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RESEARCH ARTICLE

A conceptual model of autonomous ship remote operators' competency

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Abstract

The Shore Control Centre (SCC) is being developed and tested as an autonomous ship vessel with remote control. However, since the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) regulation's competency standard has yet to be altered, it must be revised and modified. Therefore, this study aims to define the competency of remote operators on an autonomous ship from ashore and develop a conceptual model of remote operators' competency. This study used both primary data by interviewing executives from four groups of maritime experts, and secondary data from academic databases, IMO, classification society and maritime companies. Academic databases are employed to conclude the academicians' view on remote operators' (ROs') competency and the other data sources are used to conclude the industrial view on the RO's competency. The content analysis technique was used to determine the presence of keywords or concepts from secondary data and develop a conceptual model. The study's findings present four main dimensions to indicate the development of future training and development programs for RO officers: navigation, cargo handling and stowage, controlling the ship's operation and care for persons onboard, and information technology; and present 45 competencies of ROs for managing autonomous ships from ashore, which a conceptual model can explain.

1. Introduction

The autonomous vessel is the latest transportation technology employed by the maritime industry to solve problems, such as the risk of loss of life and property, environmental pollution, economic efficiency, and transportation cost reduction (Ghaderi, 2019; Lahtinen et al., 2020). Projects to investigate the viability of autonomous ships have been launched (Jo and D'agostini, 2020; ClassNK, 2021; de Vos et al., 2021). The International Maritime Organization (IMO) is developing Maritime Autonomous Surface Ship (MASS) regulations. Depending on the degree of autonomy, there can be four development stages (Rodseth and Nordahl, 2017). In the future, autonomous vessels will play a crucial role in sea transportation. Currently, the MASS is entering the development phase of degree 2 or higher, and according to information from the IMO, MASS vessels should have a minimum level of safety equivalent to conventional ships (Porathe et al., 2014; Chaal et al., 2020a).

The competency of seafarers is defined by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), and aims to ensure that seafarers worldwide possess the minimum qualifications, knowledge and skills necessary to work in various positions and fulfil their roles effectively. The convention defines the 'standard of competence' as the level of competency required for carrying out duties on a ship with international standards, and incorporating the necessary knowledge, understanding and demonstrated skill (IMO, 2014). As autonomous ships undergo development, it becomes crucial to continuously identify the competencies needed for specific

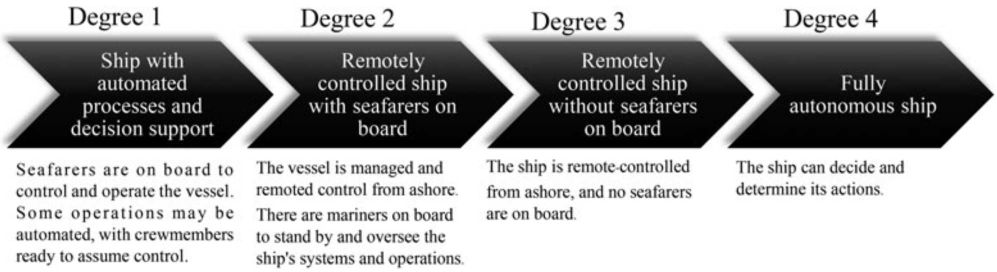

Figure 1. *Adapted from MSC 100th meeting (IMO, 2018b).*

roles to adapt to the ongoing technological advancements (Kipper et al., 2021). Fundamentally, every worker should possess the requisite knowledge and skills to effectively apply to their job in the workplace (Australian Skills Quality Authority, 2015).

The STCW specifies a total of 19 competencies for navigation officers (IMO, 2011, 2014; Sharma et al., 2019; Yoshida et al., 2020; Sharma and Kim, 2021). In the future, the work and social-technical environment of seafarers will change. For the maritime industry to maintain its effectiveness and safety levels, as well as to enable seafarers to transition into other sectors, it is essential to adapt marine education and training to future needs (Fonseca et al., 2019). Therefore, the technology of autonomous ships should be incorporated into the training of seafarers (Ahvenjärvi, 2016). There are many modern technologies (e.g. sensing, computing, dynamic positioning) available to support the autonomous ship development. Therefore, someone who works with new technology must have information technology (IT) knowledge. The SCC is already under development and has been tested to remotely control autonomous ship vessels. However, if the competency requirement in the STCW regulation is amended, revision and adaptation will be required (Pundars, 2020; Saha, 2021).

Therefore, this study aims to define the competency of ROs on an autonomous ship from the SCC and to develop a conceptual model of remote operators' competency.

2. Introduction to autonomous ships

The shipping industry is hastening the development of autonomous ships with cutting-edge technology to create cargo and passenger ships to provide transportation services to every corner of the world. Additionally, there are efforts to test navigation using remote-control systems (Pundars, 2020; Yoshida et al., 2020). MUNIN, AAWA, AUTOSHIP were projects that conducted research and developed MASS on the feasibility of unmanned autonomous shipping. AAWA particularly applied the research results to the real ships; meanwhile, AUTOSHIP is regarded as a navigation demonstration project which has already been accomplished. However, Yara Birkeland is currently an ongoing MASS project. The maritime companies, NYK, Wärtsilä, Kongsberg Maritime and others, are additionally developing the autonomous ships as they are stakeholders in the maritime industry. In the academic research, studies of autonomous ships span across many academic disciplines: technology development, remote operation, education, safety, legal issues and human factors. Such research results in critical pressure that makes autonomous ships very important to the IMO at a meeting of the Maritime Safety Committee (MSC). A scoping exercise on autonomous vessels has been added to the 98th MSC meeting's agenda to evaluate the safe, secure and environmentally friendly operation of MASS (IMO, 2017).

In the 99th MSC meeting, the committee adopted a structure for a regulatory scoping exercise, which included fundamental definitions of MASS and levels of autonomy, as well as a mechanism for completing the study and a work schedule (IMO, 2018a). Therefore, in the MSC 100th edition, it is essential to identify the degrees of autonomy for the scoping exercise. Four degrees can be specified, as shown in Figure 1.

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The use of remotely piloted or autonomous vessels in specific marine zones is anticipated within the next few years. The ship is expected to be able to operate in coastal areas and for short marine routes, as well as for international excursions, by 2030 or 2040 (de Klerk et al., 2021).

The autonomous ships on which this research focuses are those in degree 2: Remotely controlled ships with seafarers onboard. Two crucial components related to the remote control of an autonomous ship, which are essential for an overall understanding of autonomous ship control, are the SCC and the ROs.

2.1. *Shore control centre (SCC)*

The SCC is where the RO can remotely control and operate an autonomous vessel. Still requiring human management, those who can use the ship must undergo training to monitor and control the autonomous vessels (Porathe et al., 2014; Saha, 2021). Presently, at MASS degree 2, the ship will be controlled by an autonomous system guided by onboard sensors, and remote control systems will be managed through a satellite communication link, enabling them to execute standard collision avoidance manoeuvres in compliance with international regulations (Porathe et al., 2014; MacKinnon et al., 2015; MUNIN, 2015). Generally, all decisions on how to operate the ship are commanded by the SCC. The autonomous system can only be activated when the ship safely navigates according to the pre-planned route with low complexity and no risk, such as navigating in regular sea and weather conditions. Any decision-making will be carried out by the automatic system, guided by the onboard crew and the SCC. However, when there is any risk, problem or rapid changes in the external environment that affect ship navigation, the system will switch from autonomous control to SCC control. In addition, the SCC can request the officer in charge of the navigation watch to take control of the ship when necessary or in emergencies (Zhou et al., 2021).

Furthermore, an entire team of ship crew would embark, before arriving at the destination port, to carry out berthing or any other demanding operations, ensuring the safety of the ship (Wróbel et al., 2017). Three types of remote-controlled navigation consist of berth to berth, including autonomous docking, pilot point to pilot point and navigation in the open sea (Zhou et al., 2021). Therefore, the SCC must have communication equipment and infrastructure, navigation aids, and equipment for remote nautical support to cover the safe remote control of ships (ClassNK, 2021). Once the significance of the SCC is understood, the next step is to comprehend the role of the personnel responsible for controlling the ship from the SCC, known as ROs.

2.2. *Remote operators (ROs)*

ROs would not require the same level of expertise as master or chief engineers. However, ROs must comprehend the fundamentals of ship operation in a marine context (Saha, 2021). The RO is the person responsible for controlling the autonomous ship from the SCC. Their roles and duties at work will vary depending on the specific autonomous degree. However, the primary function is to monitor and supervise the operation of MASS and make final decisions regarding resolving any problems that may arise.

In some cases, a system crash occurs. The RO must be competent enough to control a faulty system manually. An RO's competence is an essential aspect of vessel control to build the MASS ships that are desired to reduce navigational errors from the ship crew. Therefore, the RO's final decision is critical to safe navigation (Deling et al., 2020; Yoshida et al., 2020; Chang et al., 2021).

The RO needs to have real-time and essential information about the status of the ship. Then, one of the primary tasks of the sensors used for MASS will be to be aware of the various environmental conditions around the ship, mainly to avoid grounding and collision with other ships or other obstructions (Ahvenjärvi, 2016; Chae et al., 2020). Therefore, when ROs require real-time and comprehensive information for monitoring and decision-making, wireless communication technologies between the ship and SCC are essential for their safe and effective operation (Chae et al., 2020).

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The term ‘remote master’ refers to an individual, excluding a pilot, who assumes command or has control over a ship without physically being present onboard. However, a ‘remote operator’ is an individual who is employed or engaged to electronically control various aspects of ship operations without being physically present onboard the vessel (Kemp, 2022). Furthermore, the IMO has outlined the role and responsibility of the RO in the outcome of the regulatory scoping exercise and gap analysis of the FAL Convention concerning MASS. It states that in the context of remote ship operations, where the master is not physically present onboard and control is conducted from a remote location, it is essential to clarify the responsibilities and obligations involved in resolving situations and declaring pre-arrival information regarding stowaways, refugees and individuals rescued at sea (IMO, 2021).

3. Methodology

This research represents a qualitative study that used a data collection method (Buchanan, 1981; Taherdoost, 2021), incorporating diverse sources of information.The study investigated academic knowledge and industrial technical skills required for the RO. In the academic aspect, the researchers identified competencies by reviewing academic articles published between 2016 and 2022. Due to the increasing prevalence of the idea and the articles to develop autonomous ships in the maritime industrial sector since 2016 up to the recent year, researchers have shown interest in studying research work during this timeframe; the researcher conducted searches using Science Direct, Scopus, Springer Link and other source databases. Keyword searches were performed using ‘autonomous competency,’ ‘seafarers’ competency,’ and ‘smart ship’, and 49 articles were found.

In the industrial aspect, the researcher collected data from four different sources. The first source was Classification Society Reports, which included ClassNK, Lloyd’s Register, Class DNV and American Bureau of Shipping (ABS). The second source involved the researchers conducting studies on IMO requirements, such as the STCW codes and IMO model courses. For the third source, semi-structured interviews were conducted with 16 experts representing key stakeholders. These experts comprised two crew department managers in the leading container shipping companies in Taiwan (i.e. Evergreen Marine Corp. and YangMing Marine Transport Corp.) and two senior crew managers from Thailand, four senior master mariners from Thailand and Taiwan, four senior navigation lecturers from Thailand and Taiwan, and four senior officers of the port/marine authority all of whom have over 30 years of experience in the maritime industry. Lastly, the researchers studied operational knowledge and skill of the RO with three companies involved in the development of autonomous ships controlled remotely, namely Wärtsilä (2017), Kongsberg Maritime (2021) and Rolls Royce (2017).

After collecting data from both academic and industrial aspects, the researchers conducted content analysis. The purpose of content analysis is to find the concept statement and focus on qualitative data to complement it. Recompenses of content analysis are statements that are examined to grasp conceptual models and a reasonable research strategy (Makkawan and Maungpan, 2021; Pariafsai and Behzadan, 2021). Through this process, the researchers could define the competencies required of remote operators on an autonomous ship from the SCC. This analysis revealed primary dimensions and encompassed all competencies for remote operators within each dimension, ultimately leading to the development of a conceptual model for remote operators’ competency, see Figure 2.

4. Finding and discussion

This study’s findings are divided into two sections. The first section discusses the competency of remote operators from the SCC on an autonomous ship. This section includes discussions on competency dimensions and presents the results of the identified competencies for remote operators. Once the competencies have been identified, in the second part, to facilitate understanding, the researchers have constructed a conceptual framework of competencies for remote operators to control an autonomous ship ashore.

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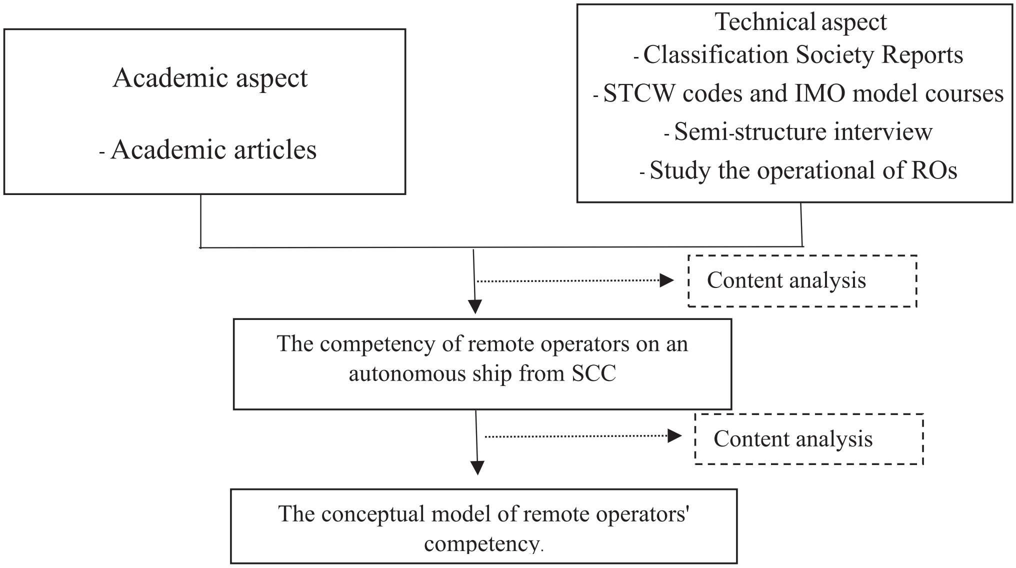

Figure 2. *Framework of the qualitative research approach. Competency for remote operators to remotely control autonomous ships ashore.*

4.1. Competency of remote operators on an autonomous ship from ashore

This research used a data collection methodology encompassing both academic and industrial aspects. The content analysis technique was used to analyse and evaluate the collected data. The research findings are categorised into two sections: the industrial aspect and the academic aspect.

4.1.1. Industrial aspect

The researchers collected data from four different sources, including classification society reports, IMO requirements, semi-structured interviews and operational reports of ROs. After collecting data and conducting content analysis, the researchers concluded that ROs must have standard competencies and additional competencies. The standard competencies are important for performing ship operations and complying with the requirements specified by the STCW. There are a total of three standard competencies which are as follows.

1. Navigation (NAV) dimension: ROs need knowledge, skills and abilities to navigate the vessel effectively. These include understanding navigation equipment, ships operations and fundamental skills necessary for navigation, fixing ships position, ships manoeuvring according to the Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs).
2. Cargo handling and stowage (CGO) dimension: ROs should have the basics of cargo management, loading and discharge operations, and cargo care during voyages.
3. Controlling the operation of the ship and care for persons onboard (COP) dimension: pertains to safety aspects, including environmental protection, crew safety, fire prevention and compliance with regulations.

Regarding the additional competency, the study findings emphasise the importance of IT systems used for ship control at the SCC. The nature of the work for ROs responsible for controlling autonomous ships requires them to have knowledge and skills related to vessel navigation, route planning and dynamic positioning systems for maintaining the vessel's position. They also need to monitor and evaluate weather conditions continuously and have the ability to manoeuvre the vessel during berthing or un-berthing operations remotely. The RO must be proficient in initiating system operations, conducting critical checks on vessel systems, using satellite communication systems to establish communication between

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the SCC and the ship, and effectively diagnosing and responding to abnormal situations. In emergency scenarios, the RO should be capable of promptly responding and taking appropriate actions. Due to the nature of the work mentioned above, the equipment and systems at the SCC are advanced technologies that enable us to make fast, accurate decisions and ensure maximum safety. These include remote control, autonomous navigation, the Internet of Things, big data, DP (dynamic positioning) systems, cargo condition monitoring and bridge control systems, among others. Therefore, the researchers can conclude that IT competency is crucial and should be classified into two groups: general IT competencies, which encompass computing, information and data processing, Internet of Things, big data, artificial intelligence, remote control and autonomous systems; and specific IT competencies that relate to the operation of autonomous ship, cargo operations and ship safety. There are additional recommendations from experts representing key stakeholders, suggesting that ROs should rely on lifelong IT education to encompass all competencies.

4.1.2. Academic aspect

Essential competency dimensions for remote operators. This research reviewed 49 articles from related keywords. Researchers found 22 articles related to the competencies required for ROs and analysed the information through content analysis. The study found that ROs must have competencies at the level of a navigation officer, which includes the three dimensions specified by the STCW. However, preliminary data from both academic journals and classification society's technical reports indicate the importance of IT competencies for the effective performance of ROs. Therefore, the researchers conducted further studies to confirm the importance of IT competencies.

Table 1, which summarises the research study on IT competencies, demonstrates the relationship between IT competency and various aspects of ship operations as defined by the STCW. In the first column, References, the relevant articles are listed. The second column provides a summary of the articles that discuss IT for autonomous ships. The authors have indicated the connections between IT and the three dimensions of the STCW, namely navigation, cargo handling and stowage, and controlling the operation of the ship and care for persons onboard (COP), as shown in the third column. From this, IT competency is an essential competency that needs to be added to the job performance of ROs.

Competencies for remote operators. After the researchers found the correlation between information technology and the three competency dimensions from the STCW by incorporating advanced technology and information technology into various ship equipment and systems, as shown in Table 1, the next step for the researchers is to define all the necessary competencies for the RO. The researchers were able to specify four competency dimensions for the RO. After determining the four dimensions, the researchers found that the IT dimension needed more clarity regarding the necessary competencies for ROs. Therefore, further studies were conducted to explore and identify the specific competencies within the IT dimension. Table 2 summarises the competencies within the IT dimension, with a total of 26 competencies identified.

Of the 25 references used in Table 2, 21 of them are from academic journals and only four are from classification society reports (i.e. Lloyd's Register, 2017; American Bureau of Shipping (ABS), 2021; ClassNK, 2021; DNV, 2021), and these are compiled into Table 3. This table provides an overview of all four dimensions, namely NAV, CGO, COP and IT. It also includes the codes for each dimension. Additionally, Table 3 presents the competencies within each dimension in the 'RO's Competencies' column. The competencies are further categorised as follows: nine competencies for NAV, two competencies for CGO, eight competencies for COP and 26 competencies for TEC. In total, 45 competencies have been identified, and their specific descriptions are provided. Identifying thorough competency descriptions facilitates their future application in educational institutions, MASS development organisations and training departments in shipping companies. After identifying all the competency dimensions and competencies, the researchers have successfully developed a conceptual model of competencies for remote operators to effectively control autonomous ships remotely from shore.

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Table 1. Summary of articles demonstrating the relationship between IT and dimensions of the STCW.

		Dimensions of STCW Related to IT Competency		
References	Information Technology for autonomous ship mentioned in articles	Navigation	Cargo	COP[a]
DNV GL (2018)	For safety, the technology design should specifically include all functions of the auto remote infrastructure needed to cooperate between traditional ship functions; others are related to automatic and remote operation consisting of supervision and remote control, navigation, communication, cargo handling, safety, security, etc.	x	x	x
Chaal et al. (2020a)	Compares each function from the STCW convention with an autonomous ship found. The Shore-Based Control Centre will take over the remote control of the ship instead of performing various aspects of the ship's crew. The SCC shows technology related to three functions of STCW with technology	X	x	x
Zhou et al. (2021)	The SCC's primary duties include ship control and route supervision, voyage and standby, and taking action in an emergency. Communication is crucial for a remote-controlled vessel to be safe and secure while navigating and complying with regulations	x	-	x
Chaal et al. (2020b)	A framework for autonomous ships using current knowledge of the operating system for autonomous vessels with expert and experienced seafarers to create a hierarchical control structure of an autonomous ship that combines technology with all functions of the STCW	x	x	x
Lloyd's Register (2017)	Design code for unmanned marine system found technology related to the autonomous ship. It explained the area of the structure, electrical system, navigation and collision avoidance systems, propulsion, fire, and auxiliary systems	x	x	x
Jo et al. (2020)	For seafarers to continue to be competitive locally and internationally, maritime-related institutions must take proactive measures in adapting their curricula to changing requirements. For example, future seafarers may find high-tech employment in remote-control operation, cargo security equipment, automatic handling of transshipment between ships, and maintenance and repair in unmanned environments	x	x	x

Continued.

Table 1. *Continued.*

		Dimensions of STCW Related to IT Competency		
References	Information Technology for autonomous ship mentioned in articles	Navigation	Cargo	COP[a]
Saha (2021)	The RO plays a crucial role in the safe and efficient operation of the vessel. The RO will need comprehensive navigation competence based on the system's technology, dependability and redundancy, and must adapt as technologies change	x	x	x
DNV (2021)	The RO can use the systems and modes that apply to autonomous, remotely operated and remotely supported vessels, and their operation. A holistic view of ship management systems and a deep understanding of RCC systems are provided. The standard contains five competency dimensions: general competence requirements, navigation, engine and machinery, communication, cargo, and ballast.	x	x	x

[a]COP: Controlling the operation of the ship and care for persons onboard.

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Table 2. *Information technology competency from literature review.*

Information Technology competencies	References: de Klerk et al.(2021)	Lahtinen et al. (2020)	Ghaderi (2019)	Størkersen (2021)	Bhardwaj et al. (2019)	Deling et al. (2020)	Oksavik et al. (2020)	Ahvenjärvi (2016)	Chaal et al. (2020b)	Li and Fung (2019)	Chang et al. (2021)	MacKinnon et al. (2015)	Cicek et al. (2019)	Kongsvik et al. (2020)	Jo and D'agostini (2020)	Jo et al. (2020)	Yoshida et al. (2020)	Li et al.(2019)	Saha (2021)	DNV (2021)	ABS (2021)	Lloyd's Register (2017)	ClassNK . (2021).	Man et al. (2015)	Porathe et al. (2014)
IT1.Computing, Information and Data Processing.	*		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
IT2.Data communication between RCC and vessel.	*	*	*	*	*		*	*	*	*	*	*	*		*	*	*	*	*	*	*	*	*	*	*
IT3.Autonomous Navigation	*		*	*	*	*	*	*	*	*	*	*			*	*		*	*		*	*	*	*	*
IT4.Artificial intelligence	*			*		*	*	*	*	*	*	*			*	*		*	*				*		
IT5.Fault diagnosis	*			*		*		*	*		*			*			*		*	*	*	*	*		
IT6.Remote control	*	*	*	*	*	*	*	*	*	*	*	*			*	*	*	*	*	*	*	*	*	*	*
IT7.Environmental information perception	*	*	*	*		*	*	*	*	*	*		*	*	*		*	*	*	*	*	*	*	*	*
IT8. Internet of Things, big data				*	*	*	*			*	*				*	*	*	*		*	*	*	*		*
IT9. Integrated bridge system and shore control centres				*		*	*	*	*	*		*					*	*		*		*	*	*	*

Continued.

Table 2. *Continued.*

Information Technology competencies	de Klerk et al.(2021)	Lahtinen et al. (2020)	Ghaderi (2019)	Størkersen (2021)	Bhardwaj et al. (2019)	Deling et al. (2020)	Oksavik et al. (2020)	Ahvenjärvi (2016)	Chaal et al. (2020b)	Li and Fung (2019)	Chang et al. (2021)	MacKinnon et al. (2015)	Cicek et al. (2019)	Kongsvik et al. (2020)	Jo and D'agostini (2020)	Jo et al. (2020)	Yoshida et al. (2020)	Li et al.(2019)	Saha (2021)	DNV (2021)	ABS (2021)	Lloyd's Register (2017)	ClassNK . (2021).	Man et al. (2015)	Porathe et al. (2014)
IT10. Safety of autonomous ship.		*	*	*			*		*		*						*	*	*	*	*	*	*	*	*
IT11. Environmental protection of the autonomous ship.				*		*	*											*		*	*	*	*		
IT12. IT security and Safety (Technological awareness)	*		*	*		*	*	*	*	*	*	*	*		*	*	*	*		*	*	*	*		*
IT13. Dynamic Positioning (DP) system				*		*	*	*	*		*	*		*						*			*		
IT14. Respond to an emergency of the autonomous ship.		*	*	*			*	*	*		*					*	*	*	*	*	*	*		*	*

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Table 2. *Continued.*

Information Technology competencies	References																								
	de Klerk et al.(2021)	Lahtinen et al. (2020)	Ghaderi (2019)	Størkersen (2021)	Bhardwaj et al. (2019)	Deling et al. (2020)	Oksavik et al. (2020)	Ahvenjärvi (2016)	Chaal et al. (2020b)	Li and Fung (2019)	Chang et al. (2021)	MacKinnon et al. (2015)	Cicek et al. (2019)	Kongsvik et al. (2020)	Jo and D'agostini (2020)	Jo et al. (2020)	Yoshida et al. (2020)	Li et al.(2019)	Saha (2021)	DNV (2021)	ABS (2021)	Lloyd's Register (2017)	ClassNK . (2021).	Man et al. (2015)	Porathe et al. (2014)
IT15. Start up and monitors autonomous ship systems.			*	*	*		*	*	*	*	*	*							*	*	*	*			*
IT16. Autonomous mooring and anchoring operation systems.			*						*					*					*	*	*	*	*		
IT17. Overall supervision of machinery system.				*	*		*		*		*	*		*		*	*		*	*	*	*	*	*	*
IT18. Energy systems management.				*					*	*										*	*	*			
IT19. Maintenance and repairs of the autonomous ship.			*	*			*				*	*	*	*		*	*	*		*	*	*	*		
IT20. Cargo planning and monitoring of the autonomous ship.			*	*	*	*	*		*			*				*		*	*	*	*	*	*	*	*
IT21. Trim, stability, and stress of autonomous ship.				*					*			*							*	*	*	*	*	*	*

Continued.

Table 2. *Continued.*

	References																								
Information Technology competencies	de Klerk et al.(2021)	Lahtinen et al. (2020)	Ghaderi (2019)	Størkersen (2021)	Bhardwaj et al. (2019)	Deling et al. (2020)	Oksavik et al. (2020)	Ahvenjärvi (2016)	Chaal et al. (2020b)	Li and Fung (2019)	Chang et al. (2021)	MacKinnon et al. (2015)	Cicek et al. (2019)	Kongsvik et al. (2020)	Jo and D'agostini (2020)	Jo et al. (2020)	Yoshida et al. (2020)	Li et al.(2019)	Saha (2021)	DNV (2021)	ABS (2021)	Lloyd's Register (2017)	ClassNK . (2021).	Man et al. (2015)	Porathe et al. (2014)
IT22. Ballasting / De-ballasting systems of the autonomous ship.				*					*										*	*	*	*			*
IT23. Plan and conduct a passage of the autonomous ship.	*	*		*	*	*	*		*	*	*	*					*	*	*	*	*	*	*		*
IT24. Maintain a safe navigational watch for autonomous ship	*	*		*	*	*	*	*	*	*	*	*					*	*	*	*	*	*	*	*	*
IT25. Ship handling of autonomous ship		*		*		*	*		*	*	*	*					*		*	*	*	*	*	*	*
IT26. Remote Control Centre Operational and management in SCC			*	*		*	*	*	*	*		*			*		*	*	*	*	*		*	*	*

Table 3. RO's competencies and competency descriptions.

Dimension	RO's competencies	Competency description
Navigation	NAV 01 Plan and conduct a passage and determine the position NAV02 Maintain a safe navigational watch NAV03 Use of radar and ARPA to maintain the safety of navigation NAV04 Use of ECDIS to maintain the safety of navigation NAV05 Respond to emergencies NAV06 Respond to a distress signal at sea NAV07 Use the IMO Standard Marine Communication Phrases and use English in written and oral forms NAV08 Transmit and receive information by visual signalling NAV09 Manoeuvre the ship	– Knowledgeable, skilled and able to work effectively in the navigation dimension by STCW requirements
Cargo handling and stowage	CGO01 Monitor the loading, stowage, securing and care during the voyage, and the unloading of cargo CGO02 Inspect and report defects and damage to cargo spaces, hatch covers and ballast tanks	– Knowledgeable, skilled, and able to work effectively in cargo handling and stowage following STCW requirements
Controlling the operation of the ship and caring for persons onboard	COP01 Ensure compliance with pollution prevention requirements COP02 Maintain the seaworthiness of the ship COP03 Prevent, control and fight the fire onboard COP04 Operate life-saving appliances COP05 Apply medical first-aid onboard the ship COP06 Monitor compliance with a legislative requirement COP07 Application of leadership and teamwork skill COP08 Contribute to the safety of personnel and the ship	– Knowledgeable, skilled, and able to work effectively in controlling the ship's operation and care for persons onboard following STCW requirements

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Table 3. *Continued.*

Dimension	RO's competencies	Competency description
Information Technology	IT1. Familiar with computing, information and data processing	– Higher knowledge and skill in computers and knowledge of control centre systems support for navigation, communication and cargo handling
	IT2. Familiar with data communication between the SCC and vessel	– Communicate the technical state of the SCC and the autonomous ships
	IT3. Familiar with autonomous navigation	– Basic knowledge about autonomous navigation for all the systems onboard and the SCC – Explain control systems and how they can react to alarms
	IT4. Familiar with artificial intelligence	– Knowledge of artificial intelligence fundamentals for all onboard systems and the SCC – Understanding systems are not functioning correctly, it is necessary to comprehend control systems, respond to alarms and handle an emergency
	IT5. Familiar with remote-control systems	– Basic knowledge of remote-control systems for all onboard systems and the SCC – Understanding systems are not functioning correctly, it is necessary to comprehend control systems, respond to alarms and handle an emergency.
	IT6. Familiar with fault diagnosis	– Understand fault diagnosis based on analytical modelling – Fault diagnosis based on signal processing – Ability to reduce the consequences of internal faults
	IT7. Familiar with environmental information perception (situation awareness)	– Understand the ship's condition and environmental conditions in real-time from the sensor, camera or other equipment – Able to act, make decisions and pass information to relevant parties appropriately

Continued.

Table 3. Continued.

Dimension	RO's competencies	Competency description
	IT8. Familiar with the internet of things and big data	– To understand the basics of the Internet of Things and big data for navigation, the application of GPS, ARPA Radar, AIS, ECDIS, video surveillance and other technical means
	IT9. Familiar with Integrated bridge systems and shore control centres	– Understand and use functions such as perfect, information centralised display, alarm monitoring, navigation and control automation displayed to the SCC
	IT10. Familiar with the safety of the autonomous ship	– Know and understand regulations related to safety, especially ISM and familiarity with the SMS – Interpret and be able to use safety data, including video streams, to monitor the safety of ship operations
	IT11. Familiar with the environmental protection of the autonomous ship	– Know the risks and steps to prevent potential pollution and describe the SCC procedures for reporting damage in the event of environmental pollution
	IT12. Familiar with IT security and safety (technological awareness)	– Describe ISPS and other applicable regulations – Describe the potential cyber threats to the RCC that can use devices and methods to prevent and correct them to achieve cybersecurity
	IT13. Familiar with dynamic positioning (DP) systems	– Describe the DP system and ability to keep the correct ship position from using the engine and steering system even in all sea conditions
	IT14. Familiar with how to respond to emergencies of the autonomous ship	– Demonstrate risks, inspect, take corrective action and assess the damage properly in case of emergency
	IT15. Familiar with how to start up and monitor autonomous ship systems	– Describe the ship's and RCC's systems for controlling. Understand how to start the system, including checking the status of the autonomous ship systems – Describe alerts and can identify system failures that may affect settings and remote control

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Table 3. *Continued.*

Dimension	RO's competencies	Competency description
	IT16. Familiar with autonomous mooring and anchoring operation systems	– Demonstrate functions of anchoring and mooring operated by the SCC
	IT17. Familiar with overall supervision of machinery systems	– Describe systems for monitoring and controlling machinery systems – Describe the efficiency and limits of the ship's machinery
	IT18. Familiar with energy systems management	– Be able to explain, operate and inspect related to battery charge management before, during and after charging, and can take care of security checks
	IT19. Familiar with how to maintain and repair the autonomous ship	– Describe system inspection. Maintenance planning, maintenance control, post-maintenance inspection and emergency repairs onboard remotely according to SCC procedures
	IT20. Cargo planning and monitoring of the autonomous ship	– Understand the principles of planning procedure for cargo operations, all systems related to the shipment, specific temperatures, humidity, vibration, etc., through sensors, and can solve problems appropriately
	IT21. Familiar with trim, stability and stress of autonomous ship	– Analyse and verify the accuracy of information obtained from the system and ship sensors that show stability, trim, stress and bending moments, and can correct the problem of ship stability
	IT22. Familiar with ballasting / de-ballasting systems of the autonomous ship	– Ability to plan ballasting/de-ballasting properly. Know the procedures and methods of ballast management, control and operate ballast for autonomous ships according to the plan – Understand the display of the bilge sensor and be able to interpret it for action
	IT23. Familiar with how to plan and conduct a passage of an autonomous ship	– Describe and be able to use the various systems available at the SCC to plan a safe voyage

Continued.

Table 3. *Continued.*

Dimension	RO's competencies	Competency description
	IT24. Familiar with how to maintain a safe navigational watch for an autonomous ship	– Familiar with using navigational equipment and navigational aids specific to the ship that the RO will have to control. The RO must have a good background in navigation knowledge, skills and operating under the guidance of the SCC
	IT25. Familiar with how to handle an autonomous ship	– Monitor and intervene when necessary to avoid collisions – Demonstrate how to control the speed and manoeuvring systems of the autonomous ship by remote control, ability to control vessel speed to be appropriate for the situation, understand and explain the ship motion of the controlled autonomous ships
	IT26. Familiar with management and operations in the SCC	– Describe the roles and responsibilities of the RO operating vessels from the SCC – Familiar with remote ship control through the remote-control systems between the SCC and the autonomous ships – Use the techniques and procedures required, recommendations for safe remote control of ships from the SCC

Source: This table is created from the literature (IMO, 2011, 2014; Rolls Royce, 2017; Wärtsilä, 2017; DNV, 2021; Kongsberg Maritime, 2021). Information Technology competencies in this article are defined by the leading explanation from Class DNV (DNV, 2021).

4.2. Conceptual model of remote operators' competency

Table 3 presents the research findings on competency dimensions, competencies within each dimension and their descriptions. Subsequently, a conceptual model was developed to illustrate the relationships between competency dimensions and RO's competencies. The conceptual model provides a significant component that represents an overview of the competencies required for the RO, making it easy to understand and applicable in practice. This conceptual framework highlights the primary dimensions and relationships among RO competencies, as presented in Figure 3, developed based on the research findings. It was found that RO competencies consist of a total of four dimensions, including standard competencies encompassing three dimensions: NAV, CGO and COP, and an additional IT competency dimension.

First, the navigation dimension in the model focuses on the competencies necessary for ROs to navigate a ship. This includes ship route planning, handling, finding and fixing the ship's position, communication, maintaining a safe navigational watch, and using navigation equipment such as ECDIS and radar. These competencies enable us to safely control the navigation of the ship and effectively respond to emergencies in general ship operations. Second, the CGO dimension is a competency that ROs must possess. ROs have the responsibility to monitor the loading, discharging and stowing of cargo to prevent any damage, and to ensure the safety of the ship, crew and the environment throughout the voyage. Third, the COP dimension is crucial. Its primary focus is to ensure the safety of the vessel and the ship's crew, as ROs in MASS degree 2 are required to work collaboratively with the ship's crew.

Additionally, it prioritises environmental protection, and aims to prevent potential hazards and emergencies during operations. Finally, the information technology dimension is of utmost importance due to the increasing automation in ship technology. Modern ships are equipped with advanced technology for navigation and equipment, making fundamental technological skills crucial for remote ships at the SCC. In addition to highlighting the importance of each dimension, the model also aids organisations and shipping companies, and educational institutions can use this model to set up their training programs for ROs. They can easily refer to the code presented in the model and further study the competency descriptions provided in Table 3, which contains comprehensive information.

The study findings have successfully achieved the research objectives, which were to define the competencies of an RO, as presented in Table 3, and develop a conceptual model of an RO, as depicted in Figure 3. The results revealed align with the findings of Saha (2021), who found the standard competency consisting of three dimensions, including NAV, CGO and COP, is necessary for an RO to work on ships as required by the STCW regulations (IMO, 2011, 2014) and align with the industrial aspect result. The additional competency is information technology, which is also essential for an RO to have to perform efficiently to remotely control a ship at the SCC, according to the studies conducted by Sharma et al. (2019), Kipper et al. (2021) and Størkersen (2021). The findings from the first objective led to the achievement of the second research objective, which was to develop a conceptual model of remote operators' competencies. This conceptual model enhances the understanding of an RO's competencies, as depicted in Figure 3.

5. Conclusion

Remote-control sailing can be regarded as the advancement of marine transportation into a new era, facilitated by the use of advanced intelligent technologies, such as remote-control systems, which align with the evolving landscape of maritime transport (Chaal et al., 2020b; Utne et al., 2020; de Vos et al., 2021). As marine navigation shifts towards remote control, the search for competencies of remote ship operators becomes increasingly crucial. This research helps to clarify that ROs are required to have three essential competencies, which are NAV, CGO and COP. Additionally, there is an additional competency that can be specified, which is IT.

This research is a study that collected data from academic articles and industrial aspects of the maritime industry. The collected data were analysed using content analysis methods. As a result, four

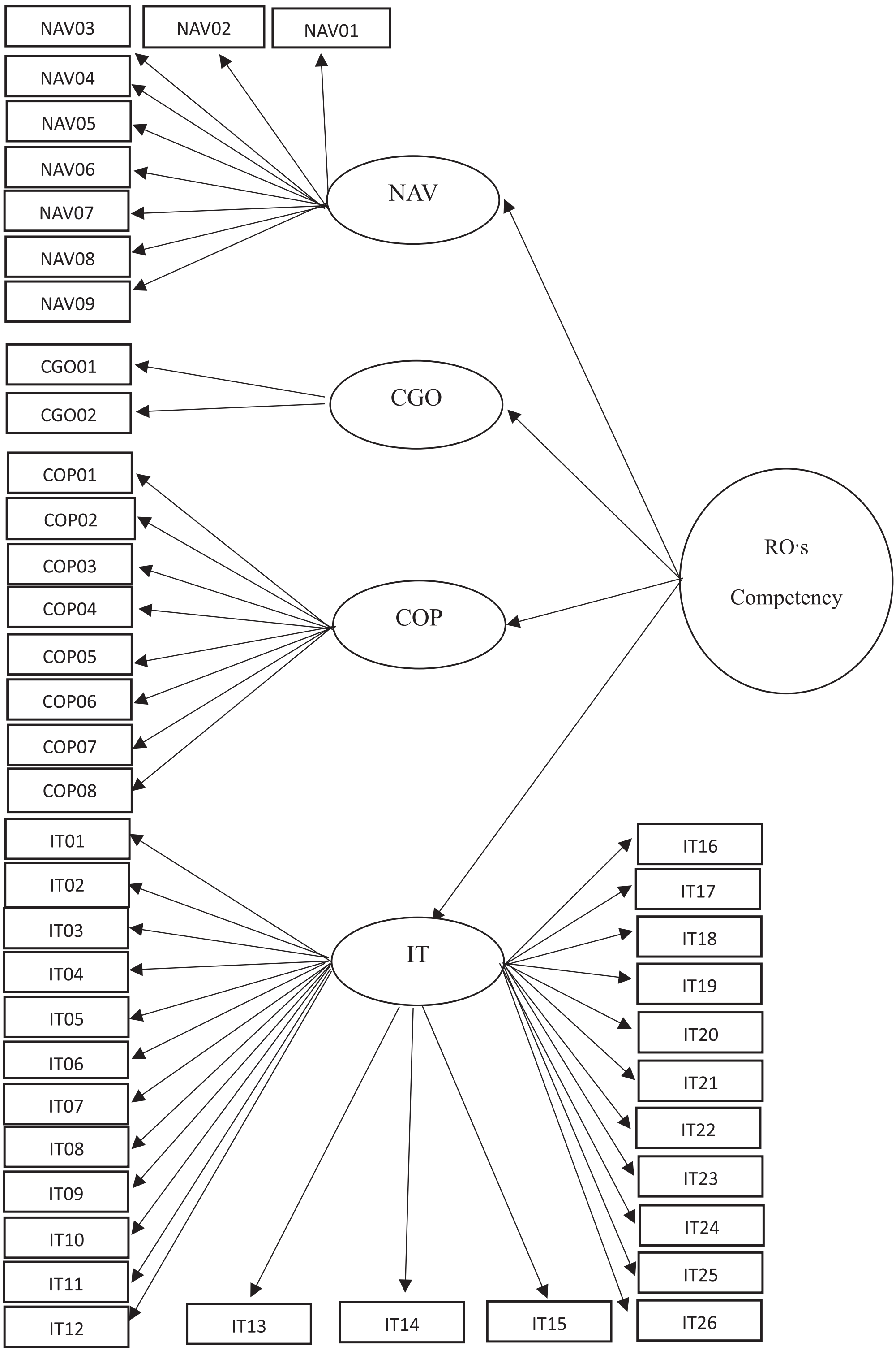

Figure 3. *Conceptual model of remote operators' competency.*

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dimensions and 45 competencies can guide determination of the competencies required for remote operators. This research aligns with the study conducted by Kennard et al. (2022), which highlighted that seafarers can transition into roles as remote operators. An RO requires relevant experience, situational awareness, safety awareness and the ability to work with advanced technologies (Chaal et al., 2020b; Jo et al., 2020; Oksavik et al., 2020; Kennard et al., 2022). However, Bachari-Lafteh and Harati-Mokhtari (2021) propose that remote operators should possess non-technical competencies. However, since an RO is a relatively new profession, the researchers focus on identifying technical skills as they can be developed quickly, and are competencies that can be demonstrated and measured.

The findings of this study lead to the presentation of a conceptual model delineating the competencies necessary for remote operators to control autonomous ships from the SCC. These abilities go towards developing the competency for seafarers to work as remote operators and can also be used to create the required courses in the future. Future research can reexamine these remote operators' competency by using confirmatory factor analysis and distributing the questionnaire to respondents across the maritime nations.

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