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Maritime Autonomous Surface Ships (MASS) and Ethical Consideration for Merchant Shipping

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ABSTRACT

The advent of Maritime Autonomous Surface Ships (MASS) represents a significant shift in the maritime industry, bringing with it a host of ethical considerations that remain insufficiently addressed. This paper critically examines these ethical dimensions, distinct from functional, legal, and regulatory aspects. Key issues such as job displacement, decision-making in maritime search and rescue (SAR) operations, societal acceptance, and environmental sustainability are explored. By analysing these challenges, this study aims to provide actionable insights for industry stakeholders and policymakers, ensuring that the integration of autonomous technologies aligns with ethical principles and societal values while supporting the sustainable development of the maritime industry.

Key Words: Autonomous, Shipping, MASS, Surface Shipping, Sustainability

Introduction

The world's merchant shipping industry has a significant impact on international trade, transporting more than 80% of global trade by volume[1]. Over the past few years, autonomous shipping has become a disruptive technology that promises significant efficiency and safety gains[2]. With the help of advanced sensors, AI, and automation technologies, autonomous vessels can carry out a wide range of maritime operations that do not require human intervention. In the commercial shipping business, autonomous shipping, often known as "unmanned vessels" or "autonomous marine vehicles," is a game-changing innovation[3]. By utilising sophisticated automation, artificial intelligence, and remote monitoring systems, this technology enables ships to function with little to no human interaction[4]. However, autonomous shipping also raises important ethical issues. In this research article, the researcher wanted to explore the key ethical considerations of autonomous shipping in the merchant shipping business, to provide insights and recommendations to industry stakeholders, policymakers, and researchers[5].

Numerous international research and development efforts have been conducted to date on the many advantages of putting autonomous ships into service[6]. They described various circumstances in which an autonomous ship could be operated. For example, a design created during the Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) project called for crew input when arriving at the port and leaving, but the ocean journey was to be completed on its own[7]. The Advanced Autonomous Waterborne

Applications Initiative (AAWA) is a different project with a different scope than the one previously described[8]. Rolls-Royce spearheaded the idea to create the blueprints and specifications for self-governing vessels appropriate for interior rivers[9].

Thus, the study's goal is to identify the advantages of autonomous ships and ethical matters associated with operating autonomous ships, including safety factors which ensure safe navigation.

Background of the Study

Ships have long been the lifeblood of the maritime sector, acting as a cornerstone of global trade and transportation[10]. From the move from sail to steam to the introduction of containerisation to the digitisation of navigation systems, technical innovations have continuously transformed the landscape of shipping throughout the decades[11]. A fresh wave of innovation has developed in recent years, moving the sector into the era of autonomous shipping[12]. The emergence of autonomous shipping is a revolutionary journey, combining cutting-edge technology to improve marine efficiency, safety, and sustainability.

The road to autonomous shipping begins with the automation of marine procedures and the incorporation of new technology[13]. The emergence of automated navigation systems, GPS technology, and satellite communication was an early advancement. These advancements opened the path for enhanced efficiency and safety, establishing the groundwork for today's more complex autonomous systems[14].

The incorporation of artificial intelligence (AI) is one of the primary drivers in the advancement of autonomous ships[15]. Artificial intelligence algorithms, machine learning, and computer vision have enabled ships to read complicated marine situations, make real-time choices, and adapt to changing conditions. These technologies are intended to simulate human-like decision-making, adding a layer of dependability and accuracy to marine operations[16].

Despite the promising advancements, the evolution of autonomous shipping faces several challenges[17]. Concerns related to cybersecurity, regulatory frameworks, and the acceptance of autonomous technologies within the maritime community need to be addressed [28]. The International Maritime Organisation (IMO) and national maritime authorities are actively working to establish guidelines and regulations to ensure the safe and responsible integration of autonomous vessels into the global maritime network[18].

Although this breakthrough offers greater sustainability, safety, and efficiency, it also raises ethical questions that need to be carefully considered. Hence, the researcher finds that there is a research gap in the area of autonomous shipping and ethics in the Indian context and no research has been conducted in this area. From the light of the above gap identification, the researchers believe that this study has contextual significance.

Citation Analysis

As per Gundolf and Filser,[19] the citation analysis provides several insights about a certain area of study. In the first place, it aids in identifying the most important writers and works that have a big effect on a certain subject of study. Second, the authors' communication channels and knowledge flow may be found. Finally, one might investigate how a knowledge domain has changed and evolved by following the connections between cited and citing works[20].

The researchers conducted a thorough search of journal papers to cover the whole study area of Maritime Autonomous Surface Ships and ethical aspects in the merchant shipping business, adhering to the technique suggested by White and Griffith (1981)[21]. The researchers took the following five steps:

(a) Gathering data was the first step. One of the most complete, reliable databases with consistent outcomes was chosen: Scopus. It was possible to obtain the meta-data of all papers pertaining to drone uses in agriculture. After that, an examination of these chosen articles was conducted, eliminating any off-topic content.

(b) After examining the literature, we determined which terms are most crucial to the field of study.

(c) To uncover underlying citation patterns, the relationship between authors and documents was investigated using citation analysis. Additionally, it was determined which publications and writers have had the biggest impact on the subject of agricultural drones.

(d) A co-citation analysis was conducted to create clusters of related papers.

(e) In order to illustrate the collaborative network, the researchers lastly examined the relationships and connections among nations, organisations, and publications.

Table 1 derives the keyword occurrence in the collected 200 literature reviews from Google Scholar and Figure 1 the interlink between the keywords listed.

In Figure 2 the researchers envisage the density of the keywords identified in the collected literature reviews, in which the researchers have substantiated that there are trivial studies conducted for tracing the ethical and security issues related to MASS. The researchers conducted the keyword analysis and Figure 3 depicts the interconnection of keywords used for the analysis.

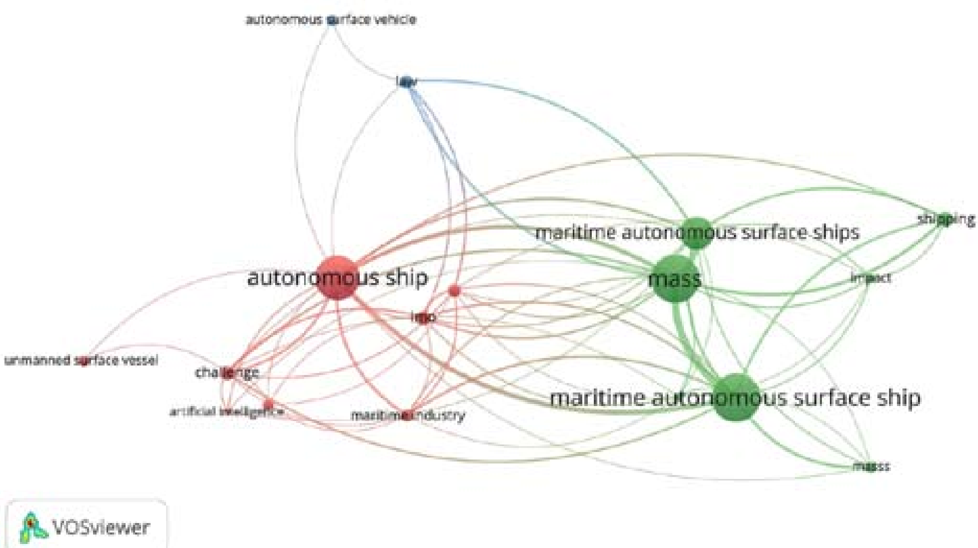
In the citation analysis, the researchers identify the most influential study on MASS and its advantages and disadvantages. Figure 4 depicts the fifty most influential papers in this area obtained through a search of the keywords.

Table 1 - Keyword Occurrence in the Collected 200 Literature

Keywords	Occurrence	Avg pub./Year
Autonomous Shipping	26	2022 (36)
Autonomous Surface Vessel	8	2022 (50)
IMO	11	2022 (52)
Maritime Industry	9	2022 (69)
Surface	28	2022 (54)
Vessel		
Maritime Autonomous Surface Ship (MASS)	48	2022 (33)
Merchant Shipping	57	2022 (70)
Unmanned Surface Vehicle (USV)	8	2022 (8)
ASV	7	2022 (4)
Autonomy	6	2022 (50)

Source: Collated by the authors

Figure 1 - Keywords occurrence visualisation for the period of 2022-2023



Source: Collated by the authors

Figure 2 - Keywords Density visualisation for the period of 2022-2023

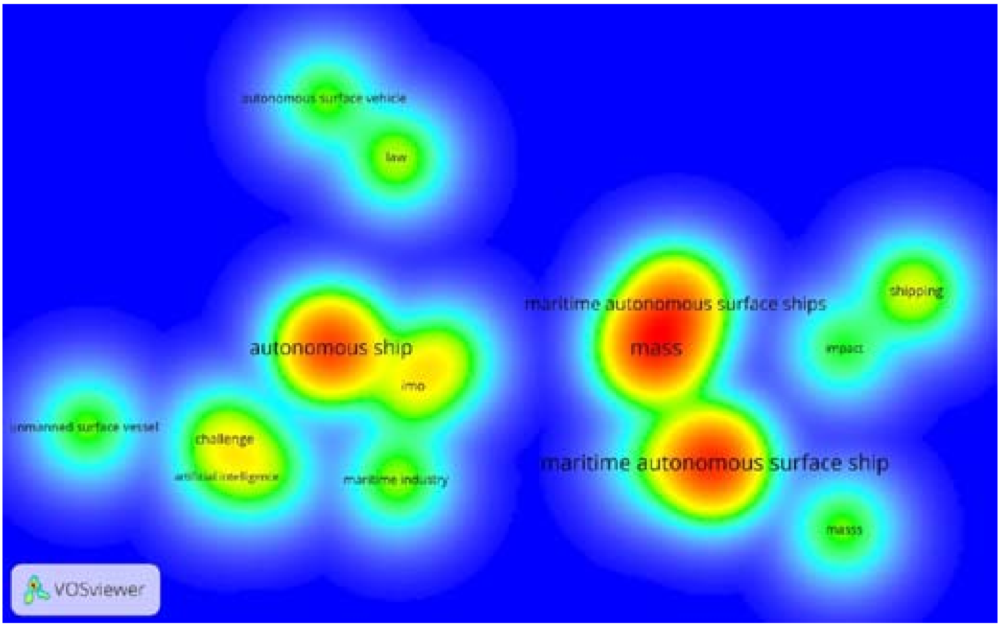


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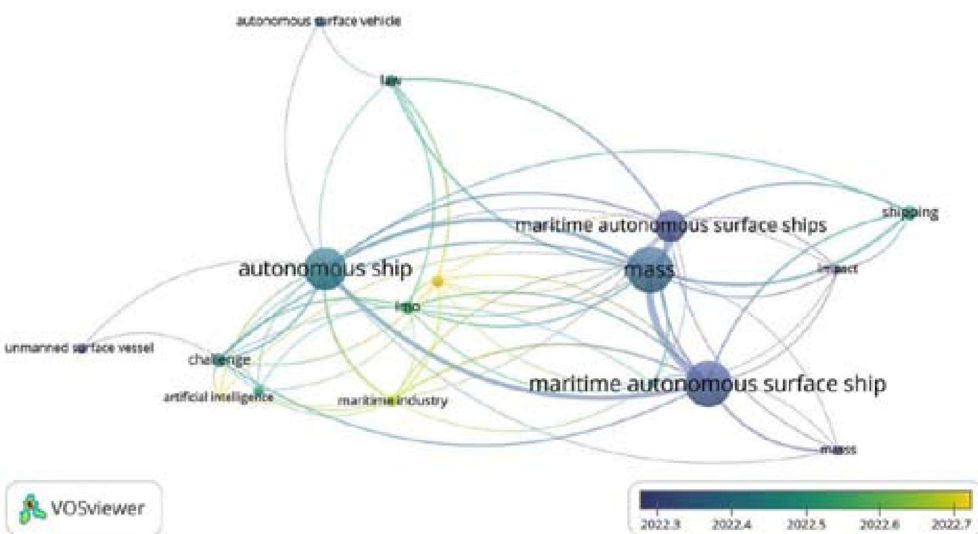
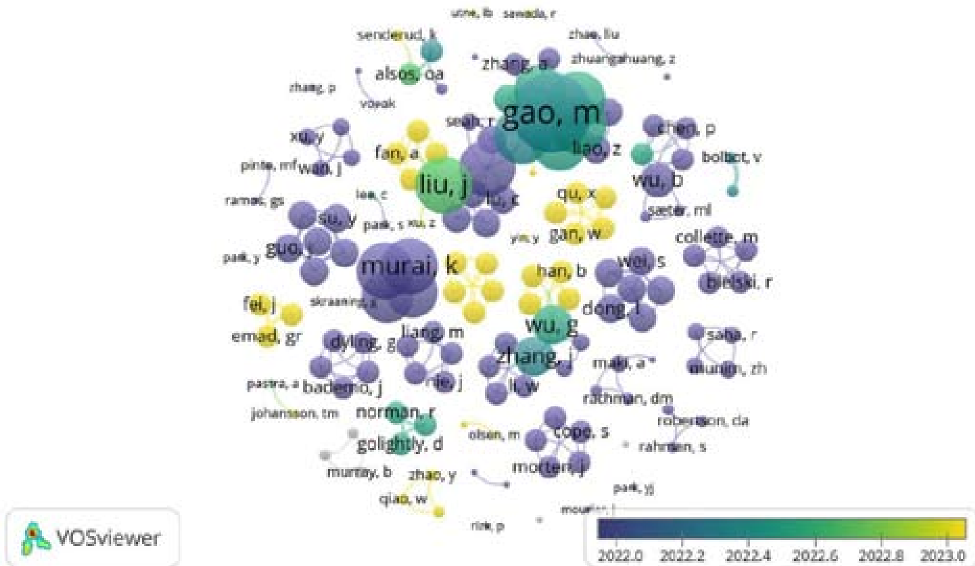
Figure 3 - Keywords interconnection visualisation for the period of 2022-2023



Source: Collated by the authors

Figure 4 - Authors' citation analysis



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Evolution of Autonomous Shipping

Ships have long been the lifeblood of the maritime industry, acting as a cornerstone of global trade and transportation[22]. From the move from sail to steam to the introduction of containerisation and the digitalisation of navigation systems, technical innovations have continuously transformed the landscape of shipping over the decades. A fresh wave of innovation has developed in recent years, moving the sector into the era of autonomous shipping[23]. The emergence of autonomous shipping is a transformative journey, combining cutting-edge technologies to improve maritime efficiency, safety, and sustainability[24].

Historical Background. The road to autonomous shipping begins with the automation of maritime procedures and the incorporation of new technologies. The emergence of automated navigation systems, GPS technology, and satellite communication were early developments[25]. These advancements paved the path for enhanced efficiency and safety, establishing the groundwork for today's more complex autonomous systems[26].

Artificial Intelligence Integration. The incorporation of artificial intelligence (AI) is one of the primary drivers in the advancement of autonomous ships[27]. Artificial intelligence algorithms, machine learning, and computer vision have enabled ships to read complicated maritime situations, make real-time choices, and adapt to changing conditions[28]. These technologies are intended to simulate human-like decision-making, adding a layer of dependability and precision to maritime operations[29].

Sensor Innovations. The advancement of autonomous shipping is primarily reliant on a variety of advanced sensor technology[30]. LiDAR (Light Detection and Ranging), radar, sonar, and cameras all contribute to a comprehensive image of the ship's surroundings. These sensors allow warships to identify obstructions, navigate through difficult weather conditions, and respond to dynamic scenarios, resulting in a level of situational awareness that exceeds traditional manual navigation[31].

Communication and connectivity. With the emergence of the Internet of Things (IoT), continuous connectivity and communication between autonomous vessels and onshore control centres has become possible[32]. Real-time data interchange is enabled by high-speed satellite communication and 5G networks, allowing operators to remotely monitor and manage ships[33]. This link between high-speed satellite communication and 5G and more networks improves overall shipping efficiency and allows for quick solutions to new difficulties[34].

Challenges and Regulatory Environment. Despite encouraging advances, the evolution of autonomous ships confronts a number of obstacles. Concerns about cybersecurity, legal frameworks, and the maritime community's acceptability of autonomous systems must be addressed [35]. The International Maritime Organization (IMO) and national maritime authorities are working hard to create rules and regulations that will ensure the safe and responsible integration of autonomous vessels into the global maritime network[36].

Sustainability and the Environment. Autonomous shipping holds the promise of enhancing the marine industry's environmental sustainability [37]. The application of artificial intelligence to optimise navigation routes, fuel consumption, and cargo management can result in lower greenhouse gas emissions and better energy efficiency[38]. The emergence of autonomous shipping is consistent with the industry's broader commitment to reaching environmental sustainability goals and reducing shipping's impact on the world's waters[39].

Concept of Autonomy

In a lot of literature, the terms "autonomy" and "automation" have been used interchangeably. Autonomy, in its traditional sense, is the capacity to make decisions for oneself and is associated with accountability, morality, dignity, uniqueness, and self-awareness. It is possible to study autonomy both at the individual and collective levels. Individually, older persons are appreciated for their capacity for self-determination [40].

What Autonomy Means. Despite the fact that automation and autonomy are connected to ship performance, they are not the same thing. Automation is physical technology (mechanical or digital) that may be applied in a specific setting. Autonomy is a state of being aware of one's surroundings[41]. This means environmental resilience, independence in action or function, and self-determination of objectives and resource allocation for a ship [42]. To put it another way, for automated systems and hence for a MASS, autonomy might be a desirable design aim. This work, likewise, views autonomy as a multifaceted construct[43]. The following two system aspects will be explored in particular.

(a) Independence or "viability" in a certain setting,

(b) Self-direction, or the ability to act and function without the assistance of other actors,

These aspects are multifaceted. For example, self-governance involves more than just the lack of outside control; it also calls for certain cognitive skills in order to learn and think strategically. Furthermore, self-directedness does not imply independence in operation because self-sufficient ships will operate within a larger maritime environment that includes, among other things, laws, other ships, pilot support, and vessel traffic service stations[44].

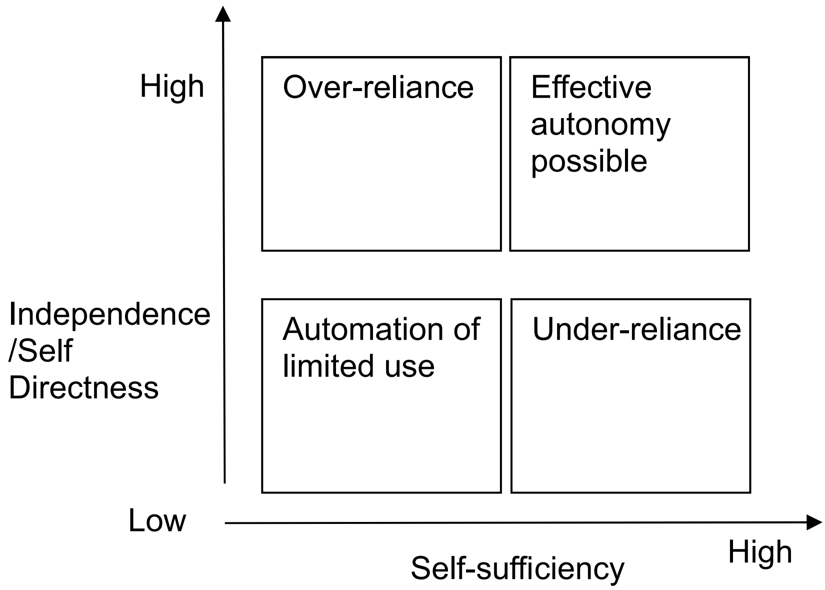
Dependency in context. The range of situations the system can handle is referred to as self-sufficiency, and the range of conditions it is authorised to handle on its own is referred to as self-directedness. Four "autonomy states" based on four possible dimension ratios are shown in Figure 5. For a variety of reasons, any imbalance in system design should be avoided. For example, the system is not employed properly when self-sufficiency is higher than Independence/Self-direction (bottom right). In the event that the order is reversed (top left), the system is permitted to manage circumstances for which it is not designed. As it can result in undesirable conditions or even deadly circumstances, this type of overreliance is risky and should be avoided for all essential systems [45]

With a constant (high) level of automation, the self-sufficiency of an autonomous ship could be sufficiently high or "viable" in the environment "A" but sub-optimal or less "viable" in environment "B" because the degree of self-directedness and self-sufficiency may vary within different contexts[46].

Self-sufficiency and self-direction, therefore, are dependent on the operational complexity of the autonomous system and cannot be considered absolute or given properties of the system. A wide range of autonomy states is conceivable due to the wide variations in operational complexity and environment dynamics[47]. These variations necessitate varied levels of support from other autonomous systems as well as from humans.

The term "first degree" describes a manned watercraft equipped with cutting-edge systems that automate ship direction and propulsion, hence lessening the mental strain on the crew[48]. Implementing the Shore Control Centre (SCC), which is in charge of the ship's navigation and other functions, becomes necessary when operating the ship from a different place. When a remotely operated vessel has seafarers on board (class 2),

Figure 5 - Automation States Metrix



Source: Provided by the authors

Table 2 - The level of independence and explanation for autonomous shipping provided by the IMO

No	Level of Autonomy	Explanation
(a)	Provide automated procedures and decision assistance on board.	The ship's systems and functions are operated and controlled by the seafarers who work on board. Automation may be used for some tasks.
(b)	Ship that can be commanded remotely and has sailors on it	The seafarers are on board, but the ship is managed and controlled from a different place.
(c)	Ship under remote control without any seafarers on board	The ship is managed and commanded from a different location. On board are no sailors.
(d)	Completely self-governing vessel	The ship's operating system is capable of making choices and choosing its own course of action.

Source: IMO

the crew is in charge of troubleshooting and port entry and departure. One could argue that under degree 3, the same is remotely achievable. According to Rødseth, the entire autonomy—degree 4—must be utilised to the maximum degree feasible in order to attain economic viability[49]

The primary motivation for implementing MASS into operations is to evaluate its financial advantages while maintaining the appropriate degree of safety[50]. The size of the advantages and the cost-effectiveness of the adopted solution are among the most important concerns for ship-owners[51]. Shipping corporations are unlikely to invest in autonomous ship technology if the economic rewards of doing so are insufficient. This is because the technology has a low return on investment (ROI). Creative solutions are typically linked to increased levels of uncertainty about their results, which implies higher risks and the need to manage them, particularly in the shipping industry, which has poor profit margins [52].

Ethical Considerations of MASS

As per Smith, ethics refers to the principles and standards that guide human behaviour in determining what is right or wrong, just or unjust, fair or unfair. It involves making decisions based on moral values such as honesty, integrity, fairness, respect, and responsibility. Ethics provides a framework for individuals and organisations to evaluate their actions and their consequences on others, ensuring that they act in ways that are respectful of others' rights and dignity. It is essential in various fields, including business, medicine, law, and technology, where the consequences of decisions can significantly impact individuals and society as a whole. In essence, ethics helps individuals and organisations navigate complex moral dilemmas while fostering trust, accountability, and positive societal outcomes[53].

The ethical implications of Maritime Autonomous Surface Ships (MASS) extend beyond functional, legal, and regulatory domains to address fundamental questions of morality in maritime operations. This section segregates ethical concerns from functional and regulatory imperatives to establish doctrinal clarity while linking them where necessary.

Workplace Displacement. The widespread use of self-driving ships may reduce the need for human seafarers, thereby eliminating a considerable number of jobs in the maritime industry.

It is critical to ensure a just transition for mariners whose jobs are threatened. Policies and methods should be put in place to retrain and reskill mariners for jobs within or beyond the maritime sector[54].

Safety. As per the research conducted by Mok et al, the MASS's capacity to manoeuvre and avoid crashes without human intervention is one of the key safety concerns. To provide real-time awareness of the vessel's surroundings and the ability to make quick, safe judgments, developers must install modern sensor technologies such as radar, lidar, and computer vision[55]. The ethical usage of autonomous ships must prioritise safety and dependability in order to avoid at-sea mishaps that could have disastrous effects on both the crew and the environment.

To ensure that autonomous systems satisfy high safety standards, they must be rigorously tested and validated. The industry must develop clear processes for dealing with system faults and emergencies, with a focus on safeguarding human lives and the marine environment[56].

MASS should be outfitted with robust systems to deal with emergency events such as inclement weather, equipment breakdowns, or unanticipated impediments. To limit risks and maintain the safety of the vessel and its surroundings, appropriate emergency response protocols, including contact with onshore control centres, must be developed[57].

Maritime Search and Rescue (SAR). Under the Safety of Life at Sea (SOLAS) Convention, maritime Search and Rescue (SAR) is a legal obligation for mariners, including those operating MASS (International Maritime Organisation [IMO], 1974). However, SAR also involves ethical considerations. For example, in a disaster scenario, how should an autonomous ship prioritise lives without the human ability to make situational judgments? Autonomous systems, guided by pre-programmed algorithms, may lack the contextual adaptability required in real-world emergencies. The inability to make real-time moral decisions highlights the need for ethical frameworks to guide MASS deployment in such contexts [58]

Environmental Sustainability. MASS has the potential to reduce fuel consumption and greenhouse gas emissions through optimised routes and intelligent navigation[59]. However, deploying MASS presents ecological challenges such as the disposal of outdated electronic systems and risks of environmental damage from system failures. Ethical maritime practices must address these sustainability challenges to ensure autonomous systems contribute positively to the industry's environmental footprint[60]. The usage of autonomous ships may have environmental consequences, such as increased maritime traffic or the possibility of accidents resulting in oil leaks. Concerns about ethics: It is critical to ensure that autonomous shipping contributes to environmental sustainability[61]. The industry should use environment-friendly techniques and follow environmental standards.

Isolation and Mental Illness. Autonomous ships may have a smaller staff or possibly operate without crewmembers on board; increasing mariner isolation. Measures should be put in place to address mariners' potential isolation and psychological damage[62]. To improve the mental health and well-being of crewmembers, adequate living accommodations, communication facilities, and support systems should be in place.

Algorithms for Ethical Decision Making. In emergency scenarios, such as avoiding collisions or responding to distress signals, autonomous systems may be required to make ethical decisions. The creation of ethical decision-making algorithms should take into account moral principles and values [63]. Transparency is vital for knowing how these algorithms work, and procedures for accountability should be in place in the event of ethical quandaries.

MASS's Attempts to Address Security Issues

Cybersecurity. MASS is primarily reliant on networked systems and communication networks. It is critical to ensure the cybersecurity of these systems in order to avoid unwanted access, cyberattacks, or potential hijacking. Robust encryption, secure communication protocols, and frequent cybersecurity assessments are critical for safeguarding the vessel's control systems against unwanted activity[64].

Data Integrity. The information used for navigation and decision-making must be correct and unaltered. Developers should put in place safeguards to maintain the integrity of data, prohibiting modification that could jeopardise the MASS's safety and security. This comprises procedures for safe data storage, transfer, and verification[65].

Remote Control Authorisation. When human participation is required, the authorisation and authentication systems for remote control must be extremely secure. Unauthorised access to control systems could result in accidents or malicious behaviour. It is critical to implement multi-factor authentication and secure authorisation mechanisms to prevent unwanted control access[66].

Physical Security Measures. MASS must be protected from physical tampering, piracy, or theft. This includes putting physical security measures in place on the ships as well as at onshore locations where MASS may dock or be serviced. Surveillance, access control, and anti-tampering technology all help to improve overall security[67].

Regulatory Compliance. MASS developers and operators must adhere to cybersecurity guidelines and laws. Compliance with industry and international standards contributes to the establishment of a baseline for security activities and ensures a consistent, accountable approach to cybersecurity[68].

To ensure the safety and security of Maritime Autonomous Surface Ships, a comprehensive and multifaceted approach is required. Developers, industry stakeholders, and regulatory agencies must work together to address these problems by incorporating modern technology, rigorous testing, ongoing monitoring, and the construction of strong regulatory frameworks. This strategy is critical for instilling confidence in the dependability and safety of MASS operations.

Reflections and the Ways Forward

Maritime Autonomous Surface Ships (MASS) are a major technological development that brings up a number of ethical questions about how they interact with society and human activity. The possible effect on jobs in the marine sector is one major worry. There's a chance that the need for human crew members may decline as autonomous ships proliferate, which might result in job displacement and financial difficulties for those in the maritime industry.

Another important ethical consideration is safety. Advocates of autonomous ships contend that by reducing human error, they can improve safety; nevertheless, detractors highlight the necessity of strong systems and backup procedures in case of unanticipated events. Making sure the technology is dependable and capable of traversing challenging marine settings without sacrificing safety is an ethical obligation.

Liability and responsibility are crucial issues. It is difficult to assign blame when autonomous ships are involved in mishaps or crashes. To handle issues of liability, insurance, and legal frameworks and guarantee that responsibility is allocated effectively in the case of catastrophes, it is imperative to establish explicit standards and laws.

The possible abuse of autonomous ships for illegal purposes like terrorism or smuggling is also a matter of ethics. Finding a balance between protecting against harmful usage and encouraging innovation in the marine sector is a difficult moral conundrum that needs serious thought.

Another important factor is the effects on the environment. There are worries about the environmental effects of growing automation, such as electronic waste and the energy footprint of creating and maintaining autonomous systems, despite proponents' claims that autonomous ships may optimise routes and cut fuel usage.

Furthermore, privacy concerns surface since autonomous ships are outfitted with cutting-edge monitoring and surveillance equipment. Ethical consideration is necessary when attempting to strike a balance between protecting individual privacy rights and using these technologies for safety and security.

To sum up, the extensive use of Maritime Autonomous Surface Ships raises various ethical questions. To ensure that the integration of autonomous technology into the marine sector is guided by ethical frameworks and reasonable regulations, it is necessary to strike a balance between the potential advantages and the requirements of responsibility, safety, employment, environmental concerns and privacy issues.

Conclusion

Autonomous ships have the potential to be more efficient and cost-effective. They have the ability to optimise routes, reduce fuel usage, and cut operational expenses. MASS can be built with additional safety features to reduce the chance of human mistakes, which is a major factor in marine accidents. Autonomous ships can operate without crew rest, resulting in greater operational hours and productivity. Route optimisation and fuel-efficient operations can help to reduce the environmental impact of shipping by lowering emissions and fuel consumption. MASS can be controlled and monitored remotely from onshore facilities, which can improve situational awareness and emergency response. On the other hand, the broad adoption of autonomous ships may result in employment losses for marine professionals such as sailors and support personnel, thus posing economic and social issues. Cybersecurity attacks are a concern for autonomous systems. Hacking or other harmful acts may jeopardise MASS's safety and security, causing dangers to the maritime industry. MASS development and deployment encounter regulatory hurdles, such as the formulation of worldwide standards and rules controlling their safe and secure operation. While autonomous systems can be trained to perform everyday tasks, they may suffer in unexpected or emergency situations where human intuition and decision-making are essential. MASS implementation needs substantial upfront investments in technology, infrastructure, and regulatory frameworks, which may be a barrier to adoption.

Finally, whether Maritime Autonomous Surface Ships are a godsend or a curse is determined by the specific circumstances, goals, and values of stakeholders. It is critical to carefully weigh the possible benefits against the associated obstacles and to work toward addressing concerns about safety, security, and the industry's human effects.

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Disclosure Statement

The views expressed by the authors are personal and do not reflect those of any organisation or entity.

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