Sustainable Operation of Unmanned Ships under Current International Maritime Law

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Abstract: The aim of this paper is to evaluate the current international maritime legislative framework and assess its relevance in sustaining the operations of unmanned ships while addressing the issue of liability from system malfunctions. The paper initially explores the legal definition of a ship and evaluates whether the existence of an on-board crew is an integral part of the definition. Subsequently, the analysis continues with assessing the legal implications and challenges for the sustainable operation of unmanned ships, such as the governing flag state legislation that defines liability parameters, taking into consideration the existing levels of vessel automation. The paper concludes with an evaluation of the contractual issues and potential stakeholder liability related to governing a flag state. In addition, the potential transfer of liability from the ship operators to manufacturers as pertains to unmanned ship operation is also addressed. The concluding remarks suggest that unmanned ship operation is sustainable under the current international maritime legislative framework; however, the current legislation should be considered as a baseline from which specific legislation for the operation of unmanned ships can be drawn. The methodology utilised for this paper is based on the legal doctrine.

Keywords: unmanned ships; MASS; sustainability; UNCLOS; maritime law; SCC; COLREG

1. Introduction

The global merchant marine fleet is an indispensable part of the global logistical chain and is hence critical within the global economy. According to the International Maritime Organization (IMO), more than 95% of the world’s cargo is transported by the global merchant marine fleet. The dominance of maritime transport within the global economy rests in its continued efficiency to transport exponentially larger commercial loads, vis-a-vis alternative modes of transport, and to reach the isolated, water-locked areas of the globe.

Marine safety remains a significant issue within the maritime sector. Following the sinking of the Titanic (1912), the International Convention for the Safety of Life at Sea (SOLAS) was adopted in 1914, reflecting the increased concern for maritime safety worldwide. The IMO, as the regulator of SOLAS, seeks to improve safety at sea by establishing regulations that relate not only to a ship itself, but also to issues such as maritime traffic and the human element [1]. The credibility of a seafaring vessel is in danger of being lost, should it become involved in a maritime accident and as such, with the use of technology, efforts are being made to reduce such occurrences. For example, modern navigation systems permit crews to monitor the exact position of a ship; hence, they can easily correct its navigational course to avoid danger. This factor, along with many others, can help reduce maritime accidents [2].

Technological advances supporting the use of unmanned ships (crewless ships), have recently become an area of interest and focus within the merchant marine sector. The use of unmanned ships by the U.S. Navy and the Royal Navy of the United Kingdom to conduct non-commercial governmental operations, has sparked a debate to evaluate their use within the merchant marine sector. The introduction of unmanned ships within international
merchant shipping represents a new era for the shipping industry. Rolls-Royce is one of the organisations leading interest and research in introducing unmanned ships to the merchant marine sector. According to the advocates of unmanned shipping, their great advantage is in the potential to reduce maritime accidents, by eliminating the human factor and, thus, human error. Proponents argue that physical human fatigue, amongst other factors, is one of the key causes of shipping accidents at sea. The advantages, vis-à-vis obstacles, of the introduction of unmanned ship within the merchant marine sector remains a matter of exploration and debate [3].

In addition to the merchant marine sector, the rail and air transport sectors are also exploring the development of unmanned autonomous transport systems. Regrettably, however, the conventions that regulate the safety of international merchant transport systems do not fully correspond to the purpose of the operation of unmanned international commercial transport; therefore, there are many aspects of the existing conventions that need to be addressed to support the introduction of unmanned vessels to commercial transportation [4]. This is equally true of the introduction of unmanned merchant marine vessels. With the advent of 5G, autonomous or unmanned ships will likely become a reality and this will cause significant disruption to the current maritime legal regimes. International maritime law has proven to be flexible enough to be able to respond to technological developments, from sail to steam to container transport, and to the absence of a crew on board. Furthermore, such a maritime vessel may have the equivalent rights to a simple, traditionally-manned ship [5].

2. Materials and Methods

This paper is an exploratory research study initially extracting primary data and information from the relevant international legal framework and case law [6]. The analysis of the relevant legislation is based on legal doctrine [7], the dominant form in legal research, aiming to provide a systematic exposition of the legal and regulatory principles and to analyse the relationship between those principles to provide clarifications [8].

This research method is qualitative and is very similar to critical analysis, the application of which is performed through (a) research and description of the existing legislation (b) prescription, the essence of which is to explore the legal issues arising by the utilisation of unmanned ships and (c) finally an evaluation of the sustainable utilisation of those ships, relying on the conceptual model of the legal doctrine of assessing international legislation and relevant case law to extract conclusions [9]. The relevant legislation is the primary source of data. At the same time, an evaluation of other similar research is often conducted to support the authors’ suggestions and to demonstrate the extent of the issue in discussion [10].

For example, a similar research was conducted recently to evaluate how legal policies affect environmental decision making. Their research was conducted by comparing different national legislations and utilising the information and conclusions on which legislation was the most suitable to address the issue in discussion [11].

3. Regulatory Issues and Implications of Unmanned Vessels

3.1. Legal Definition of Unmanned Ship

An unmanned vessel can be regarded as a ship only if it complies with the present maritime regulatory framework. For determining whether unmanned ships fall under the regime of maritime law, we need to look at the aims and scope of the various maritime conventions. Initially, the term 'ship' needs to be assessed to see whether a ship absent a crew on board can be classified as a ship. Many international conventions have established the criteria that a floating object should possess the qualification to be defined as a ship, but nevertheless, there are many differences often deriving from the different aims and the scope of each distinct convention [12].
3.1.1. International Definition

The United Nations Convention of the Law of the Sea (UNCLOS) is extremely important for understanding the rights and duties of ships, and most authors believe that unmanned ships should be equated with (manned) ships for the application of the Law of the Sea [13]. Evidently, unmanned vessels should enjoy the same rights and freedoms, but at the same time, they should also comply with the existing duties that are applied to manned vessels. Additionally, several other multilateral conventions relating to other aspects of maritime law do not consider the presentation of seafarers as an integral factor for classifying a floating object as a ship.

The definitions in international maritime law of what constitutes a ship are broad enough to include unmanned ships. Initially, pursuant to the Hague and the Hague Visby rules, a ship is “any ship used for the carriage of goods by sea” [14]; such definitions cannot bar the application of an unmanned vessel. The International Convention for the Prevention of Pollution from Ships (MARPOL) classifies as a ship, “a ship of any type, operating in the marine environment and comprising hydrofoils, submarines, floating vessels and fixed or floating platforms” [15], evidently not excluding unmanned ships. The Convention on Civil Liability for Oil Pollution Damage (CLC) defines a ship as “a sea vessel and any vessel of any kind constructed or adapted for the carriage of bulk oil as cargo” [16]; pursuant to this, even all non-oil-free vessels can fall within this definition. The London Convention on Dumping regards ships and aircrafts alike as “floating or aircraft of any type. These include airborne vessels and floating vessels, whether self-propelled or not” [17]. The United Nations Convention on the Conditions of Registration of Ships defines ships as “any self-propelled seagoing vessel used in international maritime transport for the carriage of goods, passengers or both”, again not excluding unmanned vessels from the scope of the legislation [18]. The International Collision Regulations (COLREG) establish that “each vessel description shall include any vessel, which is or can be used as a means of transport in water” [19], without commenting upon the way a ship’s movement is executed, while a similar definition can also be found in the Salvage Convention.

From the analysis above, it is evident that the different characterisations of a “ship” differ slightly, mainly depending on the subject matter of each respective convention [20]. In the above selected legislation, the presence of a crew on board is not mandatory; therefore, there is no convention that excludes the implementation of unmanned vessels by any means. We can safely assume that unmanned vessels will, therefore, have the same rights and responsibilities as manned vessels [21].

3.1.2. National Definitions

According to international maritime law, an unmanned vessel should be equated with a manned vessel and fall under the same international regimes. To evaluate if the above statement also applies to national legislation, distinct national regulatory frameworks will be assessed.

The United States national maritime legislation states that “a ship is any vessel used as a means of transport in water”; thus, an unmanned vessel can safely be classified as a ship. When there is still a debate on whether a particular vessel can be considered as a ship, the US court authorities have developed a ‘feasibility test’. This test assesses the nature of the structure and evaluates whether the vessel is floating, independently mobile and is able to carry cargo, whether it is subject to the perils of the sea and whether the status of the vessel is compatible with legal or other technical parameters. Thus, a U.S. court, upon the status of an unmanned vessel, should conclude that an unmanned vessel is by any means a ship [22].

Pursuant to the UK maritime legislation, and specifically the Merchant Shipping Act of 1995, a vessel is “any ship or vessel or any other description of a ship used in navigation” [23] whereas in French law a ship is a “floating, mobile vessel designed for ocean navigation” [24]. The Dutch Civil Code dictates that ships are “all things, which are not aircraft, and which are due to their construction that are intended to float and that float” [25].
Spain’s pilotage law refers to a ship as “any vehicle with a structure and ability to sail at sea for the carriage of persons or property, having a full deck and a length equal to or greater than 24 m.” [26]. Lastly, the Belgian Maritime Code states that shipping vessels are considered to be “all sailing vessels of 25 tonnes which are intended or widely used for the carriage of passengers or goods, fishing, towing or any other lucrative activity at sea” [27].

The intention of stating all the different national maritime legislation is to show that unmanned ships have the appropriate qualifications similar to manned ships from a legal perspective. While these definitions differ slightly, hardly any of these definitions refer to the existence of a crew aboard as a requirement; therefore, it can safely be assumed that the presence of a crew is not a crucial factor for the classification of a floating object as a ship in any national legislation. Thus, unmanned ships are subject to applicable international conventions and national laws [15].

3.2. Law of the Sea Implications and Challenges

The United Nations Convention on the Law of the Sea (UNCLOS), as amended in 1982, regulates many issues that the pre-existing legislation could not effectively address. For example, UNCLOS introduced the concept of and Exclusive Economic Zone (EEZ), enforced new obligations, such as the protection of the marine environment, and installed new judicial bodies, such as the International Court of Justice for the Law of the Sea (ITLOS).

According to UNCLOS, states should ratify all its provisions because the respective rights and duties of flags, ports and coastal states are regulated evenly. Since unmanned vessels can be considered as ships within the meaning of UNCLOS, they fall under the same rights and obligations of manned vessels, as already stated above. When examining unmanned vessels under UNCLOS, the question arises as to how these vessels and their flag states will take on some of the tasks provided for in UNCLOS.

The main conclusion drawn from UNCLOS is that the intricacies of unmanned ships are not yet defined in the convention. The basic definitions are provided in international maritime law conventions, but all issues deriving from a technology that is so advanced have not yet been taken into consideration [13]. Based on the assumption that vessels would always be manned meant that none of the international, regional and national codes written in recent years have taken into account the concept of automation; thus, it is vital that, while the process of developing automation is near to completion, the regulators should consider how to apply the existing laws to this new generation of ships. Depending on the volume of automation, a ship will have some fundamental changes needed to be implemented. This great challenge is largely presented by the United Nations Convention on the Law of the Sea (UNCLOS), where it is dictated that all ships should be “responsible for a master and officers who are appropriately qualified” [28].

The ‘freedom of the high seas’ dictates that the high seas are free of national jurisdiction and that there is an absolute freedom of navigation. Freedom of the high seas means that there is no principle for governing waters and there is no enforceable national law on the high seas, besides that of flag state. Thus, the flag state has the exclusive responsibility for the enforcement and legislation of vessels flying its flag and it should ensure that vessels flying its flag comply with the applicable international and national laws [29].

Paragraph 3 of Art. 94 of UNCLOS states that, the flag state “shall take these measures . . . which is necessary to ensure maritime safety with regard to, inter alia, the . . . manning of ships, working conditions and training of crews, taking into account existing international instruments”. Next, paragraph 4 of Art. 94, notes the necessary measures that should be installed to ensure that “each ship is responsible for the master and the officers, to be suitably qualified, in particular as regards navigation, communications and maritime engineering, and that the crew is suitable for qualifications and numbers for type, size, the ship’s machinery and equipment”. Paragraph 5 of Article 94 in UNCLOS states that, a flag state which takes certain measures is obliged to comply with the generally accepted international regulations, procedures and practices and to take the necessary measures to ensure that they are complying with Article 98, which states that any state shall require
the master of a ship flying its flag to comply with, in so far as it is liable to do so without serious danger to the ship, the crew or passengers, the provision of assistance and rescue of persons in distress, and the provision of assistance to other vessel after a collision to its crew and passengers and, where appropriate, to supply information on the name of the vessel, the port of registry and the nearest port [30].

UNCLOS indicates those tasks falling within the responsibility of each respective flag state. It stipulates that each state must exercise its jurisdiction and control effectively in administrative, technical and social matters. In addition, each state must take the necessary measures for ships flying its flag to ensure safety at sea, including with regard to the construction, equipment and enjoyability of good navigation, the manning of ships, working conditions and the training of crew, while taking into account existing international instruments. Meanwhile, it shall continue to adopt these necessary measures. One of the measures to be taken by a state is to ensure that each ship is responsible for a master and officers with the appropriate qualifications, in particular in maritime, navigation, communications and maritime engineering, and that the crew is suitable for the ship’s specialisation, size, machinery and equipment. These functions of the flag states were adopted in 1982 and were designed for conventional ships, mastered by a crew on-board [31].

The above requirements, when applied to unmanned ships, can be subject to different interpretations:

1. Unmanned ships should be regarded as illegal due to the fact that there are no masters and officers on-board who are properly qualified. Pursuant to this, each flag state should ban unmanned ships. This would be the most “draconian” interpretation and by addressing it, the utilisation of unmanned ships should be prohibited permanently.

2. Those requirements for manned ships should become obsolete specifically for unmanned ships because there is no reason for a captain and officers to be responsible for an unmanned ship. This interpretation would be the most suitable for the utilisation of unmanned vessels, but a new legal framework should be developed for the operator and for other personnel responsible for handling the unmanned vessel from afar.

3. The operator of the ship should be considered as the master of the ship and will have to fulfil the duties and requirements of a master. Nevertheless, the duties of a shore-based vessel controller should probably not be the same as those of a ship’s master. This interpretation is similar to the previous one, with the difference that the present legal framework should be utilised as a baseline upon which the responsibilities of the shore operator would expand.

Ships, including unmanned ships, must be registered to a flag state. Pursuant to UNCLOS, the existence of a genuine link between the flag state and the ship is mandatory; however, the concept of a genuine link has never been strictly defined, therefore, the imposition of a genuine connection between the ship and its flag states is a most complicated issue. The basic elements constituting a real relationship between the ship and a flag State are: (i) the ownership of the vessel, (ii) the nationality of the crew and (iii) the management of the ship. An unmanned vessel’s genuine link becomes even more remote as the ship has no crew on board; thus, the existence of a genuine link falls exclusively with the ownership and the management of the ship as the only available options. This absence of a genuine link for unmanned vessels could lead to situations where a ship is operated by a shore control centre (SCC), located in a more cost-efficient country with poorer working conditions, away from its flag state.

Despite the modernisations installed during its enactment, UNCLOS did not provide for the advent of unmanned vessels. Evidently by the time of its ratification, it was not possible to foresee the rapid technological development of the last decades. In addition to the issues above, there are still some pending issues regarding the operation and duties of unmanned ships. Without a doubt, years after the adoption of UNCLOS, it is evident that the Convention is beginning to become obsolete, in light of the unprecedented innovations and major amendments needing to be installed; however, UNCLOS remains yet a frame-
work convention, as most provisions can only be achieved by successfully adopting other legislations and conventions [32].

Undoubtedly, maritime law can easily be amended and adapted to accommodate the new technological developments, not only through official instruments, but also through state practices and even relevant case law. Additionally, international consensus is the safest and most efficient method of ensuring the installation of relevant legislation and enforcement measures for the emerging maritime law issues [33].

3.3. The Legal Status of Seafarers

Seafarers have traditionally enjoyed many rights unique to their profession. Absent of seafarers, a ship cannot sail, therefore practically, trade cannot be conducted to satisfy the volume of the present demand, but with the development of remotely controlled shipping, the utilisation of seafarers could be greatly reduced. Due to the adversities of life on board, seafarers are very different from employees onshore. The number of hazards associated with their work is higher than most onshore employment. The most distinct characteristic of the seafarers’ employment is that all their duties and ‘leisure time’ have to be performed on board. A seafarer works, sleeps and lives on board with co-workers with different cultures and nationalities. In addition, while on-board, sailors pass through different time zones, changing climates and adverse weather conditions. A sailor lives in a lonely and dangerous environment, with several annoying factors such as vibrations, sea traffic and noises. Undoubtedly, the operators of ships via remote control would operate in markedly different conditions compared to those of seafarers [34]. The International Convention for the Safety of Life at Sea, 1974, regards a seafarer as a “person employed or seeking employment as a master, officer or officer on-board” [35]. Pursuant to SOLAS, the crew of a ship is defined, unlike passengers, as “the master and the members of the crew or other persons employed or engaged in set positions on board the vessel for his operation” [36]. According to the U.S. Supreme Court, a sailor first of all “must contribute to the operation of the ship or the fulfilment of its mission”, and second, a sailor “must have a connection to a navigation ship or to an identifiable group of such vessels that is essential in terms of its duration and nature” [37]; however, it is very doubtful that the judges of the U.S. Supreme Court had unmanned vessels in mind when setting this criteria for a seafarer. The situation of seafarers is based on a number of specific elements which are essential to their work. They work many hours in an everchanging international environment, they must be physically fit, they face risks to their safety, disease, changing climate and marine hazards, and face intensive work with strict deadlines. Above all, the seafarer works for long periods of time and has to stay away from home for months, which places pressure on their private and social lives [38].

Shore businesses do not need to take into consideration any of these extreme factors. The basic task of seafarers, which is to safely complete their sea voyages, would be essentially the same compared to the operators of remotely controlled ships and those previously noted factors contribute to the operation of a vessel and the fulfilment of its mission. The operator of an unmanned vessel still has a duty to navigate the vessel safely to its destination, avoiding all kinds of liabilities, such as accidents and collisions and for the safe execution of this task, there is also great responsibility; thus, land operators must also have certain qualities as well, equal to, or even higher in comparison to those of a competent seafaring mariner. Alongside their nautical knowledge, a shore operator should possess knowledge on information technologies and state-of-the-art systems [39].

The operator of a SCC should have some authorities of a shipmaster and as such, they should possess the authority to make decisions regarding the safety of their vessel and crew. They should also have the authority to represent the owner of the ship, acting on behalf of them and the company. As such, the master of the vessel may hire sailors and dock workers, conclude towing agreements, and supply and conclude contracts of carriage. The master is bound by their contract of employment and works on the basis of commercial rules; however, thanks to new technologies, which have installed better
means of communication, automation and data exchange, the autonomy of the master of the ship in their operational duties would be further reduced. Their participation in cargo handling would be significantly reduced, as well as their liability for the ship’s documentation. It is possible that with the utilisation of unmanned vessels, all rules concerning the responsibilities and duties of the master of the ship are likely to become obsolete. Absent of a master and crew on-board in charge of the ship, it remains unclear who would represent the owner’s rights and responsibilities. The shore operator, by working ashore, would not be subject to all the challenges of working and staying on board for a lengthy time-frame and it is debatable which of the master’s private law duties they should possess. A master on-board should navigate the ship, be responsible for the crew and have an absolute authority for matters regarding the safety of the vessel. This power is accompanied by various tasks and commitments in the event of non-compliance, while the master of the vessel has also a mandate to represent the shipowner. In recent years, the scope of this mandate has been reduced. When operating a remote ship from the shore, the scope of the employer’s mandate may also be significantly reduced. Specifically, the utilisation of new technologies allows a shipowner to execute the majority of the required tasks, minimising the role and participation of the master even more. Meanwhile, the master of the ship retains certain responsibilities as a representative of the owners with regards to the loaded cargo; thus, if the consignee refuses to accept the delivery of the cargo, the master has the right to appeal to the court to be authorised to confiscate and auction the goods. In the absence of a master on board, should the consignee refuse to accept the cargo, who is the most suitable to appeal to the court and enforce the court’s decision [40]?

The director of the SCC should not act as the representative of the shipowner with regards to the ship, cargo and consignee, absent of any real connection with the majority of ship operations, especially when the ship is in a port. An agent of the carrier or consignor in the location of the ship would be better suited to assume this responsibility. The criminal and disciplinary responsibility of the master of the ship is provided by the disciplinary and penal codes for merchant shipping. The disciplinary and penal codes provide for two conditions for its implementation: (i) there is a full human community on board any merchant ship and this community consists of seafarers and passengers, and (ii) the leader of this community is arguably the captain. Evidently, none of these conditions are compatible with unmanned ships, therefore, the disciplinary and penal codes should not apply to unmanned vessels in their present form. Unmanned ships would have no personnel on board unless under exceptional circumstances, and since the director of the SCC will probably not be equated with the shipmaster, the deriving obligations and the relevant sanctions would become obsolete. The liability should eventually be transferred to the SCC because all the stakeholders require the transportation to be executed in a safe and timely manner, which could be achieved only by the successful operation of the SCC. Thus, when the SCC lead operator is responsible for the operation of a vessel, they should remain as such until the vessel remotely arrives at its port of destination. In the case of evacuation events, the master cannot leave the ship before the passengers and crew leave, because they are responsible for the execution of the evacuation. In unmanned ships, absent of any crew on board, this obligation would become obsolete as far as the unmanned vessels are concerned [41].

In the case of aiding people and ships in distress and the associated responsibilities, the penal codes penalise non-compliance. Even so, when an unmanned ship was directed to another vessel in distress with a crew on-board, there would be no available personnel on-board the unmanned ship who could provide assistance to the manned ship, the crew or its passengers in distress. Thus, a relevant regulatory framework should be issued to assess and specify the operations to be carried out by the SCC operator when approaching a (manned) ship in distress and it should install relevant liabilities in the case of non-compliance [42].

From the analysis above, it is evident that the role of the master cannot be equated with that of the director/operator of the SCC, absent of the most integral point, namely, that
of working and living on-board a ship as discussed above. The lead operator of the SCC is by any means the ipso facto leader of a distant community, so there is no need for special authorities to be bestowed upon them. With regards to the contractual responsibilities, and in particular the obligation to represent the shipowner, it could be much more efficient and advantageous to delegate some authority to the local stakeholders to handle emergency situations on behalf of the shipowner. Taking into consideration that the manager of the SCC cannot be equated with the master, and that the penal code was not established considering the concept of unmanned shipping, the rules dictating the liability of the captain of the ship could not be installed 'mutatis mutandis' with the SCC manager. Taking into consideration the great responsibility of the employment (navigating a boat with a significant amount of valuable cargo safely to its destination), the SCC operator should be regarded as liable for cases of gross negligence and deceit. Consequently, it is paramount for a new legislative framework to be introduced whereby the administrator of the SCC assumes the civil or criminal liability in such cases [43].

3.4. Levels of Autonomy

Initially, the IMO had provided the outcomes of the regulatory scoping exercise for the use of maritime autonomous surface ships (MASS) published on the 3rd of June 2021 which defined Four Degrees of Autonomy, namely [44]:

(i) Degree One: vessels with automated processes and decision support—seafarers are on board and have the operational and navigational control of the vessel, with some processes being automated and unsupervised.

(ii) Degree Two: remotely operated vessels with seafarers on board—the vessel is operated from a SCC with seafarers on board being able to take full control of the ship.

(iii) Degree Three: remotely operated vessels without seafarers on board—operation of the ship from a SCC with no seafarers on board.

(iv) Degree Four: fully autonomous ship—the operating system of the ship is able to independently navigate and operate, without the utilisation of a SCC.

On the 21 November 2021, the IMO published the MASS UK Industry Conduct Principles and Code of Practice Version 5, in which six degrees of automation were distinguished in an equal number of levels [45]:

(i) Level 0: No automation where all aspects of navigation, namely, the vessel command, the monitoring of and responding to the navigational environment and the fall-back performance of dynamic navigation tasks are conducted by a crew on-board. Consequently, there is no remote control of any sort and all the mechanical installations, such as radar, act supportively for navigation, which is conducted solely by the master of the ship.

(ii) Level 1: steering assistance where the vessel’s navigation is executed by a steering automation system while the master of the ship performs the rest of the navigational tasks and is expected to monitor and respond to navigational hazards.

(iii) Level 2: Partial automation where the vessel’s steering and automation are executed by a navigation automation system, with the shipmaster responsible for the monitoring of the system and the execution of the remaining navigation tasks. Up until this level, the ship is navigated absent of any kind of remote-control (incorporating Degree 1 of the IMO’s previous study).

(iv) Level 3: Conditional automation where the navigation is executed by an automation system, including collision avoidance, with the shipmaster receptive to intervene to system malfunctions and respond appropriately. From this level onwards, the installation of remote-control systems is possible, influencing the minimum manning or qualification requirements (incorporating Degree 2 of the IMO’s previous study).

(v) Level 4: High automation where the navigation automation system executes all the dynamic aspects of navigation, including fall-back operation, without expecting the shipmaster’s response. Human intervention is strictly limited to specific navigational aspects (incorporating Degree 3 of the IMO’s previous study).
(vi) Level 5: full automation where the navigation automation system is solely responsible for all the dynamic navigation tasks (incorporating Degree 4 of the IMO’s previous study).

It is evident that in the first three levels of automation, there is no remote-control installed in a vessel and the navigation automation system acts supportively to the ship’s navigation [46]. Consequently, the master of the ship is strictly liable for any navigation errors. The 3rd level of automation is critical because the navigation is executed by the installed navigation automation system, but the responsibility for navigational hazards falls to the master of the ship, being ultimately responsible for responding to system malfunctions. The liability is transferred to the SCC only at a Level 4 of automation, where the navigation automation system is in control of the ship and the master of the ship can only be deemed liable for the specific navigational aspects that are assigned to them. Finally, at a Level 5 of automation, there is no liability for the human element. The operation of the ship is solely performed by automated systems [47].

3.5. Convention on the International Regulations for Preventing Collisions at Sea, 1972 (COLREGs)

The Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) is the main international legislation dealing with collision prevention at sea and navigation rules and, subsequently, is ultimately affected by the initiation of the degrees of automation in the maritime industry. The objectives of the COLREGs are to make shipping safer by creating internationally accepted navigational standards and by requiring all vessels to be equipped with certain navigation tools. It deals with various issues such as the visibility requirements, safe speed, lights, light signals and the rules of priority and manoeuvres for different types of ships. In addition to the rules of navigation, the COLREGs rules also play important roles in the distribution of liability in the event of an accident, thus, it is a crucial convention for maritime law. It is a set of rules on navigation, designed to avoid collisions at sea. The International Regulations for the Prevention of Collisions at Sea of 1972 apply to all ‘ships’ of maritime law which are or may be used as a means of transport in water; therefore, an autonomous ship used for the carriage of cargo on sea voyages may be governed by these rules. The question that arises is how unmanned vessels should comply with these rules. The first rule of Article 5 of this convention states that COLREGs shall apply to all vessels on the high seas and to all waters connected with them, which are navigable by seagoing vessels, and as mentioned earlier, the word ‘vessel’ is linked to any description of a means of transport on water. An unmanned ship would be classified as a vessel according to this broad definition and for this reason, unmanned vessels would be subject to the application of the provisions of these rules. The second rule expressly states that no vessel, owner, shipowner or crew shall be released from the consequences of any type of negligence. In project MUNIN, it is assumed that the person in charge of the SCC is responsible for the operation of the remote-controlled vessel, therefore here, they are the one who must take these actions. Determining who is responsible for running an autonomous ship is still complicated, but based on the level of automation, it can be assumed that the master of the ship is liable in Levels 0, 1, 2, and 3, whereas the SCC would assume liability in Level 4. The human element evades liability in Level 5 of autonomy, where the operational and navigational hazards should be minimal. In any case, the owner of the ship is responsible, as is the operator respectively, where they should be considered as the ‘master’ of the autonomous vessel for all navigational matters [48].

With a view to avoiding collisions, each vessel must maintain at all times an appropriate surveillance with sight and sound and with all available means appropriate in the prevailing conditions, a full assessment of the situation and of the risk of a collision. As unmanned vessels are subject to the COLREGs rules, unmanned vessels should comply with this duty of appropriate surveillance at all times. With regard to ships under remote-control, SCC personnel should take care by using all the appropriate means available [49].
The aim of the standby rule is to make sure that the person operating a ship has the knowledge and experience to make the right decisions. They should not only be careful about large objects appearing in the ship’s path, such as other boats, but also be aware of any objects that fall into the water. The monitoring person is responsible for assessing data and transferring the information to the person in charge. It is only logical that this refers to Level 3, the so-called conditional automation, where the SCC can have control over the ship and monitor the performance of the automation system. The critical part here is that unmanned ships would be equipped with two kinds of sensors: (i) the electronic sensors for detecting objects within an area of 5 km and (ii) other sensors for detecting smaller objects at short distances. Those sensors in Level 3 automation will help the automation system to evade the imminent threats while the SCC would be able to monitor the case [50].

Undoubtedly, the automation systems would eliminate human errors on alert, such as fatigue, a lack of attention and situations of negligence; first of all, the information available for navigation would be much more accurate and reliable than is the case with traditional ships. In the case of ships remotely controlled, the equipment allows an SCC to have a clear picture of the ship’s environment and be able to take the correct action in a timely manner. Additionally, in the case of complete automation (Levels 4 and 5), the data collected from the sensors and other machinery would be transferred to the automation system to effectively assess and re-evaluate the safest navigational course. Thus, as far as the purpose of the standby rule is concerned, surveillance on unmanned vessels, which is carried out by advanced sensors, would be yet another improvement from this perspective. Using the terms “proper supervision by sight and hearing”, the rules of COLREG do not necessarily require a standby person, but rather an organised collection of information. The alert rule states that it must be carried out with “supervision and listening and all available appropriate means”. These “available means” have become tools that have capabilities beyond the human senses and unmanned vessels equipped with autonomous sensor systems would be the next advancement of the standby role [51].

As an outcome, it is safe to assume that Article 5 of COLREG can be applied to unmanned vessels in all levels of automation by replacing the human factor with the appropriate machinery, such as sensors, radars and sound technology.

3.5.1. The Safe Speed

Regarding the issue of safe speed, in Reg. 6 of the COLREGs it is stated that “every ship must always move at a safe speed so that it can take appropriate and effective measures to avoid a collision and to be able to stop in adverse conditions”. In the case of unmanned vessels, regarding the automation levels four and five, this obligation should be followed by the head of the SCC under all visibility conditions, as they should assume the role of master and crew. In determining the safe speed, they should consider two categories of factors [52] and the first that the SCC should take into account are the factors that need to be considered by all vessels:

- The visibility mode.
- The density of traffic, including the concentrations of fishing vessels or other vessels.
- The manoeuvrability of the boat, with reference to the stationary distance and the ability to rotate in the prevailing conditions.
- The presence of lighting at night, such as from shore lights or from the rear dispersion of lights of the boats themselves.
- The state of the wind, sea and currents, as well as the proximity of the risks of navigation.
- The draught in relation to the available water depth.

The second group concerns the factors that must be considered by ships with radar. Vessels using radar will sail mainly at higher speeds in a state of limited visibility [53]. That is why the SCC should take additional elements into account when determining a safe speed. As unmanned ships would be highly dependent on radars and sensors, they should also address the following factors:
• The characteristics, effectiveness and limitations of the radar equipment. The effectiveness of the equipment for detecting ships and other objects is also related to the ability of those observing the radars.

• All restrictions are imposed by the radar range scale during use. For example, when applying the radar on a larger range scale, the likelihood of small objects being detected is lower, and when a short-range scale is applied, the radar would not be able to detect objects that are further away; however, because unmanned vessels are also equipped with sensors and other systems, this issue is likely to be significantly reduced.

• The impact on the radar detection of the marine situation, weather and other sources of interference.

• The possibility that a range of small vessels, ice and other floating objects would not be adequately detected by a radar.

• The number, position and movement of ships detected by the radar. When there are a greater number of targets indicated on the radar, it would be more difficult to determine the risk of collision and assess the effect of certain manoeuvres; however, the most advanced radars are already able to provide navigational information in these conditions. The operators of land-based unmanned vessels should take into account all these elements when determining the speed of a vessel [54].

3.5.2. Safe Navigation

The management and sailing rules of the COLREGs apply to all vessels, but hardly any provision in the legislation specifies who should make the navigational decisions; therefore, initially, there should be no obstacle to the placement of land-based operators who are responsible for navigating ships by remote-control. When remote-control is installed, it is important to distinguish between each level of automation. For example, in Level 4, the automated navigation system has the sole control of the ship and the SCC only acts supportively. In Level 5, the human element is absent of any kind of control of the vessel. Meanwhile, the most complicated level is Level 3 of automation, where the automated navigation system navigates the ship, but the ultimate responsibility and the expectation of intervention falls to the SCC [45].

Present studies have shown that as the level of automation increases, so to increases the reliance on algorithms and advanced systems, that are able to navigate the vessel in the optimum operational conditions even under unexpected circumstances [50]. It is unknown how a computer will react to emerging threats and unexpected conditions. Evidently, there are many research projects are under development in this regard to ensure that autonomous vessels can act more confidently and safely under such conditions [55].

4. Contractual Issues and Responsibilities of Unmanned Vessels

One of the main concerns of all modes of transport is their safety and reliability and the same is true of autonomous systems. The technology is already increasingly becoming a reality, but the legal framework is still lacking [18]. Legal uncertainty, in terms of its reliability, is holding back autonomous transport. Autonomous vessels must always be reliable and capable of navigating under difficult conditions, absent of any physical intervention and the aspects of safety and reliability are closely related with legal issues of maritime liability. The shipowner traditionally supplies the vessel, and the charterer or carrier is responsible for the vessel’s operation. Initially, the ship can be leased for a specified period, namely, a time charter, or for only one trip, namely, a voyage charter, but the charterer may also choose to take complete control of the vessel, undertaking also all the subsequent legal rights and liabilities of the vessel [56]. The fact that there would no longer be any crew on board would not affect the chartered vessel or any of the shipowner’s or the charterer’s obligations. Only minor adjustments may be required, such as the definition of who is responsible for crewing an SCC in the case of a remotely controlled vessel. In the case of a time charter or voyage charter, the owner would be responsible and in the event of a bareboat charter, the charterer should hold the responsibility. As it is evident, there
would be few differences from the current situation as to who should hire a crew; therefore, the charterers’ obligations would not be practically affected by the utilisation of unmanned ships [57].

As far as transport is concerned, unmanned vessels would be utilised mainly in the transport of goods, thus, the contracts of carriage would be between the carrier and the consignor. The consequent obligations of the carrier and the consignor would be incorporated in the relevant carriage of goods contracts and in the bills of lading, pursuant to international legislation, such as the Hague Visby rules, Hamburg rules or the Rotterdam rules. Under those rules, the carrier is liable when the delivery of a cargo has been damaged, delayed or even lost, by the fault of the carrier or their employees or agents. If the cargo is damaged, lost or delayed as a result of an error on an autonomous ship, the carrier would continue to be held liable because it must enable the autonomous ship to sail safely, which means that all mechanical installations would have to function properly [58].

With an unmanned ship, the SCC would represent the carrier and, thus, would operate and control the ship. In the event of a mistake, resulting in damage, loss or delay, the carrier would again assume responsibility. According to the Hague Visby rules, they could be exempt from navigational mistakes or a vessel’s mismanagement caused by their employees, when the SCC was acting as a carrier’s employee [59]. Therefore, the transport of goods by unmanned vessels or remotely controlled or autonomous ships would not cause significant changes, as far as the carrier’s responsibilities for proper navigation and management are concerned [32].

In general, maritime law will direct responsibility to the lawful owners or vessel operators, rather than to individual stakeholders who act as employees of the aforementioned persons. In the case of an accident leading to a ship’s collision, the shipowner should be deemed liable for any damages caused by omissions or any kind of negligence of their employees and agents, or for damages deriving from the condition of the ship [13]. The liable party who committed the omission does not affect the defendants, as they could sue the shipowner for damages, on the basis of their contractual liability. Thus, it could easily be assumed that an owner’s liability would remain intact even when an unmanned vessel was utilised [60].

Additionally, the operation of unmanned vessels should limit human interaction with vessels, thus reducing the main cause of maritime accidents, namely, human error. It is a fact that maritime accidents cannot be completely avoided, and while unpredictable issues may arise—such as a vessel collision caused by malfunctions or damaged machinery, leading to bodily injury and/or property damage—an affected party could claim compensation for their loss or damages from a shipowner, who may try to reverse their responsibility. Although the maritime law concerning liability concerns does not require major reforms, an ever-increasing level of automation would surely create some emerging threats, deriving from the combined operation of state-of-the-art machinery [18].

5. Liability of Autonomous Vessels

Autonomous technology evidently minimises human interaction with a vessel, but malfunctions in technological systems may emerge. Presently, the Mayflower Autonomous Ship is being tested [61], whereas the MV Yara Birkeland, a 120 TEU container ship is currently under operation [62]. The operation of these vessels has shown so far that a machinery failure or faulty software may easily force an autonomous vessel to deviate from its route and collide with another vessel. In that case, a shipowner should be deemed responsible for any loss or damage caused and also in that case, absent of human interaction which in some cases may help to avoid an accident or which instead an owner may be deemed liable, the owner may be reluctant to invest in unmanned vessels. Subsequently, even if the chance for accidents was theoretically reduced, the cost of liability would increase and thus many operational costs, such as insurance, would consequently increase, leading to an overall increase in freight rates [63]. This issue could be resolved by transferring the responsibility of a system’s malfunction from the shipowner to the manufacturer, as
is evidenced in the autonomous motor vehicle industry [64]. Specifically, in the event of loss or damage from a malfunction in the machinery or equipment, the liability should be transferred to the product’s manufacturer, based on the Liability/Reliability Act for products when there is no fault or negligence on the part of the shipowner or their agents [65].

Issues may arise when there is a violation of the navigational or criminal rules when a ship is in a port. The liability in those cases rests mainly with the onboard crew and may result in fines, detention and even imprisonment when criminal rules are violated. Issues may arise in such instances if there was no crew on board and the owner or the vessel operator were in a remote country, or if the ship did not have a controller and instead acted autonomously [66].

A solution may be the introduction of a pilot who was located on the port and would supervise and react when a malfunction during the mooring or cargo loading emerged. This could lead to the introduction of special training and certification for such a position, based on international legislation, imposing also a measure of liability. In the case of a collision, unmanned vessels could easily cope with such an adverse situation [67]. In the case of the loss of a vessel’s control for an undefined reason or due to the ship’s operation in automation, the liability could become uncertain or unspecified by law, and the present regulatory or contractual rules are likely to become fundamentally inadequate if they remain as they are [68].

Issues may also arise when an unmanned vessel, during navigation, interacts with ships or personnel in distress. The unmanned ships, absent of a crew, would not be equipped with life jackets, food supplies or accommodation. Additionally, apart from the potential personnel who may be temporarily on board an unmanned ship, there might be the case of stowaways which, despite their difficulties, cannot be neglected. The present regulatory framework on stowaways needs amendments, and absent of a master on board to be responsible for handling those cases, the question remains for how those instances should be dealt with and what proactive measures should be taken to avoid them [69].

Additionally, pirate or terrorist attacks cannot be excluded as possible threats during the operation of unmanned ships; pirates may even consider unmanned ships as being more accessible and profitable targets. New types of piracy and terrorism may even emerge. In the case of a vessel’s cyber theft, there is no international legislation in effect, characterising the hacking of information systems and vessel controls as another method of shipping piracy [70].

6. Conclusions

The merchant marine sector is experiencing pioneering changes and is in a state of transformation. The present examples of the Mayflower Autonomous Ship and MV Yara Birkeland are illustrations of a positive development within the shipping industry, as it moves increasingly towards automisation. The implementation of unmanned vessels is a great step towards sustainable development. It is evident that, as the technological innovations are constantly evolving and new systems and, consequently, new threats are emerging, there is also a need to further explore and update the existing legal framework to successfully address the issues posed by this technological development.

Even if the concept of full autonomy is difficult to be achieved, the beneficial contribution of technological advances relating to unmanned shipping, compared to conventionally-manned ships, is quite significant. The potential to reduce maritime accidents with better technological support for navigation and the detection of obstacles is promising. Similarly, technology to detect smaller objects can provide valuable support in search and rescue operations. A maximisation of maintenance strategies can reduce technical incidents in addition to operation costs, while more technologically advanced navigational systems and platforms could be utilised to make transportation safer and more reliable.

A crucial issue is the legal definition of an unmanned vessel to effectively include all the levels of automation. Although the legislation in effect does not forbid the utilisation of
unmanned ships, specific legislation to specifically regulate the operational intricacies of unmanned vessels is required, taking into consideration all the levels of automation. The issue of the genuine link between the flag state and the vessel is easily resolved. Whereas manned vessels abide the laws of the flag state, enforceable by the master, in unmanned vessels this would simply fall to the SCC operator and the owning company. Another important element is the area of unmanned vessels’ operation, which directly affects the proportion of threats and the level of automation and requires a specific set of rules that governs the operation.

Thus, national laws and regulations are the main obstacles preventing the widespread introduction of unmanned or at least semi-autonomous vessels; however, considerable efforts have been made to adapt national legislations to meet the challenges of unmanned shipping. The first legal steps to regulate the utilisation of unmanned vessels have been already conducted; there is, however, considerable work yet to be achieved to ensure comprehensive adaptation. A solution would be for the existing regulations to be used as a baseline and, with careful additions or implementations, the unmanned vessels could be regulated in full correspondence with the regulations for manned vessels. The most important issue requiring addressing is undoubtedly the subject of liability regarding a vessel and its cargo. This crucial issue needs to be resolved before the utilisation of the unmanned technology.

Based on the IMO’s and MASS’ present guidelines, in Levels 0, 1 and 2, the liability for a navigational or operational error falls to the shipmaster, whereas at Level 3, where remote operation is established, the liability falls initially to the SCC and, ultimately, to the shipmaster, with them being responsible for the monitoring of navigation. In Level 4 the liability is transferred to the SCC and the shipmaster, should they be on-board, who would act supportively and only for specific tasks. In the Level 5 of automation, the human element is absent from any navigational or operational control over the vessel, which, being fully automated, acts independently. In this case, the liability for any kind of hazard or malfunction should be transferred only to the manufacturers, as in the case of aviation.

In the case of a system malfunction and in the absence of the human factor, specific processes may be installed, such as operators on terminals being able to navigate ships when in coastal areas and near ports, or for the initiation of response teams being able to board unmanned vessels when required. Evidently these measures, despite their effectiveness, would not be beneficial for unmanned vessels when they in the high seas.

To recapitulate, despite the difficulties with implementation, the utilisation of unmanned merchant ships is viable in the near future up to the Level 3 of automation. Nevertheless, man-to-machine interaction will still be valid for a long time to come, as ocean going vessels will continue to be, at least partially, controlled or monitored by a human element. Thus, the existing vessels will not be phased out any time soon. Many tests have already been conducted, through which progressively the technical risks of operation and strategies to minimise that risk are already being identified. Prior to the widespread operation of unmanned vessels in international waters and through countries, there remains much to be done to create a legal framework that can mitigate the prospective risks posed by unmanned ships, as a sustainable option in the merchant marine sector.

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References


8. Tiller, E.H.; Cross, F.B. What is legal doctrine. Nw. UL Rev. 2006, 100, 517. [CrossRef]


10. Karlis, T. Maritime law issues related to the operation of unmanned autonomous cargo ships. WMU J. Marit. Aff. 2011, 10, 45–61. [CrossRef]


40. Wahlström, M. Human factors challenges in unmanned ship operations—Insights from other domains. *Procedia Marit.* 2015, 3, 1038–1045. [CrossRef]


53. Öztürk, Ü.; Akdağ, M.; Ayabakan, T. A review of path planning algorithms in maritime autonomous surface ships: Navigation safety perspective. *Ocean Eng.* 2022, 251, 111010. [CrossRef]


60. Zhou, X. A study of the application barriers to the use of autonomous ships posed by the good seamanship requirement of COLREGs. *J. Navig.* 2020, 73, 710–725. [CrossRef]


