonomous surface ship or apply them in practice to different degrees, such as network information knowledge, automation knowledge, information physical system knowledge, big data knowledge, autonomous navigation and collision avoidance technology, remote control knowledge etc, which will have a considerable impact on the future maritime education and training, requiring the future maritime education and training to include the above new knowledge and technology in addition to the traditional maritime knowledge.

2. Impacts of Remote-control ships without crew on MET

Ships with this stage are equipped with remote control system or facilities that can help personnel being not on board such as remote-control navigators on shore or on other facilities to fulfil navigation tasks. Decisions will basically be made by personnel being not on board and the ship will be unmanned. Compared with the Remote-controlled ships with crew, the Remote-control ships without crew are completely dependent on the operation of the qualified personnel on shore. Therefore, the qualified personnel on shore need to have a deeper understanding of the knowledge of network information technology and automation technology, as well as an extensive knowledge reserve to cope with the remote and changeable marine navigation environment.

3. Impacts of full autonomous ships on MET

Ships in this level are equipped with the system or equipment that can enable it to accomplish the tasks of navigation autonomously. The decision-makings for ship operations are completed autonomously. There is no crew on the ship. Control personnel on shore mainly play the role of monitoring the ship's navigation performance, when necessary, can get involved in controlling the ship. Higher requirements have been put forward for suitable personnel of full autonomous ships. The supervisors need to be proficient in all the knowledge and skills listed in paragraph 1 above detailing Key Technologies for MASS.

7. WHAT TYPES OF SKILLS AND COMPETENCIES ARE REQUIRED TO PERFORM SHORE-BASED OPERATIONS OF UNMANNED AND AUTONOMOUS SHIPS?

Definitely, one would say that there should be a training on ICT, about machinery operation. They should know basics about artificial intelligence and troubleshooting skills.

They will have to be ex-seafarers. They should be like master’s licence holders at the minimum because they need to know exactly, just like you are controlling the ship, they need to know when to take over. They should be just like a master taking over the manoeuvring.

It will be critical to diminish the focus on mechanical and electrical training and focus more on electronics in the short term and on artificial intelligence and machine learning in the future, that is the real future.

They will still need the traditional seafaring skills. In addition, they will need the basic skills of how to operate a computer, computing skills, gaming skills. Also, they will need to understand the environment, they will need to understand cargo and stability, they will need to understand all of the engineering. Future operators in shore-based will need to have high cognitive skills, which will allow them to deal large amount of information on the screen displayed in shore-based stations. They should be very sound, theoretically.

Leadership, communication, decision-making, information management, risk analysis and task allocation are also among the soft skills that will be needed by shore-based operators in order to effectively do their job. Only ex-seafarers should be trained to operate autonomous and unmanned ships – is quite established. With regard to the specific certification that future shore-based operators should hold. It is suggested that a smart ship's (i.e., autonomous/unmanned ships') licence could be added above the traditional licence. Maybe we can call it like a smart ship operator's licence.

Adapted competency matrix for MASS and conventional ships as per table below: -

Table 6 - Competency Matrix for MASS & Conventional ships (Cicek & Akyuz, 2019)

MASS Competency Matrix																																
Persons	**Vessel/ Shore**	**Ship (MASS) Digital System Understanding and Technical Knowledge**	Operations monitoring and analysis (remote operations)	Equipment operations and control	Equipment maintenance and repair	Automation engineering	Trouble shooting	Data engineering (data processing and analytics)	Electrical/ electronics engineering	Autonomous maritime law and regulations	Programming	Cybersecurity	Maritime economics and logistics	**Classical Maritime Competency - Deck/ Engine (STCW i - viii)**	Navigation/ marine engineering	Cargo handling and stowage/ maintenance and repair	Ship operations/ Electrical, electronics and control engineering	Maritime law and regulations	Security Duties	Good seamanship	**Soft Skills**	IT and technology affinity	Leadership and teamwork	Good reasoning and decision making	Critical thinking and problem solving	Efficiency orientation	Good communication	Managing complexity	Cognitive ability and analytical skills	Innovativeness	Flexibility and adaptability	Continous learning - motivation to learn, learning & resaerch	Environmental awarenes and sustenability mindset
Traditional Seafareres	Conventional ships		0	0	0	0	2	0	0	0	0	1	1		2	2	2	2	2	2		1	2	2	2	2	2	2	2	2	2	2	2
Seafarers with Advanced Technology Skills	MASS (autonomy levels - 1 & 2); IMO		2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2
Remote Operator	MASS (SCC/ROC - autonomy levels - 3 & 4); IMO		2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2
Definitions: 0 - Not necessary 1 - Should have basic knowledge/skills 2 - Should have good knowledge/skill (theory &practical)	**Comments:** These competencies and task descriptions are summarily explained in (Chapters 2.8, 2.9, Tables 5 & 6, and figure 10 in chapter 5.1). The matrix is in generalty to seafaring, both traditional and MASS operations.																															

8. RETENTION, ATTRACTION, AND OPPORTUNITIES

Retention and attraction are crucial in the maritime industry, with many seafarers facing limited opportunities for career advancement and development. Lack of a career path and poor compensation can lead to a loss of experienced and talented workers, creating a skills gap in the industry which is already under strain. This is likely to be more impactful if seafarers are trained in highly specialized areas, likely to prevail in the decade of transformation when digitalization and new technologies emerge.

It is recommended that Shipowners/operators/managers should closely manage the progression opportunities of seafarers from both a retention/attraction and operational capability standpoint. Career development opportunities brought about by digitalization and decarbonization should be leveraged to retain and attract people to seafaring jobs.

Most seafarers would prefer to perform their current onboard role if it could be shore-based. This brings new opportunities for seafarers using their existing skill sets in shore-based control and monitoring facilities such as Shore Control Centres. In addition, shore-based jobs will remove many negative connotations associated with a seafaring career, bringing about significant benefits to seafarers and their families (DNV 2023).

Shipowners/operators/managers should harness the unique and desirable skill sets of seafarers and provide them with opportunities for complementary shore-based roles such as vessel control and monitoring facilities (shore control centres), which will likely become more prevalent later in the current decade and beyond.

9. CONCLUSION

In the future, ships may be controlled and operated autonomously without intervention of human if MASS can reach the level of unmanned control. It is in no doubt that the wider application of MASS will bring great changes to the shipping industry and pose great challenges to seafarers' knowledge structure and maritime talent cultivation, thus posing great challenges on the Maritime Education and Training.

As is analysed above, basically those challenges on MET are reflected on the following two aspects:

1) Application of new technologies on MASS requires higher-standard maritime talents

Shipping is now stepping into the first level of MASS, i.e., ships with the process automation and decision support. MASS in this stage is mainly dependent on operation and management of crew, which has a limited impact on modern maritime education and training. As the automatic control system and decision support system gets applied widely, new knowledge and skill needs to be increased in the existing education training. However, in terms of the current growth momentum of technologies, ships will rapidly develop into a higher level in the coming decades, and by then traditional knowledge and skills of ship navigation will not meet the requirements for MASS operation. In addition to the traditional maritime knowledge, ships' navigators are to be required to master new knowledge and technology related to MASS such as network information knowledge, automation knowledge, information physical system knowledge, big data knowledge, autonomous navigation and collision avoidance technology, remote control knowledge, etc.

Maritime universities, colleges, training institutions and maritime authorities are suggested to closely track the development of MASS and provide relative new knowledge and improve modes of maritime education in order to produce talents suitable for the development of navigation technology.

2) Mode of MET need to be adjusted to adapt to different levels of MASS

The division of four levels of autonomy, in essence, is that the ship's navigation behaviour depends on the ship's manning, in other words, operation of ships evolves gradually from entirely depending on the shipboard crew to completely getting rid of crew. The development of MASS is to bring about the adjustment of seafarer type and the hierarchical structure of maritime talents.

Different from traditional ship manning mode, in higher levels of MASS, ship navigators will be divided into two types: "shore-based" personnel and "shipboard crew". The shore-based personnel will be responsible for the navigation of ships by remote control, and the shipboard crew will undertake multiple tasks such as navigation and machine maintenance. Therefore, design of maritime curriculum system shall be adjusted to include new skills and knowledge required by MASS.

What's more, the development of MASS needs more higher standards maritime talents, so the proportion of maritime talents at the levels of technical secondary will continue to shrink, and those of high-vocational and undergraduate level will occupy the mainstream. Therefore, it is suggested that MET should closely track and follow the development of MASS, forecast the supply and demand for seafarers, dynamically control the scale of maritime talent education, reshape the curriculum system, renew the teaching content, promote innovation of the education mode, and improve the educational quality of maritime talents to adapt to the development of MASS.

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