

Autonomous Ships: Challenges and Solutions, Facing the Regulatory System

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المستخلص

في السنوات الأخيرة، ازداد الاهتمام بتصميم السفن الذاتية القيادة بشكل كبير. وقد جاء هذا الاهتمام نتيجة للتطور السريع في التكنولوجيا، واستلهاماً من التكيف الحديث للأنظمة الأوتوماتيكية والذاتية التشغيل في وسائل النقل المختلفة. ومن هذا المنطلق، يمكننا أن نتساءل عما إذا كان من الممكن تطبيق هذه التقنيات في قطاع الملاحة البحرية. إن التقدم نحو الابتكارات المتطورة أمر لا مفر منه، على الرغم من العقبات التي تظهر في كل مرحلة من مراحل التطور.

ومن هذا المنطلق، لا يمكن تجاهل التحول التكنولوجي القادم في القطاع البحري، والذي يجب الاستعداد له والتعامل معه. تناقش هذه المقالة الاتجاهات الحالية في تطور السفن الذاتية القيادة، بالإضافة إلى استعراض بعض المبادرات العالمية الحديثة. كما تبحث الدراسة في التأثيرات المنفصلة والمشاركة للسفن السطحية البحرية الذاتية القيادة (MASS) على الابتكارات، والقوانين، والصناعات، في ضوء التحول الجديد في النموذج البحري، وذلك من خلال استخدام استبيانات وتحليل بيانات نوعية وكمية بمشاركة خبراء وموظفين من القطاع البحري.

وفي الختام، توصي المقالة بضرورة اعتماد نهج شامل لبناء التكنولوجيا والإطار التنظيمي، والتأكيد على أن التواصل والتعاون بين مختلف الأطراف المعنية على أساس التفاهم المتبادل يعد أمراً أساسياً لضمان دخول السفن الذاتية القيادة إلى صناعة النقل البحري بنجاح. وتخلص المقالة إلى أن هناك نقصاً في جاهزية الاتفاقيات البحرية والموانئ والمعاهد البحرية لتطبيق آلية السفن الذاتية التشغيل في الوقت الراهن.

Abstract

In recent years, interest in autonomous ship conception has grown considerably. Inspired by the latest adaptation of automated and autonomous systems in different means of transportation and due to the swift technological development, we could question whether and if these technologies could be implemented in the maritime business or not. Progress toward cutting-edge innovations is inevitable notwithstanding the obstacles that develop throughout every evolution. Acknowledging that, one can't ignore the upcoming technological transition in the maritime sector, which must cope with and prepare for. The present article debates the current trends in the evolving autonomous ships as well as reviewing some of the latest global initiatives. Furthermore, the research looks into the separate and combined implications of marine autonomous surface ships

(MASS) on innovations, laws, and industries in light of the novel maritime paradigm change, by using questionnaire form and analysis with qualitative and quantitative data with different expertise and maritime sector employees participant .Finally, it is advised that holistic approaches to building the technology and regulatory framework be used and that communication and cooperation among various stakeholders based on mutual understanding are essential for the MASS to arrive in the maritime industry successfully .The article finds that, there is lack of readiness of maritime conventions , seaports and maritime institutes to implement the mechanism of automated ships at the present time.

Keywords: MASS, IMO, autonomous shipping, maritime law, Maritime Safety Committee, advanced sensor module, shore control center, cyber security threats.

1- Introduction

Ships are considered the largest manmade machineries ever. Newer ships are enormous, totally automated and state of arts. The shipping sector calls for superbly qualified seafarers, particularly seafaring officers in order to manage such modern ships both effectively and securely.

Throughout the 1980s, one of the important challenges within the maritime sector was crewing. Numerous investigations, for instance, the BIMCO ISF Manpower Report 2005 2010, 2016 and 2021 seafarer workforce report have highlighted an alarming seafaring officers' shortage. According to the BIMCO/ISF Sea Force Work Report 2021, estimates for shortage in seafaring officers will be 97,000 in 2020 and to be 147,500 within 2025. This situation demands the program revising along with its subjects in order for better preparation of seafaring personnel for their future tasks in addition to encouraging the young generation to enroll into the seafaring schools. The Germanischer Lloyd and Fraunhofer CML (2014) carried out a huge-scaled investigation that involved 100 ship administration businesses worldwide to determine what they have implemented for their business processes improving and what are their considerations for best practices in the sector. These organizations indicated that their major issues ship management in the med-term are to be among five domains as follows: crewing (88%), technical management (62%), financial management (50%), safety and quality (27%), and procurement (12%).

Both reports of Pourzanjani in 2002 and Schroder in 2004 have highlighted that challenges facing crewing comprise not only of the quantity. There are also lack of well qualified seafarers at different levels of seniority and quality. Also, at diverse seniority levels, there is a significant shortage of sufficiently trained seafarers. In the early 1970s, the IMO (International Maritime Organization) initiated a research to create international guidelines for seafarers which help improving the seafarers' quality. IMO's Standards for Training, Certification and Watchkeeping (STCW) describes the globally documented standards for the on board crew. The STCW competencies code are mostly centered on both the management and technical abilities along with long-termed practical at-sea training investigations. STCW is regarded as the principal reference for maritime education and training (MET). In 2011, a significant revision was implemented to the STCW which necessitated the change of MET programs as well. This change

resulted in the diversification of MET training courses, MET programs' establishing and expansion, collaborations between MET and shipping businesses, and the competitiveness of students and trainees in various MET programs. Institutions of MET ought to maintain surveillance out for such (Yongxing and Ruan, 2009). As a unique area, MET encompasses to meet with the international standards besides national vocational qualification necessities. English is the maritime industry's lingua franca, and seafaring officers must have excellent English language skills. According to Demydenko (2012) 'Maritime English as an international Language and Lingua Franca is solidly believed to be the global language of the sea'. This fact makes MET's design and delivery very complex that it necessitates more detailed evaluation.

In their paper, Porathe et al. (2014) have presented four primary arguments for how autonomous shipping is thought to be an achievable choice as follows: (1) initiatives to lower transportation expenditures; (2) the demand for workers to have improved working conditions while on board and to prevent future shortages of seafarers; (3) the necessity to reduce the emissions globally; and finally, (4) the requirement to improve the maritime safety. According to a submitted report to IMO in 2010 by the International Shipping Federation (ISF) and the Baltic and International Maritime Council (BIMCO), the maritime sector is anticipated to confront constrained recruiting markets, including continuous shortages of vessel officers (Lang, 2010). The maritime sector has witnessed excess capacity and freight rates, because of the dangerous circumstances at work and the extended durations spent off the coast, under the very challenging scale economics.

The paper depends on clarifying the challenges on implementing the autonomous ships on maritime regulatory and theoretical concept based on maritime institute by using questionnaire panel analyzed by statistical software, such as SPSS to describe strength and weakness for implementation.

2- Literature Review

The literature on autonomous systems implementation in commercial vessels has grown significantly since the late 2000s in accordance to Munim (2019). According to Budak and Beji, 2020, The results obtained from those studies reveal promising data, emphasized that smart ships could be the future of the maritime industry numerous papers and case studies on remote control, maneuvering of autonomous ships and navigation has contributed to the present body of literature. Their findings provided encouraging data, indicating that smart ships represent the next phase of maritime businesses, modernizing vessel design methodologies and commercial vessel procedures. Besides this knowledge, it was expected that the autonomous systems integration into the marine transportation might generate an all-inclusive transformation not just within marine navigation but also in the whole marine sector, from vessel building to logistic activities and even ship recycling (Gu et al., 2021; Kafali et al., 2022).

It is essential to do cutting-edge research for the change from the conventional transportation to the MASS to become a reality. Numerous novel projects have provided a firm technical foundation for

an autonomous marine environment. As an illustration, in the EU, the AUTOSHIP project has advanced the driving force for autonomous ship research. The project objective was to compete with land transport in the inland watercourses and coastal short-sea shipping by means of technical knowledge and advanced technology (Bolbot et al., 2020). Additionally, the AEGIS project has presented a secure and competitive design of a maritime logistical system for the EU through the integration of autonomous vessels and automated cargo handling technologies (Psaraftis et al., 2023). These two projects findings have indicated the significance of reliability and trust of autonomous systems according to Rødseth and Wenersberg (2023).

Based on the previous literatures, the autonomous project facing unseen prospects problems since the implement is not success yet in logistics activities and also for technical issue that leads us to the fact that the regulatory paradigm is not guided yet.

3- Challenges and Solutions

3.1 IMO Regulatory

Regarding regulations, the IMO determined to perform a regulatory scoping exercise (RSE) in order to evaluate MASS's safety, security, and environmental performance (IMO, 2022). On the other hand, the RSE may be a challenging matter, since it might cover a variety of subjects, for instance security, safety, port contacts, marine environment and pilotage in the event of an emergency. Furthermore, the international maritime conventions including SOLAS (the International Convention for the Safety of Life at Sea), COLREG (the International Regulations for the Prevention of Collisions at Sea), and STCW of Watch-keepers are all applicable to MASS. Therefore, IMO Member States will be requested for reviewing their domestic laws' scope taking the RSE in consideration.

Utilizing a cutting-edge information and communications technology (ICT) systems would enhance the vessels' control skills, communications, and interactions. Therefore, ships shall soon be controlled by land-based or remote offshore services (DNV and GL 2022). Autonomous vessels have been successfully used for aeronautical, military, and investigational objectives. Also, deep-sea explorations employ submersible automated vehicles, including autonomous underwater vehicles (AUV) and remotely operated vehicles (ROV) that are currently in development. Nevertheless, in terms of efficiency, safety and environmental sustainability, innovation that substitutes staffing must surpass personnel (Komianos, 2018).

On the manufacturing sector, autonomous cars are already being created for a variety of transportation means, including automobiles airplanes, and trains. Thus, MASS is predicted to have a substantial impression on ship-building, electronics and equipment as well as shipment and port infrastructures within the marine sector. Furthermore, autonomy, automation, unmanned procedures; enterprise-grade connectivity, huge amounts of data, and analytics will continue to increase within the marine industry (Shahbakhsh, 2022). Accordingly, efficient interaction and collaboration with the main stakeholders, principally in the shipping, ship-building, and port industries, is necessary for a successful implementation of the MASS.

To accurately depict the authors' knowledge, several reviewing researches have thoroughly or briefly explored the regulatory matters concerning MASS. The researchers' interviews and discusses with maritime professionals, including maritime officers, maritime architects, and senior naval engineers, motivated the current research. The current paper has concentrated on all of the inferences that MASS may have on the maritime sector at the humanoid level (both education and training), lawmaking level (the description of regulations and transparent laws), and technological level (e.g. security navigation). This article displays some observations on the challenges and problems that must be addressed promptly; it doesn't work with the collected data by trials, quantified scenarios or calculations. The authors' principal objective is demonstrating the scale of those issues and the effort that still needs to be made to accomplish worldwide secure autonomous surface ship navigation.

This document's structure is as follows: We began by introducing the most recent projects based on worldwide trends to build autonomous watercraft. Secondly, the MASS impact on regulations, technological advances, and businesses, as well as their relationships, has been investigated in order to recognize both past and future initiatives to gear up for the novel marine paradigmatic transition.

3.2 Conventions and Codes to be Changed

Regardless of the rapid growth of technological advancements in the maritime sector, autonomous vessels must undoubtedly comply with global norms in order to safely operate crossways nations and even into the undersea regions that are outside the national jurisdiction. Even though certain aspects of manned-ship regulations, (for example, few clauses of ISM or the International Safety Management Code and their Safety Management Code (ISM)), may be well-matched with the unmanned ships, definitely there is a necessity for exceptional global rules regarding the unmanned ships' characteristics.

3.3 Issue of Laws and Ethics

The business has adopted sophisticated and emerging technology to increase production, reduce expenditures, and improve protection. Regulations and technologies have a mutual influence on each other, thus effective and prompt regulatory processes must exist for the business to fully revenue from the innovation. Conventionally, responsibility was assigned to individuals or organizations which are acknowledged by law, such as shipment businesses. An algorithm doesn't qualify as a moral or formal body; therefore, assigning wrongdoing guilt is meaningless. The matter was comprehensively investigated in the automotive segment. The examination of conventional ethical issues is portion of the debate about the self-driving automobiles safety (Zhang, D 2022). The ISM Code (SOLAS Chapter IX) regulations, such as establishing an official entity responsible for ship safety and avoiding environmental pollution, are going to remain applicable to the MASS (Pundars, 2020).

The progress and usage of autonomous vessels will present various ethical difficulties. Historically, the human communication has governed the shipping processes, but MASS incorporates both man-machine and machine-machine interaction. This risk of implementation or shift evaluation ought to involve an analysis and approaches for situations in which any malfunctions in the machine communication is denied. Liability in law bounds must be identified, notably by establishing realistic criteria and obligation scopes between both the ship-owner and the manufacturers, in addition to an adequate security arrangement for insurance coverage.

3.4 Cyber Security

To guarantee an uninterrupted and secure connection between SCC and the ship in question, precautions must be in place to prevent other parties from intercepting the information transmitted in between. If they are intercepted, the ship's safety is jeopardized since the malicious user could be able to take control of the vessel or obtain a hold of crucial operational data. The paper "Connectivity for autonomous ships" (Gad, 2025;Höyhty et al.2017) makes an intriguing recommendation concerning the safety of information. This is the practical application of Blockchain technology. Initially, let us define what Blockchain is and then discuss how it might be utilized in operating the remote vessels. In layman's terms, a Blockchain is a digitalized distributed ledger consisting of information blocks that are constantly updated and verified in real time via a computerized network that contribute to it. As soon as data is submitted on the Blockchain, for instance the remote operator's command to guide the ship to the harbor, it is unchangeable given that the information has been encrypted and uploaded chronologically to the chain. The article "Blockchain Security of Autonomous Maritime Transport" published in 2019 studied how it can be applied to remote operations. The proposal was that all data transported from and to the ship would be stored on a distributed network accessible only to a verified operator. To gain access to the network, users have to first go through a Certification Authority (CA) and be issued a certificate that verifies their identity (see Appendix H) (Petković, Mihanović, and Vujović, 2019).

3.5 Legal Liability

Presently, the master is responsible for a traditional ship's legal responsibility. If something goes wrong, the master is responsible. However, what happens when remote operations and autonomous vessels are put into effect? Who will bear this obligation, and how would it be modified? Current laws do not address remote and autonomously operating scenarios; nevertheless, they can be evaluated and clarified in order to take steps toward covering them. By referring to the Air Traffic Act for autonomous aviation systems under Croatian law, insights can be gained and used to remote marine operations (Ordinance on Unmanned Aviation Systems, n.d.). Additionally, a table released by Kennedys Law in 2018, which outlines the legal responsibility based on the system utilized, can be found later (Delagrangé and Pellicer, 2018).

4- Novel Approaches and Technologies within the MET

MET institutes must implement novel innovations and make educational and technological advancements. They must also progress and transfer innovative ideas in their own field of interest.

This is the reason for various international MET platforms to be created, including IAMU (International Association of Maritime Universities), IMLA (International Maritime Lecturers Association), Global MET, METNET, and Mari Future etc. In MET, in terms of the emerging technologies and methods, the objective is not to list these technologies separately, but rather to assemble them conferring to the attained functions. They are as follows: 1) excessive simulator usage for representing the real, 2) life conditions and software that provide enhanced comprehension, 3) highly organized and lecturer-validated long-termed maritime training as an additional advantage to academic classes for cadet preparation to their responsibilities on the shipboard. For example, the engine rooms and the mock-up bridge precisely similar to equipment of navigation and communications. Besides, fully-equipped laboratories can assist students of having their courses leading to better understanding. Also, simulators can facilitate the students to adapt to real systems and equipment in addition to their onboard duties.

Computer-assisted training can be advantageous to students in exploring the delivered subject within the classroom. Furthermore, students can self-assess their own accomplishment along with better evaluation of the available chances for the lecturers. IT support permits the students to communicate with both the online tutors and lecturers. For problems solving, it is imperative for students to be connected with MET institutions during their sea training. Lifelong learning is a vital share of modern daily life that can provide individuals with additional possibilities for learning. E-learning offers an excellent learning and training chances for the seafarers who are very far away from land facilities. Currently, several MET institutions offer e-learning courses for the seafarers and post-graduate course works too.

Efficient utilization of Port State Control (PSC) outcomes alongside the formation of permanent evaluation /validation organizations including EMSA (European Union Maritime Safety Agency) offer an exceptional opportunity for quality assurance for MET institutions. The whole world is now a little village due to globalization. The marine industry is global in scope, necessitating the complete implementation of global treaties. To thrive in the competitive and tough shipping industry, all parties involved have to hold themselves to gold standards rather than settling for the bare minimum. Without an experienced staff onboard the ship, there is no prospect of success. The MET have a crucial role in guaranteeing shipping quality. The only technique for guaranteeing quality in the MET is to constantly improve the system through the progress and transfer of innovation while adhering and integrating the novel innovations.

5- The New Reshape for Maritime Industry

Autonomous ships are transforming the shipping sector through the implementation of new technology, procedures and business models that have the potential of changing how ships are operated today. Autonomous ships advantages include increased efficiency and safety of the ship, data-driven activities, and greater capabilities like autonomous and remote operations.

- A. **Improved efficiency and safety:** autonomous ships are equipped with Creative innovations such as machine-learning, the Internet of Things (IoT) and artificial intelligence (AI) which can assist boost vessel operations, increase safety, and lessen the risk of error made by humans.
- B. **Data-driven operations:** autonomous ships produce massive amounts of data which are analyzed for decision-making improvement, lower the expenses, and increase safety. Predictive analytics as well as machine learning algorithms can aid in discovering patterns, outcomes' prediction, and vessel operation optimization.
- C. **Remote and autonomous operations:** shore-based control centers will be responsible for controlling the autonomous via communications systems and real-time data. These centers can monitor and control movements and navigation of the ship as well as other operational functions. Hence, ships will be operated more efficiently with enhanced safety and reduced expenditures.

Integrating autonomy in the shipping sector is an extended process, with commercial operators adopting autonomous technology in stages. This staged approach allows operators to critically evaluate the technology's advantages and drawbacks along with making any necessary changes to guarantee its successful incorporation into their operations. The future of autonomous ships appears to be rather promising if the obstacles involved with their deployment are sufficiently managed. They have the potential to significantly improve safety and efficiency, minimize operational expenditures, and decrease the environmental impact of maritime activity.

6- Methods and Materials

The survey study was designed to engage graduates from diverse backgrounds, including multiple disciplines, institutions, and regions, as well as varying degrees of understanding of autonomous ships and smart shipping. The most prominent groups were those studying to become future navigators or future electrical engineers and technical officers in the engine department. In this study, researchers provide information about the participants who completed the survey, including gender, age, country of MET graduation, years of marine service, current occupation, and highest level of education. Of the 200 participants who returned and correctly completed the surveys, 180 identified as male and 20 as female, representing 89 % and 11%, respectively. The majority of participants (92%) fell under the age of 35. The highest number of participants graduated from Egypt (90%), followed by Jordan (3%) and Saudi Arabia (8%). CoC holders (98%), while the smallest group represented was trainers (2%). Holders of COC management level (70%), holder of COC operational level (30%).

Data collected from the questionnaire were analyzed using statistical analysis software, such as SPSS. This tool allowed researchers to perform descriptive statistics, such as frequencies, percentages, means, and standard deviations. The questionnaire analysis consist 10 questions distributed in 5 sections.

Participants were asked to rate their level of agreement with the statements using a five-point Likert scale. A linear scale from 1 to 5 is a common way to measure agreement or disagreement

with a statement. This scale allows respondents to indicate the extent of their agreement or disagreement on a scale ranging from "strongly disagree" (1) to "strongly agree" (5), with three possible neutral options in between (2 = "disagree," 3 = "neutral," and 4 = "agree")

Table 1 statistics analysis

Socio Demographics Data	Frequency (N=200)	Percent
Section 1		
Q1. What is your gender?		
Male	178	89%
Female	22	11%
Q2. What age range do you fall into?		
Less than 35 years old	184	92%
More than 35 years old	16	8%
Q3. In Which country did you graduate from the Maritime Education and Training institute (MET)?		
Egypt	180	90%
Jordan	4	2%
Saudi Arabia	16	8%
Q4. What is your current occupation?		
COC management level	140	70%
COC operational level	60	30%

Section 2

- In light of increasing numbers of specialized vessels over general Cargo vessels, autonomous ships are suitable for all commodities types.
- Autonomous ships apply for existing Sea born logistics trade.

Section 3

- Autonomous ships have a positive impact on labor skills.

Section 4

- The availability of financial resources to equip maritime institutes is available to all maritime countries.
- Training and certification of seafarers existing adequate for new technology era.

Section 5

- New conventions and regulations will take place with significant changes.

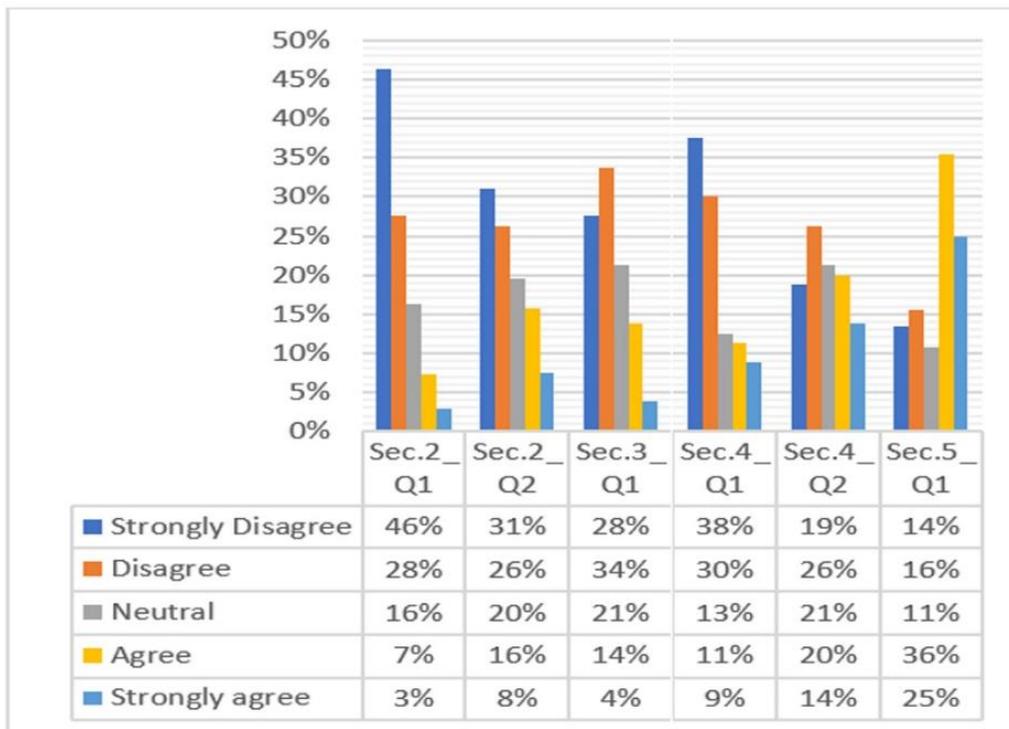


Figure (1) Survey Study Analysis

As shown in Figure 1 the percentage of responses for each survey question in different sections indicates that IMO Codes and Conventions require considerable modification to suit the MASS requirements.

The highest percentage of disagreement is for question one in section two is an indicator that MASS will not be suitable for all types of ships and lines of trade.

7- Results

Introducing the autonomous shipping will offer the chance to raise the efficiency of ship operations, while also improve sustainability, which is the most significant motivator in any sector (UN, 2008). The development of intelligent vessels would improve the scenario, resulting in an enhanced, more lucrative, and presumably more secure shipment business. Autonomous ships’ development is similar to those within the MUNIN project will offer an extensive alternative for the major issues of maritime transport sector, leading to operational expenses decrease, better environmental preserving activities, and minimizing the human effort (Burmeister et al., 2014b). Because of the rapid advancements in science within the maritime sector, this type of ship design is so innovative that no international law or regulation applies to it yet. The IMO hasn’t approved this type of ship and hasn’t received any proposals from contracting government for regulating autonomous vessels. The widespread adoption of the autonomous ship notion will have a substantial impact on industry efficiency, management of human resources, and preventing accidents. The benefits of environmental protection are equally essential. Although the existing

maritime equipment might address all safety, environmental, and commercial issues, the absence of a sufficient legislative structure might postpone the genuine implementation of such vessels.

8- Conclusion

There is an enormous gap between humanity's evolutionary vision and the automation influence on environmental sustainability and human existence. Even more important, automation rebalances authority among all stakeholders and parties in the international laws. The navigation conditions are increasingly becoming challenging and more complex, impacting contemporary life and values in the risk society era. This might be one procedure for rescuing the environment while also ensuring survival and moral sharing among each and every country or population. It is a challenging issue accomplishing that intersects with other subjects in social science, but it will undoubtedly contribute to the solution. Among the greatest obstacles for legislators and all the stakeholders are to design and improve a particular strategy for achieving a balance between both influencing the human situation and the environmental degradation with the automation progression. Finally, the IMO safety Committee should make progress on the development of a goal-based instrument regulating the operation of maritime autonomous surface ships (MASS), which is expected to be adopted by 2025 in different scope pattern to overcome the regulatory challenges on both the legal clauses and seniorities responsibilities on shore base for coastal domestic voyages which is expected to use autonomous ships effectively.

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