REPUBLIC OF TÜRKİYE
ANKARA UNIVERSITY
GRADUATE SCHOOL OF SOCIAL SCIENCES
DEPARTMENT OF MARITIME TRANSPORTATION LAW AND POLITICS

LEGAL ASPECTS OF MARITIME AUTONOMOUS SURFACE SHIPS RELATED TO THE SAFETY OF NAVIGATION

LLM Program with Thesis (conducted in English) in the Sea & Maritime Law

Dario BUFAZI

Ankara, 2025

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I state that all the information in my master's thesis titled "LEGAL ASPECTS OF MARITIME AUTONOMOUS SURFACE SHIPS RELATED TO THE SAFETY OF NAVIGATION" (2025, Ankara), which I prepared under the supervision of Asst. Prof. Kübra Var Türk was collected and presented in accordance with academic rules and ethical behaviour principles; I fully indicated the information I received from other sources in the text and the bibliography, I declare that I have acted in accordance with the ethical rules, and I will accept any legal consequences in case the contrary arises.

Date: 25/03/2025

Dario BUFAZI

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LIST OF ABBREVIATIONS

COLREG : 1972 Convention on International Regulation for Preventing Collisions at Sea

EC : The European Commission

ILO : International Labour Organization

IMCO : Inter-Governmental Maritime Consultative Organization

IMO : International Maritime Organization

ISM : The International Safety Management Code

ISPS : International Ship and Port Facility Security

ITUC : The International Trade Union Confederation

MARPOL : 1973/1978 International Convention for the Prevention of Pollution from Ships

MASS: Maritime Autonomous Surface Ships

SAR : 1979 International Convention on Maritime Search and Rescue

SOLAS: 1974 International Convention for the Safety of Life at Sea

STCW : 1978 International Convention on Standards of Training, Certification and Watchkeeping for Seafarers.

UNCLOS: 1982 United Nations Convention on the Law of the Sea

UNCTAD: United Nations Conference on Trade and Development

MSC : Maritime Safety Committee of IMO

USCG : United States Coast Guard

Vol : Volume

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INTRODUCTION

A) SUBJECT MATTER AND AIM

Technology is evolving quickly, and humanity is encountering several changes, from those that do not affect our daily lives to those that make a big difference for all of us. Looking back at the beginning of the last century, a typical ship needed at least one man per battle station. Human resources controlled every detail; the crew members executed all loading, unloading, mooring, and unmooring. After the Cold War, the competition for the most advanced technology between countries accelerated. In one century, technology has evolved more than in thousands of years. Nowadays, a crew of only ten or fifteen can operate a CV (Container Vessel). Every system is digitalized: engine room, fire alarms, loading and unloading, autopilot, mooring, and unmooring are more accessible than ever.

One of the latest developments that this article will study is MASS (Maritime Autonomous Surface Ships). Autonomous ships are vessels that can sail with no crew. They are either remotely controlled by an operator on land or can operate independently. These ships are designed to perform various tasks and can help improve safety on the water, decreasing the risk of harm to human life or health.[1]

"The International Shipping Federation "(ISF), together with the "Baltic and International Maritime Council" (BIMCO), submitted a report to the "International Maritime Organization" (IMO) in 2010, indicating that the shipping industry would face a shortage of seafarers due to harsh working conditions and long periods sailing away from home. This report highlighted the fact that labour markets would become increasingly tight, and the industry would need to find ways to address these challenges.[2] Ship safety and low/zero-carbon fuels are now more important than ever. Decreased ship pollution and emissions are crucial.

On 19 November 2021, the first MASS, *MV Yara Birkeland*, sailed to Oslo, makin

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[1] Wiesław Wasilewski, W.: "Autonomous shipping. The future of the maritime industry?", *Zeszyty Naukowe Małopolskiej Wyższej Szkoły Ekonomicznej w Tarnowie* 51(3), p.160, <https://DOI:10.25944/znmwse.2021.03.155163>, (Accessed on 10.09.2023).
[2] Issa, M.: "Maritime Autonomous Surface Ships: Problems and Challenges Facing the Regulatory Process", *Sustainability,* 14(23)<https://doi.org/10.3390/su142315630>, (Accessed on 24.11.2022).

g it the first autonomous, totally electronic container ship.[3] Many companies in various countries have since developed this technology, such as Germany, Japan, the USA, Finland, South Korea, and many others. Yet the sailing of autonomous vessels is limited to territorial waters or between countries with adjacent boundaries for safety purposes.

States and linked sectors are mainly in favour of this technical shift despite the possibility of social disruption because they are afraid of losing out on this chance. These vessels lack a legal framework in the field of maritime law, and they have technological difficulties. It is essential to completely reconsider the shipping industry in all its aspects because the construction, design, operation, and regulation of ships assume that they are manned by humans. Furthermore, the current regulatory framework still reflects this assumption, which may not be valid anymore.

B) QUESTIONS

This present study attempts to address the following questions:

- What is MASS?
- What are the gaps regarding MASS in international conventions regulating the safety of navigation?
- What advantages and disadvantages do autonomous ships?
- Will traditional navigation be faded away?
- How will SOLAS be impacted when there are no humans on board?
- How will COLREG be affected when there are no humans on board?
- What has been done by IMO to prevent possible rising issues by using MASS?

C) SCOPE AND STRUCTURE

To address the growing concerns and questions regarding the use of MASS in the maritime industry, the IMO initiated a regulatory scoping exercise (RSE) in 2017. This exercise involved the "Maritime Safety Committee" (MSC), the "Legal Committee" (LEG), and the "Facilitation Committee" (FAL) and was completed in 2021. This exercise aimed to evaluate the applicability of existing IMO regulations to ships with different autonomation degrees. The objective was to ensure that the regulatory framework remains relevant, considering

[3] Lavars, N.: "The world's first electric autonomous cargo ship takes to the water", *New Atlas*, (Accessed on 21.11.2023).

technological advancements.[4] A MASS code is anticipated to be finalized by 2025, significantly impacting safety, port interactions, pilotage during incidents, security, and the marine environment.

The thesis is organized into three chapters. The first chapter gives a better understanding of MASS, their degrees of autonomy, advantages and disadvantages related to different factors at sea and ashore. Furthermore, the second chapter looks over the legal instruments that are related to MASS and are affected by it. The third chapter analyzes the safety of MASS at open sea and the danger it may present in relation to human-driven vessels.

D) METHOD

In maritime transportation, a silent revolution is underway, aiming to transform the way commodities are shipped across the world's seas: the advent of autonomous vessels. MASS represents a paradigm shift in maritime technology, offering unparalleled efficiency, safety, and environmental benefits.

The research has been developed mostly by analytic and qualitative research methods to gather information from several papers on the topic. MASS is subject to international maritime conventions[5], such as the "International Regulations for Preventing Collisions at Sea" (COLREG)[6], the "International Convention for the Safety of Life at Sea" (SOLAS)[7], "Search and Rescue" (SAR[8]) the "Standards for Training and Certification of Watchkeepers" (STCW)[9], and other maritime instruments.This thesis aims to analyse the legal aspect of safety navigation with MASS, considering the divergent perspectives of states and maritime instruments

[4] UNCTAD: "Transport Newsletter, Article No. 97, Fourth Quarter 2022", in UNCTAD Transport Newsletter, <https://unctad.org/news/transport-newsletter-article-no-97-fourth-quarter-2022> (Accessed on 13.12.2023).
[5] Kim M., Joung T. H., Jeong B., Park H. S.: "Autonomous shipping and its impact on regulations, technologies, and industries", Journal of International Maritime Safety, Environmental Affairs, and Shipping, 4/2, <https://doi.org/10.1080/25725084.2020.1779427>, (Accessed on 14.01.2024).
[6] United Nations Treaty Collection, "Convention on the International Regulations for Preventing Collisions at Sea" (COLREGs) 1972, https://treaties.un.org/pages/showDetails.aspx?objid=08000002800fcf87, (Accessed on 24.03.2025).
[7] United Nations Treaty Collection, "International Convention for the Safety of Life at Sea" (SOLAS) 1974, https://treaties.un.org/pages/showDetails.aspx?objid=08000002800ec37f , (Accessed on 24.03.2025).
[8] United Nations Treaty Collection, "International Convention on Maritime Search and Rescue" (SAR) 1979, https://treaties.un.org/Pages/showDetails.aspx?objid=08000002800d43b3, (Accessed on 25.03.2025).
[9] United Nations Treaty Collection, "International Convention on Standards of Training, Certification and Watchkeeping for Seafarers" (STCW) 1978, https://treaties.un.org/pages/showDetails.aspx?objid=08000002800d6d42 (Accessed on 13.12.2023).

I. THE CONCEPT OF AUTONOMOUS SHIPS

A) DEFINITION OF MASS

Autonomous vessels are maritime vehicles capable of navigating and operating independently without human intervention.[10] The idea of MASS is not entirely new, with initial experiments tracing back to the 1950s. However, recent advancements in artificial intelligence (AI), sensor technology, and maritime connectivity have accelerated their development and adoption.[11]

Today's autonomous vessels are equipped with numerous sensors, including LiDAR (Light Detection and Raging), cameras, several radars, and GPS, allowing them to perceive and interpret the surroundings with remarkable accuracy. These ships are equipped with advanced AI algorithms that enable real-time data analysis, intelligent decision-making, and autonomous environmental adaptation.[12] Following multiple attempts to provide a comprehensive definition, the IMO now defines MASS as a vessel that can function with varying degrees of autonomy from human intervention.[13]

- **First degree:** Manned ships utilize decision support and autonomy processes, with seafarers to operate vessel systems. Several operations, such as autopilot, may be automated, but the crew can assume control at any moment. (Fig.1)

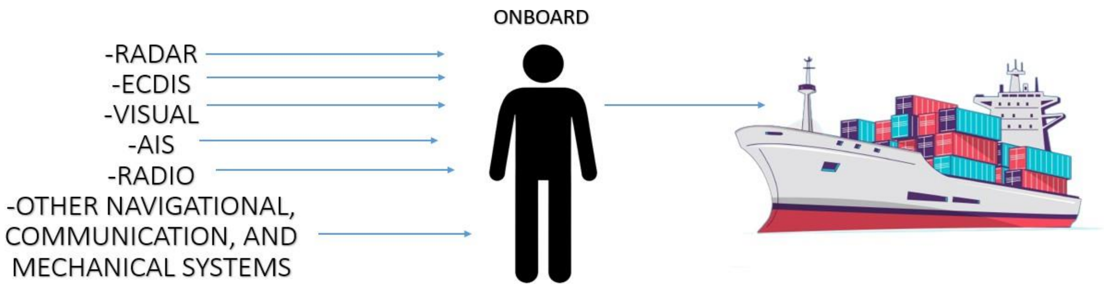

Figure 1

[10] UNCTAD: "Transport Newsletter, Article No. 97, Fourth Quarter 2022", in UNCTAD Transport Newsletter, <https://unctad.org/news/transport-newsletter-article-no-97-fourth-quarter-2022> (Accessed on 15.02.2023).
[11] Ventikos N. P., Chmurski A., Louzis K.: "A systems-based application for autonomous vessels safety: Hazard identification as a function of increasing autonomy levels", in 131 Safety Science 2020, <https://doi.org/10.1016/j.ssci.2020.104919> (Accessed on 28.10.2023).
[12] Pavlo S., Petrenko S., Kolisnyk M., Pashko S., Honchar V.: "Cybersecurity risks for autonomous shipping: The methods of attacks on a vessel", in 2020 IEEE Problems of Automated Electrodrive. Theory and Practice (PAEP), <https://ieeexplore.ieee.org/abstract/document/9207841> (Accessed on 28.10.2023).
[13] MSC.1/Circ.1638 Annex, p. 3.

- **Second degree:** The ship is remotely operated and has seafarers. Typically, the vessel is managed from an onshore position. In the event of an emergency, seafarers are on board and prepared to assume command and manage the ship's systems.(Fig.2)

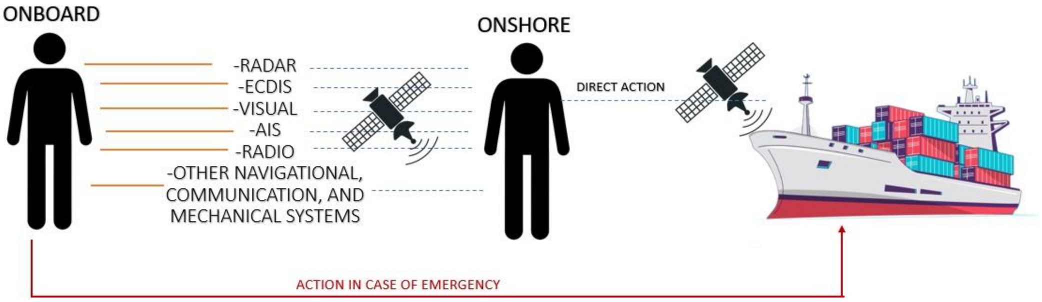

Figure 2

- **Third degree:** Vessel controlled remotely with no seafarers. The vessel is operated onshore. (Fig.3)[14]

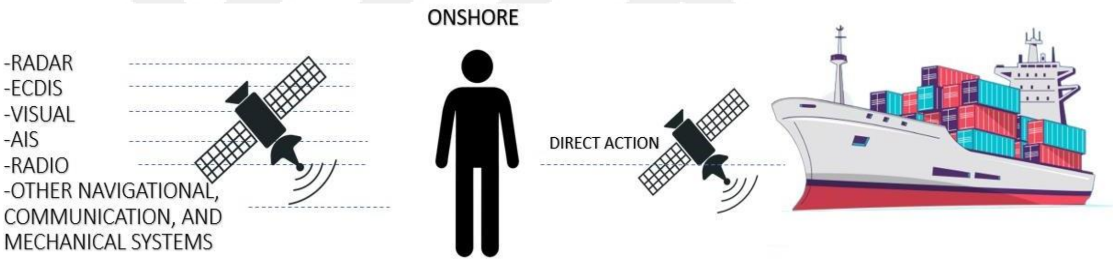

Figure 3

- **Fourth degree:** Fully autonomous ship. The operating system of the vessel can make independent decisions and take actions. While in port areas, it may be controlled remotely from any offshore station. (Fig.4)

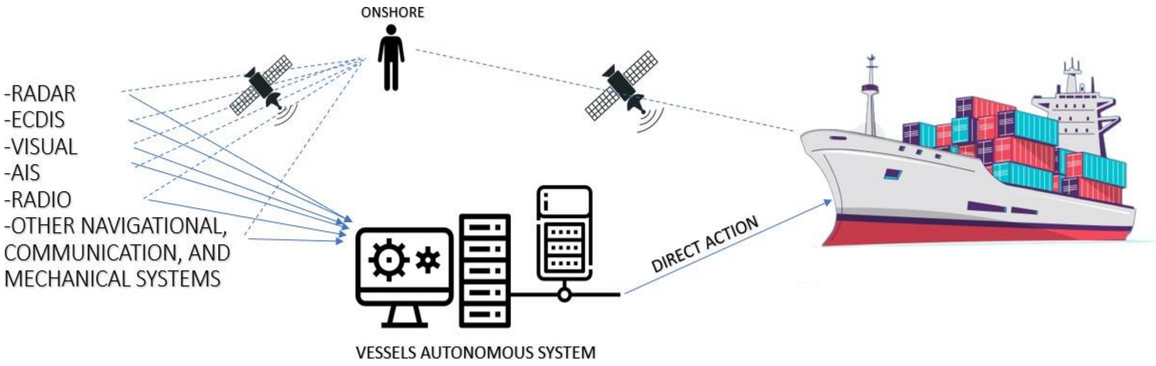

Figure 4

[14] UNCTAD: "Transport Newsletter, Article No. 97, Fourth Quarter 2022", in UNCTAD Transport Newsletter, <https://unctad.org/news/transport-newsletter-article-no-97-fourth-quarter-2022> (Accessed on 15.02.2023).

1) First Autonomous Vessels

Yara Birkeland (Fig.5) is an autonomous, electric-powered container ship developed by Yara International ASA, a Norwegian chemical company, in collaboration with Kongsberg Gruppen and SINTEF. The *MV Yara Birkeland* is a remarkable cargo vessel that stands out for being the world's first autonomous cargo ship. At 80 meters, it transports fertilizer between the ports of Herøya and Brevik in Norway. The ship was designed to be fully autonomous, and able to perform a wide range of tasks, from industrial operations to port navigation, making it a proof of concept for autonomous shipping.[15]

The primary objective behind *Yara Birkeland* was to create a more sustainable and efficient transportation mode. It aimed to reduce emissions, improve safety, and optimise logistics by eliminating the need for traditional fuel-powered ships and human crew. MUNIN, which stands for “Maritime Unmanned Navigation through Intelligence in Networks,” is another project under the MASS (Maritime Autonomous Surface Ships) initiative. This research initiative is co-funded by the European Commission. The main goal of the project is to develop and test a concept for an autonomous ship. This type of vessel is primarily guided by automated onboard decision-making systems, while a remote operator in a shoreside control station manages its operations.[16]

On the other side of the planet, Japan is a strong pioneer in the MASS revolution. Ever since 2020, the “Nippon Foundation” has been working on the “MEGURI 2040” program that seeks to create autonomous marine navigation technology. The program's first milestone was achieved when on January 17, 2022, the Japanese Ferry *Soleil* (Fig.6) successfully completed a fully autonomous voyage, including departure from and entry to the dock. In seven hours, the Soleil covered 240 kilometers between the ports of Shinmoji and Iyonada. Additionally, the world's first autonomous container ship debuted on January 24 and 25. The ship, named Mikage (Fig.7), is located 300 kilometers from the ports of Sakai in Tottori Prefecture and Tsuruga in Fukui Prefecture, Japan.[17]

On the other hand, coastguards are exploring the potential applications of autonomous vessels to enhance their maritime operations. The United States Coast Guard (USCG) has been investing in research and development to explore the feasibility and advantages of incorporating

[15] Julian Buckley, ‘Yara Birkeland electric container ship starts commercial operations’, (Accessed on 11.10.2023).
[16] MUNIN, ‘The Autonomous Ship’,(Accessed on 12..10.2023).
[17] Sym-NAVAL: "Autonomous Vessels in Japan: Sea Trials and Future Prospects", Sym-NAVAL Blog, <https://sym-naval.com/blog/autonomous-vessels-japan/#:~:text=The%20first%20result%20has%20been,and%20Iyonada%20in%20seven%20hours>, (Accessed on 21.10.2023).

autonomous vessels into its fleet. This includes collaboration with industry partners, academia, and government agencies to advance autonomous maritime technologies. In 2020, USCG ordered an autonomous test vessel from “Sharktech" (Fig.8), Metal Shark, a shipbuilder based in Louisiana, has partnered with Sea Machines, an autonomous technology developer located in Boston. The small patrol vessel can have collaborative autonomy, transit autonomy, collision avoidance, remote-control vessel monitoring and, active ride controlSince that time, the RDC has engaged in ongoing development efforts aimed at developing a thorough operational plan for incorporating uncrewed surface ships into Coast Guard operations.

Figure 5[18]

[18] Yara International: "Yara Birkeland: Two Years On", Yara International, <https://www.yara.com/knowledge-grows/yara-birkeland-two-years-on/>,(Accessed on 25.06.2024).

Figure 6[19]

Figure 7[20]

Figure 8[21]

[19] Nippon Foundation: "MEGURI 2040: The Autonomous Ship Project", The Nippon Foundation, <https://www.nippon-foundation.or.jp/en/what/projects/meguri2040>,(Accessed on 18.08.2023).
[20] Maritime Executive: "Japan Demonstrates Long-Distance Autonomous Ship Operations", The Maritime Executive, <https://maritime-executive.com/article/japan-demonstrates-long-distance-autonomous-ship-operations>, (Accessed on 15.08.2023).
[21] O'Dwyer, R., *US Coast Guard to evaluate autonomous vessel technologies*. Smart Maritime Network. Retrieved from <https://smartmaritimenetwork.com/2020/09/29/us-coast-guard-to-evaluate-autonomous-vessel-technologies/>,(29.09.2020).

2) Navigation Via Sensors

The navigation methods for future autonomous vessels can be described in numerous ways. One compelling way to characterize the operation is:

"The captain with a giant screen that overlays the environment around the vessel with an augmented reality view can navigate confidently using the onboard computer-enhanced vision of the world, with artificial intelligence spotting and labelling every water user, the shore, and the navigation markers."[22]

The idea can be broadened to describe a completely autonomous vessel simply by substituting the captain and crew with a machine.[23] Several sensors and systems are working together to create different methods of monitoring and navigation.

One of the most common applications is multi-sensor fusion. Autonomous vessels often employ multi-sensor fusion techniques to combine data from different sensors, enhancing perception and reliability. By integrating information from multiple sources, such as radar, LiDAR (Fig.9), and high-resolution cameras, the vessel can generate a more comprehensive and accurate representation of its surroundings.[24] Multi-sensor fusion also enables redundancy and fault tolerance, ensuring robust navigation performance even in challenging conditions or in case of sensor failures.[25]

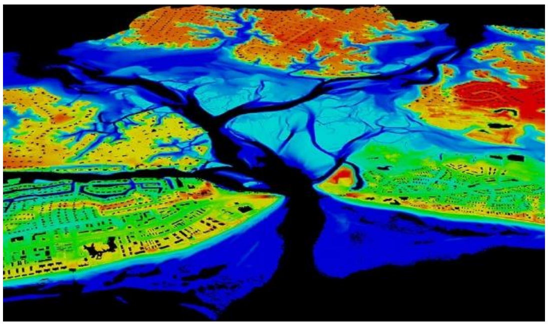

Figure 9[26]

[22] Wright, R. G.(ed. 1): Unmanned and Autonomous Ships, Ch.12, New York, 2020.
[23] Pastra, A.\ Dalaklis, D. \Skinner, J. A. \ Fernandez, J. E.z Johansson T. M.: *Autonomous Vessels in Maritime Affairs*, Ch.5, United Kingdom 2023.
[24] Dubois A.S..: "Lidar Solutions for the Shipping Industry", Insights, 2023,< https://insights.outsight.ai/lidar-solutions-for-the-shipping-industry>, (28.09.2022).
[25] Zhang Q.\ Shan Y.: "Multisensor fusion-based maritime ship object detection method for autonomous surface vehicles", Wiley Online Library 2023, <https://doi.org/10.1002/rob.22273> (28.11.2023).
[26] Scoot G.: "Lidar: Light Detection and Ranging", National Ocean Service, 2023, <https://oceanservice.noaa.gov/geodesy/lidar.html#:~:text=Lidar%2C%20short%20for%20light%20detection,to%20the%20surface%20and%20back.>

Furthermore, real-time environment monitoring is a real-time and continuous process, providing up-to-date information for navigation decision-making. Real-time data processing algorithms analyze sensor inputs and dynamically adapt the vessel's trajectory and behaviour to changing conditions, such as the presence of obstacles, weather changes, or traffic congestion. This adaptive navigation capability enables autonomous vessels to respond promptly to emerging situations and navigate safely in dynamic maritime environments.[27]

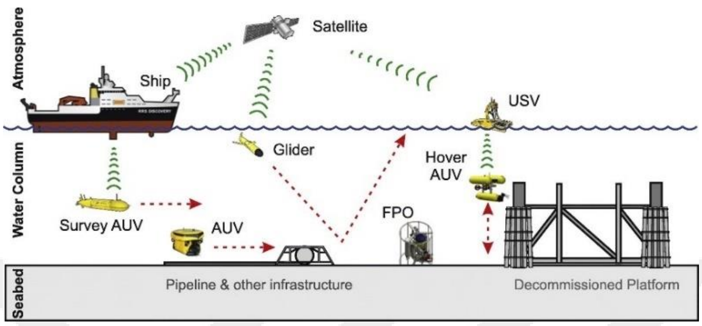

Figure 10[28]

Obstacle Detection and Collision Avoidance is one of the primary functions of navigation sensors on autonomous vessels. Numerous types of sensors such as radar, LiDAR, and cameras are equipped to detect and track objects in the vicinity, including other vessels, floating debris, and navigational hazards. Once detected, the system will automatically and safely adjust the speed and/or route of the vessel to maintain an appropriate operational distance while adhering to relevant COLREG responses.[29]

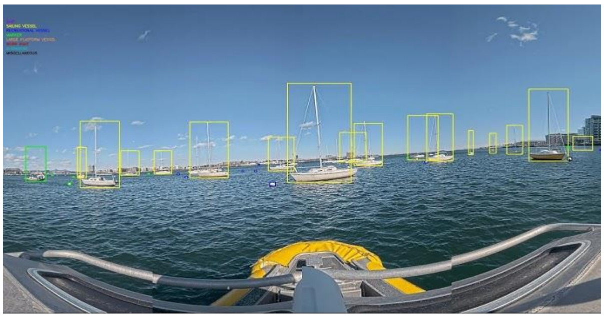

Figure 11[30]

(Accessed on 05.09.2023).

[27] Jones D. O.B. / Gates A. R.: "Autonomous marine environmental monitoring: Application in decommissioned oil fields", *Science of The Total Environment*, vol. 668, pg. 840, <https://doi.org/10.1016/j.scitotenv.2019.02.310>, (10.07.2019).

[28] Jones D. O.B. / Gates A. R.: "Autonomous marine environmental monitoring: Application in decommissioned oil fields", *Science of The Total Environment*, vol. 668, pg. 835, <https://doi.org/10.1016/j.scitotenv.2019.02.310>, (10.07.2019).(**A graphical abstract showing how an autonomous real-time environment monitoring system assists in the Oil and gas industry procedures)*.

[29] Sea Machines: "Collision and Obstacle Avoidance Solutions", *Sea Machines*, <https://sea-machines.com/why-sea-machines/solutions/collision-obstacle-avoidance>, (Accessed on 23.04.2023).

[30] Sea Machines: "Top 8 Capabilities Sea Machines Adds to Commercial Surface Vessels", Sea Machines, <https://sea-machines.com/top-8-capabilities-sea-machines-adds-to-commercial-surface-vessels/>, (Accessed on 24.02.2023).

Collision avoidance algorithms use this information to assess potential collision risks, calculate safe trajectories, and execute evasive manoeuvres if necessary to avoid accidents and ensure safe passage.[31] Autonomous Port Operations where autonomous vessels utilise navigation sensors for efficient and safe port operations, including docking, berthing, and cargo handling. Sensors such as cameras and LiDAR enable precise positioning and alignment with port infrastructure, such as quay walls, mooring buoys, and loading/unloading facilities. Autonomous port operations enhance operational efficiency, reduce turnaround times, and minimise the risk of accidents.[32]

Figure 12[33]

Figure 13[34]

Adaptive Route Planning where autonomous vessels leverage navigation sensors and real-time environmental data to optimize route planning and navigation strategy. Advanced route planning algorithms consider factors such as sea conditions, traffic density, fuel efficiency, and regulatory constraints to determine the most efficient and safe route from origin to destination.[35] Autonomous vessels can optimise performance, minimise voyage duration, and reduce fuel consumption and emissions by continuously monitoring and updating route plans based on changing conditions.[36]

In summary, navigation sensors are essential components of autonomous vessels, enabling them to perceive and interpret their environment, make informed navigation decisions, and navigate safely and efficiently in diverse maritime conditions. Continuous advancements in sensor technology, data processing algorithms, and autonomous navigation systems are driving further

[31] Wang Ch. / Zhang X.: "Collision avoidance for an autonomous ship using deep reinforcement learning and prior-knowledge-based approximate representation", *Frontiers in Marine Science*, <https://doi.org/10.3389/fmars.2022.1084763>, (19.01.2023).
[32] Behdani B.: "Port 4.0: a conceptual model for smart port digitalisation", *Science Direct*, <https://doi.org/10.1016/j.trpro.2023.11.154> (03.01.2024).
[33] Safety4Sea: "Automated mooring system reduces fuel consumption at Port of Helsinki", *Safety4Sea*, (Accessed on 21.07.2023).
[34] Chambers S.: "Cosco gives a glimpse of China's future smart ports", *Splash247* (Accessed on 12.05.2023).
[35] Anghelache F.: "iRoute—An Adaptive Route Planning Solution for Commercial Vehicle Fleets", *MDPI*, 13, 11517 <https://doi.org/10.3390/app132011517>, (20.10.2023).
[36] Kim S. / Yun S.: "Eco-Friendly Speed Control Algorithm Development for Autonomous Vessel Route Planning", *J. Mar. Sci. Eng. 2021*, 9(6), 583, <https://doi.org/10.3390/jmse9060583> (28.05.2021).

improvements in the navigation capabilities of autonomous vessels, paving the way for increased adoption and integration into the maritime transportation industry.

B) ADVANTAGES OF MASS

According to a study conducted by Allianz Global Corporate & Specialty (AGCS), the majority of marine accidents, ranging from 75% to 96%, are linked to human error. Furthermore, between 2011 and 2016, AGCS's overview of approximately 15,000 marine liability insurance claims revealed that human error played a significant role in 75% of the claims, amounting to around $1.8 billion in losses.[37]

1) Human Error

"*We now have a generation of seafarers that have grown up trusting what they see on a screen. However, they can be lulled into a false sense of security without appropriate training. This is a serious problem that we see in repeated cases. People believe that technology makes them safer, but they do not allow for the human element and the need for training – ensuring crews have a solid background in the fundamentals of sound navigation and situational awareness*."[38]

[Captain Andrew Kinsey]

According to the chart of "European Maritime Safety Agency", based on the analysis of safety investigations, it was found that between 2014 and 2022, human behaviour accounted for 50.1% of contributing causes and 59.1% of accident incidents involving human activity. When human behaviour and action events are examined together, the human element accounts for 80.7% of the looked into occurrences and casualties involving marines. These patterns are prevalent in all ship types.[39] New ships have more auto-control options, which makes the job easier for the crew. Due to the high total reliability of automated test results and the consequent reduction in security inspections, crew members become distracted by other activities, such as using phones or taking naps, a common outcome of maritime accidents.

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[37] Dobie G.: "Safety and Shipping Review 2018", *Allianz Global Corporate & Specialty*, pg.7 <https://www.allianz.com/content/dam/onemarketing/azcom/Allianz_com/migration/media/press/document/AGCS-Safety-Shipping-Review-report-2018.pdf>, (Accessed on 12.10.2023).

[38] Allianz Global Corporate & Specialty: "Human Error and Shipping Safety", *Allianz*,< https://commercial.allianz.com/news-and-insights/expert-risk-articles/human-error-shipping-safety.html>, (Accessed on 12.07.2023).

[39] European Maritime Safety Agency: "Annual Overview of Marine Casualties and Incidents 2023", *EMSA*, <https://www.emsa.europa.eu/component/flexicontent/download/7639/2713/23.html>, p.9, p.9, (Accessed on 15.11.2023).

According to the “United Nations Conference on Trade and Development” (UNCTAD) report of 2020, the commercial fleet worldwide consists of 98,140 vessels with a GT over 100 tons.[40] Gas carriers, bulk carriers, oil tankers, and container ships have seen a significant increase in numbers in the year 2020. However, despite technological advancements, processes, procedures, and regulations, 193 ships over 100 GT have been lost over three years from 2017. The primary causes of these losses were grounding (15%), sinking (62%), machinery damage/failure (6%), and fire/explosion (10%). The size of the ship and the type of cargo significantly affect the severity and consequences of a maritime accident. Crude oil made up roughly 17–20% of all seaborne cargo loaded each year between 2010 and 2019, with an average transportation volume of over 1,800 million metric tons.[41] The growing size of ships and their cargo types can affect safety, fire prevention measures, and salvage operations in the event of an accident.. The case of the *Ever-Given* ship stuck in the Suez Canal is a prime example of the challenges posed by larger vessels.[42]

On October 7, 2018, the ro-ro vessel Ulysee collided with the CSL Virginia, which was anchored approximately 17 miles from the island of Corsica. About 500 cubic meters of heavy fuel oil leaked due to Ulysse's bow deeply breaching the container ship's hull during the collision. The estimated cost of the vessel damage was 13.5 million euros, in addition to the estimated 10 million euros in cleanup expenses. According to the investigation, this accident was due to human error; the on-duty officer was preoccupied with a phone.[43]

On 13 January 2012, shortly after leaving Civitavecchia, *Costa Concordia*, a cruise ship, capsized off the coast of Rome. The Concordia diverted from its intended path as it approached Giglio Island in preparation for a maritime "salute." Schettino, a captain with over several years of experience, ordered a change of course. Language issues, however, caused the Indonesian helmsman to maneuver the boat in the wrong direction. The correction of the move took 13 seconds. When the stern struck the reef, the Concordia's port (left) side sustained a 53-meter tear,

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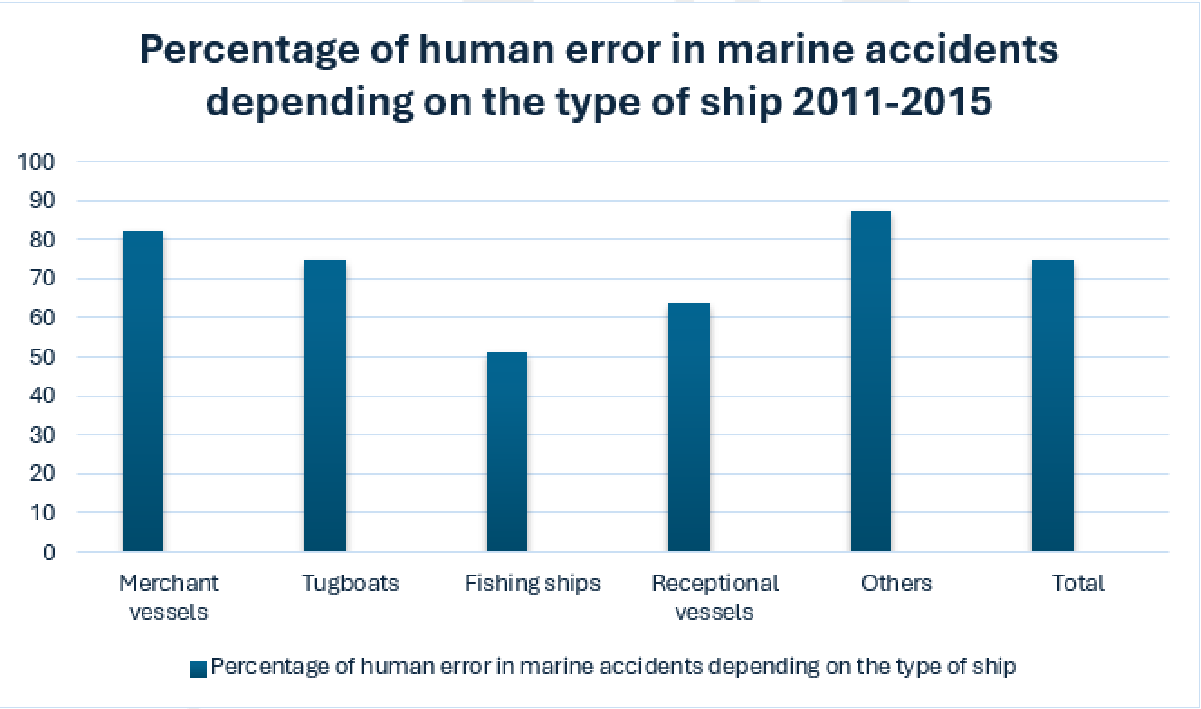
[40] United Nations Conference on Trade and Development: "Maritime Transport and the COVID-19 Pandemic”, *UNCTAD*, <https://unctad.org/system/files/official-document/tdstat46_FS14_en.pdf >, p.3, tab 1 (Accessed on 09.12.2023).
[41]United Nations Conference on Trade and Development: "Review of Maritime Transport 2022”, UNCTAD, <https://unctad.org/system/files/official-document/rmt2022_en.pdf>, p.4, tab. 1.2 (Accessed on 26.10.2023).
[42] Santos, M. / Silva, R.: "Reducing Maritime Accidents in Ships by Tackling Human Error: A Bibliometric Review and Research Agenda”, ResearchGate, 6:20, <https://www.researchgate.net/publication/356503593_Reducing_maritime_accidents_in_ships_by_tackling_human_error_a_bibliometric_review_and_research_agenda>, p.3, p.3, (20.11.2021).
[43] Schuler, M.: "Human Error ID'd in Mediterranean Ro-Ro's Collision with Containership”, *gCaptain*,<https://gcaptain.com/human-error-idd-in-mediterranean-ro-ros-collision-with-containership> (Accessed on 20.10.2023).

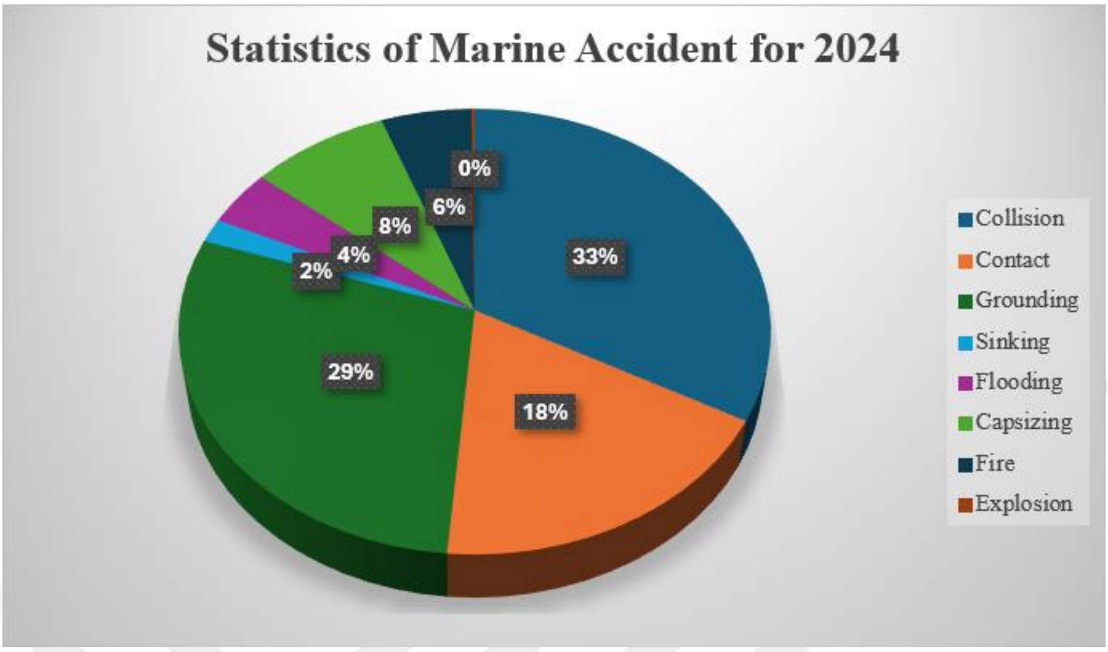
but the bow eventually swung free. Captain Schettino was found guilty and sentenced to sixteen years on February 11, 2015. The total loss paid by the insurance industry due to the *Costa Concordia's* wreck and salvage is $2 billion, not considering the $800 million for scrapping it.[44]

Upon examining various instances from the past, it has become evident that human error is a determining factor in numerous maritime accidents. However, by implementing the use of autonomous vessels, the likelihood of this error occurring can be significantly reduced to the point where it is no longer a significant concern. The implementation of MASS allows advanced technology to operate the vessel, significantly minimizing human error risks. This will result in safer and more efficient maritime transport, with a lower risk of accidents and incidents occurring due to human error.

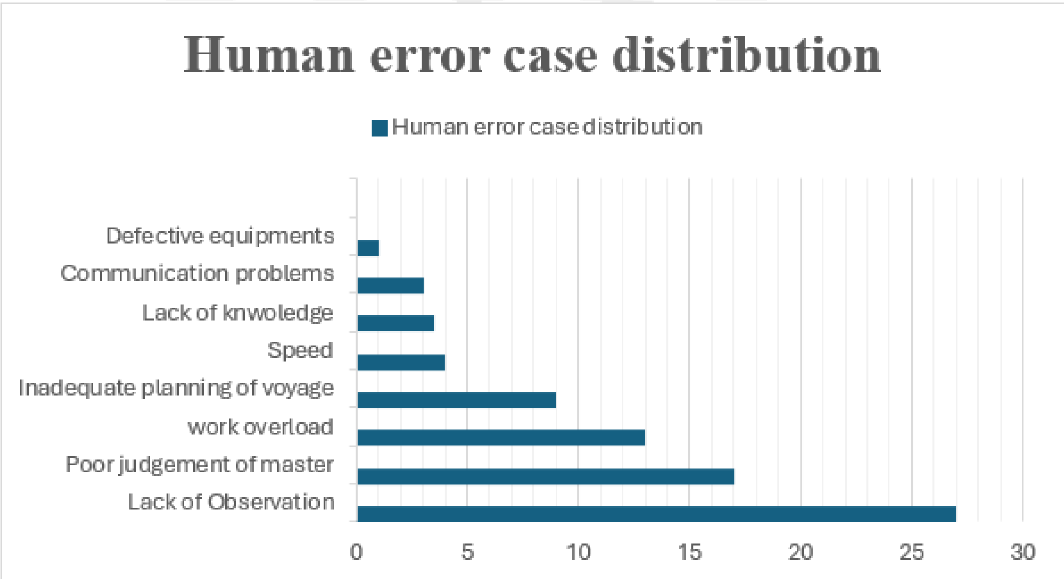


Graph 1.[45]

[44] Little, B.: "*Costa Concordia* Disaster: The Sinking of the Cruise Ship and Its Aftermath", *History*, https://www.history.com/news/costa-concordia-cruise-ship-disaster-sinking-captain (Accessed on 10.12.2023).
[45] Wang, J. / Zheng, L.: "Research on the Development and Application of Autonomous Ships", *Maritime Transport Research*, Vol. 2, 2021,< https://doi.org/10.1016/j.martra.2021.100016>, ch. Data and analysis (Accessed on 29.11.2023).



Graph 2.[46]



Graph 3.[47]

2) Fuel Consumption and Emission of CO_2

Shipping is responsible for roughly 3% of the global emission of CO_2.[48] Vessels like *MV Yara*

[46] Ministry of Land, Infrastructure, Transport and Tourism: "Maritime Accident Statistics", *Japan Transport Safety Board*, <https://www.mlit.go.jp/jtsb/statistics_mar.html> (Accessed on 23.10.2023).
[47] Kim, H. / Goh, M.: "A Study of Human Error Factors on Maritime Accident Rates in the Maritime Industry", *ResearchGate*, Asian Academy of Management Journal 24(Supp. 2):17-32, (Accessed on 21.10.2023).

[48] Kaminski I.: "Climate impact of shipping under growing scrutiny ahead of key meeting", *The Guardian*, par.3 (Accessed on 20.04.2024).

Birkeland, a fully electric vessel with zero-emission, have a tremendous environmental impact and play a significant role in the race for energy efficiency. Furthermore, a crewless vessel does not need food; therefore, no food waste exists, and no grey or black water is there to damage the environment. Being the headline of the last decades, the war against greenhouse gases will be "supported" by MASS.

3) Lower Operation and Managing Costs

According to Jr Shipping, the monthly cost for a crew of ten is 48.900 €.[49] This sum does not include the insurance cost for the crew, food, and other fees, which increase the total by several thousand Euros. The costs of salaries, crew rooms, cargo space increase, food, water, lighting, plumbing, and other necessities for seafarers, and human support can range from 30% to 44% of the total cost of a ship. This will have a positive effect on ship owners and investors in the shipping industry.[50]

Due to the operation without personnel, the vessels will be flexible and fully operationality 24/7, even in harsh and dangerous weather conditions. Although the ability to access areas is limited by humans, such as polar regions, it is worth mentioning as having positive effects on future expeditions in such areas.

4) Piracy

According to Statista, in 2010, there were 445 pirate attacks against ships worldwide.[51] In the unfortunate event of piracy, the crew members of a ship are often the prime targets of criminals. They are taken hostage and held captive until the shipowner agrees to pay a hefty amount of ransom money. This act of piracy threatens seafarers' safety and puts a significant financial burden on the shipowner. Sadly, this has become a common occurrence in many parts of the world, where pirates take advantage of vulnerable ships and their crews for financial gain. During 2018 a marked increase in attacks compared to the past few years was indicated.[52] Autonomous shipbuilding companies have reported that it is significantly more challenging for pirates to board and infiltrate MASS vessels when compared to traditional ships. The structure of MASS ships has been designed to be more secure, with advanced technology and

[49] Kooij C. / Hekkenberg H.: "Identification of a task-based implementation path for unmanned autonomous ships", *Maritime Policy & Management*, 49:7, p.959, (10.05.2021).
[50] Stephens M.: "OpCost 2018: Annual Ship Operating Cost Benchmarking Report", *Opcost*, <https://safety4sea.com/wp-content/uploads/2018/10/Moore-Stephens-Future-operating-costs-report-2018_10.pdf>, p.4, (Accessed on 12.12.2023).
[51] Statista Research Department: "Number of worldwide pirate attacks from 2006 to 2022", *Statista*, https://www.statista.com/statistics/266292/number-of-pirate-attacks-worldwide-since-2006/ (Accessed on 05.06.2023).
[52] Thibaut, E.: "Examining Autonomous Ships' Vulnerability to Piracy", The Maritime Executive, <https://maritime-executive.com/blog/examining-autonomous-ships-vulnerability-to-piracy> (Accessed on 14.09.2024).

autonomous features that improve the ship's safety and security.[53] These features include various sensors and cameras that detect and identify potential threats, such as unauthorised individuals attempting to board the ship. MASS's advanced structure and security measures make them an effective solution for preventing piracy and ensuring safe maritime transportation.

C) DISADVANTAGES OF MASS

Although autonomous vessels present a range of compelling benefits, they also bring forth several significant challenges. These issues include complex technological requirements, regulatory hurdles, and concerns about safety and cybersecurity. As the marine industry navigates this new frontier, it's essential to carefully consider both the opportunities and potential obstacles accompanying adopting these innovative ships.

1) Regulatory and Legal Challenges

The regulatory framework for autonomous ships is still evolving, and many legal issues, including liability, insurance, and compliance with international maritime laws and regulations, must be considered. Establishing clear guidelines and standards for the operation of MASS may take time. IMO and its instruments are actively developing a Code that will help adapt autonomous vessels to the laws of the sea.[54]

2) Cybersecurity Risks

Autonomous ships rely heavily on technology, including sensors, communication systems, and control algorithms. This reliance on technology makes them vulnerable to cyber threats, such as hacking, malware, and system failures, which could compromise their safety and security.[55]

3) Limited Infrastructure

[53] Levander, O.: “Autonomous ships on the high seas.” *IEEE Spectrum*, 54. 26-31. 10.1109/MSPEC.2017.7833502. (Accessed on 10.02.2024).
[54] IMO: "Regulatory Scoping Exercise Completed for Autonomous Ships”, *IMO Press Briefings,* <https://www.imo.org/en/MediaCentre/PressBriefings/pages/MASSRSE2021.aspx> (Accessed on 05.06.2024).

[55] Lund, J. / Toudal, J.: "Cybersecurity Considerations in Autonomous Ships”, NATO Cooperative Cyber Defence Centre of Excellence, <https://ccdcoe.org/uploads/2022/09/Cybersecurity_Considerations_in_Autonomous_Ships.pdf>, p.14 ch.4 (Accessed on 04.12.2023).

The widespread adoption of autonomous ships will require significant infrastructure upgrades, such as improved communication networks, shore-based support systems, and autonomous ports. Developing this infrastructure will require substantial investments and coordination among stakeholders.

4) Technological Limitations

Despite all advances in technology, there are still limitations to the capabilities of autonomous systems, particularly in complex and dynamic maritime environments. Challenges such as adverse weather conditions, congested waterways, and interactions with other vessels pose significant obstacles to the safe and reliable operation of MASS.[56]

5) Human Factors

Unlike traditional ships where experienced captains and crew can navigate unforeseen circumstances, autonomous vessels lack the intuition, adaptability, and decision-making capabilities inherent to human presence. While autonomous systems excel in following predetermined routes and protocols, they may struggle to respond effectively to complex or unpredictable situations at sea, such as sudden weather changes, maritime emergencies, or interactions with other vessels that require nuanced judgment and communication. This limitation underscores the importance of integrating advanced artificial intelligence with human oversight to ensure safety and efficiency in maritime operations.[57]

6) Public Acceptance

The public and stakeholders in the maritime industry may be hesitant to trust MASS due to concerns about safety, job displacement, and the impact on traditional maritime practices. Building trust and acceptance will require effective communication, transparency, and demonstration of the benefits of MASS.

7) Job Displacement

[56]Mallam, S.C. / Nazir, S.: "Identifying Maritime Autonomous Surface Ship (MASS) Risks and the Implications for Maritime Education and Training", *WMU Journal of Maritime Affairs*, https://link.springer.com/article/10.1007/s13437-022-00277-z (Accessed on 12.04.2024).
[57] Zhu, T. / Haugen, S.: 'Human Factor Challenges and Possible Solutions for the Operation of Highly Autonomous Ships', p.149, ch.3 (30.05.2022).

The automation of maritime operations raises concerns about job displacement within the maritime industry. As autonomous vessels require fewer crew members or may operate entirely unmanned, there is a risk of job losses for sailors, ship operators, and other maritime professionals, potentially leading to socio-economic challenges in maritime-dependent communities.[58]

Overall, while autonomous ships offer significant potential benefits, addressing the challenges and disadvantages associated with their adoption will require collaboration among governments, industry stakeholders, and all regulatory bodies to ensure their safe and responsible integration into the maritime transportation system.

[58] Babb, P.: "Autonomous Ships: Is It the End Game for Seafarers?" *Uniteam Marine*, <https://www.uniteammarine.com/autonomous-ships-is-it-the-end-game-for-seafarers/> (Accessed on 09.10.2023).

II. LEGAL INSTRUMENTS AND MASS

A) THE APPLICATION OF UNCLOS ON MASS

“The United Nations Convention on the Law of the Sea” (UNCLOS)[59] is a thorough international agreement that regulates countries' rights and obligations when using the world's seas. All usage of the oceans and their resources are governed by UNCLOS, which establishes a comprehensive framework of law and order throughout all oceans and seas worldwide. It indicates the notion that all ocean-related problems are related to one another and must be handled as a single issue.[60]

On December 10, 1982, UNCLOS was officially made ready for signature at Montego Bay, Jamaica. With the involvement of more than 150 nations from various worldwide areas, political and legal histories, and economic development levels, this event marked the end of more than 14 years of negotiations. At the time, the Convention consolidated traditional ocean-use regulations in one treaty, presenting several legal frameworks and addressing emerging concerns in ocean governance. It also set a foundation for further advancements in specific areas of maritime law.[61]

UNCLOS officially came into effect on November 16, 1994, as outlined in Article 308, one year after the 60th ratification or accession was deposited. Nowadays, it is the internationally recognized framework for aspects of maritime law. Comprising 320 articles and nine annexes, UNCLOS addresses the regulation of ocean spaces, covering issues like environmental protection, boundary delimitation, marine scientific research, economic activities, dispute resolution and technology transfer.[62]

While UNCLOS does not specifically address autonomous vessels, the principles and regulations outlined in the convention can have implications for the operation of autonomous vessels in several key areas. Both the terms “ship” and “vessel” are used all through UNCLOS, and they have the same meaning.[63] The convention does not define these terms, even though reliance on

[59] United Nations Treaty Collection, “United Nations Convention on the Law of the Sea” (UNCLOS) 1982, https://treaties.un.org/pages/ViewDetailsIII.aspx?src=TREATY&mtdsg_no=XXI-6&chapter=21&Temp=mtdsg3&clang=_en, (Accessed on 13.10.2023).
[60] United Nations: "The United Nations Convention on the Law of the Sea: A Historical Perspective”, *United Nations, Originally prepared for the International Year of the Ocean, 1998* <https://www.un.org/depts/los/convention_agreements/convention_historical_perspective.htm>, (Accessed on 13.10.2023).
[61] United Nations: "Overview - Convention on the Law of the Sea”, *United Nations*, <https://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm> (Accessed on 13.10.2023).
[62] Same as footnote 59. United Nations: "The United Nations Convention on the Law of the Sea: A Historical Perspective”, *United Nations, Originally prepared for the International Year of the Ocean, 1998* <https://www.un.org/depts/los/convention_agreements/convention_historical_perspective.htm>, (Accessed on 13.10.2023).
[63] Chircop, A.: "Maritime Autonomous Surface Ships (MASS) and the Law of the Sea”, *International Maritime Organization*, <https://wwwcdn.imo.org/localresources/en/OurWork/Safety/PublishingImages/Pages/MASS/01_Aldo%20Chircop_MASS%20and%20the%20Law%20of

definitions is generally accepted by international rules applied by IMO under UNCLOS is sufficient. UNCLOS and IMO are both integral to international maritime governance, but they play complementary roles. The IMO develops particular rules and standards about environmental protection, marine safety, and the operational aspects of shipping, while UNCLOS defines the general legal framework describing the rights, obligations, and borders of nations in maritime zones.[64][65]

Like conventional vessels, MASS has to be registered with a flag State, which assumes jurisdiction over the vessel and ensures it complies with applicable laws. Under Art. 91 from UNCLOS, vessels are required to operate under the flag of only one state, which establishes the vessel's nationality and subjects it to the responsibility of that flag State.[66] MASS must adhere to this requirement, registering with a flag State and displaying the flag while operating at sea. For MASS, the flag State must make sure that appropriate regulations are in place to govern the operation of autonomous systems, including navigation, collision avoidance, cybersecurity, and emergency response. This may involve developing specific guidelines or standards for autonomous vessels and verifying compliance through inspections and audits.

Art. 94 from the UNCLOS outlines the flag State's duties concerning enforcing laws and rules on vessels flying its flag. Every state is obligated to;

> *"…(a)assume jurisdiction under its internal law over each ship flying its flag and its master, officers, and crew in respect of administrative, technical, and social matters concerning the ship".* [67]

As mentioned, the jurisdictions of the state stans upon the ship's master and the crew, which has yet not been clarified in terms of MASS. Furthermore

> *"…(b) that each ship is in the charge of a master and officers who possess appropriate qualifications, in particular in seamanship, navigation, communications, and marine engineering, and that"* [68]

The qualifications and numbers of the crew are suitable for the ship's size, type, machinery, and equipment;

%20the%20Sea.pdf> (06.09.2022).

[64] Captain Norris, A.: "Legal Issues Relating to Unmanned Maritime Systems Monograph", *IQPC* ,p.24, p.4 (24.12.2023).

[65] Beckman, R. / Sun, S.: "The Relationship Between UNCLOS and IMO Instruments", *Asia-Pacific Journal of Ocean Law and Policy*, 2(2), 201-246. <https://doi.org/10.1163/24519391-00202003>, (Accessed on 09.04.2024).

[66] UNCLOS, Art. 91(1).

[67] UNCLOS, Art.94(2.a).

[68] UNCLOS, Art.94(2.b).

"...(b)that the master, officers, and, to the extent appropriate, the crew are fully conversant with and required to observe the applicable international regulations concerning the safety of life at sea, the prevention of collisions, the prevention, reduction, and control of marine pollution, and the maintenance of communications by radio"

Art. 94 of UNCLOS, states that "the flag State ensures that vessels flying its flag comply with applicable laws and regulations."[69] This includes liability for any violations of international law, accidents, or environmental damage caused by the vessel. Determining liability and accountability for autonomous vessels may pose unique challenges, particularly in cases where accidents or incidents are caused by failures in autonomous systems or human-machine interactions.[70] Flag States must establish mechanisms for investigating accidents, apportioning liability, and providing compensation for damages following international law.

Moreover, Art. 98 outlines all States' duty to assist anyone in danger or distress at sea. This obligation is essential to guarantee the security and welfare of people at sea and applies to all vessels, including MASS.

"Every State shall require the master of a ship flying its flag, in so far as he can do so without serious danger to the ship, the crew or the passengers;

… (a) to render assistance to any person found at sea in danger of being lost …" [71]

Autonomous vessels equipped with enhanced sensors and communication systems have the potential to detect distress situations at sea, such as a vessel in distress, a person overboard, or a maritime accident. These vessels may utilize radar, sonar, AIS (Automatic Identification System), cameras, and other sensors to monitor their surroundings and identify distress signals or indicators. Autonomous systems can analyze sensor data and recognise patterns associated with distress situations, alerting the vessel's operators or initiating an automated response.[72]
In a distress situation, autonomous vessels must be capable of communicating with nearby vessels and coastal authorities to request assistance and coordinate rescue operations. Autonomous communication systems, including VHF radios, satellite communication, and AIS, enable vessels to transmit distress signals, relay information about the situation, and receive instructions or

[69] UNCLOS, Art. 94(4).
[70] Petrig, A.: "Unmanned Vessels as a Multi-Dimensional Concept Ship Under UNCLOS 1982", in *The United Nations Convention on the Law of the Sea*, 1st edition, p.58, 2023.
[71] UNCLOS, Art. 98.
[72] DNV: "Setting the Standards for the Future of Shipping: DNV GL Releases Autonomous and Remotely Operated Ship Guideline", *DNV*, <https://www.dnv.com/news/setting-the-standards-for-the-future-of-shipping-dnv-gl-releases-autonomous-and-remotely-operated-ship-guideline-128471/>, (Accessed on 26.03.2024).

assistance from authorities or nearby vessels.[73] Autonomous vessels should also be equipped with automated distress beacons or emergency notification systems to facilitate rapid response.

Autonomous vessels may be programmed to respond to distress situations by altering course, deploying life-saving equipment, and assisting individuals in distress. Depending on the type of the distress situation and the capabilities of the autonomous vessel, response measures may include deploying life rafts, launching rescue drones, initiating emergency communications, and providing medical assistance to injured persons. Autonomous systems can execute predefined emergency procedures or adapt their response based on real-time data and situational awareness.[74]

While autonomous vessels can autonomously detect and respond to distress, they may also rely on human operators to oversee rescue operations, make critical decisions, and interact with authorities or other vessels involved in the response. Human operators aboard autonomous vessels play a vital role in coordinating rescue efforts, assisting individuals in distress, and ensuring compliance with international regulations and best practices for search and rescue operations. Collaboration among autonomous systems and human operators enables effective response to distress situations while leveraging the capabilities of both.[75] Autonomous vessels must be equipped with the necessary capabilities, including sensors, communication systems, and response protocols, to detect, respond to, and assist in distress situations while complying with international legal obligations and ensuring the safety and well-being of individuals at sea.[76]

According to Art. 73, “Enforcement of laws and regulations of the coastal State,” in the second paragraph states that:

> *“..Arrested vessels and their crews shall be promptly released upon posting reasonable bond or other security.”*[77]

Furthermore, Article 218, “Enforcement by port States,” states the rights of coastal states, port control, and coast guard to board a ship, inspect, question, and ask for the responsible person.[78] The crew members and master act upon all the abovementioned rights, but how will the coastal

[73] Kim, M., Joung, T. H., Jeong, B., & Park, H. S.: “Autonomous shipping and its impact on regulations, technologies, and industries”, *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, *4*(2), 17–25, <https://doi.org/10.1080/25725084.2020.1779427> (14.06.2020).
[74] Zolich, A. / Abdelaal, M.: "Autonomous Surface Vessel for Search and Rescue Operation”, *Bulletin of Electrical Engineering and Informatics*, Vol. 10, No. 3, p.1072, p.3 (Accessed on 04.03.2024)
[75] Meland, P. H. / Neshein, D. A.: “Keeping the Human Element to Secure Autonomous Shipping Operations*”, Human Factors in Cybersecurity*, Vol. 91, 2023, 10–19, < https://doi.org/10.54941/ahfe1003715>, (Accessed on 22.12.2023).
[76] Vio, I.: “Maritime Autonomous Surface Ships – International and National Legal Framework”, *Journal of Maritime & Transportation Science* 62(1), < https://doi.org/10.18048/2022.62.09>, p.145, (Accessed on 20.11.2023).
[77] UNCLOS, Art. 73(2).
[78] UNCLOS, Art. 218.

state apply its right on an autonomous vessel with no one to arrest or be responsible for any incident in territorial waters?[79] Coastal States may face difficulties in adapting existing laws and regulations to accommodate autonomous vessels, including issues related to jurisdiction, liability, certification, and compliance verification. The presence of autonomous vessels in coastal waters presents challenges in monitoring for coastal states. These vessels may operate autonomously without direct communication with coastal authorities, making it difficult to track their movements and activities. Identifying and attributing responsibility for autonomous vessels engaged in illegal activities or violations of maritime regulations presents a significant challenge for coastal States. The lack of onboard human operators makes it difficult to hold individuals accountable for violations, raising questions about liability, enforcement mechanisms, and legal recourse in cases of non-compliance.[80]

UNCLOS was not formally included in the IMO Legal Committee's regulatory scoping exercise because it is not an IMO convention, but the results of the exercise acknowledged this. UNCLOS does not expressly forbid the operation of MASS, but it is clear from the abovementioned issues that it is presently insufficient to allow MASS in the maritime domain.[81]

[79] Dr Logchem, Y. V.:" MASS and the 1982 Law of the Sea Convention – A Paradigm Shift or Old Wine in New Wineskins*?", IMO Seminar on Development of a Regulatory Framework for Maritime Autonomous Surface Ships (MASS),* (Accessed on 06.09.2023).
[80] Coito, J.: "Maritime Autonomous Surface Ships: New Possibilities—and Challenges— in Ocean Law and Policy", *Stockton Center for International Law*, Vol. 97, p.268, (Accessed on 21.01.2024).
[81] Parker, J. "Autonomous vessels and international law", *Australian and New Zealand Maritime Law Journal*, < https://maritime.law.uq.edu.au/index.php/anzmlj/article/view/1433/1404 > vol.35 no.1, p.34 (Accessed on 14.01.2024).

B) THE APPLICATION OF SOLAS CONVENTION ON MASS

The SOLAS convention is a comprehensive treaty that lays out the fundamental safety requirements for ship design, equipment, and operation as well as protocols for guaranteeing maritime safety. Following the terrible sinking of the RMS Titanic in 1914, SOLAS was first established. Since then, it has been through multiple amendments, the most recent of which being SOLAS 1974. The IMO oversees SOLAS, a fundamental component of international maritime law. In order to reduce hazards and guarantee the safety of ships, passengers, and crew at sea, the convention addresses a broad range of safety-related issues of ship design, construction, and operation.[82]

Key provisions of SOLAS include regulations for fire protection, which specify requirements for fire detection and extinguishing systems, and the provision of fire-resistant materials on board ships. Life-saving appliances are also addressed, with regulations mandating the provision of lifeboats, life rafts, and other equipment to facilitate the safe evacuation of passengers and crew in an emergency. SOLAS is applicable to vessels involved in international and certain domestic trips, depending on the size and type of vessel. While port states have the power to inspect foreign ships to confirm their compliance, flag states are in charge of making sure that ships flying their flag adhere to the convention's standards.[83]

Navigation safety is another important focus of SOLAS, with requirements for the maintenance and installation of some navigational aids, such as lights, signals, and radar systems to help prevent collisions at sea. Additionally, the convention includes provisions aimed at enhancing maritime security, such as steps to stop illegal activity against ships and to ensure the safety of marine transport infrastructure.[84]

MASS represents a paradigm shift in maritime operations, leveraging artificial intelligence, remote monitoring, and autonomous navigation systems to operate with minimal or no human intervention. Unlike conventional vessels, autonomous vessels lack onboard crews and rely on technology to execute navigation, collision avoidance, and emergency response tasks. While

[82] IMO: : "SOLAS Conference and Amendments", *IMO Knowledge Centre*,<https://www.imo.org/en/KnowledgeCentre/ConferencesMeetings/Pages/SOLAS.aspx>,(Accessed on 22.11.2023).
[83] IMO: "International Convention for the Safety of Life at Sea (SOLAS), 1974", IMO, <https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx>, (Accessed on 22.11.2023).
[84] Lloyd's Register: "SOLAS Compliance", Lloyd's Register, <https://www.lr.org/en/services/statutory-compliance/solas/>, (Accessed on 22.11.2023).

these advancements offer potential benefits such as environmental performance, improved safety, and efficiency, they also raise complex legal and regulatory issues.

SOLAS is specifically designed for vessels operated by human forces. It includes the STCW requirements for training and qualification of officers and unlicensed crewmembers.[85] Moreover, several chapters in the convention mandate the presence of qualified crew members to operate essential ship functions, monitor safety systems, and respond to emergencies.

1) Chapter II-1: “Construction – Machinery, Subdivision and Stability, and Electrical Installation”

This chapter covered subjects such as building ships with a designated design life to reduce ship loss, maintaining electrical installations, maintaining machinery, and subdividing ships into waterproof compartments.[86] However, the absence of onboard crew in MASS fundamentally alters traditional vessel design and layout concepts. Revised regulations must consider the unique structural requirements of autonomous vessels, including integrating advanced sensor systems, autonomous control centres, and modular construction techniques. Furthermore, the subdivision criteria should be redefined to account for the absence of crew compartments while ensuring adequate protection for critical systems and cargo in unmanned operations. When considering degrees one and two of autonomy, these regulations are considered as applied to MASS, don’t require any actions and do not stop MASS operations. Regarding the third and fourth degrees, these rules are considered as they applicable to MASS and did not stop MASS activities; nonetheless, they may need to be clarified and may have certain gaps.[87]

2) Chapter II-2: “Construction - Fire Protection, Fire Detection, and Fire Extinction”

This chapter aims to mandate the highest level of fire safety, detection, and extinguishment that ships can have.[88] Autonomous vessels may require tailored fire suppression systems, such as autonomous fire detection and suppression systems, to mitigate the risks of fires in unmanned areas. Additionally, using advanced materials with enhanced fire-resistant properties can further improve fire safety onboard autonomous vessels. Revised regulations under SOLAS

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[85] MarEx: "IMO Moves Ahead with Voluntary Rules for Autonomous Ships”, The Maritime Executive, <https://maritime-executive.com/article/imo-moves-ahead-with-voluntary-rules-for-autonomous-ships>, (Accessed on 14.06.2024).
[86] SOLAS, Ch. II-1.
[87] Wright, R. G.(ed. 1): Unmanned and Autonomous Ships, Ch.11, New York, 2020.
[88] SOLAS, Ch. II-2.

Chapter II-2 should encourage the integration of advanced fire detection systems, including multi-sensor arrays, video analytics, and machine learning algorithms, to improve the accuracy and reliability of fire detection onboard autonomous vessels.[89] Furthermore, remote monitoring capabilities can enable real-time assessment of fire risks and facilitate timely intervention measures. Regarding degree one of Autonomy, no action is required. Degrees two and three require clarification of terms such as “master,” “crew,” and “responsible person”. Definitions of terms like "manned spaces," "control stations," and "safety centers" should be made clearer. In some fire-extinguishing scenarios, firefighters are required for degrees three and four. All things considered, these rules apply to MASS and do not prohibit MASS operations; however, they may need to be clarified, changed, or have gaps.[90]

3) Chapter III: “Life-Saving”

This chapter thoroughly presents the availability of lifeboats, their construction, capacity, and other technical specifications related to life-saving.[91] However, MASS operates without traditional onboard crews or with significantly reduced crew sizes. This creates a legal gap in ensuring the readiness and effectiveness of life-saving equipment and procedures in the absence of crew members to perform these tasks. Revised regulations are needed to address the unique challenges of evacuating passengers and crew from autonomous vessels and providing for their survival in emergency situations.

Autonomous vessels may incorporate unmanned lifeboats, remote-controlled rescue drones, and automated distress signal transmission systems to inprove the effectiveness of search and rescue operations. SOLAS regulations may not explicitly address the integration and certification of autonomous rescue and survival systems, creating a legal gap in ensuring their compliance and effectiveness. Better guidelines are required to regulate the design, installation, and operation of autonomous life-saving equipment onboard MASS.[92]

Effective communication and coordination are crucial for ensuring the success of search and rescue operations and safely evacuating passengers and crew from distressed vessels. However, the absence of onboard crews in MASS raises concerns about communication protocols,

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89 IMO, MSC.1/Circ.1638 Annex, p. 20.
90 IMO, MSC.1/Circ.1638 Annex, p. 20.
91 SOLAS, Ch. III.
92 Meriam , Ch. / Ren, X. / BahooToroody, A.: “Research on risk, safety, and reliability of autonomous ships: A bibliometric review”, *Safety Science*, <https://doi.org/10.1016/j.ssci.2023.106256.> Vol. 167, (11.11.2023).

emergency response coordination, and interfacing with external search and rescue authorities. Legal uncertainties arise regarding the responsibilities and obligations of autonomous vessels in distress situations and the coordination mechanisms between autonomous vessels and search and rescue authorities. Revised regulations should establish clear communication protocols and coordination mechanisms to facilitate effective search and rescue operations involving autonomous vessels.[93]

The main issue related to operating an Autonomous passenger ship should not be considered because the personnel assisting with the life rafts should be certified. [94]During the MSC revision of this chapter of the SOLAS convention, it was identified that the MASS of degrees three and four cannot safely carry passengers until technological developments have been implemented.

4) Chapter IV: "Radiotelegraphy and Radiotelephony"

This chapter explains all the necessary radios onboard, frequencies, radio stations, operators, etc., based on onboard radio operators' presence.[95] Without dedicated radio operators, this creates a legal gap in ensuring continuous and reliable radio communication capabilities. Revised regulations are needed to address the unique challenges of maintaining effective radio communication onboard autonomous vessels and ensuring compliance with SOLAS requirements.[96] Autonomous vessels may incorporate artificial intelligence-driven communication protocols, automated distress signal transmission systems, and remote monitoring capabilities to streamline radio communication processes. However, existing SOLAS regulations may not explicitly address the integration and certification of automated radio communication systems, creating a legal gap in ensuring their compliance and effectiveness. Clear guidelines and standards are needed to regulate autonomous radio communication systems design, installation, and operation onboard MASS. According to the review of the MSC, several gaps were pointed out, such as new terms and definitions, requirements for radio workers, radio watch requirements, and functional and maintenance needs. This chapter applies to MASS and doesn't exclude MASS activities; nonetheless, it may require revisions, clarifications, or gaps.[97]

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[93] Issa, M./ Ibrahim H.: "Maritime Autonomous Surface Ships: Problems and Challenges Facing the Regulatory Process", *Sustainability* 2022, 14(23), 15630,< https://doi.org/10.3390/su142315630>, (Accessed on 22.11.2023).
[94] IMO,MSC.1/Circ.1638 Annex, p. 28.
[95] SOLAS, Ch.IV.
[96]IMO, MSC.1/Circ.1638 Annex, p. 30.
[97] Wright, R. G.(ed. 1): Unmanned and Autonomous Ships, Ch.11, New York, 2020.

5) Chapter V: “Safety of Navigation”

This chapter contains all the safety measures needed to be taken by the crew, such as templates of danger messages, distress signals, and SAR operations; it lays down requirements for navigation equipment, voyage planning, and watchkeeping procedures based on the presence of onboard navigational personnel responsible for vessel navigation and safety. The absence of dedicated navigational personnel challenges ensuring continuous and reliable navigation capabilities. It is crucial that revised regulations take into account the distinct challenges of ensuring efficient navigation on autonomous vessels while also guaranteeing compliance with SOLAS requirements. These regulations are essential for the safe operation of MASS, and it is imperative that they are comprehensive, practical, and effective.[98]

According to the RSE, the regulations of this chapter apply to MASS and don't stop MASS from operating, but they may need to be modified and have gaps.[99] Definition, roles, responsibilities, qualification of shipmasters, manning requirements, training and drilling, and ship-to-shore communications were the potential barriers to the applicability of MASS. This chapter contains more gaps mainly because all the related operations include the human factor.[100]

6) Regulation 13: “Manning”

This regulation, designed for crewed vessels, outlines requirements for onboard personnel responsible for various operational and safety duties.[101] However, MASS operate without crews or with significantly reduced crew sizes, challenging the applicability of Regulation 13. The absence of onboard personnel raises questions about compliance and enforcement and the allocation of responsibilities for tasks traditionally performed by human operators. Addressing this legal gap requires revising Regulation 13 to accommodate the unique characteristics of MASS and ensure effective oversight and safety standards in the absence of traditional crew members.[102]

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98 SOLAS, Ch.V.
99 IMO, MSC.1/Circ.1638 Annex, p. 31.
100 IMO, MSC.1/Circ.1638 Annex, p. 28.
101 SOLAS, Ch. V, Reg. 13.
102 Eriksen, S./ Lützen, M.: “Manning The Unmanned Ship: Is Safe Manning Legislation A Bottleneck In The Development Of Autonomous Ships?” *The Royal Institution of Naval Architect,* Ch.3, p.40, (Accessed on 01.05.2024).

7) Regulation 15: “Search and Rescue”

This regulation provides detailed guidelines and responsibilities for coordinating search and rescue operations for traditional crewed vessels. The rise of MASS with reduced or no crew has raised certain concerns regarding the application of Regulation 15. Without dedicated onboard personnel, it becomes essential to establish clear communication protocols, emergency response coordination procedures, and effective mechanisms for interfacing with external search and rescue authorities. These mechanisms should include clear and concise means of communication between MASS and search and rescue authorities, including the provision of relevant information about the vessel's location, status, and any hazards present. Additionally, it is important to establish effective coordination between MASS and search and rescue authorities, ensuring that all parties are well-informed and able to respond quickly and efficiently to any emergency situations that may arise. To address these issues, it is crucial to revise Regulation 15 and establish clear guidelines for search and rescue operations involving autonomous vessels. These guidelines should ensure that the safety of crew and passengers is fully maintained and that effective coordination and communication protocols are in place to minimise the risk of accidents or incidents occurring.[103]

8) Regulation 16: “Life-Saving Signals”

The current regulation requires crewed vessels to use specific signals and distress signals for communication during emergencies.[104] However, the rise of unmanned or minimally manned vessels has raised serious concerns about the efficacy of traditional life-saving signals in such vessels. This legal gap can be bridged by revising Regulation 16 to suit the unique characteristics of autonomous vessels. The revised regulation must ensure alternative methods for signalling distress and communicating emergencies effectively in the absence of traditional crew members. This will not only facilitate the safe operation of unmanned ships but will ensure safety for all vessels on the water. It is, therefore, imperative that the regulation be revised to address this issue and to guarantee the safety of all maritime vessels.

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[103] Wu, J./ Cheng, L.: “An autonomous coverage path planning algorithm for maritime search and rescue of persons-in-water based on deep reinforcement learning”, *Ocean Engineering*, Vol. 291, <https://doi.org/10.1016/j.oceaneng.2023.116403.>, (Accessed on 10.06.2024).
[104]SOLAS, Ch. V, Reg. 16.

9) Regulation 17: “Pilot Ladder”

The safe embarkation and disembarkation of pilots from crewed vessels is greatly dependent upon the construction and maintenance criteria for pilot ladders, which are outlined in this regulatory framework.[105] However, the emergence of autonomous ships which run without a traditional crew has brought up important issues about the suitability and usefulness of pilot ladders.[106] Regulation 17 has to be reviewed in order to take into consideration the special features of MASS and close this legal gap. In the event that regular crew members are not available, the amendment shall provide backup procedures for pilot boarding and disembarkation that guarantee compliance and safety.[107]

10) Regulation 19: “Use of the Automatic Pilot”

This rule controls the use of automatic pilots to aid in vessel navigation; these devices are usually handled by persons onboard.[108] Nevertheless, MASS functions independently without conventional crews, making Regulation 19 less relevant. Issues concerning the supervision and management of automated pilot systems are brought up by the lack of crew members on board. In order to close this legal loophole, Regulation 19 must be updated to take into consideration the special qualities of MASS and provide precise instructions for the management and control of automated pilot systems when conventional crew members are not present.

11) Regulation 31: “Manning Of Lifeboats And Liferafts”

> “…(a) A deck officer or certified lifeboatman…
>
> …(b) A man capable of working the motor…
>
> …(c) A man capable of working the radio and searchlight installations…
>
> …(d) A man practised in the handling and operation of liferafts shall be assigned…”[109]

It outlines requirements for the crewing and operation of lifeboats and liferafts on ships. It

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[105] SOLAS, Ch. V, Reg. 17.
[106] Ringbom, H./ Røsæg, E./ Solvang, T. (ed.1) Autonomous Ships and the Law, Ch. 17, . (2020).
[107] MSC.1/Circ.1638 Annex, p. 39.
[108] SOLAS, Ch. V, Reg. 19.
[109] SOLAS, Ch. V, Reg. 31 a-d.

specifies the minimum number of trained personnel who must be available to safely launch and operate these life-saving appliances in the event of an emergency.[110] With the shift towards automation and remote operation, the training and certification requirements for personnel involved in the manning of lifeboats and liferafts may need to be updated. Crew members and shore-based operators must receive adequate training in operating and maintaining automated life-saving systems to ensure effective response during emergencies. The advent of autonomous vessels necessitates a reevaluation of Regulation 31 of the SOLAS Convention to accommodate the unique challenges and opportunities posed by automation, remote operation, and reduced crew presence in the manning of lifeboats and liferafts. It requires updating training standards, cybersecurity measures, and operational protocols to ensure the continued safety of life-saving operations at sea.[111]

12) Chapter VI: "Carriage of Grain"

This chapter regulates the safe carriage of grain cargoes, outlining specific requirements for vessels engaged in the transportation of grain.[112] Still, the use of MASS poses new difficulties in guaranteeing the secure and effective conveyance of grain loads in the absence of customary personnel. To comply with safety standards, regulations pertaining to the integration of autonomous technology into grain handling equipment and processes need to be revised.[113] Autonomous vessels may require adjustments to stability criteria and load management practices to account for the absence of onboard personnel responsible for cargo monitoring and ballast operations. Clear protocols and procedures are needed to address potential grain-related emergencies, such as cargo shift or contamination, in the absence of onboard crews to execute response measures effectively. The RSE determined that MASS was covered by the provisions of this chapter. They may need to be clarified, changed, or have gaps, but they did not stop MASS activities. One of the significant challenges regarding these provisions is the establishment of procedures that deal with the leakage of goods and all the measures that need to be taken by the certified crew members.[114][115]

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110 SOLAS, Ch. V, Reg. 31.
111 Stępień, B.: "Can a ship be its own captain? Safe manning of autonomous and uncrewed vessels", *Marine Policy*, Vol.148,<https://doi.org/10.1016/j.marpol.2022.105451.>, (Accessed on 09.12.2023).
112 SOLAS, Ch. VI.
113 MSC.1/Circ.1638 Annex, p. 39.
114 MSC.1/Circ.1638 Annex, p. 31.
115 Wright, R. G.(ed. 1): Unmanned and Autonomous Ships, Ch.11, New York, 2020.

13) Chapter VII: “Carriage of Dangerous Goods”

This chapter regulates the safe transportation of dangerous materials by sea, prescribing requirements for the classification, packaging, storage, and handling of hazardous materials onboard vessels.[116] To ensure safety and compliance, Chapter VII must be revised in light of the special concerns and difficulties that the use of MASS in the transportation of dangerous commodities brings. Autonomous vessels must adhere to strict regulations regarding the compatibility and segregation of dangerous goods to prevent chemical reactions or hazards during transport. Revised regulations should address the integration of autonomous technology into cargo management systems, ensuring proper segregation and handling of dangerous goods without human intervention. MASS must have robust emergency response capabilities to address incidents involving dangerous goods, such as leaks, spills, or fires. Updated regulations should outline requirements for autonomous vessels to have onboard firefighting equipment, containment measures, and emergency response plans tailored to hazardous material incidents.[117] Enhanced regulation should include mandates that self-sufficient boats keep communication equipment that can notify other vessels and land authorities of dangerous materials and distress signals. The regulatory scoping exercise determined that MASS is covered by this chapter's provisions. They may need to be updated, clarified, or have gaps, but they did not stop MASS activities. Establishing protocols for handling goods leaks and all the necessary actions that trained crew members must follow is one of the major issues associated with these rules.[118]

14) Chapter IX: “Management For The Safe Operation Of Ships”

This chapter describes the criteria for safety management plans, ship management systems, and the division of duties with the personnel board.[119] With MASS, revised regulations are needed to establish guidelines for the management of autonomous vessels, including the allocation of responsibilities, oversight mechanisms, and communication protocols in the absence of traditional crew members. Safety management plans, which specify protocols for risk assessment, emergency response, and ongoing improvement, are essential to guarantee the

[116] SOLAS, Ch. VII.
[117] Bačkalov, I.: “Safety of autonomous inland vessels: An analysis of regulatory barriers in the present technical standards in Europe”, *Safety Science*, Vol. 128, <https://doi.org/10.1016/j.ssci.2020.104763.>, (Accessed on 03.05.2024).
[118] MSC.1/Circ.1638 Annex, p. 32.
[119] SOLAS, Ch. IX.

safe operation of vessels.[120] Autonomous vessels require tailored safety management plans that account for the unique characteristics of autonomous technology, such as automation systems, remote monitoring capabilities, and cybersecurity measures. Revised regulations should incorporate provisions for developing and implementing safety management plans specifically designed for autonomous vessels, addressing operational and safety considerations relevant to crewless or minimally manned operations. For safe and effective operation, typical crewed vessels depend on highly qualified individuals with a variety of nautical specialities under their belts.[121] However, because MASS are autonomous, staff members involved in vessel operation, maintenance, and emergency response need to have a new set of skills and undergo additional training. For those in charge of managing and supervising autonomous boats, updated legislation should set up training requirements and competency standards to guarantee they have the abilities and know-how to operate and maintain MASS safely and efficiently. The provisions were determined to apply to MASS and did not impact MASS operations, but they may need to be modified and may have gaps, based on the RSE of the MSC degrees three and four.[122] The role and replacement of the crew and master, cybersecurity, basic concerns about lowering the risk due to the lack of people on board, the use of MASS in SAR missions, and connectivity were the primary deficiencies that were found.[123]

15) Chapter XI: "Special Measures To Enhance Maritime Safety And Security"

This chapter has to be modified to reflect the special difficulties and factors presented by autonomous shipping. It was initially created to improve safety and security procedures for regular crewed vessels.[124] The operation of MASS challenges the effectiveness of current safety and security procedures without personnel. To comply with safety and security requirements without traditional crew members, revised rules are required to provide specialised safety and security procedures adapted to autonomous vessels.

Cybersecurity, remote operation, and autonomous decision-making pose additional dangers

[120] Porathe, T./ Hoem, A.: "At least as safe as manned shipping? Autonomous shipping, safety and human error", *Research Gate*, Safety and Reliability – Safe Societies in a Changing World – Haugen et al. (Eds) p. 421 (Accessed on 07.05.2024).
[121] Abudu, R./ Bridgellal, R.: "Autonomous Ships: A Thematic Review", *World 2024*, 5(2), 276-292, Ch.3.2.1, <https://doi.org/10.3390/world5020015>, (28.05.2024).
[122] MSC.1/Circ.1638 Annex, p. 61.
[123] Tirado, M. A./ Brown. R.: "Risk and safety management of autonomous systems: a literature review and initial proposals for the maritime industry", <https://www.researchgate.net/publication/332734496_Risk_and_safety_management_of_autonomous_systems_a_literature_review_and_initial_proposals_for_the_maritime_industry> , (Accessed on 23.12.2023).

[124] SOLAS, Ch. XI.

and weaknesses for autonomous vessels. In order to enhance maritime security and safety, revised rules should include clauses pertaining to the performance of thorough risk assessments that are unique to autonomous vessels, the identification of possible dangers, and the implementation of risk mitigation strategies.[125] Guidelines for ongoing risk monitoring and management should also be included. According to the RSE of Maritime Safety Committee degrees three and four, it was decided that the provisions were determined to be applicable to MASS and did not impede MASS operations; nonetheless, they may require clarification or amendment and may have gaps.[126]

16) General Evaluation

In conclusion, the rise of autonomous ships poses significant challenges to the current framework of the SOLAS Convention, which is tailored to traditional manned vessels. Many of its safety requirements, such as manning, watchkeeping, and emergency response, rely on human presence, creating gaps when applied to unmanned or remotely operated ships.

To address these challenges, SOLAS must evolve to account for the unique risks and operational models of autonomous shipping, including the need for robust cyber security, reliable automation, and new approaches to safety protocols. The shift from onboard crews to shore-based control and AI-driven systems demands a comprehensive reassessment of how safety standards are defined and implemented.

As the IMO works to modernize maritime regulations, it is crucial to balance technological innovation with the core principles of maritime security and safety. Adapting SOLAS to the era of autonomy will ensure the convention remains relevant and effective in safeguarding lives and property at sea.

C) THE APPLICATION OF COLREG’S ON MASS

“The International Regulations for Preventing Collisions at Sea” 1972 (COLREGs) outline the navigational guidelines that ships and other vessels must abide by when at sea to stop two or

[125] Victor, B./ Theotokats, G.: “Safety related cyber-attacks identification and assessment for autonomous inland ships”, *Maritime Safety Research Centre, University of Strathclyde, UK,* p.102, <https://www.researchgate.net/publication/350721088_Safety_related_cyber-attacks_identification_and_assessment_for_autonomous_inland_ships>, (Accessed on 20.08.2024).
[126] MSC.1/Circ.1638 Annex, p. 34.

more ships from colliding. Adopted on October 20, 1972, the convention became applicable on July 15, 1977. It was designed to modernize and replace the 1960 Collision Regulations, which were ratified concurrently with the 1960 SOLAS Convention. It was developed in order to modernize and replace the 1960 Collision Regulations, which were ratified concurrently with the 1960 SOLAS Convention.[127]

All vessels operating in the territorial waters of nations that have ratified the agreement as well as those traversing international waters are subject to COLREGs. They address a variety of scenarios, such as navigating in broad waters, constrained channels, traffic separation plans, and low visibility. COLREGs are based on fundamental principles of seamanship and common sense. They establish rights and responsibilities for vessels to avoid collisions, maintain a proper lookout, and take early and decisive action to prevent accidents. The regulatory scoping exercise also reviewed COLREG as an instrument of IMO.[128] As autonomous vessels become more prevalent, certain regulations within the COLREGs may be affected.

1) Rule 2: "Responsibility"

This rule states that not only must a vessel comply with the COLREGs but also adapt her behavior to the prevailing circumstances.[129] With autonomous vessels, the responsibility for adhering to regulations and adapting to circumstances shifts from human operators to the developers, operators, and designers of these autonomous systems. There may be discussions on who bears the legal responsibility in case of a collision involving autonomous vessels, especially considering the absence of a human to make real-time decisions.[130]

2) Rule 5: "Look-Out"

This regulation requires all vessels to keep a proper watch using all available means, including sight and hearing:[131]

> *"…Every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to*

[127]IMO: "Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)", IMO, <https://www.imo.org/en/About/Conventions/Pages/COLREG.aspx>, (Accesed on 02.12.2023).
[128] MSC.1/Circ.1638 Annex, p. 10.
[129] COLREG's, Rule 2.
[130] Stępień, B.: "Towards a New Horizon: 1972 COLREG in the Era of Autonomous Ships", *Ocean Development & International Law*, *55*(1–2), 170–184. <https://doi.org/10.1080/00908320.2024.2359908>, (Accessed on 21.07.2024).
[131] COLREG's, Rule 5.

make a full appraisal of the situation and of the risk of collision…"

Early warning of collision dangers requires the employment of radar equipment, radar plotting, or comparable systematic observation of identified objects. Mariners are cautioned by this rule not to make assumptions based on incomplete information. The IMO and other member nations must make sure that sufficient sensor capabilities are available for remote operators in the case of MASS. Furthermore, it is necessary to develop onboard reasoning capabilities to guarantee that all pertinent data is accessible. This will help operators stay fully informed about their circumstances and enable them to make well-informed decisions.[132] Autonomous vessels rely heavily on sensors, cameras, radar, and other technological means for navigation and collision avoidance. Therefore, compliance with this rule may involve ensuring that these sensors function correctly, adequately cover the surroundings, and are continuously monitored and maintained. This rule may comply with degrees one and two of MASS but is unsuitable for degrees three and four.[133]

Annex IV of (COLREGs) covers the "Distress Signals" that vessels use to communicate their need for assistance in emergency situations.[134] While the core principles of distress signals remain unchanged, the introduction of autonomous vessels can impact how these signals are activated, interpreted, and responded to.[135] In traditional vessels, distress signals are activated by the crew in response to emergency situations such as collisions, grounding, or other hazards. With MASS, there may not be a crew to recognize and respond to emergencies. Instead, distress signals may need to be activated automatically by the vessel's autonomous systems when certain predefined criteria or thresholds are met, such as sensor data indicating a collision or malfunction.

When distress signals are activated, other vessels and maritime authorities must interpret and respond appropriately to provide assistance. Autonomous vessels must be capable of transmitting distress signals in a format that can be recognized and understood by other vessels and search and rescue authorities. This may involve standardized communication protocols or automated distress calls transmitted via radio or satellite communication systems.[136]

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[132] Norton Rose Fulbright: "The Collision Regulations and Autonomous Shipping", *Norton Rose Fulbright,* <https://www.nortonrosefulbright.com/en/knowledge/publications/5fedab67/the-collision-regulations-and-autonomous-shipping>, (Accessed on 10.06.2024).

[133]Alsos, O. A./ Honde, P.: "Maritime Autonomous Surface Ships: Automation Transparency for Nearby Vessels", Journal of Physics, 012027, <https://doi:10.1088/1742-6596/2311/1/012027>, (23.11.2022).

[134] COLREG's, Annex IV.

[135] MSC.1/Circ.1638 Annex, p. 86.

[136] Ferreira, F.: "Discussing COLREGs adaption for fully Autonomous Surface Vessels", *NATO CMRE* <https://iuc.hr/file/1032>,(Accessed on 08.09. 202).

In accordance with COLREGs, vessels receiving distress signals are obligated to render assistance to the extent possible without endangering their own safety. Autonomous vessels must be programmed to respond to distress signals by altering course, providing assistance if feasible, and notifying relevant authorities of the emergency situation. This may require integrating collision avoidance algorithms with protocols for responding to distress signals to ensure a coordinated and effective response.[137]

3) Rule 6: "Safe Speed"

Autonomous vessels need to determine and maintain a safe speed based on factors like visibility, traffic density, manoeuvrability, and environmental conditions. The technology governing the speed of autonomous vessels must comply with this rule to prevent collisions.[138]

4) Rule 7: "Risk of Collision"

This rule is focused on the assessment of collision risks and the necessary actions to avoid them, which may require adjustments to accommodate the emergence of autonomous vessels.[139] With autonomous vessels, this means their onboard systems must continuously assess collision risks using sensors and algorithms. They must autonomously adjust course or speed to avoid collisions, ensuring compliance with Rule 7. Additionally, communication systems enable them to interact with other vessels to mitigate collision risks effectively. Autonomous ships need to be configured to recognize collision risks and take the necessary precautions to prevent them. This may involve algorithms that analyze data from sensors and make decisions to alter course or speed to minimize collision risk.[140]

5) Rule 8: "Action to Avoid Collision"

To prevent a collision, autonomous vessels must be able to act quickly and decisively. This could involve communication with other vessels, altering course or speed, or deploying

[137] MSC.1/Circ.1638 Annex, p. 86.
[138] Hannaford, E./ Maes, P.: "Autonomous ships and the collision avoidance regulations: a licensed deck officer survey", *WMU Journal of Maritime Affairs*, vol. 21, p.252<https://doi.org/10.1007/s13437-022-00269-z>, (Accessed on 11.10.2024).
[139] COLREG's, Rule.7.
[140] Hannaford, E./ Maes, P.: "Autonomous ships and the collision avoidance regulations: a licensed deck officer survey", *WMU Journal of Maritime Affairs*, vol. 21, p.253<https://doi.org/10.1007/s13437-022-00269-z>, (Accessed on 11.10.2024).

collision avoidance measures autonomously.

"... if the circumstances of the case admit, be positive, made in ample time and with due regard to the observance of good seamanship." Can autonomous vessels apply this principle?[141]

6) Rule 13: "Overtaking"

This rule addresses the responsibilities of vessels involved in overtaking manoeuvres. Rule 13 requires vessels to communicate their intentions during overtaking manoeuvres. Autonomous vessels must be equipped with communication systems to indicate their intentions to the vessel being overtaken and any other nearby vessels. This ensures that all parties know the manoeuvre and can take appropriate action to avoid a collision.[142] MASS must comply with Rule 13 during overtaking manoeuvres. This includes maintaining a safe distance from the vessel being overtaken, avoiding impeding its manoeuvrability, and giving way to overtaking the vessel if it's in a narrow channel. This may not be an issue for degrees one and two of autonomy where the human factor is included but for degrees three and four, newly developed technologies.[143]

7) Rule 34: "Manoeuvring and Warning Signals"

This rule addresses the warning signals between vessels when passing by each other or in dangerous situations. Rule 34 assumes human operators can interpret and respond to traditional signalling methods.[144] However, autonomous vessels may use non-standard or automated signalling methods, leading to ambiguity in communication between autonomous and manned vessels. Manned vessels, on the other hand, may not be accustomed to interpreting signals from autonomous vessels, leading to potential misinterpretation or lack of response. Clear guidelines are needed to ensure that manned vessels understand and appropriately respond to signals from autonomous vessels. There may be gaps in regulatory oversight regarding the standardization and certification of autonomous signalling systems. Ensuring the reliability and effectiveness of these systems requires clear guidelines and oversight mechanisms. Rule 34 does not address interoperability issues between autonomous vessels and existing maritime communication systems. Ensuring seamless communication between autonomous and manned vessels is

[141] Wright, R. G.(ed.1): Unmanned and Autonomous Ships, Ch. 10, New York, (2020).
[142] COLREG's, Rule 13.
[143] Ortega, J./ Ortega, M.: "Systematic review of overtaking manoeuvres with autonomous vehicles", <https://doi.org/10.1016/j.treng.2024.100264>,(Accessed on 25.09.2024)
[144] COLREG's, Rule 34.

crucial for safe navigation but may require additional standards or protocols.[145]

8) General Evaluation.

As autonomous vessels revolutionize the maritime industry, their integration raises complex legal and regulatory challenges, particularly concerning pilotage. In conclusion, the integration of autonomous vessels into maritime traffic highlights several gaps in the existing regulations, such as the COLREGs. These gaps include ambiguity in communication protocols, uncertainties in response to autonomous signals, challenges in adapting to technological advances, gaps in regulatory oversight, and issues related to interoperability and interaction with existing maritime systems. Addressing these gaps will be crucial to make sure the safe and effective integration of MASS into maritime traffic, uphold navigational safety standards, and promote harmonious interaction between autonomous and manned vessels.[146]Clear norms and standards that are adapted to the special qualities and capabilities of autonomous vessels must be developed and implemented through cooperation between regulatory agencies, industry stakeholders, and technology developers. The MSC regulatory scoping exercise concluded that specific requirements needed addressing regarding MASS related to COLREG, especially for degrees three and four of autonomous ships, which represented a more significant shift in shipping the need for new terminology, light shapes, sound signals, distress signals, and the most emphasised gap,the responsibility of the remote operator and the role of the capitan.[147][148]

D) THE IMO'S APPROACH

All IMO-regulated maritime security and safety issues, including those involving passenger and freight ships, are governed by the MSC. This includes updating the pertinent SOLAS Convention, hazardous material, fire safety system, and life-saving appliance codes. Among the many topics on the MSC's current agenda are goal-based standards, MASS, e-navigation, cyber security, piracy and armed robbery against ships, and modernizing the "Global Maritime Distress and Safety System."

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145 MSC.1/Circ.1638 Annex, p. 87.
146 Wrobel, K.: "The Vagueness of COLREG versus Collision Avoidance Techniques—A Discussion on the Current State and Future Challenges Concerning the Operation of Autonomous Ships", *Sustainability*, 14(24), <https://doi.org/10.3390/su142416516>, (09.12.2022).
147 MSC.1/Circ.1638 Annex, p. 86.
148 Issa, M./ Ilinca, A./ Ibrahim, H.: "Maritime Autonomous Surface Ships: Problems and Challenges Facing the Regulatory Process", *Sustainability*, 14(23), <https://doi.org/10.3390/su142315630>, (22.11.2022).

During the proceedings of MSC 98 in June 2017, it was observed that the maritime sector is increasingly using MASS to offer secure, high-quality and cheaper results. The Maritime Safety Committee's 98th session has incorporated the matter of RSE on usage of MASS in its agenda for 2018-2019. The anticipated completion year for this output is 2020.[149]

During the MSC 99, the Committee created a framework for the RSE to define the MASS with their degrees of autonomy. To test the framework of the RSE and, specifically, the methodology, a correspondence group on MASS was formed. To begin, SOLAS regulation III/17-1, "Recovery of persons from the water," SOLAS regulation V/19.2, "Carriage requirements for carriage of shipborne navigational equipment and systems," and Load Lines regulation 10 were evaluated.[150]

MSC 100 granted the RSE framework, which contained procedures, a work plan, and definitions, in December 2018. The methodology suggests a two-step approach. The MSC encouraged interested Member States and international organizations to actively engage in the exercise. For each degree of autonomy, provisions related to maritime security and safety will be identified by applying the relevant instruments:

a) The text outlines different scenarios regarding the application of MASS.
b) The application prevented any MASS operations.
c) The application did not prevent any MASS operations and did not require any actions.
d) The application did not prevent any MASS operations but may need amendments or clarifications, and might contain gaps.
e) The application had no relevance to MASS operations.

After the first phase, a second one started to analyse and ascertain the best approach to handle MASS operations, taking into consideration, the operational, technological, and human aspects of: [151]

[149] IMO, MSC.1/Circ.1638 Annex, p. 2.
[150] International Maritime Organization: "IMO Completes Regulatory Scoping for Maritime Autonomous Surface Ships", *IMO Press Briefings*, <https://www.imo.org/en/MediaCentre/PressBriefings/Pages/08-MSC-99-mass-scoping.aspx >, (Accessed on 25.05.2014).
[151] IMO, MSC.1/Circ.1638 Annex, p.5.

a) similarities according to evolving interpretations or the instruments and/or
b) updating current instruments and/or
c) new instruments development; or
d) None of the aforementioned due to analysis.

During the MSC 101 in June 2019, The Committee gave its approval to the interim MASS trial guidelines. According to the recommendations, trials must be carried out in a way that ensures environmental protection, safety, and security, at least as much as is specified by the applicable laws and regulations. It is necessary to identify the trials' hazards and take action to bring them down to a manageable level.[152]

The MSC 103 completed the RSE and approved a circular providing the outcome.[153] The completion of the RSE is the initial approach towards ensuring that regulation keeps pace with technological advancements.

The safe and efficient integration of MASS operation into the regulatory framework depends on some basic potential gaps and/or themes that span several IMO instruments. These issues were considered a high priority and may necessitate policy decisions before addressing individual instruments. Such high-priority issues include:[154]

1- Clarification of the terms: master, crew, and responsible person.

Under consideration were the definitions, duties, and obligations of a master, particularly with reference to degrees of autonomy. A frequent pattern that was noted in multiple instruments as a possible gap was Degrees Three and Four when shoreside persons might control the ship.

2- Remote control station/centre

Focus should be on the functional and operational needs of the remote-control station and monitoring center. Additionally, since a remote-control center is a novel concept, it should be integrated into IMO instruments.

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152 IMO, MSC 101st session, (05-14.06.2019).
153 IMO, MSC 103rd session, (05-14.05.2021).
154 IMO, MSC.1/Circ.1638 Annex, p.10.

3- Remote operator as seafarer

The RSE pointed out that a common theme in multiple instruments suggested that a remote operator would be classified as a seafarer, suggesting a potential regulatory gap. The qualifications, responsibility, and function of the remote operator in the role of a seafarer are among the most difficult problems to resolve.

4- Terminology

It was acknowledged that deciding on terminology usage and making policy decisions are necessary before considering changes to existing instruments or creating new ones.[155]

In October 2021, the MSC 104 added a new output on “Development of a goal-based instrument for maritime autonomous surface ships”, with 2025 as the intended completion year.[156] Afterwards, in April 2022, the MSC 105 approved a road map that included a work plan for the development of IMO instruments for MASS and started working on the creation of a goal-based instrument that would regulate the operation of MASS. The roadmap outlines a plan to create a goal-oriented tool in the shape of a non-compulsory code. As the main step, this code is anticipated to be adopted in the second half of 2024. On January 1st, 2028, a mandatory MASS Code will be created based on the lessons learned from the non-compulsory MASS Code.[157]

In November 2022, the Joint Working Group at MSC 106 developed a table that is intended to be a living document to identify the most effective methods for addressing frequent problems, including the definitions of terms like "remote operator" and "remote control station," the roles and responsibilities of the MASS master and crew, and the competencies required for them. During the meeting, the MSC MASS Working Group presented the draft MASS Code, which included a new section on fire safety. This section was developed based on the model for creating the MASS Code's functional requirements. The MSC noted the structure and content of the draft, which the group further developed.[158]

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155 MSC.1/Circ.1638 Annex, p. 8.
156 IMO, MSC 104th session, (04-05.10..2021).
157 IMO, MSC 105th session, (20-29.04.2022).
158 IMO, MSC 106th session, (11.11..2022).

The MSC 107 held in June 2023 agreed on the following regarding training and certification requirements for seafarers on MASS:

1. STCW applies to seafarers on a MASS.

2. The MASS Code establishes the training and certification criteria for remote operators and masters at ROC who are not on board; nonetheless, STCW should be taken into consideration as a foundation.

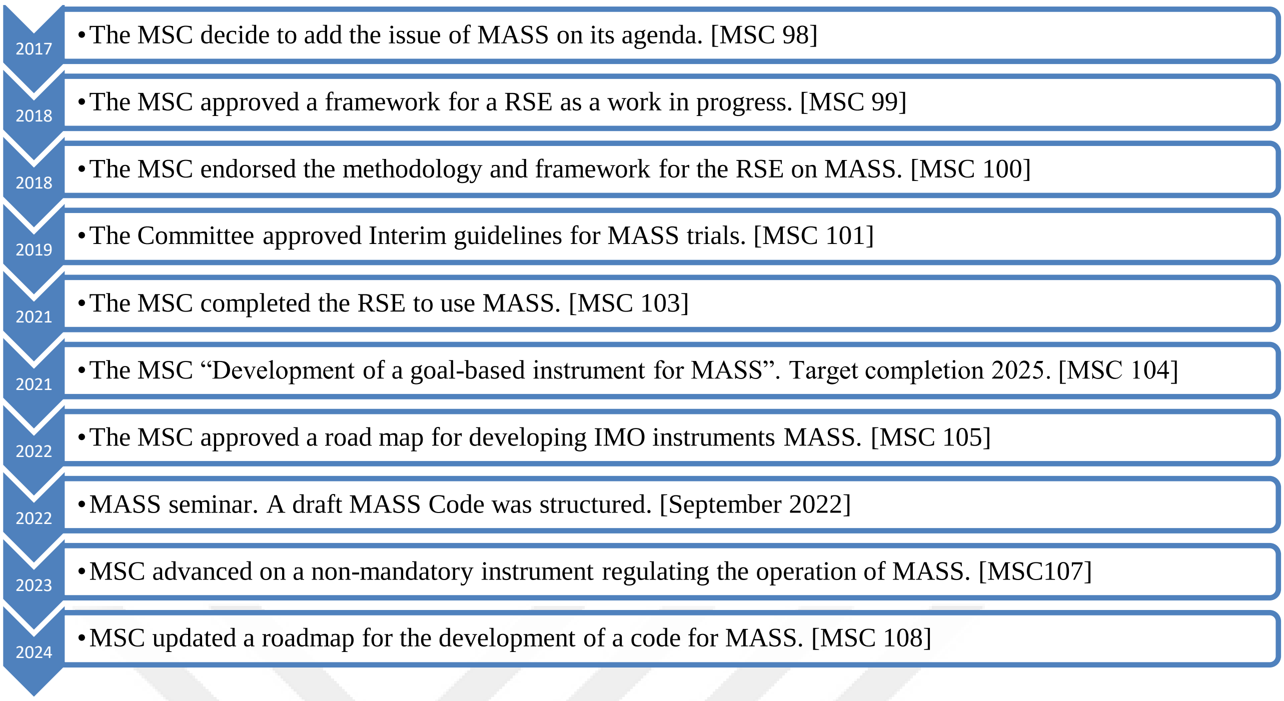
3. The MASS Code should address watchkeeping and other principles in STCW, even if it does not apply.

The GBS Working Group discussed the MASS Code's functional requirements (FRs) and offered observations and recommendations to the MASS Working Group. They emphasised the importance of conducting a HAZID study to identify hazards, mitigating functions, expected performances (EPs), and associated FRs. This study would provide the necessary tools to identify and address all relevant hazards appropriately.[159]

The roadmap for creating a code to control MASS navigation was updated by MSC during its 108th session. The main points of this revised roadmap are:

- By May 2025, a non-mandatory MASS Code must be finalized and adopted.
- By the first half of 2026, a framework for an experience-building phase (EPB) must be developed.
- To start creating the mandatory MASS Code based on the non-mandatory Code and consider adding a new chapter to SOLAS to approve the Code by 2028.
- Adopting an obligatory code by July 1, 2030, for implementation on January 1, 2032. [160]

[159] IMO, MSC 107th session, (09.06..2023).
[160] IMO: "108th Session of the Maritime Safety Committee (MSC 108)," *IMO Meeting Summaries*, <https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MSC-108th-session.aspx>, (24.05.2024).



Graph 4.[161]

E) THE DRAFT MASS CODE

The draft MASS Code represents a significant step toward establishing a regulatory framework for MASS. It aims to address the unique challenges posed by these ships, bridging the gap between traditional maritime conventions and the technological realities of unmanned operations. It outlines requirements for different degrees of autonomy, from ships that can be operated remotely to ones that are completely autonomous, focusing on safety, security, and environmental protection. Key areas include design and construction standards, operational requirements, remote-control center regulations, and guidelines for integrating autonomous systems. It also addresses critical issues such as cybersecurity, system redundancy, collision avoidance, and crew or remote operator responsibilities.[162] However, while the draft demonstrates progress, it also reveals several areas requiring further refinement to ensure comprehensive safety, security, and environmental standards.

One strength of the draft MASS Code is its flexibility in accommodating different degrees of autonomy, from ships that can be operated remotely to ones that are completely autonomous.

[161] Graphic showing the progress of MASS Code by the Maritime Safety Committee
[162] MSC/ISWG/MASS 2/WP.1 Annex, p. 1.

This tiered approach allows for gradual implementation and adaptation, catering to diverse operational scenarios. The code also highlights critical areas such as cyber security, remote control center standards, and AI integration, demonstrating awareness of the technological complexities involved. However, the lack of clarity on the division of responsibilities between onboard systems, shore-based operators, and vessel owners creates potential ambiguities, especially in legal and liability contexts.

Despite its advancements, the draft MASS Code still faces challenges in harmonizing with existing frameworks. The integration of autonomous vessels into mixed-traffic waterways, alongside conventional ships, requires clearer collision avoidance protocols and enhanced communication standards. Additionally, while the draft identifies cyber security as a key focus, it needs more detailed provisions to address evolving cyber threats effectively. Overall, while the MASS Code is a promising foundation, it requires further stakeholder collaboration and iterative updates to ensure it adequately supports the integration of autonomous vessels in a sustainable and secure manner into global shipping.

III. SAFETY OF NAVIGATION FOR MASS

A) SAFETY CHALLENGES RELATED TO AUTONOMOUS SHIPS IN MIXED NAVIGATIONAL ENVIRONMENTS

The emergence of MASS represents a notable change in maritime transportation, offering improved operational efficiency, cost reduction, and potentially enhanced safety. The integration of autonomous ships into mixed navigational environments, where traditional manned vessels operate, presents distinct safety challenges. [163]This section delves into these challenges, with a focus on collision avoidance systems, communication protocols, regulatory frameworks, and the human factors involved in making sure the safe coexistence of autonomous and manned ships.

Central to the safe operation of MASS in mixed navigational environments are robust collision avoidance systems (CAS).[164] Unlike conventional vessels that rely heavily on visual cues and human decision-making, autonomous ships utilize a combination of sensors, artificial intelligence, and real-time data processing to detect and respond to surrounding vessels. Key challenges include the accurate detection and prediction of the behaviour of both manned and unmanned vessels, accounting for variables such as speed, course changes, and environmental conditions. The effectiveness of CAS is crucial in preventing collisions and maintaining safe distances between ships. Continuous refinement and validation of collision avoidance algorithms through simulations and real-world testing are essential to enhance reliability and performance in diverse maritime scenarios. Furthermore, integrating advanced sensor technologies, such as radar, LiDAR, and AIS, is pivotal in improving situational awareness and reducing the risk of accidents in congested waterways and adverse weather conditions. Effective communication between autonomous ships and manned vessels is imperative for mutual awareness and coordinated navigation.[165]

Challenges arise from ensuring seamless interoperability between autonomous ship systems and existing communication infrastructure, minimizing latency in data transmission, and

[163] Felski, A./ Zwolak, K.: "The Challenges of Unmanned Ships", *Journal of Marine Science and Engineering*, 8(1), p.7, (Accessed on 15.01.2024).
[164] Goerlandt, F. / Kujala, P.: "On the reliability and validity of ship–ship collision risk analysis in light of different perspectives on risk", *Safety Science*, vol. 62, p.330, <https://doi.org/10.1016/j.ssci.2013.09.010.>, (Accessed on 07.03.2024).
[165] Rødseth, O. J./ Wennersberg, L. A.: "Improving the safety of interactions between conventional and autonomous ships ", *Ocean Engineering*, vol.284, <https://doi.org/10.1016/j.oceaneng.2023.115206>, (Accessed on 15.11.2023).

establishing clear protocols for resolving conflicts in navigation rights and responsibilities. Moreover, the development of adaptive communication technologies, such as VHF (Very High Frequency) radio, satellite communication, and emerging 5G networks, is essential to support real-time data exchange and enhance operational efficiency in mixed navigational environments.[166] The successful integration of autonomous ships into mixed navigational environments hinges on robust regulatory and legal frameworks that address liability, accountability, and compliance with international maritime laws.

The integration of autonomous ships in maritime operations has led to a reduction in direct human involvement, emphasising the continued importance of human factors in overseeing system performance and responding to unforeseen events. As this transformative technology emerges, comprehensive training programs are essential for both shore-based personnel and onboard operators. These programs should focus on developing technical proficiency in autonomous technologies, facilitating effective decision-making in mixed navigational environments, and ensuring mastery of emergency response protocols. Addressing human factors is crucial to ensure a smooth and successful transition from conventional to autonomous maritime operations, fostering confidence in the dependability and security of autonomous ship systems.[167]

Additionally, promoting a culture of ongoing learning and development among maritime professionals is crucial for adapting to technological advancements, enhancing operational resilience, and ensuring high standards of safety and efficiency in autonomous ship operations.. In addition to technical training, there is a growing recognition of the need to emphasize the development of non-technical skills in maritime professionals as they navigate the shift towards autonomous technologies. These skills include effective communication, teamwork, leadership, and decision-making under stress, all of which are vital in ensuring safe and efficient operations.[168] As the industry evolves, investing in the holistic development of maritime professionals is imperative, recognising that human expertise remains an integral part of the transition to autonomous maritime operations.

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[166] Guo, W. / Zhang, X.: "Traffic Organization Service for Maritime Autonomous Surface Ships (MASS) with Different Degrees of Autonomy*", J. Mar. Sci. Eng.* , 10(12), <https://doi.org/10.3390/jmse10121889>, (Accessed on 04.12.2023).
[167] Kim, T./ Perera, L.: "Safety challenges related to autonomous ships in mixed navigational environments", *WMU Journal of Maritime Affairs* 21(4), <https://doi.org/10.1007/s13437-022-00277-z>, (Accessed on 30.05.2024).
[168] Ringbom, H.: "Regulating Autonomous Ships—Concepts, Challenges and Precedents", *Ocean Development & International Law*, p.14, <https://doi.org/10.1080/00908320.2019.1582593>, (Accessed on 23.05.2024).

The integration of autonomous ships into mixed navigational environments presents transformative opportunities for the maritime industry and requires addressing significant safety challenges. By advancing collision avoidance systems, establishing effective communication protocols, developing comprehensive regulatory frameworks, and enhancing human factors training, stakeholders can foster the safe and efficient deployment of autonomous ships alongside manned vessels. Continued collaboration between industry leaders, regulators, and research institutions is essential to realize the full potential of autonomous technologies while ensuring maritime safety remains paramount. Through proactive measures and innovative solutions, the maritime industry can navigate the complexities of mixed navigational environments and embrace autonomous technologies as a catalyst for sustainable growth and operational excellence.[169]

B) PILOTAGE

As autonomous vessels revolutionize the maritime industry, their integration raises complex legal and regulatory challenges, particularly concerning pilotage. Regulation 29 of COLREG and Chapter V, Regulation 23 of SOLAS deal specifically with this matter.

1) SOLAS Chapter V, Regulation 23: Pilot Ladder Requirements

This chapter sets forth regulations governing the design, construction, and use of pilot ladders, ensuring pilots' safe embarkation and disembarkation. These regulations are designed to protect the safety of pilots and ensure efficient pilotage operations.[170]

These regulations were primarily developed for manned vessels, assuming the presence of human pilots who require safe embarkation and disembarkation procedures using pilot ladders. With the advent of autonomous vessels, there is a lack of specific regulations addressing pilotage operations in the absence of traditional onboard personnel. This regulatory gap leaves uncertainty regarding compliance with SOLAS requirements for autonomous shipping operations. Legal frameworks lack clear guidelines for certifying the safety and effectiveness of pilot ladder systems on autonomous vessels. While SOLAS regulations mandate safety standards for pilot ladders on traditional ships, similar standards tailored to autonomous vessels are

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[169] Tao, J. / Liu, Z.: "Hazard identification and risk analysis of maritime autonomous surface ships: A systematic review and future directions", Ocean Engineering, Vol. 307, <https://doi.org/10.1016/j.oceaneng.2024.118174>, (01.09.2024).
[170] SOLAS, Ch. V, Regulation 23.

lacking.[171] As a result, there is uncertainty about the safety and reliability of pilotage operations involving autonomous vessels, raising concerns about compliance with SOLAS safety requirements. Pilot ladder systems must adapt to accommodate the integration of autonomous technology on vessels. However, there is a legal gap in addressing the compatibility of pilot ladders with autonomous navigation systems and onboard automation.[172] Existing SOLAS regulations do not provide guidance on how pilot ladder systems should interface with autonomous vessel systems, access points, or onboard sensors. This lack of clarity creates challenges in ensuring compliance with existing regulations while accommodating the unique features of autonomous vessels. Legal gaps also exist in determining responsibility and liability for pilotage operations involving autonomous vessels. SOLAS regulations traditionally assign responsibility for safe navigation and compliance with safety standards to vessel operators and crew members. In the context of autonomous shipping, questions arise about the allocation of responsibility between autonomous systems, vessel operators, and shore-based authorities. Clarity is needed regarding the roles and responsibilities of various stakeholders to ensure accountability and mitigate risks in pilotage operations. The interaction between autonomous vessel systems and human operators during pilotage operations presents another legal challenge.[173]

2) COLREG's, Regulation 29: Pilot Vessels

It mandates that these vessels must not obstruct others in narrow channels, display appropriate lights, and follow navigation rules for safe passage. Compliance ensures safe pilotage operations and maritime safety. However, these regulations were developed according to manned vessels and may not adequately address the unique challenges posed by autonomous vessels.

Traditional pilotage regulations may require the presence of pilots on board vessels navigating in restricted or congested waters. The autonomous nature of these vessels raises questions about the necessity of pilots and the evolution of their role in autonomous navigation. In incidents involving autonomous vessels, determining liability and responsibility becomes complex.[174] Pilotage regulations traditionally assign responsibility to the pilot for safe navigation, but questions arise about liability for navigational errors or accidents involving autonomous vessels.

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[171] Davies, M.: (ed.1)"Autonomous Ships and the Law", Ch. 17, 2023.
[172] SOLAS, Ch. V, Regulation 23.(4).
[173] Sinohara, H. T.: "Port's technologies for autonomous ships in restricted waters", *Emerald Insight*, Vol. 7 No. 1, p.8, <https://www.emerald.com/insight/2397-3757.htm> (Accessed on 14.03.2024).
[174] COLREG'S, Rule 29.

Pilotage regulations involve regulatory oversight to ensure the competency and qualification of pilots.[175] However, the absence of regulatory frameworks for overseeing the operation of autonomous vessels and assessing the competence of their onboard systems raises questions about the need for implementing a new framework. Autonomous vessels must navigate alongside piloted vessels in shared waterways. Legal gaps exist in addressing interoperability issues and ensuring smooth coordination between autonomous and manned vessels to prevent collisions and maintain navigational safety.[176]

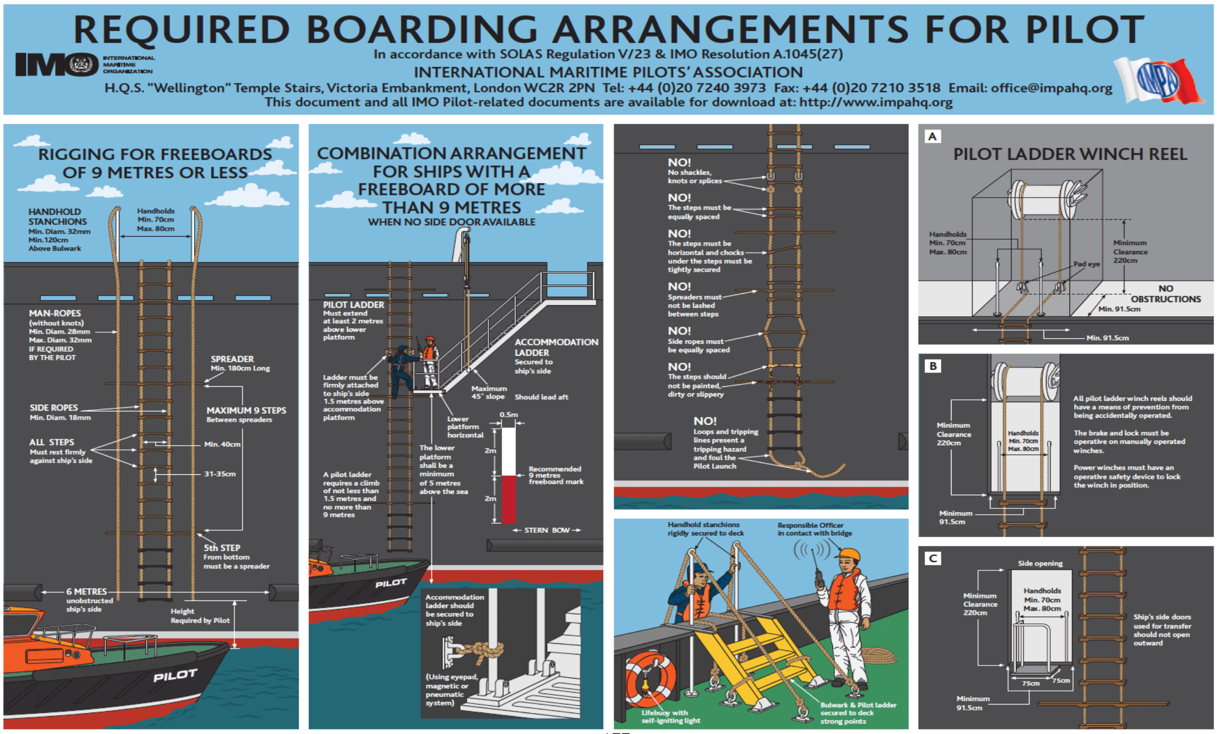

Figure 14.[177]

[175] Pretorius, G.: "Remotely Controlled Autonomous/Unmanned Ships in Rotterdam Pilot Waters" Research gate, <https://10.13140/RG.2.2.34158.74563> , (Accessed on 12.05. 2024).
[176]Carey, L.: "All Hands Off Deck? The Legal Barriers to Autonomous Ships", *NUS Law Working Paper*, No. 2017/011, ch. 6, p. 23, (Accessed on 01.04.2024).
[177] Station de Pilotage: 'Pilot transfer guide', pg.10 <https://piloteslehavre.fr/en/service-to-ships/boarding-arrangements/>, (Accessed on 10.04.2024).

C) GOOD SEAMANSHIP

Good seamanship in autonomous vessels begins with meticulous attention to navigation and route planning. While human sailors rely on charts, landmarks, and experience to navigate, autonomous vessels depend on a complex interplay of sensors, GPS, and advanced algorithms. Ensuring the accuracy and reliability of these systems becomes paramount. Seamanship extends to the continuous monitoring and updating of navigation data, considering factors such as weather patterns, sea conditions, traffic density, and navigational hazards. Additionally, it involves the development of efficient and safe routing algorithms that optimize fuel consumption, minimize environmental impact, and adhere to maritime regulations.[178]

Traditional seamanship emphasizes the importance of maintaining a proper lookout and taking evasive action to avoid collisions.[179] With autonomous vessels, this responsibility shifts to collision avoidance algorithms and sensor systems. Good seamanship now involves the design and implementation of robust collision detection and avoidance mechanisms capable of accurately identifying potential hazards and navigating around them safely. This includes the integration of radar, lidar, sonar, and other sensor technologies, as well as sophisticated decision-making algorithms that prioritize safety while considering factors such as vessel speed, course, and the surrounding environment.[180]

Human sailors rely on their experience and intuition to handle vessels in various conditions and respond effectively to emergencies. Autonomous vessels must be equipped with advanced manoeuvring capabilities and contingency plans to navigate safely and respond to unforeseen circumstances. Good seamanship entails designing autonomous systems capable of autonomously executing complex manoeuvres, such as docking, anchoring, and navigating through narrow channels. Moreover, it involves developing emergency response protocols that enable autonomous vessels to mitigate risks and communicate effectively with shore-based operators or nearby vessels in the event of emergencies such as engine failure, grounding, or adverse weather conditions.[181]

Seamanship requires the ability to adapt to changing weather, sea conditions, and operational

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[178] Stankiewicz, P. / Heistand, M.: “Quantifying Good Seamanship For Autonomous Surface Vessel Performance Evaluation”,*2020 IEEE International Conference on Robotics and Automation*, p.01 <doi: 10.1109/ICRA40945.2020.9197572.>, (31.08.2020).

[179] Mathew, F.: “What Is Involved In Maintaining A Proper Lookout?”, *Sailing Savvy*, <https://sailingsavvy.com/what-is-involved-in-maintaining-a-proper-lookout/>, (Accessed on 05.12.2023).

[180] Zhou, X./ Huang, J.: “A Study of the Application Barriers to the Use of Autonomous Ships Posed by the Good Seamanship Requirement of COLREGs”, *Journal of Navigation*, 73(3), p.710-725, <doi:10.1017/S0373463319000924>, (Accessed on 11.12.2023).

[181] Stankiewicz, P.: “A Primitive-Based Approach to Good Seamanship Path Planning for Autonomous Surface Vessels”,*International Conference on Robotics and Automation*, < doi: 10.1109/ICRA48506.2021.9561507.>,(Accessed on 05.06.2024).

requirements. Autonomous vessels must be programmed to monitor and respond to changes in real-time. Good seamanship involves designing adaptive algorithms and systems capable of making informed decisions based on current conditions and forecasts. This includes dynamically adjusting course and speed to optimize performance and safety, as well as recalibrating sensor systems to account for variations in environmental conditions. Additionally, it involves incorporating machine learning and artificial intelligence techniques to improve the vessel's ability to anticipate and respond to changing circumstances effectively. Ethical conduct and compliance with maritime laws and regulations are fundamental principles of seamanship. With autonomous vessels, ethical programming becomes crucial.[182]

While autonomous vessels operate without direct human control, human oversight remains essential for ensuring safety and addressing unforeseen circumstances. Good seamanship involves defining clear protocols for human intervention, remote monitoring, and control of MASS to mitigate risks and ensure compliance with established standards. This includes establishing communication channels between autonomous vessels and shore-based operators, implementing remote diagnostics and troubleshooting capabilities, and providing training to operators and crew members on how to interact with autonomous systems effectively.[183] Additionally, it involves establishing mechanisms for collecting and analysing data from autonomous operations to identify areas for improvement and enhance the overall safety and performance of autonomous vessels.[184]

Good seamanship in autonomous vessels combines traditional maritime principles with cutting-edge technology and advanced algorithms. Ensuring accurate navigation, robust collision avoidance, adaptive manoeuvring, and ethical conduct are essentialfor autonomous vessels' safe and effective operation. Moreover, maintaining human oversight and establishing clear protocols for intervention and accountability are critical components of this new era of seamanship. By addressing these factors, the maritime sector can maintain the highest standards of safety and accountability while utilizing the advantages of autonomous technology.

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[182] Singer, P./ Fai, T.: "Self-Driving Cars and AI Ethics", *Project Syndicate*, <https://www.project-syndicate.org/commentary/san-francisco-self-driving-cars-ethical-implications-by-peter-singer-and-tse-yip-fai-2023-09>, (Accessed on 08.11.2023).
[183] Noussia, K.: The Regulation of Automated and Autonomous Transport, UK, 2023, p.210.
[184] Xu, H./ Rong, H.: "Use of AIS data for guidance and control of path-following autonomous vessels", *Ocean Engineering*, 194(3):106635, <https://doi.org/10.1016/j.oceaneng.2019.106635>, (15.12.2019).

D) SEAWORTHINESS

Seaworthiness refers to the condition of a vessel that enables it to safely navigate and operate in the maritime environment. It encompasses various factors such as structural integrity, stability, propulsion systems, navigational equipment, and crew competency. A seaworthy vessel is appropriate for its intended use, able to withstand maritime dangers, and capable of protecting its passengers, crew, cargo, and the marine environment. Seaworthiness assessments are conducted to determine whether a vessel meets the necessary standards and requirements for safe operation at sea, as outlined by international maritime regulations, classification societies, and industry best practices.[185]

The seaworthiness of autonomous vessels represents a novel challenge for maritime regulators, industry stakeholders, and legal scholars. In this chapter, we examine the concept of seaworthiness in relation to MASS, focusing on the legal gaps and navigational safety considerations that arise in ensuring these vessels' safe and reliable operation at sea. It explores the regulatory frameworks, international conventions, and legal principles relevant to seaworthiness assessments, as well as the unique challenges posed by autonomous technology.[186][187]

The legal framework for the seaworthiness assessment of autonomous vessels multifaceted, drawing on international conventions, national laws, and industry standards. While existing maritime laws and regulations provide a foundation for assessing the seaworthiness of manned vessels, they may not fully address the unique characteristics and operational challenges of autonomous vessels. Therefore, in order to guarantee the efficient governance of autonomous vessel operations, substantial legal loopholes must be filled.[188]

Determining liability and responsibility in the event of accidents, collisions, or incidents involving autonomous vessels poses challenges due to the absence of human operators onboard. Legal frameworks may need to be adapted to clarify liability issues and establish mechanisms for allocating responsibility among stakeholders, including vessel owners,

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[185] Menon, A.: “What is Seaworthiness And Why it is Important?”, *Marine Insight,* (Accessed on 08.06.2024).
[186] Ewuru, B.: “The Concept of Seaworthiness: Understanding Its Various Legal Aspects”,<https://www.linkedin.com/pulse/concept-seaworthiness-understanding-its-various-legal-bright-ewuru/>, (Accessed on 16.02.2024).
[187] Bernard, R.: “Autonomous Shipping and Seaworthiness: How Emerging Technologies Will Affect the Carriage of Goods by Sea”, *Canadian Transportation Research Forum,* p.4, (Accessed on 16.02.2024).
[188] Sooksripaisarnkit, P. / Kan, D.: “Seaworthiness and autonomous ships: legal implications in the 21st century*”, Australian and New Zealand Maritime Law Journal,* Vol. 35, No. 1, (Accessed on 28.02.2024).

operators, manufacturers, and developers of autonomous systems.[189]

The certification process for autonomous vessels may differ from that of manned vessels, requiring new standards, guidelines, and procedures for assessing the seaworthiness of autonomous systems. Regulatory authorities may need to develop specialized certification frameworks that address the unique features and capabilities of autonomous technology while ensuring compliance with international standards and best practices.[190] While autonomous vessels operate without direct human intervention, there may be situations where human oversight or intervention is necessary to ensure navigational safety and compliance with legal requirements. Legal frameworks should define the roles, responsibilities, and authority of human operators onboard or in control centers, specifying when and how the human intervention may be required in autonomous vessel operations.

Autonomous vessels must be equipped with collision avoidance systems that enable them to detect, track, and respond to other vessels, obstacles, and hazards in their vicinity. [191] These systems should be capable of autonomously manoeuvring the vessel to avoid collisions and maintain safe distances from other traffic. Autonomous vessels require robust situational awareness capabilities, including sensors, cameras, radar, and communication systems, to monitor their surroundings and detect potential threats or risks. Real-time data processing and analysis are essential for providing accurate situational awareness and informing decision-making processes onboard autonomous vessels.[192]

[189] Kampantais, N.: "Seaworthiness in autonomous unmanned cargo ships", *Research Gate*, ch. 3, p.18, <https://DOI:10.13140/RG.2.2.23001.11369>, (11.06.2016).
[190]Vergani, E.:" The regulatory framework tackling the rise of unmanned and automated vessels and its limits*", International Bar Association*, (Accessed on 14.06.2024).
[191] Huang, Y.: "Collision Avoidance Systems for Maritime Autonomous Surface Ships Considering Uncertainty in Ship Dynamics", *IFAC*, vol.35, iss.2, p.14619, <https://doi.org/10.1016/j.ifacol.2020.12.1470>, (Accessed on 24.05.2024).
[192] Kircher, A.: "Rise of the Machines – A Legal analysis of Seaworthiness in the context of autonomous shipping", p.23, <https://lup.lub.lu.se/student-papers/record/8977227/file/8984495.pdf>, (Accessed on 05.03.2024).

CONCLUSION

Integrating MASS into the global shipping industry signifies a transformative shift, reshaping traditional maritime operations and necessitating comprehensive adjustments in the regulatory framework to ensure safety and efficiency. With an emphasis on legal issues pertaining to navigation safety, this thesis has examined the many potential and challenges brought about by the development of autonomous vessels.

Key Findings:

Legal Framework under UNCLOS:

- UNCLOS establishes the rights and obligations of states in marine affairs and provide the general legal framework for maritime governance. However, UNCLOS was established in an era when autonomous ships were not envisioned, leading to several areas of ambiguity regarding MASS. For instance, UNCLOS provisions on the rights of coastal states, the duties of flag states, and the responsibilities in international waters need to be revisited to address the operational realities of autonomous vessels.

- Flag states' obligations under UNCLOS, like as making sure ships carrying their flag adhere to international laws, must be modified to take MASS's particular needs into account. This includes certification processes, inspections, and compliance with safety standards that account for the absence of a human crew. Similarly, the coastal states rights to regulate navigation within their territorial waters must be balanced with the need to facilitate the safe passage of autonomous ships, ensuring that local regulations do not create barriers to the global operation of MASS.

Regulatory Gaps in SOLAS and COLREGs:

- SOLAS Convention, the cornerstone of international maritime safety regulations, currently does not fully address the unique operational dynamics of MASS. Traditional SOLAS regulations are predicated on the presence of a human crew, with specific requirements for onboard safety equipment, emergency procedures, and crew training. Autonomous ships, particularly the third and the fouth degrees, challenge these assumptions. For instance, fire protection systems on MASS must be capable of operating without human intervention, and life-saving appliances must be redesigned to function in unmanned scenarios. Furthermore, the structural integrity of autonomous ships must be reassessed to ensure they meet safety standards without the continuous oversight of a human crew.

- COLREGs also face significant challenges with the integration of MASS. These regulations rely heavily on human judgment for collision avoidance and navigational decisions. Autonomous systems must be equipped with advanced sensor technologies, such as radar, LiDAR, and AI algorithms, to interpret complex maritime environments and make real-time decisions that adhere to COLREGs. Ensuring that these systems can reliably mimic or surpass human decision-making capabilities is crucial for the safe operation of MASS alongside manned vessels.

Technological Adaptations:

- The successful deployment of MASS depends on developing and integrating advanced technological solutions. These include sophisticated fire detection and suppression systems that can function autonomously, robust autonomous life-saving devices and enhanced communication protocols for distress signalling and coordination with search and rescue operations. The future holds a safer navigation envinronmet, but it needs rigorous testing and certification processes to support the implementation of these technologies to ensure they meet international safety standards.

Legal and Considerations:

- The introduction of autonomous ships raises several legal and ethical questions that must be addressed. One of the main questions is who is responsible for accidents. Traditional maritime law holds the ship's master and crew responsible for the vessel's navigation and safety. Even though the terms master, remote operator, etc, are somehow explained in the last MASS draft code, they need better clarification in all degrees to ensure accountability.

- Ethical considerations also come into play, particularly concerning replacing human crews with autonomous systems. This shift could lead to significant changes in maritime employment, potentially resulting in job losses and requiring a reevaluation of the skills and training necessary for maritime professionals. The ethical implications of such a transition must be carefully managed to balance technological progress with social responsibility.

Future Outlook:

Regulatory Evolution:

- IMO and national regulatory bodies must continue to evolve their frameworks to accommodate the unique needs of autonomous vessels. This includes not only revising existing conventions like SOLAS, COLREGs, and UNCLOS but also developing new regulations specifically tailored to the operational realities of MASS. The anticipated completion of a comprehensive MASS Code by 2025 is a significant step in this direction.

Technological Advancements:

- Maintaining the safety and dependability of MASS will need ongoing improvement in autonomous navigation systems. Enhancing these systems' capacity to manage progressively complex maritime environments and operational scenarios should be the primary goal of research and development. Collaboration between industry, academia, and regulatory bodies will be critical to driving these advancements and ensuring they meet the stringent safety standards required for maritime operations.

Legal Framework:

- Developing clear legal and ethical frameworks for operating autonomous ships is paramount. Establishing liability procedures, outlining the duties and responsibilities of autonomous systems and remote operators, and addressing the possible socioeconomic effects of automation on the maritime labor are all part of this.

The future of MASS holds immense potential to transform global shipping through enhanced efficiency, reduced human error, and lower operational costs. However, realising this vision requires addressing key challenges, including the development of reliable and secure technologies, integration with existing maritime infrastructure, and adaptation of international regulations like SOLAS and COLREGs. Public acceptance, liability concerns, and the impact on maritime jobs will also play a critical role. Ultimately, the widespread adoption of MASS will require a well-rounded strategy that incorporates strong regulatory frameworks technical innovation, and collaboration across the maritime industry to ensure safety, security, and sustainability.

ACADEMIC RESOURCES

A) PRIMARY SOURCES

1. Convention-Based Regimes

Convention on the International Regulations for Preventing Collisions at Sea (COLREG, adopted 1972).

International Convention for the Safety of Life at Sea (SOLAS, adopted 1974 entry in force 1980).

International Convention on Maritime Search and Rescue (SAR, adopted 1979).

International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW, adopted in 1978).

The United Nations Convention of Law of the Sea (UNCLOS 1982).

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ABSTRACT

The advancement of Maritime Autonomous Surface Ships (MASS) represents a paradigm shift in the maritime industry, offering potential improvements in efficiency, cost reduction, and safety. However, this innovation also presents significant legal and regulatory challenges, particularly regarding the safety of navigation. This study examines the legal implications of MASS within existing international frameworks, including UNCLOS, SOLAS, and COLREGs, identifying regulatory gaps and potential reforms. It explores the advantages of autonomous vessels, such as reduced human error and environmental benefits, while also addressing critical concerns, including cybersecurity risks, liability issues, and the need for updated safety standards. The thesis further assesses the International Maritime Organization's (IMO) approach to integrating MASS into global shipping regulations, analyzing the ongoing development of the MASS Code and its implications for the future of maritime law. Ultimately, this research highlights the necessity of adapting legal instruments to ensure the safe and effective integration of autonomous ships into international waters.

Keywords: MASS, autonomous, SOLAS, ship, navigation, UNCLOS, COLREGs, remote controller, remote control center.

ÖZET

Deniz Otonom Yüzey Gemilerinin (MASS) ilerlemesi, denizcilik sektöründe bir paradigma değişimini temsil ediyor ve verimlilik, maliyet düşürme ve güvenlikte potansiyel iyileştirmeler sunuyor. Ancak bu yenilik, özellikle navigasyon güvenliğiyle ilgili olarak önemli yasal ve düzenleyici zorluklar da sunuyor. Bu çalışma, UNCLOS, SOLAS ve COLREG'ler dahil olmak üzere mevcut uluslararası çerçeveler içindeki MASS'ın yasal etkilerini inceleyerek düzenleyici boşlukları ve potansiyel reformları belirliyor. İnsan hatasının azaltılması ve çevresel faydalar gibi otonom gemilerin avantajlarını araştırırken, siber güvenlik riskleri, sorumluluk sorunları ve güncellenmiş güvenlik standartlarına duyulan ihtiyaç gibi kritik endişeleri de ele alıyor. Tez, Uluslararası Denizcilik Örgütü'nün (IMO) MASS'ı küresel nakliye düzenlemelerine entegre etme yaklaşımını daha da değerlendiriyor, MASS Kodunun devam eden gelişimini ve deniz hukukunun geleceği için etkilerini analiz ediyor. Sonuç olarak, bu araştırma, otonom gemilerin uluslararası sulara güvenli ve etkili bir şekilde entegre edilmesini sağlamak için yasal araçların uyarlanmasının gerekliliğini vurguluyor.

Anahtar kelimeler: MASS, otonom, SOLAS, gemi, navigasyon, UNCLOS, COLREG'ler, uzaktan kumanda, uzaktan kumanda merkezi.