Legal Challenges Within the Framework of International Maritime Conventions Pertaining to Autonomous Ships

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المُستخلص:
يقدم البحث تحليلًا مفصلًا لمفهوم السفينة المُسيرة ذاتياً (MASS) ويقيّم التحديات المتعلقة بإطار الاتفاقيات البحرية الدولية. يتناول الإجراءات التشغيلية الأساسية التي تحكم تشغيل هذه السفن، مع استعراض أهم اللوائح الحالية، مما يساهم في توفير فهم واضح للإطار التنظيمي الراهن.
تم استخدام منهج بحث وصفي تحليلي لتحليل وتفسير النصوص القانونية. شملت الدراسة مراجعة دقيقة للإجراءات التشغيلية الرئيسية واللوائح الحالية، حيث تم دمج البيانات التي تم جمعها وتحليلها للإشارة إلى عدد من الحلول والنهج المحتملة للتغلب على التحديات ضمن إطار الاتفاقيات البحرية الدولية.
أبرز البحث مجموعة من الحلول المبتكرة والاستراتيجيات التي يمكن تبنيها لمواجهة التحديات المحددة. كما شدد على أهمية تطوير نهج متعدد الأبعاد يدمج بين الجوانب التقنية والقانونية والتنظيمية لضمان سلامة وكفاءة تشغيل السفن المُسيرة ذاتياً.

الكلمات الافتتاحية: مَفهوم السفينة، السُفن السطحية المُسَيرة ذاتياً MASS، الصكوك القانونية، الإتفاقيات البحرية الدولية.

ABSTRACT
A comprehensive analysis of the Maritime Autonomous Surface Ships (MASS) concept is presented, along with a detailed evaluation of the challenges related to the framework of international maritime conventions. The essential operational procedures that govern the functioning of these ships are thoroughly examined, and a review of the most significant current regulations is conducted, thereby contributing to a clearer understanding of the existing regulatory framework.
A descriptive and analytical research methodology has been employed to analyze and interpret legal texts. Following a thorough review of the primary operational procedures and current regulations, the collected data were analyzed and synthesized, identifying several potential solutions and approaches to overcome the challenges within the framework of international maritime conventions.
Through this review, various innovative solutions and strategies that can be adopted to address the identified challenges are highlighted. The importance of developing a multidimensional approach

that integrates technical, legal, and regulatory aspects to ensure the safety and efficiency of these ships is emphasized.

Keywords: MASS, Autonomous Ships, Legal Frameworks, International Maritime Conventions.

1. Introduction

Autonomous vehicles, such as drones, self-driving cars, and now autonomous ships, have become essential to everyday existence. This technological progress poses fresh challenges and creates prospects for developing international maritime law to align with these transformations. The lack of a dedicated legal framework for autonomous ships results from existing maritime laws formulated using principles derived from international conventions and treaties established more than two centuries ago. Field trials on large autonomous vessels designed for long voyages underscore the necessity to develop and amend regulatory legal frameworks to accommodate these new technological innovations (Pundars, 2020).

The primary obstacle in determining whether autonomous ships are subject to existing international maritime law lies in addressing the diverse range of capabilities that autonomy encompasses. Unmanned or autonomous ships should not be considered a uniform group but a category encompassing various types. Given the swift progress in artificial intelligence and automated control, it is crucial to reevaluate and implement current maritime laws and regulatory frameworks. These laws are derived from the fundamental premise that a captain and crew are present on the ship. Hence, there is a necessity to redefine the conventional responsibilities of the crew and the involvement of artificial intelligence and remote control crews in autonomous maritime transportation (Issa et al., 2022). In 2017, the International Maritime Organisation (IMO) took a significant step by initiating the scoping of relevant legislation, which was crucial for progress in this area. This procedure necessitated an examination of legal documents to guarantee the secure planning, building, and functioning of self-governing vessels and verify that the legal structure offers operational safeguards on par with those accessible for traditional ships (IMO, 2018)

In 2021, the Maritime Safety Committee (MSC) continued the process of regulatory scoping. The objective was to evaluate how IMO instruments could be applied to ships with different levels of automation. The committee agreed on a framework for the regulatory scoping process concerning utilizing MASS. The following degrees of automation for this process were defined in Figure (1) (Mohamed & Elnoury, 2023):

- **Degree One**: Vessels equipped with automated processes and decision support systems, with seafarers on board to manage and oversee shipboard systems and functions. Certain operations can be automated and sometimes unsupervised; seafarers are prepared to assume command while on board.

- **Degree Two**: Ships operated by remote control but still have seafarers on board. The vessel is remotely operated and controlled from a separate location, while seafarers are present on board to oversee and manage the ship's systems and operations.
- **Degree Three**: Unmanned ships controlled from a distance, with no crew members on board. The vessel is remotely operated and controlled.
- **Degree Four**: Fully autonomous ships equipped with an operating system capable of independently making decisions and executing actions.

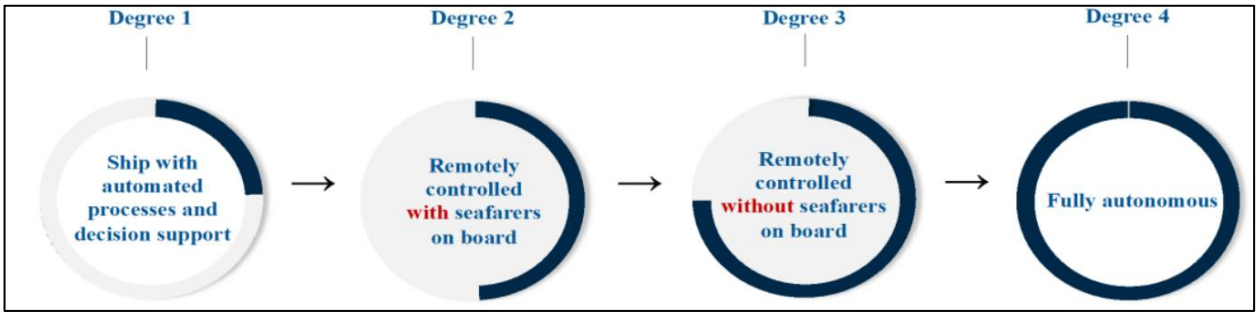

Figure 1. Degrees of autonomy as defined by IMO (2018)

The methodology for this regulatory scoping process consists of two steps. First, for each safety and security-related instrument and each degree of automation, provisions are identified that apply to different scenarios: provisions applicable to MASS and prohibiting its operation; those relevant to MASS without preventing its operation but requiring no measures; provisions applicable to MASS but possibly needing amendments or clarifications and having gaps; or those not relevant to MASS operations (IMO, 2018). Second, the most appropriate approach to address MASS operations is analyzed, considering human elements, technology, and operations factors. The analysis will determine whether it is necessary to provide equivalents as per the instruments, prepare interpretations, amend existing instruments, develop new instruments, or decide that none of these actions are required based on the research results.

This research paper aims to identify and examine the legal challenges within the framework of international maritime conventions related to MASS. A descriptive and analytical research methodology is employed to analyze and interpret legal texts. After reviewing the main operational procedures and current regulations, the collected and analyzed data were synthesized to propose several potential solutions and approaches to overcome the challenges identified within the international maritime conventions included in this process. As in Figure (2), These conventions are as follows:

Figure 2. Identification of international maritime conventions

- The International Regulations for Preventing Collisions at Sea (**COLREG**), 1972.
- The International Convention for the Safety of Life at Sea (**SOLAS**), 1974, as amended.
- International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (**STCW**), 1978, as amended.
- The International Convention for Preventing Pollution from Ships (**MARPOL**), 1973.

2- The relationship between MASS and SSCC

The given Figure (3) depicts the complex correlation between MASS and the Ship-Shore Control Centre (SSCC), highlighting their interdependent functions in autonomous maritime operations. The MASS is equipped with an advanced decision-making system that incorporates a range of sensors, including RADAR, AIS, LIDAR, cameras, and sonar. These sensors collect extensive data about the ship's surroundings. In addition, the ship utilizes automated reporting mechanisms and sophisticated navigation systems such as GNSS and INS to guarantee precise position, course-plotting and instantaneous data transmission to the SSCC. The ship's onboard operating system improves situational awareness and self-diagnosis capabilities, allowing it to independently manage machinery and equipment using intelligent control systems, which include robotic maintenance and repair. Energy optimization and monitoring systems are incorporated to ensure optimal energy utilization.

Additionally, the SSCC is crucial in ensuring the safety and efficiency of MASS. The SSCC's safety system includes smart alarms and controls to prevent accidents like collisions and groundings. It provides safety support and maintains continuous awareness of the ship's operations. The remote control system allows the SSCC to monitor and manage the ship's navigation, sensors, machinery, and equipment, ensuring real-time supervision and intervention when necessary. The constant data exchange between the MASS and the SSCC ensures that the autonomous vessel operates safely and efficiently. This highlights the essential collaboration required for successful autonomous maritime operations (Mallam et al., 2020).

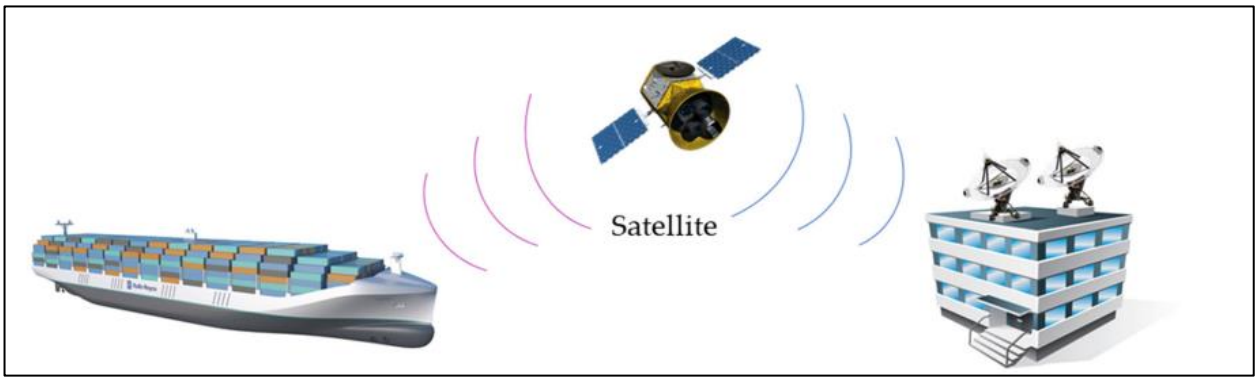

Figure 3. The relationship between MASS and the ship-shore-control-center (SSCC)

3. Ship's definition within the Framework of IMO Conventions

Firstly, it is important to acknowledge that the idea of a ship is essential to numerous international conventions. Nevertheless, no globally accepted international definition of "ship" exists. Typically,

international agreements establish the meaning of the term "ship" in particular articles to specify the extent to which they apply. The definitions may differ depending on the characteristics of the convention, whether it relates to general or specific maritime law. The extent of these definitions is contingent upon the specific objective of the international convention. As a result, the range of situations where the convention can be applied will vary depending on the specific convention (Komianos, 2018).

The importance of defining the term "ship" and whether "autonomous or self-driving ships" qualify as ships in the conventional sense lies in the fact that traditional ships enjoy many rights and freedoms stipulated in international conventions, such as the right of innocent passage at sea (Lim, 2018).

It is noteworthy that no definition of the term "ship" is found in the United Nations Convention on the Law of the Sea (UNCLOS) of 1982, despite it being the most significant maritime convention concerning the term "vessel or ship." Although there are numerous references throughout its articles, the text of UNCLOS uses both terms interchangeably, with no distinction in English. The term "ship" is used exclusively in the official Arabic convention translation. The absence of a definition in the convention is crucial because the topics it governs—such as the nationality of the ship, its legal status, or the flag it flies—are primarily based on the provisions of UNCLOS. The lack of a definition in the convention implies that its provisions will apply to both traditional ships and MASS. Thus, autonomous ships (MASS) will benefit from the rights outlined in this convention, such as freedom of navigation on the high seas and innocent passage rights in territorial waters (IMO, 2019).

The same applies to many international maritime conventions concerning specific maritime laws that focus on ships, as they do not provide any definition of a ship. Examples include the 1910 Brussels Convention for the Unification of Certain Rules of Law concerning Collisions between Vessels, the 1976 Convention on Limitation of Liability for Maritime Claims, and the 1926/1993 International Conventions on Maritime Liens and Mortgages. It is worth mentioning that the lack of definitions does not affect or change the current status of existing maritime conventions or treaties when using autonomous ships, provided these ships meet the technical requirements specified for definitional purposes (Lützhöft et al., 2019).

4. Method

The research provides a comprehensive description of MASS, as illustrated in Figure (4). The researcher adopted a descriptive and analytical research methodology to identify and examine the legal challenges related to the development and deployment of such ships. This involved a thorough review of existing operational procedures and an in-depth interpretation of legal texts within the frameworks of international maritime conventions. The collected data was then integrated and analyzed to highlight key challenges and gaps in current maritime regulations.

Based on this analysis, various innovative solutions and strategic approaches were developed to address the identified challenges. These solutions consider the technical, legal, and regulatory aspects necessary to ensure the safety and efficiency of autonomous maritime operations. The research aims to provide actionable insights that will improve maritime safety, security, operational use, and productivity, thereby facilitating the future deployment of MASS.

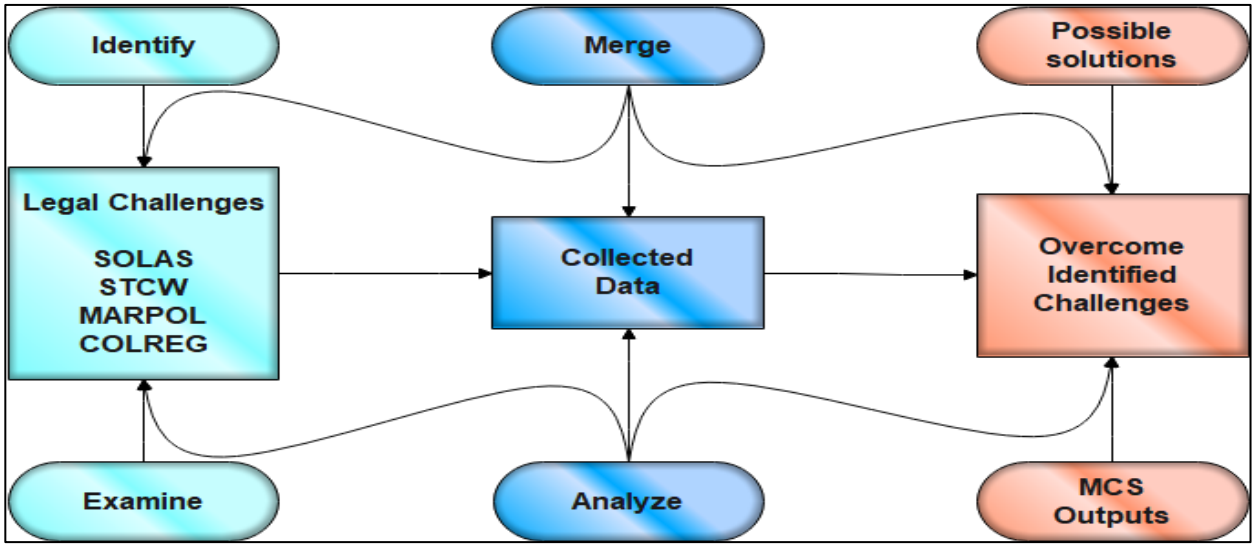

Figure 4. Framework for analyzing and overcoming legal challenges in MASS

5- Issues and Challenges Facing the Regulatory Process

A reassessment of the technical and legal regulations of maritime safety, environmental preservation, and training and monitoring standards is necessary in light of the assumption that humans would carry out specific tasks in the context of MASS. A few examples are enough to demonstrate the deficiencies of the current regulatory framework when applied to the operations of MASS without any changes (Zhang et al., 2022).

5-1 COLREG, 1972

The International Regulations for Preventing Collisions at Sea, 1972 (COLREG), is an international treaty established to prevent ship collisions at sea. Adopted by the International Maritime Organization (IMO) in 1972 and effective from 1977, it includes rules for ship behavior, maneuvering, lights, and sound signals under various conditions. These regulations are binding on all ships in international waters and those flying the flag of a state party to the convention. COLREG is integral to national maritime legislation and fundamental to marine training and certification for seafarers (IMO, 1972).

Under the first degree of autonomy, as defined by MASS, where seafarers are onboard the ship to operate and manage the ship's systems and functions, some operations may be automated and occasionally unsupervised, but seafarers are ready to take control. This situation conflicts with the requirements for navigation as stipulated in SOLAS V/14 and STCW Chapter VIII, Part 4.1, which state that "at times the ship may be unsupervised." This statement regarding watchkeeping in the

bridge highlights a significant difference between current conventional ships, where automated systems on board may primarily be responsible for navigation for specific periods in the bridge, and whether a degree of MASS can comply with COLREG as it currently stands (IMO, 2018).

Rule 5, for instance, states that "every vessel shall at all times maintain a proper lookout by sight and hearing." The question arises whether automated systems can be considered a proper lookout. This is not explicitly mentioned in COLREG, which likely did not anticipate this circumstance when it was drafted, and human-centric principles are at the core of this convention (Hannaford et al., 2022; Chircop, 2019).

Within the framework of the second level of autonomy, which involves the remote control and operation of a ship from a different location, the primary point of contention lies in the varying interpretations of the role of seafarers on board a Maritime Autonomous Surface Ship (MASS) when it is being controlled and operated from a remote site. There are concerns about how seafarers can assume control and manage the ship's systems and functions and how this process will be regulated. Another concern is the challenges of interpreting and responding to signals transmitted through remote control and operation, particularly when analyzing and transmitting sound signals. At the same time, seafarers are always present on the ship but not on the bridge (IMO, 2019). Therefore, information transmitted to the remote-control center must adhere to COLREG regulations. An observed potential solution involves utilizing the Automatic Identification System (AIS) as a substitute for the obligatory sound signals.

In the third and fourth degrees of autonomy, where the ship is controlled and operated from another location with no seafarers on board, this represents a significant change for the industry, and several potential issues requiring clarification have been noted. This includes the possibility that unmanned MASS could be constructed differently from traditional ships, requiring a separate section in the appendices similar to Annex I/13 for high-speed crafts (IMO, 2017). Annex IV also posed significant challenges regarding the ability of unmanned MASS to signal distress, requiring further clarification and discussion. Questions have arisen concerning whether a remote operator can assume the role of "master or crew" and whether the remote operator can meet the same standards required as a watchkeeper on board, especially under challenging weather and sea conditions, and their ability to detect smaller vessels that Radar and ARPA may struggle to identify. Another issue pertains to the need for continuous communication between the remote operator SCC and the ship itself, where disruptions or loss of communication could directly prevent the remote operator from maintaining a "proper lookout." This also applies to Rule 19, "Conduct of Vessels in Restricted Visibility," necessitating further clarification (Hirst, 2020).

Within the framework of the fourth degree of autonomy, as specified by the IMO, there is a need for further clarification regarding the requirement of an "electronic lookout" to effectively detect, interpret, and appropriately respond to relevant sound and light signals emitted by other vessels. The significance of this technology attaining, at the very least, the equivalent standards for

watchkeeping cannot be underestimated. This rule may prevent MASS operations unless it is determined that a fully autonomous ship can maintain a proper lookout using visual and auditory senses (Zhou et al., 2020).

However, it was found that the nature of Rule 6, "Safe Speed," and its requirements were not intended for application to fully autonomous ships, resulting in a gap. Rule 8, "Actions to Avoid Collision," also presented a similar issue regarding whether a fully autonomous ship could apply the principles of "good seamanship" when navigating, necessitating further research on what might require clarification or amendment (IMO, 2018). Rule 18, "Responsibilities between Vessels," by its nature, requires an understanding of the types of vessels involved, and questions have been raised about the ability of a fully autonomous ship to identify these different types of boats and act accordingly.

Rule 19, "Conduct of Vessels in Restricted Visibility," showed complexities for fully autonomous ships to understand, interpret, and adhere to the application of multiple rules requiring further discussion. Additional challenges were observed regarding terminology, lights, shapes, sound signals, compliance with maritime laws, and whether a sailboat could be considered a MASS and its interactions with other vessels and MASS.

5-2 SOLAS, 1974

The International Convention for the Safety of Life at Sea (SOLAS), 1974, commonly called SOLAS, is a global agreement establishing universal regulations for ensuring safety in maritime operations. IMO adopted this convention in 1974 and became effective in 1980. SOLAS encompasses various safety regulations about commercial ships' construction, equipment, and operation. Its primary objective is to guarantee the safety of individuals at sea. SOLAS is a vital international treaty in the field of maritime safety. It acts as a critical point of reference for regulating and improving ship and maritime crew safety on a global scale.

Chapter V, Regulation 24 of the SOLAS Convention requires manual steering control to be established during hazardous navigation. Consequently, an unmanned autonomous ship could not comply with this regulation. A general observation has been made those terms such as "master," "crew," "person in charge," and others should be clarified for the second, third, and fourth degrees of autonomy as defined by the IMO, considering the potential absence of seafarers on board. Researchers have noted that for the second, third, and fourth degrees of autonomy, definitions of "control stations" and "safety center" might need to be amended to include a remote-control center or a distant supervisory location. Additionally, the term "safety center on passenger ships" should be modified, as the safety center could be remote, and the provision of necessary safety systems functions should be available from the safety center to include automated or autonomous systems (IMO, 1974).

For the second, third, and fourth degrees of autonomy, definitions of areas where the crew is present might need to be adjusted. Since decision-making will occur remotely, either autonomously or automatically, there may be a need for additional functional requirements to demonstrate that the remote-control center or autonomous system can detect and control fires. For the third and fourth degrees of autonomy, several provisions have been identified that require manual operations and other procedures by individuals on board, such as firefighting, and some provisions related to accommodation, access, alarms, and safety centers (Pedersen et al., 2020). These apply to MASS without preventing their operation but may need amendments or contain gaps. A future issue includes evaluating risk reduction due to the absence of personnel on board (IMO, 2019).

It has been commented that unmanned shipping might not be practically applicable, as lifeboats would require a certified crew for lifeboats and personnel to assist in evacuation and possibly in firefighting. For this reason, researchers believe that operating MASS without seafarers should not be considered for passenger ships (Sharma, 2023).

Further challenges include that under the third and fourth degrees of autonomy, significant consequences could arise, particularly for cargo ships, in the event of a fire resulting in a loss of communication with the remote-control center and whether the remote location could be a continuously manned central control station. It has been investigated whether designated stations can be transferred between the remote location and the ship. Regulations may also need amendments, clarifications, or gaps concerning smoke generation and toxicity, fire detection and alarms, smoke spread control, fire containment, and notification to crew and passengers. Operational readiness and maintenance guidelines may also need to be reviewed. Existing instructions on onboard fire training and drills might prevent MASS operations. They may need complete rephrasing or amendments to identify responsible parties for fire drills other than seafarers when transporting passengers or other individuals. Other challenges relate to helicopter facilities that require firefighting personnel, potentially preventing MASS operations, and fire patrol requirements that necessitate a crew and the protection provided by portable fire extinguishers and manual firefighting equipment. There are also inconsistencies and gaps concerning post-incident safe return to port and safety areas, fire patrol requirements in passenger ships, and effective fire patrol systems for specific spaces (IMO, 2019).

The greatest challenge identified is when passengers are transported on a passenger ship or a cargo ship carrying more than 12 passengers, as the presence of seafarers on board is required to assist and evacuate these passengers in emergencies. Unless future means are developed to provide these functions autonomously, this will impede the operation of autonomous ships under the third and fourth degrees of autonomy, as the presence of certified personnel on board is essential to perform these functions.

Chapter V on Safety of Navigation considers the requirements to ensure that all ships are adequately and effectively manned from a safety perspective. There are no remote control requirements in the current regulations. Given the importance of remote control for operating autonomous ships in the second and third degrees of autonomy, new rules are necessary, particularly those related to function, design, visibility, employment, training, drills, and information transfer (IMO, 2018). Employment requirements, responsibilities, qualifications, and the necessity of having a shipmaster for autonomous ships should be revised or clarified for each degree of autonomy, especially for remotely controlled and fully autonomous ships. Current definitions in this chapter are applicable. However, gaps may exist for MASS operations, necessitating review and amendments, such as introducing a definition for MASS and other potential new definitions due to regulatory amendments in this chapter (Pundars, 2020).

5-3 STCW, 1978

The International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), established in 1978, is a global treaty establishing worldwide benchmarks for seafarers' education, certification, and supervision. The IMO adopted it in 1978, which came into effect in 1984. The STCW convention is crucial in establishing the training criteria, abilities, and proficiencies for seafarers on global merchant vessels. The convention aims to bolster maritime safety and safeguard the marine environment by guaranteeing seafarers the necessary training and qualifications to carry out their responsibilities (IMO, 1978).

The different levels of control employed in MASS impact their capacity to adhere to specific provisions of international maritime law intended for crewed vessels. According to the previously established definition, a MASS operating under the first degree of autonomy will have a crew on board. As a result, a vessel with a crew will be required to comply with the STCW Convention, which applies to "all individuals working on ships that operate at sea." Currently, the STCW Convention does not encompass fully autonomous ships of the fourth degree. Given that the STCW Convention does not encompass fully autonomous ships, it raises the question of who is responsible for training and certifying the individuals who develop the programs that guide the decision-making of these ships. This example illustrates the lack of uniformity in MASS capabilities and the potential dangers of integrating MASS into the existing framework of international maritime law, which was initially designed for manned ships (Parker, 2021).

A review of the STCW was submitted by the United States, supported by China, Cyprus, Japan, the Republic of Korea, the Russian Federation, and Spain (IMO, 2019). The STCW Convention and its associated Code were examined simultaneously since the convention outlines the requirements, and the Code provides the standards that parties must maintain to give complete and comprehensive effect to the convention's provisions. The term "seafarer" concerns degrees of autonomy, which refers to those trained and qualified to perform the ship's operational duties and responsibilities under the STCW Convention. The term "remote operator" is understood for the

regulatory exercise as the person not onboard the ship whose training and qualifications are not currently covered (IMO, 2019).

This distinction implies that amendments to the convention and the Code may be necessary to include requirements and standards for the training and qualification of remote operators, particularly in the context of MASS operating with varying degrees of autonomy. Such updates will be essential to ensure that operators controlling these ships remotely are adequately trained and qualified to perform their duties safely and effectively.

Assumptions for the third and fourth degrees of autonomy, as defined by the IMO, rely on duties and responsibilities derived from the requirements of other transport and operational agreements. For example, the STCW Convention would apply when seafarers, such as officers and engineers, on a third-degree autonomous ship conducting maintenance work. At the same time, security personnel may be on a fourth-degree autonomous ship. The regulatory application does not account for these options. The general assumption is that the "remote operator" operates and controls the ship's systems and functions. The initial review found that the convention and Code's requirements remain valid when seafarers are onboard the ship and do not apply when there are no seafarers onboard (Meštrović et al., 2023).

5-4 MARPOL, 1973

The International Convention for the Prevention of Pollution from Ships, also called MARPOL, is a worldwide agreement ratified by the International Maritime Organisation (IMO) in 1973 and subsequently amended in 1978. It was officially enforced in 1983. The maritime treaty is highly ratified and encompasses six annexes that specifically target different forms of marine pollution, such as oil, hazardous chemicals, sewage, garbage, and air pollution. MARPOL implements rigorous protocols to minimize the release of pollutants from ships, serving as a vital component in worldwide endeavors to safeguard the marine environment against the detrimental consequences of human actions (IMO, 1973).

The incorporation of MASS poses numerous significant obstacles to the MARPOL Convention. A paramount concern is the restricted scope of MARPOL, which is determined by the size of the ship. Convention solely pertains to tankers with a gross tonnage exceeding 150 and other vessels with a gross tonnage surpassing 400. current MASS are below these thresholds, indicating that although they meet the general criteria of being a "ship," according to MARPOL, the convention may not apply to them. This results in a regulatory gap where smaller autonomous vessels can operate without being required to comply with MARPOL's pollution control regulations (IMO, 2024).

As the capabilities of MASS improve and their dimensions grow, they may eventually become subject to the regulations outlined in MARPOL (International Convention for the Prevention of Pollution from Ships). Nevertheless, the current convention is insufficient to meet the particular requirements of pollution prevention and response for autonomous vessels. The Conventional

regulations of MARPOL do not consider the distinct operational attributes of MASS, such as their dependence on remote operators or autonomous systems. This deficiency underscores the need for customized regulations targeting the ecological consequences of autonomous maritime operations (MASS and SAR, 2023).

Another notable obstacle is the lack of clarity regarding the duties and obligations of MASS operators. MARPOL imposes specific obligations on a vessel's "captain" and "crew," positions that do not directly correspond to the remote operators or autonomous systems overseeing a MASS. The lack of clarity in this situation makes it more difficult to establish responsibility and blame in the case of a pollution incident involving a self-governing vessel. Precise guidelines are necessary to establish the specific duties and obligations of individuals who operate and supervise MASS to ensure accountability and efficient pollution management (UNCTAD, 2022).

To regulate the management of ship-generated waste under the International Convention for the Prevention of Pollution from Ships (MARPOL), it is imperative to implement targeted modifications. The proposed amendments should specifically focus on addressing concerns related to remote operations, autonomous navigation, pollution monitoring, and response to unmanned ships. The existing structure of MARPOL was not originally intended to accommodate autonomous ships, thus requiring a reassessment and adaptation of the convention to include measures that guarantee the environmental security of MASS (Parker, 2021).

Overall, the MARPOL Convention encounters considerable obstacles when overseeing pollution prevention and response for autonomous maritime vessels. These challenges arise from the convention's reliance on vessel size as a determining factor, the absence of provisions tailored explicitly to autonomous ships, and the underlying assumptions about conventional ship operations. To tackle these challenges, it is necessary to make extensive changes to the convention to align it with the technological advancements and operational realities of Autonomous Ships.

6- Results and Finding

6-1 Need for a Specialized Legal Framework

The research underscores the necessity for a specialized legal framework tailored to Maritime Autonomous Surface Ships (MASS). This framework can be achieved by amending existing international conventions, treaties, and maritime laws or establishing a new, comprehensive legal system. These autonomous ships introduce innovative technology with unique operational characteristics and risks that significantly differ from conventional ships. Therefore, specific legal provisions are crucial to regulate their operation and ensure their safety effectively. Modifying current international conventions and treaties appears to be the most practical solution, as it would provide uniformity in the legal regulations governing MASS at the international level, facilitating global compliance.

6-2 Training and Qualification Necessities

The study highlights the imperative to amend existing legislation or introduce new laws regarding the training and qualification of seafarers in remote control centers. This includes addressing the specific technology and communication systems operating autonomous ships. Figure (5), labeled "Seafarer 4.0," visually represents the essential skills and competencies required for modern seafarers operating within the context of MASS. These competencies include the digital operation of physical entities, proficiency in general digital skills, knowledge of maritime-specific computer science applications, and a solid foundation in classical maritime competencies. Additionally, skills in software engineering, coding/computer programming, and data fluency/data analytics are critical for troubleshooting, optimizing ship operations, and making informed decisions.

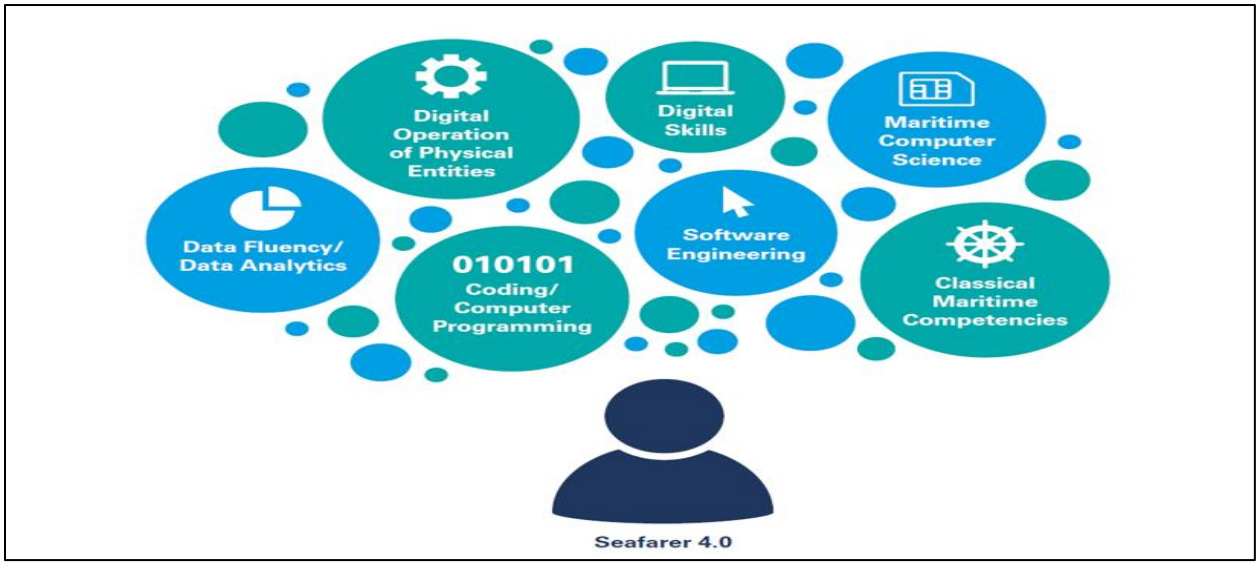

Figure 5. Essential competencies for Seafarer 4.0 in MASS

It is essential to designate a "human" master responsible for the autonomous surface ship, regardless of its operational method or level of autonomy. Depending on the technology, the Master might not need to be physically on board but must be able to intervene when necessary. A comprehensive list of the Master's roles and responsibilities, as outlined in IMO instruments and UNCLOS, should be compiled to identify which duties can be delegated to alternative parties. Integrating these advanced skills and competencies will ensure that the remote operation of MASS meets the required safety and efficiency standards. This shift in training paradigms addresses the unique challenges posed by the autonomy of these vessels, equipping seafarers with the necessary tools to manage and operate MASS effectively.

6-3 Applicability of Existing Conventions

The study meticulously considered the applicability of existing conventions, particularly the COLREG Convention. For instance, it was found that COLREG Rule 5, which pertains to "lookout" duties, explicitly refers to requirements to be performed by the "ship" rather than by a "person." This indicates that no human presence or intervention is required, and consequently,

there is no need to amend the COLREG Convention as it can fully apply to autonomous ships. Additionally, the STCW Convention's requirements remain applicable when seafarers are present on an autonomous ship. However, remote operators and the Master in the Remote Operation and Control Center (ROC) are not subject to STCW requirements, necessitating the MASS Code to encompass all necessary training, certification, and competency requirements per the STCW Convention.

6-4 Environmental Considerations under MARPOL

Challenges related to the MARPOL Convention were also highlighted. One significant issue is MARPOL's size-based applicability, which excludes many more minor MASS below the tonnage thresholds. As MASS capabilities and sizes evolve, they may eventually fall under MARPOL's scope. However, the current provisions of MARPOL are inadequate for addressing pollution prevention and response, specifically for autonomous ships. Thus, MARPOL's framework must be updated to include the environmental impacts of remote and autonomous operations and to clarify responsibility for pollution incidents.

6-5 Proposed amendments and regulatory updates

The research suggests specific amendments to address remote operations, autonomous navigation, and pollution monitoring and response for unmanned ships to regulate MASS effectively. The MARPOL framework, along with other conventions like SOLAS and STCW, needs reevaluation and modification to incorporate provisions that ensure MASS's environmental safety and operational integrity.

In conclusion, the findings highlight a pressing need for a dedicated legal framework for MASS. Addressing specific operational and safety concerns through amendments to existing laws or the creation of new regulations will standardize the legal landscape for autonomous ships, ensuring their safe and effective operation within the international maritime framework. These legal advancements will facilitate the successful integration of autonomous technology in the maritime industry, enhancing safety, security, and environmental protection.

7- Research Discussion

Before considering the role of the Master of an autonomous ship, it is crucial to discuss the roles and responsibilities assigned to the crew members of MASS. Understanding these roles will clarify how the responsibilities can be distributed and managed in autonomous operations.

The Remote Operation Center (ROC) and remote operator roles should be thoroughly investigated. This includes scenarios where the ROC is located outside the flag state. Such investigations will help address jurisdictional and operational challenges, ensuring smooth and practical remote control and management of MASS.

There is a need to integrate provisions requiring MASS to assist persons in distress at sea promptly. This includes receiving and relaying distress messages, monitoring GMDSS distress frequencies, and facilitating communications related to search and rescue operations. MASS should have the necessary means and tools to transfer rescued persons onboard. Additionally, the MASS operator (RO) should be enabled to coordinate search and rescue efforts efficiently.

To keep up with technological advancements and ensure widespread understanding, it is recommended that seminars be organized focused on the technological developments related to MASS. These seminars would provide valuable information and updates, fostering knowledge sharing and stakeholder collaboration.

8- Conclusion

The continuous advancement of MASS technology is pushing the maritime industry toward a future where fully autonomous cargo and passenger ships could become a reality. This evolution necessitates significant adjustments to existing international maritime laws to ensure autonomous ships' safe and efficient integration into global shipping operations.

This research highlights the substantial challenges that MASS operations pose to current maritime legal frameworks. While the fundamental principles of significant conventions like COLREG, SOLAS, STCW, and MARPOL do not inherently obstruct autonomous ships' operation, notable gaps and ambiguities need addressing. These include defining key terms, the applicability of regulations designed for manned ships, and the specific operational and safety requirements for unmanned and remotely operated vessels.

A specialized legal framework must be developed to facilitate MASS integration into the maritime sector. This could involve amending existing international conventions and treaties or creating a new comprehensive regulatory system. Key considerations should include the training and certification of remote operators, establishing clear roles and responsibilities for autonomous ship masters, and the development of technical standards for autonomous operations.

A proactive approach by the international maritime community is essential to adapt to these technological advancements. Creating a MASS Code, similar to existing codes within conventions like SOLAS, could provide the necessary clarity and regulatory structure to govern autonomous ships effectively. This would ensure that the legal framework evolves with technological innovations, maintaining the safety, security, and environmental protection standards central to international maritime law.

In conclusion, as the capabilities of MASS continue to expand, regulatory bodies, industry stakeholders, and international organizations must collaborate in developing and implementing a robust legal framework. This will support the safe and efficient operation of autonomous ships and reinforce the maritime industry's commitment to innovation and sustainability in an increasingly

automated world. The establishment of a comprehensive regulatory system for MASS will not only facilitate their integration into global shipping operations but also set a precedent for the regulation of other autonomous technologies in various sectors. Through proactive regulation and international cooperation, the maritime industry can successfully navigate the challenges posed by autonomous technology and ensure a safe, efficient, and sustainable future for global shipping.

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