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Collisions at Sea Involving Maritime Autonomous Surface Ships: Notes on Prevention and Liability Rules

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Abstract

With Maritime Autonomous Surface Ships (MASS) slowly but steadily nearing worldwide implementation, this innovative technology's technical and legal aspects still require resolution. These issues are currently under the scrutiny of the International Maritime Organisation. The authors believe that specific attention should be given to the area of collision avoidance at sea and rules governing liability arising from collisions involving MASS, respectively, the 1972 Convention on the International Regulations for

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Preventing Collisions at Sea and the 1910 Convention for the Unification of Certain Rules of Law with respect to Collisions between Vessels. The first part of the study analyses technical issues to identify policy implications for handling the not-always-successful collision avoidance of MASS from a legal point of view. An in-depth examination of the current liability rules applicable to such collisions follows. The paper finishes with a few policy outcomes on the optimal regulatory approach on the international level.

Keywords

Maritime Autonomous Surface Ships – remote operator – artificial intelligence – liability – collision – international conventions

1 Introduction

With Maritime Autonomous Surface Ships (MASS) slowly but steadily moving toward large-scale deployment, expectations for them are growing. These vehicles are seen not only as a solution to the shortage of workforce and shipping profitability[1] but also to their safety. In virtually all discussions related to MASS, the bottom line is that they shall be at least as safe as vessels operated nowadays.[2] That, however, does not imply their overall safety. Although the number of maritime accidents might be reduced by introducing MASS, and perhaps even their consequences, neither will likely be brought to zero.

The issue of liability for such events has already been raised on several occasions, ranging from barely acknowledging it[3] to being the main storyline of

1 Ziaul Haque Munim, "Autonomous Ships: A Review, Innovative Applications and Future Maritime Business Models", 20(4) *Supply Chain Forum: an International Journal* (2019) pp. 266–279; Ewelina Ziajka-Poznańska, Jaabkub Montewka, "Costs and Benefits of Autonomous Shipping – A Literature Review", 11(10): 4553 *Applied Sciences* (2021).

2 Osiris A. Valdez Banda, Sirpa Kannos, Floris Goerlandt, Pieter H.A.J.M. van Gelder, Martin Bergström, Pentti Kujala, "A Systemic Hazard Analysis and Management Process for the Concept Design Phase of an Autonomous Vessel", 191:106584 *Reliability Engineering & System Safety* (2019).

3 Mayank Suri, Krzysztof Wróbel, "Identifying Factors Affecting Salvage Rewards of Crewless Vessels – Lessons from a Case Study", 21(2) *WMU Journal of Maritime Affairs* (2022) pp. 213–232; Fran Humphries, Rachel Horne, Melanie Olsen, Matthew Dunbabin, Kieran Tranter, "Uncrewed Autonomous Marine Vessels Test the Limits of Maritime Safety Frameworks", 22 *WMU Journal of Maritime Affairs* (2023) pp. 317–344; Igor Bačkalov I, "Safety of Autonomous Inland Vessels: An Analysis of Regulatory Barriers in the Present Technical Standards in Europe", 128: 104763 *Safety Science* (2020).

the scientific work. To the authors' best knowledge, however, none of them analysed issues of hands-on collision avoidance and related liability outcomes simultaneously, providing a comprehensive view of the incidents and consequences of the MASS operations.

Meanwhile, collisions are one type of maritime accident with some unique traits. As practitioners imagine it as simply an unfortunate event in which two separate ship hulls come into unwanted contact, the mindset of their legal representatives may be different. The former would likely reflect on what Rules of Convention on the International Regulations for Preventing Collisions at Sea, 1972 (herein: COLREG) have been violated, resulting in damage to their own and the other ship, how to reduce the consequences, and how to prevent similar events in the future. The latter would instead start by listing the violations committed by the counterparts of their clients and might then be tempted to argue about the peculiarities of the Convention for the Unification of Certain Rules of Law concerning Collisions between Vessels, 1910 (herein: the Collision Convention 1910, CC 1910).

CC 1910 is currently under assessment by the Comité Maritime International (CMI). Two questions raised by the Working Group's questionnaire concerned the suitability of the Convention to MASS. Simultaneously, the CMI's Working Group on MASS conducts its research into the legal ramifications of MASS. Its result were submitted and presented at the Legal Committee's (LEG) 111 session of the International Maritime Organisation (IMO). The summary of the CMI's research included a thorough analysis of possible regulatory approaches to liability issues arising from MASS operations and presented the pros and cons of several solutions, including upholding the status quo. However, most States at the LEG thought there was no time pressure to discuss liability issues.

The presence of a human on board, crewmembers' reliance on their knowledge, experience and seamanship, as well as the ability to assign potential liability, are just some of the cornerstones of the maritime legal regime[4] - and they are all changing with the emergence of potential crewlessness as a part of a broader concept of maritime autonomy. On top of this, as the outcome of this ongoing shift remains largely unknown, considerable uncertainty affects the usability of most MASS-related analyses.

Therefore, the objective of the herein study is to combine the two perspectives on collision avoidance – practical and legal – concerning the upcoming of MASS and to identify issues that may affect the conduct of liability

4 Luci Carey, "Contractual and Tortious Maritime Liability Regimes and the Introduction of Autonomous Vessels", 23/03 *NUS Center for Maritime Law Working Paper SSRN Electronic Journal* pp. 5–9; Massimiliano Musi, *La nozione di navi*, Bonomo Editore 2020, pp. 123–124.

proceedings should a collision occur. This was achieved through an analysis of both COLREG and CC 1910, focusing on issues determining the liability of MASS-related agents for potential collisions. The novelty of the analysis consists in extending the common notion of Responsibility (COLREG Rule 2) for MASS collisions with the notion of liability (CC 1910 Art 2 through 5).

The remainder of the manuscript is structured as follows. Firstly, some issues affecting liability for collisions are highlighted, stemming from COLREG. These are then analysed further within the framework of CC 1910. The findings of these analyses are then discussed, along with their policy implications.

2 COLREG

In order to elaborate on liability for a specific unwelcome event, one must first review the guidelines for desirable and correct conduct. In case of collisions at sea, that means reaching the bottom line, COLREG. Only then can findings from such a review be elaborated to determine liability outcomes under CC 1910. With this in mind, it shall be noted that whenever MASS is involved in a collision, such an event can be of one of two types: (A) MASS collides with a fully-manned ship or (B) two MASSes collide. Collision-like events of ships ramming into stationary objects are excluded from further analyses as these are covered by neither COLREG nor CC 1910.

The general, high-level findings emanate from Part A of the Rules (2 through 8 in particular), which apply to all ships regardless of visibility conditions and area of operation. These are characterised in the following subsections. Notably, this does not prevent case-specific issues from arising under other Rules, but it helps establish the general principles for MASS collision liability discussion.

2.1 *Rule 2: Responsibility*

Apart from the detailed discussion on who the master and crew of MASS are, it is apparent that this Rule applies to at least the vessel herself, which is thereby obliged to follow the Rules. One could argue that the vessel's crew does not include persons located outside. However, certain English dictionaries broadly define a crew as 'all the people who work together, esp. to operate a ship', not necessarily on board. By this, some autonomous ships may be crewless in a strict sense (by not carrying a crew), but no ship is truly crewless – not even the fully autonomous ones.[5] Such vessel, owner, master or crew must not

5 Barbara Stępień, "Can a Ship Be Its Own Captain? Safe Manning of Autonomous and Uncrewed Vessels", 148: 105451 *Marine Policy* (2023).

neglect any precautions when operating MASS. This statement underlines that Rules are not the only thing that matters in real-world applications and that the precautionary principle always applies. The ultimate goal is to avoid any dangerous conditions, including collisions, and ensure the safety of navigation. No legal act nor using common sense shall be discarded, especially in safety-critical circumstances, simply because a particular vessel is of a special type – autonomous or crewless.[6]

This also includes Rule 2b), where said special circumstances may include the presence of MASS in the area or being in charge of MASS with all her potential discrepancies from how normal ships are operated. These include differences between humans and machines in sensory abilities, data processing, decision-making, fuzzy reasoning, situational awareness, and communication issues, to begin with.[7] All in all, it can be anticipated that, as a result of these issues, MASS will behave differently from manned ships, which can lead to misunderstandings of their actions by humans controlling other ships. Thus, these special circumstances may mean that a MASS may be considered a danger to navigation as she may depart from the Rules in line with Rule 2b) if that is considered feasible by the algorithm/operator. It can also do so unintentionally because a thoughtless algorithm tells her to do so. Although such algorithm-generated action by MASS may occasionally be incomprehensible by other human-operated ships in the vicinity, that does not make her immune to its consequences under Rule 2a). Accordingly, it may be argued that if the very fact that MASS navigates a given area falls under special circumstances designation, then all other ships are obligated to take any precaution necessary for her potentially incomprehensible behaviour. Such a setup can be labelled as illogical as it would virtually release MASS from any responsibility for her actions, which would, in turn, be against Rule 2.

2.2 *Rule 3: Definitions*

Although there has been some initial discussion in academia, MASS should be considered a vessel under 3a) but not restricted in her ability to manoeuvre

6 Xiang-Yu Zhou, Jin-Jing Huang, Feng-Wu Wang, Zhao-Lin Wu, Zheng-Jiang Liu, "A Study of the Application Barriers to the Use of Autonomous Ships Posed by the Good Seamanship Requirement of COLREGS", 73(3) *The Journal of Navigation* (2020) pp. 710–725.

7 Ørnulf Jan Rødseth, Lars Andreas Lien Wennersberg, Håvard Nordahl, "Improving Safety of Interactions between Conventional and Autonomous Ships", 284: 115206 *Ocean Engineering* (2023); Krzysztof Bogusławski, Jan Nasur, Jie Li, Mateusz Gil, Krzysztof Wróbel, Floris Goerlandt, "A Cross-Domain Scientometric Analysis of Situational Awareness of Autonomous Vehicles with Focus on the Maritime Domain", 10:50047–50061 *IEEE Access* (2022).

(RAM), as previously suggested.[8] By default, it is not the nature of work carried out by MASS that may restrict her ability to manoeuvre as required by the Rules, but possible shortcomings of her software, hardware, or lifeware. Neither of these (such as underperformance of navigational equipment or insufficient crew qualifications) would be grounds for labelling a regular manned vessel a RAM one. A similar principle should apply to fully manned ships and MASS regardless of the latter's mode of operation.

2.3 *Rule 5: Look-out*

Upon the undisputable conclusion that an autonomous vessel is, in fact, a vessel, she must maintain a look-out as prescribed by Rule 5. From the liability deliberations perspective, however, there is a significant difference between MASS and regular ships. This consists of the provability of maintaining a proper lookout. While an autonomous ship could, in theory, produce actual, verifiable, and explainable evidence that she was, in fact, maintaining a look-out using her sensors due to the expected use of a redundant array of sensors,[9] data storage and fusion, such an ability is limited in the case of manned ships. The latter cannot prove beyond any doubt that the watch-keepers were looking out the bridge window or at sensor display screens, or that they could comprehend what they observed. Such provability is limited by the functionalities of Voyage Data Recorder (VDR) and its operational issues.[10]

Between these two cases are remotely operated ships that would likely produce evidence of sensors detecting environmental features correctly. However, remote operators' use of such data could not easily be proven. This, in turn, may be affected by various factors ranging from data connection latency and operator distraction to criminal interference with the data link.

On the other hand, the expected design of the MASS system can lead to interesting issues related to the ownership of data produced by MASS, including those related to the look-out. If the data generated by MASS can be transmitted

8 Craig H. Allen, "The Seabots Are Coming Here: Should They Be Treated as Vessels?", 65(4) *The Journal of Navigation* (2012) pp. 749–752; James Kraska, "The Law Of Unmanned Naval Systems In War And Peace", *Journal of Ocean Technology* (2010) pp. 52–53.

9 Rob McLaughlin, "Unmanned Naval Vehicles at Sea: USVs, UUVs, and the Adequacy of the Law", 21(2) *Journal of Law, Information and Science* (2012) pp. 111–112; Robert Veal, Michael Tsimplis, Andrew Serdy, "The Legal Status and Operation of Unmanned Maritime Vehicles", 50(1) *Ocean Development & International Law* (2019) p. 39.

10 Mario Piccinelli, Paolo Gubian, "Modern Ships Voyage Data Recorders: A Forensics Perspective on the Costa Concordia Shipwreck", 10 *Digital Investigation* (2013) pp. 41–49.

and stored ashore so as not to be lost in case of MASS sinking, then it can be used in further legal proceedings. If that data can then be used to prove the lack of fault of MASS, the case is clear, and such data will likely be used in court or any other tribunal in favour of the MASS owner or operator. However, if such data suggests otherwise, one can easily imagine that they are unavailable to third parties: lost (overwritten by accident) or even purposefully damaged if stored under a convenient jurisdiction. Regardless of the reason, they might only be presented to an investigative board or a court of justice if proper tools, such as discovery or other disclosure regimes, are provided under the relevant procedural law.

2.4 *Rule 6: Safe Speed*

Although no Rule prescribes a crisp value of what a safe speed is in given circumstances, this can be determined by experience or with the assistance of procedural guidelines. Rule 6a-b) provides a list of factors to consider when determining the safe speed but fails to provide any formula for doing so. It can be argued that, in principle, the purpose of maintaining a sufficiently low, safe speed is to ensure that the stopping distance of a vessel is such that she can reduce her speed to aid collision avoidance manoeuvres. On manned ships, officers may have limited knowledge of the hydrodynamic characteristics of their vessel (not to mention other ships in the area), primarily drawn from experience and the wheelhouse poster. At the same time, MASS would likely contain a detailed hydrodynamic model of themselves to calculate their manoeuvres to conduct them safely and later prove that they were safe to conduct, at least in the intention of MASS.[11] This knowledge of one's own hydrodynamic characteristics, combined with collision avoidance algorithms, should guarantee that evasive action is appropriately conducted by MASS, provided that:

- the hydrodynamic model is correct;
- algorithms are correct;
- the data fed to the above are correct.

11 Mateusz Gil, "A Concept of Critical Safety Area Applicable for an Obstacle-Avoidance Process for Manned and Autonomous Ships", 214:107806 *Reliability Engineering & System Safety* (2021).

As with Rule 5, remotely operated ships would be stuck in the middle. Their technological superiority over traditional manned ships might support the remote operator's decision-making. However, it will not ensure that these decisions are correct, not only in terms of speed but also in terms of *Actions to avoid collision*.

2.5 *Rule 7: Risk of Collision*

As discussed in the literature, some of the Rules are written vaguely, and their interpretation by MASS can be challenging in real-life situations.[12] However, the discussion on liability differs and can only be carried out in hindsight. Concerning Rule 7, this brings the discussion back to the issue of provability and how specific actions were taken. For instance, all available means appropriate to the prevailing circumstances and conditions have been used to determine the risk of collision. Moreover, all the software and hardware were, in fact, operational on board MASS, feeding data of a good and verifiable quality, and that data was used to calculate the risk of collision in the presence of assumptions supported by either logical conditions or artificial intelligence (AI) reasoning.[13] These assumptions may not always be correct, but so is the case with assumptions made by humans – at least, MASS can prove its way of reasoning at the moment of collision to determine fault. None of this can be proven by the manned vessel except through the testimonies of her crewmembers (which can be unavailable or flawed for various reasons) or, partly, VDR.

However, remotely operated ships find themselves in between – although the flow of data between the ship and her remote operator and collision risk calculations can be evidenced, the cognitive processes within remote operators' minds cannot. On the other hand, if these persons were to be stationed in land-based facilities, their testimonies could be collected almost immediately after the accident, thus reducing the risk of misrepresentation or loss of evidence.

2.6 *Rule 8: Action to Avoid Collision*

Nevertheless, regarding liability proceedings, the most significant difference between autonomous and manned vessels lies in the provability and

12 Krzysztof Wróbel, Mateusz Gil, Yamin Huang, Ryszard Wawruch, "The Vagueness of COLREG versus Collision Avoidance Techniques – A Discussion on the Current State and Future Challenges Concerning the Operation of Autonomous Ships", 14(24):16516 *Sustainability* (2022).

13 Agnieszka Lazarowska, "Research on Algorithms for Autonomous Navigation of Ships", 18(2) *WMU Journal of Maritime Affairs* (2019) pp. 341–358.

explainability of the processes executed by the former. Data collected by MASS and skillfully interpreted can be highly beneficial in proving that MASS fulfilled the requirements set by Rule 8. This puts significant pressure on system designers, whose responsibility would then be to design the MASS so that she chooses the best option of collision evasive action out of available ones, and such action meets the requirements prescribed in Rule 8a). Notably, these requirements (positive, made in ample time, and with due regard to the observance of seamanship) are somewhat vague in their wording.

In a MASS-manned ship collision case, the provability of the line of reasoning and availability of data supporting it might be an advantage in allowing for the dismissal of statements made by the opposing party and putting MASS in a better position for civil liability proceedings, provided that this reasoning led to the execution of a correct action. On the other hand, the due regard to the observance of good seamanship can serve as an argument in favour of a manned ship as follows. Her crew followed good seamanship because they were well-trained, experienced professionals whose well-being and perhaps survival depended on the ability to avoid any incidents. However, neither of the above factors applies to an autonomous vessel, and therefore, she is incapable of having good seamanship.

Having learnt seamanship through experience, one can explain their actions when questioned, including those undertaken to avoid collision. Although navigators involved in a collision may give in to the temptation to whitewash in an attempt to minimise their guilt, some information can usually be extracted from them through interrogation. These can then be cross-checked with data available from VDR and other records. With MASS taking the stage, only the latter would be available: raw data with little to no explanation of its significance to the decision-making process. Collision avoidance is a complex process that considers many variables like speed, water depth, onboard equipment performance, target ship's navigational status, etc. Such data can be highly redundant. Especially in the presence of a probabilistic AI instead of deterministic algorithms, this can increase the complexity of reasoning behind each decision taken by MASS. With its operating system deciding on the course of its actions every second or even more often, each decision might be considered independent from the previous one and be taken based on different circumstances. It would require built-in explainability features or highly skilled experts to navigate and comprehend such data sets, provided the data is made available in the first place.

For MASS-MASS collision, since both ships could present data supporting their respective reasoning, the evasive action itself (and algorithms elaborating it) would be in the spotlight. Moreover, since the collision results from at least

one evasive action being incorrect, this would imply that a collision avoidance algorithm of at least one of the MASS was counter-productive. Which, in turn, necessitates understanding how two (or more) potentially unexplainable entities affected each other.[14]

3 CC 1910

The applicability of CC 1910 to MASS does not raise significant concerns.[15] A number of states have adopted CC 1910. However, it is far from providing complete harmonisation. Among states that are not parties to the Convention are big flag states like Panama, Liberia, and the Marshal Islands. There are other limitations to consider. The Convention will not be a legal basis for claims for compensating damages other than those caused to the vessels or any things or persons on board unless extended explicitly by national law. Thus, claims for compensation for harbour infrastructure damage or other installations will not be covered by CC 1910.[16] On the other hand, CC 1910 extends to situations where damage was caused by a vessel by the execution or non-execution of a manoeuvre or by the non-observance of the regulations, even if no collision had taken place.[17]

3.1 *Identification of the Liable Person*

The CC 1910 does not channel liability to any particular actor. Instead, it links the liability with a ship. According to Art 3, liability is triggered by the vessel's fault. Thereby, Art 3 represents an example of a ship's personification,[18] which is the influence of common law. Thus, it will be for a national law to determine who bears the liability established under the norms of the Convention for collisions between crewless ships or crewless ship and manned ship.

14 Jong Kwan Kim, Deukjin Park, "Understanding of Sailing Rule Based on COLREGS: Comparison of Navigator Survey and Automated Collision-Avoidance Algorithm", 159: 105894 *Marine Policy* (2024).

15 Eric Van Hooydonk, "The law of unmanned merchant shipping – an exploration", 20 *Journal of International Maritime Law* (2014) pp. 407–408; Leonida Giunta, "The enigmatic juridical regime of unmanned maritime systems", *OCEANS 2015 – Genova* (2015) pp. 1–9.

16 Such claims will be governed by national laws which often provide for strict liability of the shipowner or the ship's operator, e.g., UK Harbour Docks and Piers (Clauses) Act 1847, Polish Civil Code Art 436.

17 Francesco Berlingieri, *International Maritime Conventions* (*Volume 2*). *Navigation, Securities, Limitation of Liability and Jurisdiction* (1st ed., 2014) p. 8.

18 Ibid, pp. 13–14.

National laws often point to the shipowner or the operator of the ship,[19] being vicariously liable for the negligence of their employees. Thus, in cases of collision caused by a negligent act of a remote operator employed by a shipowner, their employer will be liable. However, in cases where the collision resulted from a third party's wrongdoing, i.e., an independent contractor, the shipowner or ship operator will typically not be liable, provided that they took reasonable care while choosing the contractor, according to some national laws.[20] Therefore, when the negligence of a remote operator of the MASS is a cause of a collision and when such an operator is an independent contractor chosen with due care, the shipowner will not be liable. However, some national laws provide for vicarious liability of the shipowner for those who perform work in the service of the ship, not being the shipowner's employees.[21]

Claims could potentially be brought against a Remote Operating Centre (ROC) or ship operator acting as an entity independent from the shipowner[22] on the condition that the victims could prove at least its negligent act. As in the case of manned ships, an accident might be caused by a human factor,[23] with a difference from the case of crewless ships, where negligent acts will likely not occur on board a ship but on land.

19 The phrase 'operator of the ship' should not be confused with the 'remote operator'. The ship's operator is used in the text to denote a person or a corporate body operating the vessel in its own name, however not necessarily being the shipowner. Under some national laws it is the ship's operator who is the central person bearing liabilities incident to the operation of the vessel, see: Jan Łopuski, *Maritime Law in the Second Half of the 20th Century. Selected Articles* (1st ed., 2008) pp. 92–93. Below in this paper we use the term 'shipowner', to denote both, the shipowner and the operator of the ship.

20 That is the case under English law, see: Simon Baughen, "Who Is the Master Now?: Regulatory and Contractual Challenges of Unmanned Vessels", in B. Soyer, A. Tettenborn (eds.), *New Technologies, Artificial Intelligence and Shipping Law in the 21st Century* (2023) pp. 129–147; and Polish law, which also relives from vicarious liability when one can prove that it chose a professional party (Art 429 of the Polish Civil Code).

21 E.g., Scandinavian law, which adopts a broader concept of vicarious liability, allowing the shipowner's liability for those independent agents who perform services for the ship. Such vicarious liability would encompass faults of the remote operator acting as an independent contractor, but would not reach as far as to make the shipowner liable for acts of the MASS manufacturer or supplier of the MASS operating system; see: Vibe Ulfbeck and Asli Arda, "Remote Control and Remote Risk of Liability? – Vicarious Liability for Remotely Controlled Vessels in Scandinavian and English Law" in T.M. Johansson, J.E. Fernández, D. Dalaklis, A. Pastra, J.A. Skinner (eds.), *Autonomous Vessels in Maritime Affairs* (2023) pp. 263–275.

22 Kristine Vedal Størkersen, "Safety Management in Remotely Controlled Vessel Operations", 130:104349 *Marine Policy* (2021).

23 Krzysztof Wróbel, "Searching for the Origins of the Myth: 80% Human Error Impact on Maritime Safety", 216:107942 *Reliability Engineering & System Safety* (2021).

Whenever a remote operator supports a MASS, and a collision occurs during such a voyage, the success of claims brought against the shipowner (when a remote controller is the servant of the shipowner) or ROC will heavily depend on the evidence presented by the victims. This will entail evidence that the remote operator was in the position to intervene, i.e., such intervention was allowed by the operating algorithm and was required based on sensor data.

In the case of an autonomous MASS, potential, successful claims with regard to collision damage might be brought against the shipowners as long as evidence brought by a victim supports a negligent act that can be attributed to them. For instance, this can be invoked when the operating system has not been updated to align it with the most recent data available as required or when an earlier noticed malfunction has not been eliminated. Thus, the shipowner breached its duty of maintenance and inspection. Nevertheless, designing collision avoidance algorithms following industry standards of software development and performance, having them certified to be in accordance with COLREG, keeping them up to date and running them on certified hardware lifts the liability from the shipowner or operator.

3.2 *Basis of Liability*

According to CC 1910, liability is attached to the fault of a vessel. This concept has not been further explained by the norms of CC 1910, except Art 5, which clarifies that the pilot's fault remains the fault of the vessel. Therefore, it is the role of case law to determine the concept of fault of the vessel. It is generally understood that such fault exists in cases of breach of the COLREG's principles.[24] Thus, in manned ships, a negligent act leading to collision may occur on board a vessel. It would be an act falling short of an objective standard of what would be expected from good seamanship. Nevertheless, the English case law indicates that unreasonable manoeuvres made in the 'agony of the moment', i.e., under psychological pressure caused by sudden danger by the default or negligence of another vessel, will not be considered as the fault of the vessel, lacking any other negligence on its part.[25]

Fault of the vessel might also be determined when a negligent act relates to equipping the vessel, in the management, or in handling the vessel. As Tsimplis

24 Michael Tsimplis and Richard Shaw, "The Liabilities of the Vessel" in: Y. Baatz Y (ed.), *Maritime Law* (3rd ed., 2014) p. 227.

25 Under English law see: The Bywell Castle 1878–79; The Tian E Zuo [2018] SGHC 93; see also: Aleka Mandaraka-Sheppard A., *Modern Maritime Law. Volume 2: Managing Risks and Liabilities* (3rd ed., 2013) p. 432. The 'Agony of the moment' defence would also be valid in other jurisdictions, see: Jan Łopuski, *Odpowiedzialność za szkodę w żegludze morskiej* (1st ed., 1969) p. 317.

vividly explains, it may originate on land before the collision occurred – for instance, in the shipowning or managing company office, which failed to make the ship seaworthy.

Unless amended, in the wake of a collision between a MASS and a manned ship or two MASSes, the fault-based liability of CC 1910 will apply. Conversely to manned ships, any fault of the autonomous vessel would be triggered by a negligent act caused solely on land, not on board the vessel. As rightly noted by F. Collin,[26] there will be incidents of collisions involving MASS which do not pose a specific problem in terms of finding negligence on the part of a remote controller (e.g., when a remote controller proceeds with excessive speed in a port area) or shipowner (e.g., who did not conduct required maintenance of the MASS operating system). However, with autonomous ships, by shifting the control over the vessel from humans to machines, we open the door wide to incidents where no fault exists, i.e., the collision is purely accidental. Moreover, even when a fault does exist, it is not easy to identify. As has been noted concerning emerging digital technologies in general, the problem with fault-based liability regimes is that, for the time being, there is no well-established model for the proper functioning of maritime autonomy technologies,[27] an equivalent to what good seamanship is for conventional vessels. Also, any potential model will evolve over time owing to machines' capacity to self-learn without direct human control. In these circumstances, requiring the victim to prove the defendant's breach of applicable standards of care might be a deterrent that does not exist in claims arising from collisions between manned ships.

Last but not least, the concept of no fault in the agony of the moment should also be scrutinised concerning MASS. It should not apply to fully autonomous MASS, as none of the potentially liable persons act under pressure of the situation since it is the machine making decisions free from human emotions in the very agony of the moment. Whether an agony-of-the-moment defence should be allowed to navigational decisions of a remote operator located away from the board of a ship remains an open question. Indeed, one can argue that the same level of psychological pressure may arise in situations of extreme peril and difficulty created by negligent manoeuvres, regardless of whether seen from a ship's bridge or on a screen of the monitor in a remote operating

26 Felix Collin, "Unmanned Ships and Fault as the Basis of Shipowner's Lability" in: H. Ringbom, E. Røsæg, T. Solvang (eds.) *Autonomous Ships and the Law* (1st ed., 2021) p. 85.

27 European Commission, Liability for Artificial Intelligence, Report from the Expert Group on Liability and NewTechnologies – New Technologies Formation; available on line, accessed 10 October 2023, https://www.europarl.europa.eu/meetdocs/2014_2019/plmrep/COMMITTEES/JURI/DV/2020/01-09/AI-report_EN.pdf, p. 23.

centre. On the other hand, the influence of remote operators' emotions on their actions remains under-investigated. It is debatable whether the stress of circumstances forced upon the remote operator by the defendant's servants (or, e.g., the remote operator of another MASS) might be similar to the pressure felt on board the vessel by a crewmember. Thus, the 'agony of the moment' remedy should not be available to the remote operator located in the ROC on land rather than on a ship.

3.3 *Burden of Proof*

According to CC 1910, especially its Art 6, the burden of proving fault lies upon the parties alleging it. It has already been noted that even in the case of conventional, i.e., manned ships, this burden may be challenging for the victims. Automated but manned ships, which rely heavily on complex technological equipment, make the requirement of proving fault understood as the fault of those responsible for the ship's operations or technical maintenance challenging for the victims. Even more so, in the case of a MASS, this requirement may lead to socially unfair and unacceptable outcomes, putting potentially liable persons in a better position than those against whom claims are brought for a similar collision but involving only manned ships.

Inability to prove fault, or the consequence of an unrecognised cause of the collision, is that in these circumstances, damages are borne by the victims. This is because the fault liability pins the costs of the non-negligent accidents on the victims of the activity.[28]

CC 1910 does not allow any presumption which would help the victims meet the fault-based system threshold. According to its straightforward Art 6, all legal presumptions of fault regarding liability for collision are abolished. Notably, this is a material rule only and does not interfere with national procedural rules, which relate to the standard of proof. Therefore, the national or case law determines the level to which the claimant has to prove his case, and this standard varies significantly from state to state. Moreover, national law will determine procedural devices allowing the logical deduction of negligence from circumstances shown, like the doctrine of res ipsa loquitor. Thus, the actual extent of the burden of proof will depend on the jurisdiction in which claims are sought.

28 Gregory C. Keating, "The Theory of Enterprise Liability and Common Law Strict Liability", 54(3) *Vanderbilt Law Review* (2001) p. 1286.

4 Discussion

From the intersection of technical and legal viewpoints, previously raised issues concerning collisions at sea involving MASS, constitute a mere tip of the iceberg. The frequently raised and investigated ambiguity of Rules and their comprehensibility by non-human agents remains an issue, particularly for developing collision avoidance algorithms. Furthermore, in case of collision occurring, crewmembers can easily invoke that they simply followed a (vague) guideline prescribed in COLREG, a step that a MASS was not only incapable of executing but also comprehending, and that they cannot be held liable for the fact that MASS was unable to understand their intentions. This ambiguity of the Rules and differences in understanding them by different ships (manned and autonomous) may lead to an accident. It would thus be analyzed with respect to safety improvement recommendations and liability considerations. In the present analysis, three issues are significant for the latter: the basis of liability, the burden of proof, and the explainability of technology.

4.1 *Basis of Liability*

Maintaining fault as the basis of liability for collisions involving MASS will inevitably lead to situations when the shipowner's liability cannot be determined. For instance, once it is established that the shipowner used an approved and accepted MASS decision-making system, the malfunction of which nevertheless caused an accident, the shipowner's negligence might only be found if the shipowner did not take due care with regard to the maintenance of the said system. Otherwise, it is hard to see how the shipowner could be negligent in such a scenario. Similarly, when a remote operator loses connection with a MASS and a collision is caused due to a defect in the transfer of control to the operating system, there might be no negligence in the conduct of the remote operator.

At the same time, one may convincingly claim that the location of a crewmember making decisions on actions to avoid collisions appears relatively insignificant in comparison to the type of the agent doing so: human or a machine, or, to be more precise, the degree to which a ship is autonomous and can make decisions on her own.[29] In other words, the type of decision-making agent may matter due to their specific traits, but not their location. The latter

29 Barış Soyer, "Autonomous Vessels and Third-Party Liabilities: The Elephant in the Room", in B. Soyer, A. Tettenborn (eds), *New Technologies, Artificial Intelligence and Shipping Law in the 21st Century* (2019) p. 111.

can matter in specific incidents related to the remote operation, such as outage of communication links or cyber-security issues.

Such an approach entails a conclusion that new liability rules should be considered for fully autonomous MASS, but in the case of those that are remotely controlled, fault-based liability maintains its adequacy. In the end, fault – a concept designed for human errors, not machines – will be suitable for negligent acts of remote operators. However, such a solution raises a few concerns. First, even with MASS operated from the ROC, there is a high level of reliance on data produced by sensors and a requirement for constant and effective remote connection with the vessel. Such heavy reliance allows for new technological malfunctions that cannot be remediated by the crew onboard a ship. As noted earlier, proving any human error in those accidents may be impossible or at least challenging.[30] Even if tracks of errors lead to manufacturers of remote operating systems, generally, vicarious liability of the shipowner does not extend to their faults. Moreover, even in the case of errors committed by remote operators, the vicarious liability of the shipowner for collisions caused by the fault of an independent remote operator seems unlikely in many jurisdictions. As noted earlier, national laws often exclude the shipowner's vicarious liability for the independent contractor's wrongdoings if the latter was chosen with due care.

Consequently, maintaining the current legal framework for collision liability may result in MASS shipowners being in a better legal position than the shipowners of conventional, i.e., manned ships, who are vicariously liable for faults of the crew.

Eliminating shipowners from the ambit of potentially liable parties or reducing their vulnerability to claims will hinder the victims' prospect of compensation. As noted earlier, victims may direct their claims against ROCs acting as independent contractors. Whether such claims are successful depends on the financial standing of an ROC. In the case of an uninsured ROC, with poor financial standing to cover often substantial collision claims, the likelihood of obtaining compensation will be vague.

Malfunction of the operating system or its components leading to a collision of the vessel might be attributed to the system's or component's manufacturer or provider.[31] First and foremost, a MASS performance will likely result from

30 See also: Massimiliano Musi, "The phenomenon of «MASS»: is it time to rethink the current maritime liability regime?", 2 *Rivista del Diritto Della Navigazione* (2021), p. 779.

31 Alice Kennard, Zhang Pengfei, Sriram Rajagopal, "Technology and Training: How Will Deck Officers Transition to Operating Autonomous and Remote-Controlled Vessels?", 146:105326 *Marine Policy* (2022).

input from a bundle of different providers or manufacturers. This is similar to contemporary ships with one critical distinction: a multitude of hardware and software outputs is fused in the onboard crewmember's mind to produce decisions on how to proceed. A crewmember who, as an employee of the shipowner, is a personification of the latter's liability. Changing that characteristic will make identifying against whom victims should direct their compensation claims especially difficult. This complex MASS characteristic will make it challenging to apportion fault between multiple negligent parties.

Liability of the autonomous service provider or manufacturer might be established on the grounds of national tort laws, which usually establish fault-based liability regimes. Thus, victims will have to prove a causative link between the fault of the provider or manufacturer and their loss. Additionally, in many jurisdictions, product liability laws exist that target manufacturers of defective products, introducing their strict liability.[32] The lack of a requirement to prove the fault of a producer makes product liability laws an especially attractive basis for claims from the victims. However, the adequacy of the EU product liability norms to compensation of damages caused by MASS is questionable owing to the limited scope of compensable damage, which, concerning property damage, excludes damage to property used exclusively for professional purposes.[33] Thus, damages to a ship's hull or harbour infrastructure would not be covered based on these norms.

4.2 *Burden of Proof*

The harshness of the requirement to prove fault is not lifted by a concept known in many jurisdictions as anonymous fault, which some courts could adopt under the CC 1910. It is a type of fault that does not require pointing to a particular tortfeasor if the character of damage and surrounding circumstances undoubtedly demonstrate the negligence of 'a person' for whose acts the defendant is liable. This concept of fault is adopted in many areas of civil liability where the burden of proving fault raises considerable problems, especially in cases of personal injury (e.g., medical malpractice). However, it is still based on the premise that 'somebody' was negligent. Meanwhile, in the operation of MASS, involving complex operating systems with self-learning ability,

32 See more: Jill G. Okun, Ryan J. Rawlings, "Mitigating Potential Liability Posed by Autonomous Vehicle Crash Optimization Systems", 11 *For the Defense* (2018) pp. 64–65.

33 See Art 6 of Directive (EU) 2024/2853 of 18 November 2024 on liability for defective products and repealing Council Directive 85/374/EEC; also: Vibe Ulfbeck, "Autonomous Ships and Product Liability under the EU Directive", in H. Ringbom, E. Røsæg, T. Solvang (eds.), *Autonomous Ships and the Law* (1st ed., 2021) pp. 144–154.

the probability of purely accidental collision caused by technical malfunction for which nobody is at fault rises significantly.[34]

Requiring the victims to prove fault may also have a hindering effect in terms of costs and length of litigation. The cost of pursuing claims involving highly specialized expert witnesses may turn out to be an insuperable obstacle when faced with AI's opacity. When proving their case, the victims will be confronted with the difficulty in determining how or why the algorithm made a decision. As long as there is no sufficient level of explainability of the machine-made choices relating to, e.g., speed or manoeuvres made by a fully-autonomous MASS, the availability of highly specialised technical expertise and, therefore, their cost will hinder victims' prospects of compensation.

Pointing at one particular person or agent to prove their fault may be particularly challenging due to several factors:

– inaccessibility of data produced by MASS regarding her actions due to their storage in a convenient (i.e., difficult to legally obtain) location, physical destruction, or tampering with information stored beyond the reach of interested parties (coastal state, flag state, victims, etc.). This can be relevant, especially if the data MASS collects makes her liable. MASS'es reliance on sensors-delivered data and algorithm processing may affect the scope of liability proceedings by delivering indisputable data on the chain of events, at least from a MASS perspective. On the other hand, this imbalance may foster the installation of complex data storage systems, even onboard manned ships, beyond the current functionalities of VDR. These, however, will only be able to collect data from pre-installed sensors, but the traits, actions, and assumptions made by humans would still be problematic in terms of their storage;
– inability to interrogate the crew of a crewless ship concerning the circumstances of the accident and their role in it – either because the ship sailed in a fully-autonomous mode or because she was controlled remotely from a ROC located under jurisdiction different from that of the accident location or the ship's flag. Even though humans involved in the collision may be tempted to bend the facts (for instance, to protect themselves from criminal liability), they have one significant advantage over soulless algorithms: they can easily explain themselves.

The last of the traits above of humans, their explainability, may pose a challenge in deciding on the liability for a collision involving ships operating, to a certain degree, without human intervention.

34 Trond Solvang, "Man, Machine, and Culpa. Or Finding Path toward Strict Liability", in H. Ringbom, E. Røsæg, T. Solvang (eds.), *Autonomous Ships and the Law* (1st ed., 2021) p. 104.

4.3 *Explainability*

The complexity of logic programming or the stochastic nature of artificial intelligence involved in fusing environmental data and producing collision avoidance action out of them can be difficult to grasp by individuals unfamiliar with the peculiarities of these constructs. Potential victims of accidents, legal representatives, judges, and even maritime experts can be affected. Questioning a crewmember on the circumstances of a collision may be considered more humane and convincing, an option that would be absent for crewless ships. Herein, the amount of data collected by MASS and rules of inference related to it can be beyond the comprehension of those accustomed to simply referring to seamanship as a legitimate explanation of actions taken. Inevitably, expert witnesses' statements will be involved. However, the availability and, thus, costs of such expert testimonies might be a considerable obstacle faced during civil proceedings. In small or medium claims, plaintiffs might be cost-barred from pursuing their cases in court.[35] Moreover, it is under the assumption that such data and algorithms for processing them will be made available in the first place. Ways of processing vast amounts of internal and external data gathered by MASS will likely be the most valuable asset of their manufacturers – a secret they would prefer not to reveal to external parties.[36]

The European Commission has also noted the plaintiffs' difficulty obtaining access to evidence. In its proposal for a Directive on adapting non-contractual civil liability rules to artificial intelligence (AI Liability Directive), the European Commission planned to introduce common rules on evidence disclosure obligation.[37] According to the proposal, when grounds for a claim are plausible, and a plaintiff manages to prove that it has undertaken appropriate steps to obtain the evidence but failed, a national court will order the disclosure and, upon request, the preservation of evidence. This measure was proposed for so-called high-risk AI systems, as defined by the Artificial Intelligence Act,[38]

35 Greg Swanson, "Non-Autonomous Artificial Intelligence Programs and Products Liability: How New AI Products Challenge Existing Liability Models and Pose New Financial Burdens", 42(3) *Seattle University Law Review* (2019) p. 1220.

36 Jenna Burrell, "How the machine 'thinks': Understanding Opacity in Machine Learning Algorithms", 3(1) *Big Data & Society* (2016).

37 Proposal for a directive of the European Parliament and of the Council on adapting non-contractual civil liability rules to Artificial Intelligence (AI Liability Directive), 28.9.2022. COM(2022) 496 final.

38 Regulation (EU) 2024/1689 of the European Parliament and of the Council laying down harmonised rules on Artificial Intelligence amending Regulations (EC) No 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1139 and (EU) 2019/2144 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 (Artificial Intelligence Act), OJ L, 2024/1689, 12.7.2024.

which include systems covered by the Directive on marine equipment,[39] and thus is relevant for MASS. The proposal for a Directive has, however, been withdrawn recently by the European Commission from its 2025 work programme.[40] At the time of submission of this paper, its future is unclear.

Considering a potentially limited number of individuals or organisations capable of comprehending data and actions taken by MASS to the very core on one hand and a potential multitude of MASS software and hardware manufacturers on the other, some standardisation of data formats and analytic tools may be required to allow a legal proceeding to be conducted. As any MASS would likely have to undergo a verification[41] by a classification society, these would first need to analyse it thoroughly. Having learnt and certified it, they might be nominated as being responsible for analysing accident data for legal proceedings. However, their business model would still include acting in the best interest of ship operators as their clients and not necessarily for the benefit of the general public or victims of alleged negligence by the ship operator or its business partners. On the other hand, being recognised by flag states as organisations, they may be obliged to serve the general public, yet not necessarily individual plaintiffs. This creates a vacuum for organisations specialised in legal analysis of maritime autonomy data, possibly for profit, but does not address such hypothetical consultants' accessibility to specialised software or other tools for data analysis.

Whether the maritime industry should follow the suit of aviation and support using a (semi-) standardised data format for safety-related analysis (such as Flight Recorder Electronic Documentation, FRED, and related data frames) remains an open question. If so, that could help establish a network of independent analysts who could potentially assist in legal proceedings. Even if that were the case, another open question is the industry's ability to standardise and fully comprehend inputs, outputs, and perhaps hidden layers

39 Directive 2014/90/EU of the European Parliament and of the Council of 23 July 2014 on marine equipment and repealing Council Directive 96/98/EC, OJ L 257, 28.8.2014, p. 146.

40 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Commission work programme 2025, COM(2025) 45 final, p. 26. The reason for withdrawal as stated by the European Commission: "No forseeable agreement – the Commission will asess whether another proposal should be tabled or another type of approach should be chosen."

41 Tom Arne Pedersen, Chanjei Vasanthan, Kristian Karolius, Øystein Engelhardtsen, Koen Pieter Houweling and Are Jørgensen, "Generating Structured Set of Encounters for Verifying Automated Collision and Grounding Avoidance Systems", 2618:012013 *Journal of Physics* (2023).

of artificial neural networks likely to be employed to resolve collision avoidance problems.[42]

5 Policy Outcomes

With the advent of MASS operations, multiple legal acts require adaptation to new challenges posed by specific features of crewless ships. The above discussions indicate that the revision should also concern the regulation of liability for ship collisions. Maintaining a fault-based liability system with the burden of proving fault on the plaintiffs may leave them without compensation in accidents caused by MASS malfunction or aberration. The possibility of a technical malfunction of the highly sophisticated autonomous systems operating MASS creates a potential for accidents without the shipowner's fault. In such a situation, those who suffered damage might seek compensation from the manufacturers or autonomous system providers.

Nevertheless, the complexity of MASS, which will likely involve input from multiple manufacturers or providers, coupled with the problems of proving fault and challenges posed by AI explainability, might prevent victims from pointing to a party at fault and gaining compensation. Moreover, in the case of remote operators of MASS acting as independent contractors, some current national laws will free the shipowners from vicarious liability. That puts the shipowner in a much better position than conventional ships, as the shipowner is vicariously liable for acts of the crewmembers on board a ship. The shipowner is also normally liable under national laws for the pilot's negligence. The latter's role is to have the conduct of navigation, while command of the ship remains with the master. According to some national laws, the pilot informs and advises the shipowner. This shows some similarity to the functions of the remote operator in ROC. It is, therefore, even more justified to provide similar vicarious liability of the shipowner for the faults of the remote operator.

Thus, the current legal regime for civil liability in shipping needs revision to accommodate MASS. Several solutions have already been proposed in the literature[43] in this respect. Problems linked to the heavy burden of proving

42 Zbigniew Pietrzykowski, Piotr Wołejsza, Łukasz Nozdrzykowski, Piotr Borkowski, Paweł Banaś, Janusz Magaj, Jarosław Chomski, et al, "The Autonomous Navigation System of a Sea-Going Vessel", 261:112104 *Ocean Engineering* (2022).

43 Erik Røsæg, "Diabolus Ex Machina: When an Autonomous Ship Does the Unexpected", in H. Ringbom, E. Røsæg, T. Solvang (eds.), *Autonomous Ships and the Law* (1st ed., 2021) pp. 125–143.

fault could be solved by a liability system where the fault of a shipowner is presumed by shifting the burden towards the potentially liable persons. Such a solution offers the advantage of enabling the people in control of the MASS to overcome the challenges posed by machines' opacity. It is more likely that they will have better means and capacities to prove a lack of negligence on their part than the parties suffering damage or outsiders would have to prove fault. However, in cases where there is, in fact, no negligence of the shipowner or remote controller, neither programmer nor manufacturer, again, the fault-based liability leaves the victims to bear the negative consequences of the accident.

The other, further-going solution is to abandon fault as the basis of liability and to adopt instead strict liability of the shipowner for damages arising from collisions of MASS. Such liability would be imposed on a shipowner, regardless of lack of negligence, unless the shipowner proves the provided ground of exoneration. Therefore, identifying the shipowner as the person strictly liable would rectify the inadequacies of the negligence as the basis of liability, which are not omitted by the reversed burden of proof.[44] At the same time, eliminating the element of fault from the shipowner's liability would introduce a much stricter regime for the MASS shipowner than in comparison with conventional ships.

As long as we believe that MASS creates greater danger than in comparison with conventional ships, the no-fault liability of the MASS shipowner, including liability for damage caused to other ships, might be justified by the fact that its activity imposes non-reciprocal risks. One of the strategies to fairly distribute the burdens in a legal system is to impose the liability on the defendant, who generates a disproportionate, excessive risk of harm compared to the victim's risk-creating activity.[45] There are other valid justifications for strict liability for damages caused by MASS to third parties.[46] Among them is the idea that fairness requires the party which benefits from the activity causing harm to carry its risks (*cuiuscommodum eius periculum*). Also, one should consider the risk-spreading argument, according to which accident costs ought to be allocated to ensure liable persons can bear them. The availability of affordable insurance for the shipowners who are given virtually unbreakable right to limit their liability[47] indicates that such liability might be channelled towards

44 Ibid, p. 139.

45 Geroge P. Fletcher, "Fairness and Utility in Tort Theory", 85(3) *Harvard Law Review* (1972) pp. 537–573.

46 Erik Røsæg (supra n 40), p. 139.

47 Norman A. Martínez Gutiérrez, "New Global Limits of Liability for Maritime Claim", 15(3) *International Community Law Review* (2013) pp. 341–357.

them.[48] The strictly liable shipowner will retain the right to seek recourse on the basis of recourse claims from others contributing to the created risk, like the manufacturer or remote operator.

6 Conclusions

The close arrival of Maritime Autonomous Surface Ships (MASS) compels evaluation of the adequacy of today's regulation to crewless ships. Although, for the time being, it mainly concerns small vessels and prototypes to test previously designed technical solutions, a change in maritime law regarding MASS is imminent. One of the legal aspects that need to be regulated in the operation of autonomous vessels is their activity in ensuring safe navigation and, in particular, avoiding collisions with other vessels and obstacles. Among the numerous more and less critical issues, one of the overriding ones in pursuing future claims is the issue of MASS' liability, its basis and to whom it should be applied.

Such evaluation should be performed from the perspective of the regulation's applicability to MASS and the policy's point of view. There are multiple and often conflicting interests which should be considered. Among them are the interests of aggrieved parties, shipowners, manufacturers or providers of autonomous systems, and the newly created industry of remote operators.[49] Demanding proof of fault for machine-made errors from the aggrieved parties coupled with challenges arising from the explainability of the artificial intelligence systems and the availability of evidence data is a threshold that may make the liability system illusory. At the same time, reversing the burden of proof to the shipowners will not remediate all of the inadequacies of the fault-based liability system. The alternative is to introduce strict liability for the MASS shipowner who retains recourse claims against the remote operator, algorithm provider or manufacturer of the MASS. Although strict liability is known for some regions of liability in maritime law under several of the IMO liability conventions (e.g., oil pollution or bunker liability, or passenger liability for shipping incidents), its introduction for collisions would constitute a significant change for shipowners traditionally liable for faults of the vessel. There are, however, justified grounds for such a shift, including remotely controlled MASS.[50]

48 Barış Soyer (supra n 29), p. 112.

49 Anastasia Tsvetkova, Magnus Hellström, Henrik Ringbom, "Creating Value through Product-Service-Software Systems in Institutionalized Ecosystems – The Case of Autonomous Ships", 99 *Industrial Marketing Management* (2021) pp. 16–27.

50 Massimiliano Musi (supra n 30), p. 779.

The human element involved in the latter case suggests that a fault-based system might still be suitable. It should be noted, however, that remotely-controlled vessels also pose threats of remote operating systems' errors, which lead to similar evidentiary problems as in the case of fully-autonomous MASS. In hybrid-like systems, when the algorithm assumes the conduct of the vessel from the remote operator, a mixed liability system, which requires a shift from fault to strict basis, may again lead to evidentiary problems. The ability to change the MASS degree of autonomy seamlessly and bi-directionally will complicate matters since, during a single voyage, an autonomous ship can be considered in several different ways. At the same time, the transition process should be handled appropriately, including in terms of legal aspects.

The above considerations of liability of autonomous ships were investigated concerning only two of the legal acts used nowadays in the daily routine of the maritime industry, namely COLREG and CC 1910. The complexity of issues raised reaffirms the concerns of maritime industry preparedness for MASS being of a more legal nature than a technological one, with more nuances to surface upon a closer look at further legal instruments.

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