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AUTONOMOUS/UNMANNED MARITIME VEHICLES: AN EVALUATION OF REGULATORY COMPLIANCE IN TERMS OF INTERNATIONAL MARITIME CONVENTIONS AND MARINE ACCIDENTS

Abstract

In recent years, the integration of artificial intelligence and automation systems into the maritime industry has significantly accelerated the development of autonomus/unmanned maritime vehicles, bringing their potential operational advantages to the forefront. However, since the existing international maritime regulations are based on human-centered frameworks, they contain substantial gaps regarding the legal status, liability, safety, and regulatory oversight of autonomous/unmanned ships. This study examines role and status of autonomus/unmanned maritime vehicles within the international maritime conventions, such as UNCLOS, SOLAS, COLREG, MARPOL, STCW, and analyzing liability regimes in terms of marine accidents and evaluating potential elements of regulatory framework required for their effective integration into the existing regulatory system. Furthermore, drawing upon regulatory frameworks established for autonomous land vehicles, this study explores regulatory approaches that could be adapted to the maritime industry and presents some recommendations for the development of a comprehensive international regulatory framework governing autonomus/unmanned maritime vehicles.

Keywords: *Maritime Management, International Maritime Conventions, Maritime Safety and Security, Marine Accidents, Autonomous Unmanned Maritime Vehicles.*

OTONOM/İNSANSIZ DENİZ ARAÇLARI: ULUSLARARASI DENİZCİLİK SÖZLEŞMELERİ VE DENİZ KAZALARI AÇISINDAN MEVZUATA UYGUNLUĞUNA YÖNELİK BİR DEĞERLENDİRME

Öz

Son yıllarda yapay zekâ ve otomasyon sistemlerinin denizcilik sektörüne entegrasyonu, otonom/insansız deniz araçlarının gelişimini hızlandırmış ve bu teknolojinin sunduğu potansiyel operasyonel avantajları gündeme getirmiştir. Bununla birlikte mevcut uluslararası denizcilik mevzuatı; insan merkezli düzenlemelere dayandığından otonom/insansız deniz araçlarının yasal statüsü, sorumlulukları, emniyet ve denetim süreçleri açısından önemli boşluklar barındırmaktadır. Bu çalışma; otonom/insansız deniz araçlarının, denizcilik sektöründeki rolünü ve statüsünü UNCLOS, SOLAS, COLREG, MARPOL ve STCW gibi başlıca uluslararası denizcilik mevzuatı çerçevesinde analiz etmekte, deniz kazaları bağlamında sorumluluk rejimlerini irdelemekte ve bu teknolojinin denizcilik sözleşmelerine entegrasyonu için gereksinim duyulan düzenleyici çerçevenin potansiyel unsurlarını tartışmaktadır. Ayrıca otonom kara taşıtları için oluşturulmuş düzenleyici çerçeveden hareketle denizciliğe uyarlanabilecek düzenleyici yaklaşımlar ve otonom/insansız deniz araçları için kapsamlı bir uluslararası düzenleyici çerçevenin geliştirilmesine yönelik bazı öneriler sunulmaktadır.

Anahtar Kelimeler: *Denizcilik Yönetimi, Uluslararası Denizcilik Sözleşmeleri, Deniz Emniyeti ve Güvenliği, Deniz Kazaları, Otonom İnsansız Deniz Araçları.*

INTRODUCTION

The concept of autonomus/unmanned maritime vehicles (UMVs) was introduced into our lives through unmanned underwater vehicles. Although there is no consensus on who developed these vehicles initally, historical records trace their origins back to the 'Programmable Underwater Vehicle (PUV), a torpedo which was carrying gunpowder and remotely controlled via cable, produced in 1864 by the Luppis-Whitehead Automobile company (Robberts & Sutton, 2006). In 1898, Nikola Tesla remotely controlled a boat and obtained a patent titled 'Method of and Apparatus for Controlling Mechanism of Moving Vessels or Vehicles', demonstrating that boats could be controlled remotely using electromagnetic waves (Tesla, 1898). Furthermore, he made a significant prediction by stating that "*Teleautomata will be ultimately produced, capable of acting as if possessed of their own intelligence, and their advent will create a revolution.*" (Tesla, 1919). Another noteworthy example is the unmanned underwater vehicle named *Poodle*, developed in 1953 by Dmitri Rebikoff (Ahmed, Yaakob & Sun, 2014).

The United States Navy has led pioneering efforts in the development of UMVs. As a result of these initiatives, remotely operated vehicles (ROVs) were developed for military applications. These vehicles, without artificial intelligence capabilities, are tethered to a mother ship and operated remotely by human operators. The primary objective of their development was to conduct mine countermeasures operations—tasks that pose significant risks to human life—as well as to facilitate safe exploration in the Arctic region and deep-sea research (Canlı, Kurtoğlu, Canlı & Tuna, 2016). In 1963, the U.S. Navy introduced the 'Special Purpose Underwater Research Vehicle (SPURV)', which was effectively utilized in scientific oceanographic research and, notably, in the detection of naval mines in the Strait of Hormuz during the Iran-Iraq War (Widditsch, 1973). In 1966, the U.S. Navy's 'Cable-Controlled Underwater Recovery Vehicle (CURV)' gained international recognition when it successfully retrieved a lost thermonuclear bomb from the seabed following an aircraft accident (Pierson, 2009). CURV also achieved success in 1973 during the rescue operation of two crew members trapped at a depth of 480 meters in the 'PISCES III' submarine off the coast of Ireland, an achievement recorded in the Guinness Book of World Records as the 'deepest underwater rescue' (Guinness, 2024). As a result of these developments, the potential of UMVs to undertake particularly hazardous and superhuman tasks became more evident.

This period also marked a significant turning point in demonstrating the capabilities of these vehicles and their effectiveness in critical missions.

These developments attracted the attention of other countries, including United Kingdom, Russia, Japan, and France. By the 1980s, many nations had initiated research and development (R&D) projects on UMVs, leading to their widespread adoption for both scientific and military applications on a global scale (Liu, Zhang, Yu & Yuan, 2016). While UMVs were initially designed as small underwater vehicles primarily for military use, today, various R&D projects and initiatives extend across both military and commercial domains, encompassing surface vessels and larger-scale platforms (Uyan, Yılmaz & Sönmez, 2024). For instance, under the 'Medium Unmanned Surface Vehicle (MUSV)' program, the U.S. Navy incorporated the 145-ton, 40-meter-length prototype vessel 'Sea Hunter' into its inventory in 2016, followed by its sister ship, 'Sea Hawk', in 2021 (Lagrone, 2021). Additionally, as part of the 'Ghost Fleet Overlord (GFO)' program launched in 2018, the Navy has commissioned several unmanned surface vessels, including 'USV Ranger', 'USV Nomad', 'USV Mariner' and 'USV Vanguard'. It is also known that projects for other types of UMVs, such as the 'Large Unmanned Surface Vehicle (LUSV)'—length between 60 and 90 meters—and the 'Extra-Large Unmanned Underwater Vehicle (XLUUV)', are currently underway (O'Rourke, 2024). Similarly, as of the end of 2024, the People's Liberation Army Navy (PLAN) of China has commissioned the 'JARI-USV-A Orca', a 58-meter-long, 420-ton combatant unmanned surface vessel with a helicopter deck (Odin, 2024).

The Russia-Ukraine War has demonstrated that UMVs can play a critical role in modern warfare. Ukraine has employed these systems in operations targeting Russia's strategic assets. Notable examples include attacks on the 'Admiral Makarov' frigate and a mine countermeasure vessel in Sevastopol Harbor, the intelligence ships 'Ivan Khurs' and 'Priazovye', the Kerch Bridge, the landing ship 'Olenogorsky Gornyak', and the fuel tanker 'Sig' recognized as a Russian state vessel. These attacks were not limited to areas near Ukraine's coastline but also occurred in international waters of the Black Sea, including approximately 150 nautical miles off the İstanbul Strait and 180 nautical miles southeast of the Ukrainian coast (Özyurt, 2024). This underscores the potential of UMVs in long-range operations. During this conflict, Ukraine established a military unit known as 'Brigade 238', reportedly the world's first naval drone brigade, consisting of 100 UMVs. These low-cost and high-speed vehicles have not only transformed both offensive and defensive strategies but also serve as an indication that future naval warfare will become increasingly autonomous and asymmetric. Meanwhile, Russia’s efforts to enhance its offensive and defensive capabilities against UMVs further highlight the transformative impact of unmanned systems on military strategies (Bursuc, Munteanu & Rus, 2024).

In recent years, significant UMV projects have also been implemented in the commercial shipping industry. One notable example is ‘YARA Birkeland’, the world’s first (according to YARA) fully electric and autonomous container ship. This vessel, comparable in size to conventional commercial ships, was commissioned for maritime transport between Norwegian ports in 2022. Gradually advancing toward full autonomy, it continues undergoing tests for autonomous navigation, port maneuvers, and cargo handling (YARA, 2024). Similarly, China’s feeder container ship ‘Zhi Fei’ made its maiden voyage in April 2022, demonstrating its ability to operate in three different control modes: conventional, remote, and autonomous. Currently, this highly autonomous vessel is in service for maritime transport between Qingdao and Dongjiakou ports, covering approximately 30 nautical miles (Cui & Liang, 2024). In 2022, Avikus developed 'PRISM COURAGE', the first ultra-large LNG ship to cross the ocean with autonomous navigation technology, which navigated approximately 5,400 nautical miles autonomously in 33 days. According to Avikus, the use of this technology increased fuel efficiency by 7%, reduced greenhouse gas emissions by 5% and successfully perform 100 autonomous maneuvers (course and speed adjustments) to avoid collisions (Avikus, 2024). Japan's ‘MEGURI2040’ project, initiated by The Nippon Foundation and its consortium in 2020, represents a significant advancement in AI applications for maritime transport. The primary goal of the project is for half of maritime transportation operations to be conducted autonomously by 2040. As of 2025, practical demonstration tests for autonomous voyages are planned. Unlike similar initiatives, ‘MEGURI2040’ conducts autonomy tests on six different vessel types, including a 200-meter-length high-speed ferry RoPax, an amphibious vessel, a container ship, and a leisure boat (The Nippon Foundation, 2024). Other notable UMV projects are the ‘Maritime Unmanned Navigation through Intelligence Networks (MUNIN)’ initiative led by the European Commission, the ‘Advanced Autonomous Waterborne Applications (AAWA)’ initiative by Rolls-Royce, South Korea’s ‘Korean Autonomous Surface Ship (KASS)’ project, the ‘Mayflower Autonomous Ship (MAS400)’ developed by Promare, the ‘Autonomous Marine Operations and Systems (AMOS)’ project by the Norwegian University of Science and Technology, and ReVolt, a project developed by DNV GL (Uyan et al., 2024; Anh, Mai, Yoon, 2023; Deling, Dongkui, Huang & Changyue, 2020; Komianos, 2018).

As evidenced by the literature summarized thus far, numerous countries, institutions, and organizations worldwide are actively conducting or implementing significant UMV projects in both military and civilian maritime industries. In recent years, Türkiye has also made notable advancements in UMVs, particularly within the defense industry. Examples include 'LEVENT', 'ALBATROS', 'MİR', and 'MARLİN', developed by ASELSAN; 'SANCAR' and the submersible 'ÇAKA', developed by HAVELSAN; 'ULAQ', jointly developed by Meteksan Defense and Ares Shipyard; and 'SALVO', developed by DEARSAN Shipyard. Additionally, the 2024-2028 Defense Industry Sectoral Strategy Document, published by the Presidency of Defense Industries, highlights the significance of UMVs and autonomy-related technologies (SSB, 2024).

2. STATUS PROBLEM FOR UMVs

The most significant entities in contemporary international maritime legislation are ships. Therefore, the rights, obligations, responsibilities, and regulations specified in legal sources apply exclusively to *ships* (Arslan, 2018). In this context, determining the legal status of UMVs and establishing whether an unmanned or autonomous maritime vehicle qualifies as 'a ship' is of critical importance. The 'Component Theory' exists in doctrine for remotely controlled maritime vehicles. This theory posits that a remotely operated maritime vehicle is deployed from a mother ship, cannot operate independently of it, remains physically tethered, cannot stray far from it, and thus shares the same legal status as the mother ship (Klein, 2019). From a legal perspective, this is a reasonable approach, as remotely controlled maritime vehicles are generally small in size and primarily operate in underwater activities, thereby covering only a limited scope. However, the primary legal challenge lies in the legal status of UMVs. The question of whether UMVs qualify as ships remains a subject of debate. Currently, there is no international legal framework regulating their status, and uncertainties persist regarding their legal standing and liabilities, particularly in relation to different levels of autonomy. For UMVs that are remotely operated from land-based 'Remote Operation Centers (ROC)' over long distances or those that are fully controlled by artificial intelligence, the application of the 'Component Theory' appears impractical. For example, due to the current lack of regulations and safety concerns, the 'YARA

BIRKELAND' vessel, which is currently operating with a crew of three (YARA, 2024), faces legal uncertainties regarding which rules will apply if it begins fully autonomous navigation without any crew on board. Issues such as maritime accidents, search and rescue operations, salvage and assistance activities, insurance, compensation, and liability remain unresolved. Furthermore, as UMVs become increasingly utilized in international voyages, new legal challenges may emerge concerning passage regimes, maritime accidents, coastal, port, and flag state authorities, crimes committed at sea, piracy, and maritime security threats. The widespread deployment of military or state-operated UMVs is likely to further complicate these legal issues. An example of this can be seen in the 2016 incident between the United States and China.

The U.S. Department of Defense reported that on December 15, 2016, in the South China Sea, a Chinese Navy submarine rescue vessel seized an Unmanned Underwater Vehicle (UUV) deployed by the U.S. research (state) vessel 'USNS Bowditch' while conducting research operations in international waters. Pentagon Press Secretary Peter Cook stated: *"The is a sovereign immune vessel of the United States. We call upon China to return our UUV immediately, and to comply with all of its obligations under international law."* (Crook, 2019). The newly elected U.S. President Donald Trump made a statement on social media account: "China steals United States Navy research drone in international waters – rips it out of water and takes it to China in unpresidented act". In response, China's Ministry of Defense stated that the U.S. military frequently conducted close-range reconnaissance and military surveys by deploying ships and aircraft in Chinese waters. According to China, the UUV was found within its maritime jurisdiction, retrieved to ensure navigational safety in the region, and after a detailed examination, it was confirmed to belong to the United States, leading to the decision to return it appropriately (Xinhua, 2016). The U.S. Navy's 2022 publication, 'The Commander's Handbook on the Law of Naval Operations', defines the legal status of unmanned maritime systems in the U.S. Navy inventory as follows:

"*In all cases, U.S. Navy UMSs are the sovereign property of the United States and immune from foreign jurisdiction. When flagged as a ship, a UMS may exercise the navigational rights and freedoms and other internationally lawful uses of the seas related to those freedoms. Unmanned systems may be designated as USS if they are under the command of a commissioned officer* *and manned by a crew under regular armed forces discipline, by remote or other means."* (U.S. Navy, 2022).

To better understand the status of UMVs, it is essential to examine the 'Maritime Autonomous Surface Ships (MASS)' initiatives led by the International Maritime Organization (IMO), as well as the definitions of 'ship' and liability/human-related provisions in the core international maritime conventions.

3. MATERIALS AND METHODS

The aim of this study is to examine the status of UMVs in terms of existing core international maritime conventions and liability in marine accidents, as well as to analyze the need for regulatory frameworks. With this aim, the study employs a combination of literature review and documentary analysis, as qualitative research methods. Documentary analysis method is a systematic review and evaluation of electronic or printed documents (Bowen, 2009). It refers to the process of thoroughly examining documents containing information on the phenomena or events under investigation and synthesizing this information into a coherent whole (Baltacı, 2019). In this study, relevant documents to be analyzed such as IMO meeting reports, core international maritime conventions (in terms of "ship definition" and "liability/human-related provisions") and previous studies on the subject have been reviewed.

As the first step of this study, an overview of the regulatory scope and liability assessment efforts conducted by the IMO regarding UMVs has been presented. This review is based on meeting documents published in 'IMO-DOCS (https://docs.imo.org/)' (IMO, 2024a), the IMO's online document database, by the IMO's Maritime Safety Committee (MSC), Legal Committee (LEG), and Facilitation Committee (FAL), as well as the Joint Working Group on MASS (MASS-JWG), which was established jointly by these committees.

In the second step, core international maritime conventions such as UNCLOS, SOLAS, COLREG, MARPOL, and STCW have been analyzed to determine whether they may apply to UMVs or not. Summaries of relevant sections, such as liability provisions and the definitions of "ship/vessel," have been noted.

In the third step, an assessment has been conducted on liability issues scenario that may arise if UMVs are involved in marine accidents. Since UMVs have not yet been widely adopted and used in the maritime industry nowadays, this analysis draws on the more established automotive industry by examining liability frameworks and regulations applicable to accidents involving autonomous unmanned land vehicles.

Finally, based on the findings of these analyses, a general evaluation has been presented, along with conclusions and recommendations for future research areas. For the purpose of this study, the term ‘Autonomus/Unmanned Maritime Vehicle (UMV)’ refers to maritime vehicles with autonomy ‘Level III’ or ‘Level IV’ under the IMO’s classification of autonomy, remotely controlled or fully autonomous vessels that operate without onboard crew, as further explained in the following section.

4. IMO'S EFFORTS ON DEVELOPMENT OF A REGULATORY FRAMEWORK FOR MASS

The IMO has accelerated its efforts on MASS since 2017, incorporating them into its 2018–2023 strategic plan. The IMO defines MASS as "*a ship that, to varying degrees, can operate independently of human interaction*" (IMO, 2018). In its 105th session in 2018, the LEG initiated a new work program for MASS, targeting 2020. The first step involved conducting a regulatory scoping exercise for MASS, reviewing 40 conventions and 700 codes to assess their applicability to MASS, determine how they could be applied, and identify any regulatory barriers. The process was structured into two phases: the first phase focused on examining MASS operations in terms of safety, security, and environmental protection to analyze existing IMO regulations; the second phase aimed to determine the most appropriate approach for assessing MASS operations while considering human factors, technology, and operational aspects (IMO, 2018). The regulatory scoping exercise conducted by the International Federation of Shipmasters’ Associations (IFSMA) and the International Transport Workers’ Federation (ITF) highlighted the necessity of evaluating UNCLOS provisions, defining different levels of autonomy, delineating the boundaries of human oversight and control, and examining the human element. The study emphasized that until an international regulatory framework governing remotely controlled or unmanned vessels is adopted, such vessels should not be permitted to engage in international voyages (MSC, 2018). The MSC established a theoretical framework defining MASS categories, the use of artificial intelligence, and levels of autonomy, as well as outlining the roadmap for further studies in this field (IMO, 2020). Additionally, IMO formed the Joint Working Group on MASS (MASS-JWG), to address high-priority topics related to MASS.

Regulations were categorized into high, medium, and low priority levels (IMO, 2021). The first meeting of the MASS-JWG took place in 2022, during which a roadmap was established for the development of a non-mandatory MASS code in the second half of 2024, followed by a mandatory MASS code set to become effective on January 1, 2028 (IMO, 2022). In 2023, the group conducted its second session (MASS-JWG 2) and published report MSC 107/5/1. This report addressed critical issues, including the roles, responsibilities, competencies, and requirements of MASS masters and crew, the potential for a single MASS master to be responsible for multiple MASS vessels, the possibility of multiple masters being responsible for a single MASS vessel, and the roles and responsibilities of ROCs, particularly in scenarios where MASS is operated by different ROCs (IMO, 2023a). In its 2024–2029 strategic plan, IMO reaffirmed that the LEG and FAL committees would implement MASS-related measures within their respective domains, with the goal of completing these initiatives by 2025. Furthermore, the plan outlined that the MSC would develop goal-based regulations for MASS by 2025 (IMO, 2023b). During the MSC 108th session in 2024, the third report of the MASS-JWG and a revised roadmap for MASS codification were approved. The latest decisions set forth a timeline in which the non-mandatory MASS code is to be completed and adopted by May 2025, a framework for the experience-building phase is to be developed in the first half of 2026, a new SOLAS chapter will be added in 2028 to incorporate necessary amendments for the mandatory MASS code, the mandatory code is to be adopted by July 1, 2030, and its entry into force is scheduled for January 1, 2032 (IMO, 2024b). This process aims to ensure the gradual development and implementation of the MASS code. During the MSC 109th session in December 2024, it was noted that draft sections 7 (Risk Assessment), 12 (Connectivity), and 18 (Search and Rescue) of the MASS Code had been completed. The roadmap for developing the MASS Code was revised, and the adoption of the non-mandatory MASS code, initially scheduled for completion in May 2025, was postponed by one year (IMO, 2024c).

4.1. Levels of Ship Autonomy

The concept of ‘level of autonomy’ refers to the extent to which a human or artificial intelligence is involved in a given activity. In the literature, various perspectives and classifications exist regarding MASS and their levels of autonomy (Bi, Gao & Ma, 2018; Lloyd’s Register, 2017; Noma, 2016; Rødseth & Nordahl, 2017; Sözer, 2020; U.S. Navy, 2004; U.S. Navy, 2007a; U.S. Navy, 2007b; Veal, Tsimplis & Serdy, 2019; Van Hooydonk, 2014). The IMO has designated autonomous ships as "MASS" as mentioned earlier and categorized their autonomy into four levels, as outlined in Table 1 (IMO, 2020).

Table-1. MASS Autonomy Levels (IMO, 2020)

Level	Description
I	Ship with Automated Processes and Decision Support: In this type of vessel, intelligent systems are automatically utilized. Crew members are present on board to operate and monitor these systems. Maritime operations are conducted under human supervision, similar to conventional ships. However, certain control functions and processes are performed automatically and overseen accordingly.
II	Remotely Controlled Ship with Onboard Crew: The ship is remotely controlled from a Shore Control Center (SCC). Crew members remain on board to take over control in case of any adverse situation and to ensure the proper functioning of systems, as well as to carry out maintenance, upkeep, and testing duties.
III	Remotely Controlled Ship Without Crew: The ship is remotely operated and controlled from the SCC using data transmitted via radio and satellite communication systems, which are processed by onboard computers. To ensure real-time situational awareness for remote operators, the vessel is equipped with multiple optical and acoustic sensors such as cameras, radars, laser scanners, and microphones, along with traditional navigation aids like GPS, AIS, and ECDIS. The SCC operator interprets all incoming data, transmits commands back to the ship, and directs its movements accordingly.
IV	Fully Autonomous Ship: This is the highest level of autonomy, where decisions are made independently without human operator intervention. Ships controlled by artificial intelligence systems at this level are referred to as autonomous ships. Navigation decisions are automated through next-generation sensors and systems, eliminating the need for human interaction. The ship continuously collects various types of data from onboard sensors and transmits it to a central main computer, which processes the information and sends commands to machinery, steering, navigation, and cargo-handling equipment. In case of maintenance or emergencies, the autonomous ship can connect to the SCC for intervention.

In the literature, various criticisms suggest that the IMO's classification does not fully reflect advancements in artificial intelligence. For instance, Schelin (2019) argues that the autonomy levels defined by the IMO are based on shifting degrees of automation rather than addressing different types of autonomous ships. He points out that the same vessel could operate manually (Level I) at one time and fully autonomously (Level IV) at another, creating ambiguity. Consequently, he recommends a more detailed classification of automation levels. The Norwegian Forum for Autonomous Ships (NFAS) has also emphasized the necessity of classifying MASS based on the presence of bridge personnel, as this distinction would have different implications for both operations and regulations (e.g., responsibilities). NFAS further highlights the importance of applying the concept of variable autonomy in maritime operations. Their proposal for dynamic autonomy across different operational periods is presented in Table 2 (Rødseth & Nordahl, 2017).

Table-2. Dynamic Autonomy Periods Proposed by NFAS (Rødseth & Nordahl, 2017)

Class / Operation	**Berthing & Unberthing**	**Port Arrival & Departure**	**Navigatıın**	**Exceptional Situations (Severe Weather/Sea Conditions, Malfunctions, etc.)**
Periodically Unmanned Ship	Onboard Control Team	Onboard Control Team	Constrained Autonomous	Emergency Control team
	Automatic Bridge/Ship	Automatic Bridge/Ship		Direct Control
	Direct Control	Direct Control		
Periodically Unmanned Bridge	Manned	Manned	Constrained Autonomous	Manned
	Automatic Bridge/Ship	Automatic Bridge/Ship		Direct Control
	Direct Control	Direct Control		
Continuously Unmanned Ship	Automatic Bridge/Ship	Remote Control	Constrained Autonomous	Remote Control

4.2. Liability Definitions by MASS-JWG

During its second and third sessions (JWG-2, JWG-3), MASS-JWG made significant decisions regarding liability issues. These decisions are summarized below.

4.2.1. JWG-2 Outcomes (IMO, 2023a)

- General Views and Decisions on the Role and Responsibilities of the Captain: It was stated that the existing definition of a ship's captain is sufficient for MASS. Since the operational framework and human intervention in autonomous ships have not yet been fully established, discussions on redefining the captain's role were considered premature. It was emphasized that even in fully autonomous mode, a designated individual should remain responsible for MASS operations. While the captain does not need to be physically present onboard, their responsibility should persist. Furthermore, the captain should retain control and intervention authority in all circumstances.

- A Captain Being Responsible for Multiple MASS: It was agreed that a MASS captain could be responsible for multiple autonomous ships simultaneously. However, it was highlighted that limitations should be imposed in emergency situations, high-traffic maritime areas, or environmentally sensitive regions. Further research on this issue was deemed necessary.

- Remote Execution of MASS Operations: It was decided that a single ROCs (facilities that manage MASS operations remotely) should be responsible for only one MASS at a time. However, multiple ROCs could assume control of a single MASS during a voyage under specific conditions, which would need to be clearly defined.

- Definition of a Remote Operator: A ‘remote operator’ was defined as a qualified individual who manages some or all functions of a MASS from a ROC. It was acknowledged that the qualifications of remote operators should be subject to the legal regulations of the flag state.

- MASS Crew and Crew Roles: The crew of a MASS could be divided into a remote crew operating from a ROC and a local crew onboard the vessel. However, since the captain’s role could impact the duties of the crew, further discussions on this matter were postponed to the next session.

- Legal Issues and Flag State Responsibility: Jurisdictional issues were raised regarding situations where a ROC is established outside the flag state’s territory. It was suggested that the relationship between the flag state and the ROC should be framed similarly to the International Safety Management (ISM) Code.

- Future Work: It was decided that further work would be conducted on developing the legal and technical framework for MASS. Future studies will focus on captain and crew competency requirements, the legal responsibilities of ROCs, operational standards, and issues related to the Maritime Labour Convention (MLC).

4.2.2. JWG-3 Outcomes (IMO, 2024b)

- Captain's Responsibilities: The captain holds ultimate responsibility for the safety of the vessel, its personnel, and the environment, and this authority cannot be transferred. While the overall responsibility remains with the captain, certain duties and functions may be delegated to qualified personnel. It was noted that if the captain is located at a ROC, a qualified person onboard the vessel may temporarily assume the captain’s responsibilities in case of a communication loss between MASS and ROC until the connection is restored. Additionally, when the captain carries out their duties from shore, clear conditions must be established regarding when and how responsibility is transferred.

- ROC Responsibilities: The ROC is responsible for the remote operation of MASS when the captain is not onboard. It was emphasized that the ROC must have contingency plans in place for communication loss, demonstrate compliance with safety requirements, and possess the necessary certifications and documentation to support safe operations.

- Crew Responsibilities: The crew may support the captain, particularly when the captain is located at the ROC or in emergency situations. Crew members must have the necessary qualifications to effectively assist the captain and ensure the safe operation of the vessel.

- Additional Considerations: It was emphasized that the roles and regulations concerning the captain, crew, and ROC must be clearly defined, particularly as maritime technology continues to advance. Flag states must ensure effective oversight of ROC operations, especially when the ROC is located outside their jurisdiction. Furthermore, issues such as connectivity, cybersecurity, and information sharing with coastal and port states were highlighted as areas requiring further attention.

5. STATUS OF UMVs IN TERMS OF CORE INTERNATIONAL MARITIME CONVENTIONS

Bolat and Koşaner (2019) argue that the definitions of "ship" in international legislation are flexible enough to encompass UMVs. While this implies that there is no strict legal barrier to their inclusion, the existing legal framework remains insufficient in clearly defining the status of UMVs. They further highlight that in the event of a maritime incident or accident involving UMVs, the perspectives of those assessing the situation—both in terms of maritime legislation and the operational nature of UMVs—will play a crucial role in legal interpretations. In this context, it is essential to examine the relevant provisions of UNCLOS and IMO conventions that specifically address or impact the legal status of UMVs.

5.1. United Nations Convention on the Law of the Sea (UNCLOS)

UNCLOS does not explicitly define the terms "ship" or "vessel" in its provisions, using both interchangeably (Kara, 2020). The only explicit definition provided in the convention is in Article 29, which defines a "warship." According to this article, military UMVs that display the external markings of their respective armed forces and operate under the command of a commissioned officer may still not qualify as warships due to the absence of an onboard crew. Vallejo (2015) argues that the ambiguity surrounding command authority (whether it rests with the programmer or the remote commander) and the high level of autonomy involved prevent military UMVs from being classified as warships under UNCLOS. Given these legal uncertainties, granting UMVs warship status should be abandoned.

Apart from this, UNCLOS does not provide a general definition of a 'ship'; however, it includes provisions concerning 'merchant ships', government ships operated for commercial purposes', and 'other government ships used for non-commercial purposes'. Var Türk (2019) suggests that, based on the general interpretation rules outlined in the Vienna Convention on the Law of Treaties, the broad nature of the term 'ship' in UNCLOS could allow existing regulations for conventional ships to extend to UMVs.

Article 19 of UNCLOS governs the right of 'innocent passage', stipulating that acts such as "*collecting information to the prejudice of the defence or security of the coastal State*" and "*carrying out research or survey activities*" can nullify this right. Given that UMVs inherently operate with various sensors—such as cameras, radar, lidar, ladar, and acoustic systems—questions arise regarding whether data collected through these means could be considered intelligence gathering or research activities prejudicial to the coastal state. Furthermore, issues such as how such data is recorded, stored, and accessed, and who is authorized to handle this information, remain unresolved.

Regarding flag state responsibilities under Article 94(4)(b) and (c), there are differing opinions on whether these obligations apply to UMVs (Deketelaere, 2019; Ringbom, 2019; Rodriguez Delgado, 2018). Boviatsis and Vlachos (2022) outline three possible legal interpretations: 1) The absence of an onboard captain and crew could render flag state responsibilities inapplicable, necessitating new legal frameworks, 2) Remotely responsible individual could be designated as the captain, allowing the current legal framework to remain in force, 3) The lack of a qualified captain on board could lead flag states to deem the international operation of UMVs unlawful. Ece (2018) argues that in the absence of a captain and crew, the coastal state may deny entry into its territorial waters, and suggests the responsibilities of SCC operators in unmanned ships should be clearly defined, and the relevant legislation (UNCLOS Article 94, 98, 110) should be amended accordingly for UMVs.

5.2. International Convention for the Safety of Life at Sea (SOLAS)

SOLAS contains various definitions for ships, including "passenger ship," "cargo ship," "tanker," "fishing vessel," "nuclear ship," and "new ship." Additionally, it states that "all ships, regardless of type and purpose, refer to any ship, boat, or craft." The definitions are based on factors such as the type of cargo carried, the number of passengers, the ship's launch date, its operational activities, and propulsion methods. However, there is no specific regulation regarding whether ships must be manned. The applicability of SOLAS to UMVs poses significant challenges that would require substantial modifications. Since the primary goal of SOLAS is to ensure the safety of human life at sea, the emergence of UMVs introduces a new dimension to maritime safety. The replacement of human factors with artificial intelligence and automation necessitates fundamental changes in responsibility, safety, and security regulations. Specifically, the design and operation of UMVs require enhanced cybersecurity measures and the development of appropriate legal frameworks.

5.3. Convention on the International Regulations for Preventing Collisions at Sea (COLREGs)

COLREGs, 'General Definitions', provides definitions for terms such as 'vessel', 'power-driven vessel', 'sailing vessel', 'vessel engaged in fishing', 'seaplane', 'vessel not under command', 'vessel restricted in its ability to maneuver' and 'vessel constrained by her draft'. The definition of a 'vessel' is broad, stating: *"The word "vessel" includes every description of water craft, including non-displacement craft, WIG craft and seaplanes, used or capable of being used as a means of transportation on water."*

Because these definitions focus on the maneuverability of vessels rather than their manned or unmanned status, there is no immediate need for a separate definition of UMVs within COLREGs.

Under Rule 2: Responsibility COLREGs state: *"(a) Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case."*

Vallejo (2015) argues that UMVs should not be designed to merely comply with COLREGs, as the convention is fundamentally based on human decision-making and actions. Current technology does not yet possess the ability to fully replicate human judgment and situational awareness. Key challenges include how to teach autonomous systems qualitative aspects of navigation, such as good seamanship and discretionary deviations from standard rules when necessary. For COLREGs to be effectively applied to UMVs, several complex issues must be addressed, including: training autonomous systems to interpret and apply COLREGs, beyond basic sensor-based visual and auditory watchkeeping, ensuring that remote operators have bridge-like situational awareness for effective decision-making, establishing clear responsibility definitions and limits that account for varying levels of autonomy. These challenges require further technological advancements and regulatory adjustments (Chircop, 2018; Gogarty & Hagger, 2008; Ringbom, 2019).

5.4. International Convention for the Prevention of Pollution from Ships (MARPOL)

Article 2 of MARPOL, defines a ship as: *" vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, floating craft and fixed or floating platforms."* Additionally, the convention provides definitions for ‘new ship’, ‘existing ship’, ‘tanker’ and ‘combination carrier’. However, none of these definitions explicitly require ships to be manned. MARPOL, along with other maritime environmental protection regulations, outlines the responsibilities of the ship's master, crew, and owner in pollution-related incidents. These include reporting pollution, responding to spills, and taking necessary actions to mitigate environmental damage. With the introduction of UMV’s, the role of artificial intelligence and remote operators in detecting, diagnosing, and reporting marine pollution must be clearly defined. Chircop (2018) highlights that, beyond MARPOL, the transition from human crew members to automation could impact compliance with other environmental conventions. For instance, the management of ballast water and related operations may need to be overseen by remote operators or conducted entirely autonomously.

5.5. International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW)

In STCW convention, the following definitions are provided: ‘Seagoing ship’ refers to “a ship other than those which navigate exclusively in inland waters or in waters within, or closely adjacent to, sheltered waters or areas where port regulations apply”, ‘Fishing vessel’ refers *“a vessel used for catching fish, whales, seals, walrus or other living resources of the sea”*

Article 1(2) of the convention states:

“The Parties undertake to promulgate all laws, decrees, orders and regulations and to take all other steps which may be necessary to give the Convention full and complete effect, so as to ensure that, from the point of view of safety of life and property at sea and the protection of the marine environment, seafarers on board ships are qualified and fit for their duties.”

Article 3 states:

"The Convention shall apply to seafarers serving on board seagoing ships entitled to fly the flag of a Party except to those serving on board:…” The convention includes requirements related to the manning of ships and watchkeeping duties, both of which assume the physical presence of crew members. As a result, in its current form, STCW presents legal barriers to its applicability to UMVs (Chircop, 2018; Ringbom, 2019). On the other hand, for UMVs operations, the standards for ROC watchkeeping and the training processes for remote operators must be addressed in detail. In this context, key considerations include: identifying additional training requirements beyond existing programs, determining the institutions responsible for delivering such training and the structure of the curriculum, establishing certification processes for remote operators. Furthermore, the extent to which Industry 4.0 technologies (e.g., digital twins, augmented reality, Internet of Things) should be incorporated into training and operational processes should also be explored.

6. STATUS OF UMVs IN TERMS OF MARINE ACCIDENTS

According to statistics on maritime accidents and incidents published by the European Maritime Safety Agency (EMSA), during the ten-year period between 2014 and 2023, a total of 26,595 maritime accidents and incidents involving 29,116 ships occurred. These incidents resulted in 650 fatalities, 7,604 injuries, and 602 cases of marine pollution. Safety investigations have determined that the human factor played a role in 80.1% of these maritime accidents and incidents, regardless of vessel type (EMSA, 2024). Since UMVs operate without a crew, fatalities and injuries caused by individual workplace accidents will not be a concern. However, in the case of UMVs used for passenger transportation, the safety of passengers will depend on the vehicle’s ability to avoid maritime accidents such as collisions, allisions, contacts, and groundings. Similarly, the protection of the marine environment, particularly against large-scale oil pollution, will rely on the accident prevention capabilities of UMVs carrying petroleum. Despite all preventive measures, determining how criminal liability will be addressed in cases where UMVs are involved in maritime accidents presents a challenge for flag states, port states, coastal states, and P&I insurers. Additionally, in the event of a maritime accident, there are uncertainties regarding how a UMV can fulfill the legal obligation of a ship's captain to provide the most appropriate assistance available, as required by UNCLOS, SOLAS, the International Convention on Maritime Search and Rescue (SAR), International Convention on Salvage and national commercial laws. These uncertainties arise from the assumption that a UMV is designed without a crew and lacks lifeboats, life rafts, food, water, and first aid supplies. Currently, despite various tests being conducted, UMVs are not yet widely used in global maritime transportation and there has not been a significant maritime accident involving a UMV. However, the issue of criminal liability in maritime accidents involving UMVs can be examined by drawing comparisons with the more widely adopted autonomous vehicle industry.

Dremliuga and Rusli (2019), in their study aimed at applying lessons from autonomous cars to UMVs, stated that the existing legal framework is insufficient in assessing the complexity of autonomous navigation, particularly in terms of cybersecurity and privacy concerns. They argued that the anthropocentric legal system, which does not take into account the autonomous decision-making capabilities of AI-powered vessels, would be inadequate in evaluating potential incidents. They also highlighted significant privacy concerns regarding the collection, processing, and deletion of data by autonomous ships, suggesting that privacy approaches adopted for autonomous cars could also be applicable to autonomous ships.

Similar discussions in the literature extend to the limits of criminal liability for damages, injuries, and fatalities caused by unmanned vehicles (Churilov, 2018; Radutniy, 2017). Different scenarios have been examined, including the responsibility of human drivers in partially autonomous vehicles and the liability of developers and technicians in fully autonomous ones. Legal frameworks are proposed to regulate the autonomous vehicle industry, with efforts to hold developers accountable for autopilot failures in fully autonomous vehicles (Ivanova & Kalashnikov, 2022).

In 2018, an autonomous car tested by Uber struck and killed 49-year-old Elaine Herzberg, who was crossing the road with her bicycle. This incident marked the first pedestrian fatality involving an unmanned vehicle. The victim's family sued Uber, Volvo, and the state government, arguing that the latter was liable for permitting the use of autonomous vehicles. However, Uber was acquitted due to a pre-crash agreement with the test driver, Volvo demonstrated that Uber had disabled its vehicle's safety features, and the state government was not held accountable because there was no designated pedestrian or bicycle crossing at the accident site (Griggs & Wakabayashi, 2020). The test driver, Rafael Vasquez, was sentenced to three years in prison for negligent homicide (Riess & Sottile, 2023).

Mingtsung, Qiaoying and You (2020) emphasized the need for legal frameworks to address liability in autonomous vehicle accidents. They argued that responsible parties—including drivers, vehicle owners, manufacturers, and AI system designers—must be clearly defined. They proposed establishing a 'reversal of burden of proof' regulation to facilitate liability determination, creating a 'black box' data analysis center, setting standards for 'product defects' in autonomous vehicles, considering liability exemptions for manufacturers, and developing high-risk liability concepts through comprehensive insurance and compensation funds for autonomous vehicle accidents.

Since traditional insurance frameworks are primarily designed for crewed vessels, and may not adequately cover the risks, responsibilities, and legal uncertainties associated with unmanned operations, the legislation concerning P&I Clubs and insurance companies should be specifically reviewed and updated to address the unique operational, technical, and liability aspects of UMVs (Ece, 2018; Zhu & Xing, 2019).

7. CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

The widespread integration of UMVs into the maritime industry has revealed substantial legal and regulatory deficiencies. Current international maritime conventions were designed for a world of manned shipping and fail to adequately address the complexities introduced by UMVs. The absence of a standardized and universally accepted definition of a "ship," coupled with the lack of clarity regarding whether existing provisions apply to vessels that operate without a crew, has created considerable ambiguity. These conventions were not drafted with artificial intelligence, remote-control systems, or fully autonomous operations in mind, and as such, their current scope is insufficient for the evolving maritime environment.

The question of legal responsibility, particularly in incidents involving Level IV MASS that operate entirely without human input, remains unresolved. There is no consensus on how liability should be distributed among shipowners, operators, manufacturers, AI developers, or shore-based personnel in the event of a collision, mechanical failure, or cyberattack. Furthermore, the phenomenon of dynamic autonomy — where control over a vessel may shift between human operators and autonomous systems — introduces an additional layer of complexity that is not addressed by existing legal instruments. Additionally, recent developments have shown that the primary focus of regulatory efforts, particularly those led by the IMO, has been on commercial applications of MASS. However, the legal status and operational regulation of military and government-owned UMVs remain largely undefined.

Equally pressing is the issue of cybersecurity, which represents a new frontier of risk in maritime legislation. UMVs rely heavily on sensors, data communication systems, and machine learning processes, all of which are susceptible to manipulation, malfunction, or attack. The absence of a legal framework that regulates data protection, system integrity, and liability in case of cyber incidents exposes the maritime industry to significant threats. A comprehensive, forward-looking, and inclusive regulatory structure is urgently needed to ensure the safe, secure, and accountable operation of MASS in international and national waters.

This study contributes to the existing literature by providing an overwiew focused to uncertainties surrounding the regulation of UMVs. While previous studies have primarily discussed the technological feasibility and operational benefits of MASS and UMVs, this study centers on the legal and regulatory challenges that stem from their integration into global maritime systems. It highlights how current core international maritime conventions, in their present form, fall short of addressing the legal complexities associated with AI-based decision-making, unmanned operation, and dynamic control mechanisms. Furthermore, the study distinguishes itself by emphasizing the necessity of incorporating both commercial and especially non-commercial (military/governmental) vessels into future regulatory frameworks. It identifies and classifies critical gaps in responsibility allocation, liability, cybersecurity, and data governance such as UNCLOS Article 19. Furthermore, unlike most of other studies, this work particularly focuses on the status issues of military and state UMVs, emphasizing the importance of this subject as a potential source of inter-state disputes and political conflicts. Also it goes further by drawing insights from cases of autonomous land vehicle accidents to suggest that these two emerging fields (autonomous land vehicles and UMVs) can mutually benefit from shared lessons. In future studies, further analysis and exemplification of developments in both domains could be pursued.

This study is expected to stimulate interdisciplinary dialogue among stakeholders of maritime industry, regulators, insurers, policymakers, and researchers. It is also expected to contribute to the international efforts for aligning maritime legislation with the rapid advancements in automation and artificial intelligence and laying a more resilient, adaptable, and forward-looking maritime governance.

7.2. Recommendations

In light of the regulatory gaps identified in this study, it is clear that an up-to-date and comprehensive regulatory framework is needed for the safe and secure operations of UMVs. In this regard, the Authors would like to express the following recommendations to the stakeholders of the maritime industry for further discussion and consideration:

- IMO has been already undertaking significant valuable efforts to develop a regulatory framework for MASS operations, including the amendment of existing instruments such as SOLAS, COLREGs, STCW, and MARPOL etc. The Authors consider that particular emphasis should be placed on clarifying the relationship between the MASS Code and current regulations in accordance with the lex specialis derogat legi generali principle whereby specific provisions take precedence over general ones. In other words, rather than focusing solely on the amendment of existing instruments, more attention should be directed towards the legal pathway for integrating the newly proposed MASS Code into the existing maritime legal framework.
- Furthermore, the regulatory framework for MASS/UMVs should take into account not only different levels of autonomy but also the dynamic nature of control transfer between AI systems and human operators.
- Maritime authorities should develop their complementary national regulatory frameworks aligned with the international regulations. These

frameworks should include training and certification mechanisms for shore-based personnel operating autonomous/unmanned vessels, as well as legal mechanisms for testing and piloting MASS/UMVs within territorial waters under controlled conditions. Additionally, legal clarity regarding the use and status of military and state-owned MASS/UMVs is essential, particularly given their potential for cross-jurisdictional operations.

- Marine insurers and P&I Clubs should also be aware that they are face a changing risk environment. Traditional insurance models are not suited to account for the decentralized, digital, and AI-driven nature of MASS/UMVs. Tailored insurance frameworks need to be established, incorporating specific clauses related to cyber incidents, technical system failures, and AI decision-making processes. Risk-based technical evaluations and scenario-based liability planning should become a standard component of the insurance approval process. Without these adjustments, marine insurers may struggle to fairly assess and manage the risks posed by autonomous vessels.

- It seems that the challenges related to MASS/UMVs will directly affect a wide range of stakeholders, including shipowners, flag and coastal States, port authorities, marine insurers and P&I clubs, AI developers, and maritime professionals. As MASS/UMVs continue to enter commercial fleets and defense systems, a harmonized legal approach that considers both operational practicality and technological sophistication is imperative. Scenario-based planning, close cooperation among states, and a data-driven, risk-focused legislative process should guide the future of maritime autonomy governance.

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