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## SOMMARIO

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LA CONVENZIONE DI LONDRA DEL 1989 SUL SALVATAGGIO: L'ESPERIENZA ITALIANA A 30 ANNI DALLA RATIFICA



## NOTIZIARIO

# LIABILITY IN THE AGE OF AUTONOMOUS VESSELS: CHALLENGES AND OPPORTUNITIES IN INTERNATIONAL, EU AND NATIONAL MARITIME LAW

SEBASTIANO GIANINO

ABSTRACT

The advent of Maritime Autonomous Surface Ships (MASS) presents both transformative opportunities and profound legal challenges for the global maritime sector. As autonomous technologies evolve rapidly, existing legal frameworks, rooted in assumptions of human operation, struggle to accommodate these innovations. This research critically examines the interplay between international maritime law, European Union regulations, and the national legal systems of Italy and Denmark in the context of MASS. The analysis begins with a comprehensive review of key international conventions, including SOLAS, COLREGs, UNCLOS, and the LLMC, assessing their applicability to autonomous vessels. The study also evaluates the International Maritime Organization's interim guidelines and the outcomes of its Regulatory Scoping Exercise, identifying significant legal gaps and areas requiring reform. At the regional level, the research investigates the EU's efforts to harmonize maritime safety and operational standards, emphasizing the role of the EU AI Act and legislative instruments such as the EU's Product Liability Directive. It highlights the integration challenges between EU and international standards, particularly regarding liability mechanisms. A comparative analysis of Italy and Denmark illustrates contrasting national approaches: Denmark's proactive and adaptive regulatory strategy versus Italy's more traditional and evolving legal framework. These case studies provide valuable insights into best practices and legislative shortcomings in addressing autonomous shipping. This study ultimately underscores the urgent need for coherent, multi-level legal reform and sustained international cooperation to ensure that the legal infrastructure evolves concurrently with technological advancement in the maritime sector.

## I. INTRODUCTION

Driven by the pursuit of enhanced efficiency and operational safety, the maritime industry has historically served as a platform for the implementation of innovative and advanced technologies, resulting in the progressive development of automation across both shipboard and shore-based operations[1]. With over 80% of global trade relying on maritime transport, the shipping industry is on the verge of major changes driven by the integration of sensors and digital technologies[2]. These advancements are reshaping maritime practices, particularly through the emergence of maritime autonomous surface ships (MASS)[3]. According to a study conducted by the World Maritime University (WMU) in 2019, human-supervised autonomous vessels are projected to account for approximately 11 to 17 percent of global shipping by the year 2040[4].

In 2017, the International Maritime Organization (IMO) initiated a 'regulatory scoping exercise' to examine the regulatory challenges arising from the introduction of MASS[5]. The objective of the scoping exercise is to assess the extent to which existing IMO instruments can address the safety, security, and environmental implications of MASS operations. In May 2018, the first substantive discussions on the topic were held. During these discussions, a working group was assigned the task of developing a framework for the regulatory scoping exercise. This framework was to include the identification of aims and objectives, methodology, instruments, types and sizes of ships, provisional definitions, as well as the various types and concepts of autonomy, automation, operations, and manning that would be considered[6].

Numerous projects and initiatives are currently being implemented to advance and evaluate the capabilities of autonomous maritime vessels. Among these, the Yara Birkeland in Norway stands out as one of the world's first fully electric and crewless autonomous container ships. Additionally, the Mayflower Autonomous Ship represents a significant development in the field, utilizing artificial intelligence to carry out transatlantic research missions[7]. The introduction of autonomous ships

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[1] E. Jokioinen, *Remote and Autonomous Ships – The next steps, in AAWA Redefining Shipping*, 2018, pag. 4.

[2] D. Tejwani, *Navigating the Future: How AI, Big Data, and Autonomous Systems Are Reshaping Maritime Transport, in eTrade for All*, 2024.

[3] X. Lie, K.F. Yuen, *A human-centred review on maritime autonomous surfaces ships: impacts, responses, and future directions*, in *Transport Reviews*, 2024, vol. 44, N°. 4, pag. 791.

[4] J.U. Schröder-Hinrichs, D.W. Song *et al.*, *Transport 2040: automation, technology, employment – the future of work*, World Maritime University, Malmö, 2019, pag. 17.

[5] The IMO – the I*nternational Maritime Organization* – is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships. IMO's work supports the UN sustainable development goals.

[6] M. Menicucci, *Le unmanned ships: profili applicativi e problemi normativi*, Bari, 2023; see also H. Ringbom, *Regulating Autonomous Ships – Concepts, Challenges and Precedents*, in *Ocean Development and International Law*, 2019, pag. 142.

[7] MARINELINK, *Autonomous ships: charting the course for the future of maritime navigation*, in *MarineLink*, 2025.

is likely to result in a decrease in crew sizes, potentially leading to the emergence of fully unmanned vessels. Numerous advantages are associated with operating vessels with fewer crew members. Furthermore, it is anticipated that a manpower shortage will arise in the foreseeable future, with forecasts suggesting that by 2025, an additional 147,500 officers will be required[8]. In addition, another widely recognized advantage is the potential for autonomous ships to improve maritime safety. It is well-established that human error plays a significant role in a large proportion of maritime accidents[9]. According to EMSA data, human error is the primary contributing factor in 65% of recorded maritime accidents[10].

By compensating for human limitations such as fatigue, short attention spans, information overload, and normality bias, automation has the potential to create a safer environment[11]. According to a report by the United States Coast Guard (USCG), marine casualties associated with MASS and Shore Control Centers (SCC) were attributed to human error in approximately 75% to 96% of cases. These errors were primarily linked to factors such as fatigue, deficiencies in maintenance and regulatory standards, insufficient knowledge and information, and ineffective communication[12]. In contrast, a quantitative safety assessment conducted under the MUNIN project suggested that unmanned bulk carriers may offer enhanced safety compared to conventional vessels, although the study acknowledged limitations due to the lack of comprehensive data regarding the design and operational characteristics of such autonomous ships[13].

Nevertheless, traditionally, the attribution of responsibility for misconduct has been reserved for human agents or legally recognized entities, such as shipping companies. In contrast, holding algorithms accountable poses a substantial challenge, given that they are not recognized as moral or legal agents[14]. As well as liability issues, the transition to autonomous vessels introduces significant uncertainty into existing maritime insurance frameworks, which have historically

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[8] J. De Vos, R.G. Hekkenberg, *The Impact of Autonomous Ships on Safety at Sea – A Statistical Analysis*, in *Reliability Engineering and System Safety*, 2021, pag. 210.

[9] K. Wróbel, J. Montewka *et al.*, *Towards the assessment of potential impact of unmanned vessels on maritime transportation safety*, in *Reliability Engineering & System Safety*, Vol. 165, 2017, pag. 165.

[10] EMSA, *Annual Overview of Marine Casualties and Incidents 2019*, in *European Maritime Safety Agency,* 2019, pag. 28.

[11] T. Porathe, Å. Hoem *et al.*, *At Least as Safe as Manned Shipping? Autonomous shipping, Safety and "Human Error"*, in *Safety and Reliability – Safe Societies in a Changing World – Haugen et al. (Eds*), 2018, pag. 422.

[12] A.M. Rothblum, D. Wheal *et al.*, *Human Factors in Incident Investigation and Analysis*, in *Proceedings of the 2nd International Workshop on Human Factors in Offshore Operations*, 2002, pag. 7.

[13] Ø.J. Rødseth, H.C. Burmeister, *Risk Assessment for an Unmanned Merchant Ship*, in International *Journal on Marine Navigation and Safety of Sea Transportation*, 2015, pag. 361.

[14] K. Mingyu, B. Jeong *et al.*, *Autonomous Shipping and its impact on regulations, technologies, and industry,* in *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, 2020, Vol. 4, No. 2, pag. 23.

been predicated on human agency and liability. As noted, responsibility for maritime accidents has overwhelmingly been attributed to human error, ranging from fatigue and communication failures to inadequate training. Insurance policies are therefore structured around the actions and omissions of identifiable human agents or legally accountable entities, such as shipowners or operators[15].

However, the deployment of MASS disrupts this paradigm by introducing non-human decision-making systems and control software that do not fit neatly into current legal definitions of responsibility[16]. This raises critical questions for insurers: Who is liable in the event of a collision or environmental incident involving an autonomous vessel? Is it the vessel's manufacturer, the software developer, the operator of the shore control centre, or another party?[17]

Furthermore, the absence of comprehensive data on the operational behaviour and reliability of autonomous vessels, as highlighted in the MUNIN study, limits actuarial assessments and complicates the underwriting process[18]. Until regulatory and legal frameworks evolve to clearly define liability in autonomous operations, insurers may adopt conservative approaches, such as increased premiums, limited coverage, or refusal to insure fully autonomous ships[19].

## II. METHODOLOGY

This paper adopts a doctrinal legal research methodology, supplemented by a comparative legal analysis, to examine the interaction between international maritime law, European Union law, and selected national legal frameworks in the regulation of autonomous ships[20]. The objective is to critically evaluate how current legal instruments address, or fail to address, the legal complexities introduced by MASS, particularly with respect to liability.

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[15] M. Jones, *Autonomous Ships and Liability Issues: Maritime Law Will Need to Navigate Uncharted Waters*, in *Vassallo Associates*, 2024.

[16] E. Marchisio, *In support of "nofault" civil liability rules for artificial intelligence*, in *SN Soc Sci*, 2021, Vol. 1, Issue 2, Art. No. 54.

[17] M. Jones, *op. cit.*

[18] HC Burmeister, W. Bruhn *et al.*, *Autonomous Unmanned Merchant Vessel and its Contribution towards the e-Navigation Implementation: The MUNIN Perspective*, in *International Journal of e-Navigation and Maritime Economy*, 2014, pag. 4.

[19] CORE ADVOKATFIRMA, CEFOR, *Maritime Autonomous Surface Ships – Zooming in on civil liability and insurance,* 10 December 2018, pag. 17.

[20] Comparative legal analysis – the action of identifying and comparing the findings resulting from the analysis of different legal systems, traditions, national, regional, or international laws, organizations, etc. – is the methodology at the heart of Comparative Law. See I. Calboli, *Comparative Legal Analysis and Intellectual Property Law: A Guide for Research*, in *Handbook of Intellectual Property Research: Lenses, Methods and Perspectives*, 2021, pag. 48; instead, Doctrinal legal research (DLR) is the most frequently applied, and professionally a more popular, method of legal research. Doctrinal research, at its best, involves rigorous analysis and creative synthesis, the making of connections between seemingly disparate doctrinal strands, and the challenge of extracting general principles from an inchoate mass of primary materials. See P. Ishwara Bhat, *Doctrinal Legal Research as a Means of Synthesizing Facts, Thoughts, and Legal Principles*, in *Idea and Methods of Legal Research*, 2020, pag. 143 and pag. 145.

The doctrinal component is centred on a close textual and normative analysis of key international conventions, including the International Convention for the Safety of Life at Sea (SOLAS), the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), the United Nations Convention on the Law of the Sea (UNCLOS), and the Convention on Limitation of Liability for Maritime Claims (LLMC)[21]. These instruments are analysed to determine their applicability to autonomous maritime operations, with specific attention to issues such as the legal definition of "ship", the role and responsibilities of the "master," and the presence or absence of a crew. The study also engages with the ongoing work of the International Maritime Organization (IMO), particularly the development of the MASS regulatory scoping exercise, to assess the direction of potential international reforms.

In parallel, the paper conducts a comparative legal analysis between the European Union, Italy, and Denmark. The EU dimension focuses on relevant maritime safety regulations and directives and evaluates their interaction with the abovementioned international conventions. The analysis considers how the EU positions itself as both a regional regulatory actor and a participant in global maritime governance through alignment with IMO initiatives.

At the national level, the research investigates how Italian and Danish legal systems engage with both international and EU law in the context of autonomous vessels. Italy's legal treatment is examined primarily through its *"Codice della Navigazione"*, while Denmark's legislative and regulatory approach is examined considering its leadership in autonomous maritime technology and its active

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[21] The United Nations Convention on the Law of the Sea lays down a comprehensive regime of law and order in the world's oceans and seas establishing rules governing all uses of the oceans and their resources. It enshrines the notion that all problems of ocean space are closely interrelated and need to be addressed as a whole. The Convention was opened for signature on 10 December 1982 in Montego Bay, Jamaica and entered into force in accordance with its article 308 on 16 November 1994.

The International Convention for the Safety of Life at Sea in its successive forms is generally regarded as the most important of all international treaties concerning the safety of merchant ships. The first version was adopted in 1914, in response to the Titanic disaster, the second in 1929, the third in 1948, and the fourth in 1960. The 1974 version includes the tacit acceptance procedure - which provides that an amendment shall enter into force on a specified date unless, before that date, objections to the amendment are received from an agreed number of Parties. The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety.

The 1972 Convention on the International Regulations for Preventing Collisions at Sea was designed to update and replace the Collision Regulations of 1960 which were adopted at the same time as the 1960 SOLAS Convention. One of the most important innovations in the 1972 COLREGs was the recognition given to traffic separation schemes - Rule 10 gives guidance in determining safe speed, the risk of collision and the conduct of vessels operating in or near traffic separation schemes.

The 1976 Convention on Limitation of Liability for Maritime Claims raised considerably the limit of liability for claims covered, in some cases up to 250-300 per cent. Limits are specified for two types of claims - claims for loss of life or personal injury, and property claims (such as damage to other ships, property or harbour works).

engagement in shaping international norms. These national frameworks are compared to assess their coherence with supranational obligations and their potential as models for broader legal harmonization.

The analysis of Denmark's legal framework offers insights into how a country with an advanced technological infrastructure and a proactive stance on maritime innovation can influence international legal reform[22]. In contrast, Italy's approach highlights the challenges faced by a country with a long-standing maritime tradition, which must reconcile technological advancements with its commitments to international maritime law and EU regulations[23].

No empirical data is collected in this study; the analysis is strictly normative and interpretative. Primary sources include international treaties, EU legal instruments, and national legislation, while secondary sources consist of academic commentary, legal scholarship, and official policy documents. The research aims to identify existing legal gaps, challenges to harmonization, and opportunities for coordinated reform, culminating in targeted policy recommendations at the international, regional, and national levels.

## III. THE DRIFT OF LIABILITY: REGULATING AUTONOMOUS MARITIME VESSELS UNDER INTERNATIONAL LAW

Given that existing technical maritime regulations encompassing navigational safety, environmental safeguards, and standards for training and watchkeeping, were originally conceived with human operators as central to their execution, it is imperative to critically reassess these frameworks in light of the operational paradigms introduced by autonomous vessels[24]. A comprehensive examination of the legal liabilities associated with autonomous maritime vessels necessitates an initial clarification of the term "autonomy" within this context. In May 2018, during its 99th session, the IMO's Maritime Safety Committee, through the work of its Correspondence Group, adopted an official definition of MASS, describing them as ships capable of operating with different levels of autonomy and with reduced or no direct human involvement[25].

Concurrently, the IMO has undertaken a regulatory scoping exercise to assess the implications of MASS on existing international maritime conventions[26]. This initiative has led to the development of a draft, goal-based instrument aimed at

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[22] *Maritime and Tech*, in *Ministry of Foreign Affairs of Denmark – Invest in Denmark*, 2022, pag. 3.

[23] P. Ribuffo, *(Re)discovering the Italian maritime vocation*, in *Italian Institute for International Political Studies*, 2024.

[24] I. Durlik, T. Miller *et al.*, *Enhancing Safety in Autonomous Maritime Transportation Systems with Real-Time AI Agents*, in *Applied Sciences*, 2025, pag. 2.

[25] R. Veal, *Maritime autonomous surface ships: Autonomy, manning and the IMO,* in *Shipping & Trade Law,* 2018, pag. 1-4.

[26] International Maritime Organization, *Autonomous ships: regulatory scoping exercise completed*, 25 May 2021.

regulating the operation of MASS, with the Maritime Safety Committee (MSC) actively working on this framework[27]. Once finalised its Regulatory Scoping Exercise, the IMO is now engaged in discussions on the elaboration of a dedicated MASS Code, with prospective adoption scheduled for 2026 and entry into force anticipated in 2028. In a parallel development, the Republic of Korea enacted the Autonomous Ships Act in December 2023, with the dual objective of promoting technological innovation and advancing the development of core systems for autonomous vessels, while simultaneously establishing a regulatory framework to guarantee their safe operation and to enhance the efficiency of maritime logistics[28].

As part of this Regulatory Scoping Exercise, the IMO has delineated four distinct degrees of autonomy for maritime vessels:

1. Degree One: Ships equipped with automated processes and decision-support systems, wherein seafarers are present on board to operate and control shipboard systems and functions. While certain operations may be automated and occasionally unsupervised, crew members remain ready to assume control as necessary.
2. Degree Two: Remotely controlled ships with seafarers on board. These vessels are operated from another location, yet seafarers are available on board to take control and manage shipboard systems and functions when required.
3. Degree Three: Remotely controlled ships without seafarers on board. Such ships are controlled and operated entirely from another location, with no crew members present on the vessel.
4. Degree Four: Fully autonomous ships, wherein the operating system can make decisions and determining actions independently, without human intervention[29].

Therefore, the IMO is in the process of formulating the MASS Code, intended to establish a coherent regulatory framework governing the operation of autonomous vessels. This instrument is designed to cover both remotely operated and fully autonomous ships, with the objective of ensuring that safety, security, and environmental protection standards remain equivalent to those applied

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[27] The Maritime Safety Committee (MSC) deals with all matters related to maritime safety and maritime security which fall within the scope of IMO, covering both passenger ships and all kinds of cargo ships. This includes updating the SOLAS Convention and related codes, such as those covering dangerous goods, life-saving appliances and fire safety systems. The MSC also deals with human element issues, including amendments to the STCW Convention on training and certification of seafarers. The MSC has a wide range of issues on its current agenda, including goal-based standards, autonomous vessels, piracy and armed robbery against ships, cyber security and e-navigation.

[28] L. Xue, K.F. Yuen, *Autonomous ships: A study of critical success factors,* in *Maritime Economics & Logistics*, 2022, pag. 231-254.

[29] International Maritime Organisation (IMO), *Outcome of the regulatory scoping exercise for the use of maritime autonomous surface ships (MASS)*, MSC.1/Circ.1638, 3 June 2021.

to conventional shipping. A central element of the MASS Code concerns the reliability and safety of onboard software systems. It sets out detailed requirements to guarantee that software performing critical functions such as navigation, communication, and vessel control is developed, implemented, and maintained in a manner that effectively mitigates operational risks[30].

The MASS Code establishes a comprehensive set of principles to ensure the safety and reliability of software systems integral to autonomous ship operations. Central to the Code is the requirement that software governing critical functions, such as navigation, collision avoidance, and emergency response, must demonstrate a high degree of robustness and be capable of operating effectively under a wide range of conditions, including adverse weather and congested maritime environments. To address the risks inherent in software-dependent systems, the Code embeds risk management practices throughout the lifecycle of MASS, from design and development to deployment and maintenance. These practices include the systematic identification and evaluation of hazards, the specification of safety requirements, rigorous testing regimes, and the incorporation of fail-safe mechanisms. Recognising the vulnerability of digital infrastructures, the Code also prioritises cybersecurity and data integrity, mandating the use of secure communication protocols, routine updates, and redundancy in critical functions to prevent unauthorized access and reduce single points of failure[31].

At the same time, it acknowledges the continuing role of human oversight, requiring software interfaces to be intuitive and transparent so that remote operators can monitor system performance, receive real-time safety information, and intervene when necessary. Furthermore, the Code stipulates that software must be subject to continuous monitoring and updating, supported by automated diagnostic tools, error detection mechanisms, and patch management procedures, thereby ensuring adaptability and long-term safety. Finally, it imposes strict obligations for validation and verification, requiring both simulation-based and real-world testing, formal verification techniques, and ongoing performance assessments to confirm the reliability of software deployed in autonomous vessels[32].

## 1. *Adapting UNCLOS to the Era of Autonomous Vessels: Legal Considerations and Implications*

The IMO plays a pivotal role in formulating new regulations and interpreting existing ones to address the unique requirements of MASS. This proactive approach to harmonizing the legal framework underscores the IMO's authority in ensuring

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[30] International Maritime Organization, *Report of the Maritime Safety Committee on its 108th Session* (MSC 108/WP.7, 2024), London, UK, 2024, pag. 4-14.

[31] C. Lee, S. Lee, *A Risk Identification Method for Ensuring AI-Integrated System Safety for Remotely Controlled Ships with Onboard Seafarers*, in *Journal of Marine Science and Engineering,* 2024, pag. 2-3.

[32] C. Lee, S. Lee, *op. cit.*, pag. 3.

maritime safety and environmental protection, facilitating the seamless integration of autonomous vessels into the current regulatory system[33].

Under the UNCLOS, various provisions mandate States to collaborate with the IMO, recognized as the competent international organization, to consider, implement, and adhere to applicable international rules and standards. While IMO holds a leading position in establishing regulations for MASS operations, a critical question arises regarding its authority to enact necessary modifications to address the regulatory challenges posed by emerging technologies in autonomous shipping[34]. Article 1 of the IMO Convention serves as a primary source of this authority, with paragraph (a) emphasizing the importance of governmental cooperation in regulating the technical aspects of international shipping[35]. The IMO's commitment to adapting the legal landscape in response to technological advancements ensures that the integration of autonomous vessels aligns with international maritime law, maintaining safety and environmental standards across the global shipping industry[36].

Article 1(a) of the Convention on the International Maritime Organization delineates the organization's primary objective as facilitating cooperation among governments in regulating technical matters affecting shipping engaged in international trade[37]. Consequently, the IMO's regulatory scope is confined to international maritime activities, excluding certain categories of vessels. Specifically, IMO instruments often do not apply to warships, government-operated vessels not involved in commercial trade, and ships operating exclusively within inland waters, as these are typically governed by national legislation[38]. Nonetheless, States Parties retain the discretion to extend the application of IMO conventions to such vessels, a decision frequently influenced by domestic policy considerations[39].

IMO's commitment to the progressive development of maritime law is evident in its policy framework. This dedication is exemplified by the Secretariat's study titled *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization*, which elucidates the integration of UNCLOS provisions into the IMO's regulatory activities. The document further explores the diverse legal interpretations and claims of States concerning maritime jurisdiction,

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[33] M. Bilawal Khaskheli, S. Wang *et al.*, *Technology Advancement and International Law in Marine Policy, Challenges, Solutions and Future Prospective*, in *Frontiers in Marine Science*, 2023, pag. 6.

[34] B. Stępień, *Navigating New Waters: IMO's Efforts to Regulate Autonomous Shipping*, in *Chinese Journal of International Law*, 2024, pag. 601-604.

[35] *Convention on the International Maritime Organization* (adopted 6 March 1948, entered into force 17 March 1958) 289 UNTS 3, art. 1(a).

[36] R. P. Balkin, *The IMO and Global Ocean Governance: Past, Present, and Future*, in *The IMLI Treatise on Global Ocean Governance,* Oxford, 2018, pag. 1-26.

[37] *Convention on the International Maritime Organization*, *op. cit.*

[38] N. Wissner, M. Cames *et al.*, *Integration of maritime transport in the EU Emissions Trading System,* published by *Oeko-Institut and Transport & Environment*, 2021, pag. 16.

[39] International Maritime Organization, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization* (IMO LEG/MISC.8, 2014), pag. 12.

particularly emphasizing the delineation of responsibilities between coastal and flag States. While UNCLOS establishes a foundational legal structure for ocean governance, the IMO plays a pivotal role in interpreting and implementing its provisions, thereby addressing emerging challenges and evolving legal issues within the maritime domain[40].

Article 94 of the UNCLOS mandates that flag States exercise effective jurisdiction and control over ships flying their flag, encompassing administrative, technical, and social matters[41]. This includes ensuring that each ship is in charge of a master and officers who possess appropriate qualifications, particularly in seamanship, navigation, communications, and marine engineering, and that the crew is appropriate in qualification and numbers for the type, size, machinery, and equipment of the ship[42]. The advent of autonomous ships presents unique challenges to these requirements, as the traditional roles of masters and officers may be redefined or rendered obsolete by autonomous technologies.

The Danish Maritime Authority has highlighted these challenges, suggesting that the current UNCLOS framework may not adequately accommodate the operation of fully autonomous ships. They propose that amendments to UNCLOS might be necessary to effectively govern this emerging sector. However, the amendment procedures outlined in Articles 312 and 313 of UNCLOS are notably cumbersome and have never been utilized, making the prospect of formal amendments unlikely[43].

Despite this, UNCLOS exhibits a degree of flexibility, particularly through Article 94(5), which requires States to conform to generally accepted international regulations, procedures, and practices[44]. This provision allows for the incorporation of evolving international standards, often developed by the IMO, without necessitating formal amendments to UNCLOS. Such adaptability ensures that the legal framework remains responsive to technological advancements in maritime operations[45]. In this context, while UNCLOS provides the foundational legal structure for maritime governance, the IMO plays a pivotal role in interpreting and implementing its provisions, particularly in addressing the regulatory challenges posed by autonomous ships. The development of a comprehensive regulatory

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[40] IMO Secretariat, *Implications of the United Nations Convention on the Law of the Sea for the International Maritime Organization: Study by the Secretariat of the IMO*, IMO Doc. LEG/MISC.7 (19 January 2012), pag. 7.

[41] *United Nations Convention on the Law of the Sea* (adopted 10 December 1982, entered into force 16 November 1994) 1833 UNTS 3, art. 94(4)(b).

[42] K. Siig, *Private classification societies acting on behalf of the regulatory authorities within the shipping industry*, in *Marlus*, 2017, pag. 221-224.

[43] Danish Maritime Authority Study Report, *Analysis of Regulatory Barriers to the Use of Autonomous Ships,* by Ramboll & Core, 2017, attached to IMO Doc. MSC 99/INF.3.

[44] *Supra* note 36, art. 94(5).

[45] CMI questionnaire of 2017 summarized in IMO Doc. MSC.99/INF.8 wherein '10 out of 12 responding states' maritime law associations took a similar view of UNCLOS and considered that the IMO has the formal competence to regulate unmanned ships.

framework by IMO is essential to ensure the safe and lawful integration of autonomous vessels into international maritime operations[46].

## 2. *Legal Implications of the SOLAS Regime for the Liability of Autonomous Vessels*

SOLAS sets forth mandatory minimum safety standards for the construction, equipment, and operation of ships engaged in international voyages[47]. An important legal issue requiring clarification concerns the permissibility, under existing maritime regulations, of performing navigational and operational bridge functions from locations remote to the vessel. Specifically, the question arises as to whether shore-based personnel or remotely situated crews may legally fulfil the duties traditionally assigned to the ship's bridge team. Although recent trials suggest that the technological infrastructure necessary for remote ship operations is either emerging or already in place, the compatibility of such practices with the current legal framework remains uncertain[48].

A central regulatory framework governing ship manning is found in SOLAS Regulation V/14, supplemented by the non-binding IMO Guidelines on Safe Manning (Resolution A.1047(27))[49]. Under this framework, the responsibility for determining appropriate manning levels lies with the flag State administration, which evaluates whether the number and qualifications of the crew are adequate for the safe operation of a given vessel. This evaluation is typically based on a proposal and justification submitted by the ship's owner or operator. If deemed satisfactory, the administration issues a Safe Manning Document for the vessel[50].

Substantively, Regulation V/14 mandates that all ships must be "sufficiently and efficiently manned" to ensure the safety of life at sea[51]. While this is the primary legal requirement, the accompanying guidelines offer a broader interpretive scope, highlighting additional considerations such as the protection of the marine environment, cargo safety, and ship security[52]. These guidelines are advisory in nature, expressed primarily in terms of objectives rather than prescriptive rules, which allows for flexibility in implementation, including the possibility of remote operation or autonomous functionalities.

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[46] A. Akbarov, *Analysis of the impact of mass on the international regulatory framework in the example of UNCLOS terminology: issues, legal challenges, possible solutions*, in *World Maritime University Dissertations*, Malmö, 2024, pag. 34.

[47] International Maritime Organization, *International Convention for the Safety of Life at Sea (SOLAS)*, 1974 (IMO).

[48] P. K. Mukherjee, *Maritime Autonomous Surface Ships (MASS): Precarious Legal Position of the Shore-Based Remote Controller*, in *Autonomous Vessels in Maritime Affairs – Law and Governance Implications,* 2023, pag. 281-282.

[49] International Maritime Organization, *International Convention for the Safety of Life at Sea (SOLAS)*, 1974 (adopted 1 November 1974, entered into force 25 May 1980) Regulation V/14.

[50] International Maritime Organization, *Guidelines on the Application of the Principles of Safe Manning, Resolution A.1047(27)* (Adopted 30 November 2011).

[51] *Supra* note 44, pag. 3.

[52] *Supra* note 44, pag. 3-4.

Notably, the guidelines do not explicitly preclude a flag State from approving arrangements in which essential operational functions are conducted from locations external to the vessel. The concept of a ship being "manned" does not inherently equate to continuous physical presence on board; it may extend to functions performed by shore-based personnel. Remote crews could feasibly manage navigation and communication duties, while land-based technical teams might handle necessary maintenance tasks. Moreover, the guidelines explicitly state that decisions on manning should consider the technological sophistication and level of automation present on the vessel[53].

From a legal standpoint, it is therefore challenging to identify a specific provision in the current safe manning guidelines that would categorically prohibit a flag State from certifying a remotely operated or autonomous vessel, provided that the overarching safety objectives are met. Nonetheless, the introduction of fully autonomous ships, which operate entirely without onboard personnel, does present a direct challenge to the traditional interpretation of "sufficient and efficient manning" under Regulation V/14[54]. The absence of crew could be construed as non-compliance with SOLAS, thereby exposing operators to regulatory and liability risks, particularly in the event of an incident[55].

While SOLAS does not establish a direct civil liability regime, non-compliance with its provisions can serve as evidence of negligence in both public enforcement and private disputes. Shipowners bear the primary responsibility for ensuring that their vessels comply with SOLAS requirements. The operation of an autonomous vessel that fails to meet these standards may render the ship owner liable for negligence[56]. For instance, Regulation V/14 mandates that ships be "sufficiently and efficiently manned", a requirement that may be incompatible with fully autonomous operations. Non-compliance with this regulation could affect the vessel's seaworthiness status, impacting on obligations under charterparties and bills of lading[57].

Regulation V/33 of SOLAS imposes an obligation on masters of vessels to render assistance to persons in distress at sea[58]. In the context of MASS, the absence of a human master raises questions about how this duty can be fulfilled. Failure to render assistance could result in liability for the shipowner or operator, especially if the autonomous system lacks the capability to detect and respond to

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[53] *Supra* note 44, Annex 2, paras. 1.1.3 and 1.1.4.

[54] A. Javed, *Safe manning of ships in the era of new and emerging technologies*, in *World Maritime University Dissertations*, 2023, pag. 31.

[55] Ship Universe*, When No One's at the Helm: Top Legal Risks of Autonomous Vessels* (Ship Universe, 27 April 2024).

[56] Gard, *Maritime Autonomous Surface Ships – Identifying and Covering the Risks,* (Gard, 14 June 2023).

[57] International Maritime Organization, *International Convention for the Safety of Life at Sea (SOLAS), 1974* (adopted 1 November 1974, entered into force 25 May 1980), Regulation V/14.

[58] *Supra* note 52, Regulation V/33.

distress situations[59]. The integration of advanced technologies in MASS operations introduces additional actors who may bear liability. Shore-based operators, system integrators, and software developers could be held accountable if their actions or products contribute to SOLAS non-compliance. For example, a malfunction in the autonomous navigation system due to a software defect may implicate the developer under product liability laws, particularly within jurisdictions that recognize such claims. Similarly, inadequate oversight by remote operators could result in liability if it leads to incidents at sea[60].

The operation of MASS introduces several challenges to the existing framework of Regulation V/19 of SOLAS. It assumes human presence for the interpretation and response to navigational data[61]. In the context of MASS, the absence of onboard crew necessitates that autonomous systems not only collect but also interpret and act upon navigational information. This raises questions about the adequacy of current equipment standards and whether autonomous decision-making systems meet the intent of the regulation. The integration of advanced technologies in MASS may involve equipment that does not conform to existing standards set by SOLAS. For instance, the use of artificial intelligence for navigation decisions may not align with current certification processes. This discrepancy could lead to challenges in demonstrating compliance with Regulation V/19, potentially affecting the vessel's certification and operational legitimacy[62].

Non-compliance with Regulation V/19 can have significant legal implications. For instance, if a MASS lacks the required navigational equipment or if such equipment fails to function correctly due to inadequate maintenance or software errors, and this deficiency contributes to a maritime incident, courts may find the shipowner or operator negligent. This finding can affect obligations under charter parties and bills of lading, potentially rendering the vessel unseaworthy and impacting on the enforceability of contractual agreements[63].

### 3. *Navigating COLREGs and Liability Frameworks for Autonomous Vessels*

As highlighted in the 2012 MUNIN study, autonomous navigation appears feasible in the open ocean, where maritime traffic is relatively sparse and can be managed through the application of advanced collision-avoidance algorithms. However, this assumption does not hold in more congested maritime zones, such as coastal waters, port approaches, and harbors, where the complexity and density of

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[59] T. Heidar, *The Duty to Render Assistance at Sea under International Law*, International Foundation for the Law of the Sea, 17 March 2018, pag. 6-7.

[60] S. Baughen, *Civil Liability all at Sea: The Challenges of Unmanned Cargo Ships*, in Phillip Morgan (ed), *Tort Liability and Autonomous Systems Accidents: Common and Civil Law Perspectives*, 2023, pag. 211-233.

[61] *Supra* note 52, Regulation V/19.

[62] International Maritime Organization, *Resolution MSC.74(69) – Adoption of New and Amended Performance Standards* (Adopted 12 May 1998).

[63] G.J.M. Pollock, *SOLAS V Carriage Requirements*, in *The Master Mariner.*

traffic pose significant operational and safety challenges for autonomous systems[64]. A number of provisions within the 1972 COLREGs are grounded in assumptions regarding traffic density and rely heavily on the exercise of good seamanship, including adherence to the established norms encapsulated in the notion of the "ordinary practice of seamen"[65].

The obligation to exercise good seamanship remains a cornerstone of navigational conduct in all actions undertaken to avoid collisions at sea. Within the context of MASS, this principle gives rise to substantial legal and operational concerns[66]. A pressing question is whether a remote shore-based operator, lacking seafaring experience and not physically present in the maritime environment, can meet the standards of good seamanship or conform to the "ordinary practice of seamen" as envisaged under Rule 2 of the COLREGs.

Rule 15 of the COLREGs, which addresses head-on encounters, presents a peculiar navigational challenge. In circumstances where two vessels are on reciprocal or nearly reciprocal courses, both are required to alter their course to starboard, ensuring a port-to-port passage. The precise moment at which these course alterations should occur depends on the judgment of both vessels' operators, who must assess the collision risk in real time[67]. While advanced collision avoidance systems are likely to be available to shore-based remote operators, significant complications arise when one of the vessels is a MASS and the other remains manned. In such instances, ensuring adherence to rules that necessitate nuanced navigational decisions, such as those aimed at collision avoidance, becomes a formidable challenge. This is particularly true for MASS, where the capacity for real-time, judgment-based decision-making may be compromised, especially for vessels operating at higher levels of autonomy[68].

Rule 5 of the 1972 COLREGs imposes an obligation on all vessels to "maintain a proper lookout by sight and hearing, as well as by all available means appropriate

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[64] Z.H. Munim, H. Haralambides, *Advances in Maritime Autonomous Surface Ships (MASS) in Merchant Shipping*, in *Maritime Economics & Logistics,* 2022, pag. 183.

[65] International Maritime Organization, *Convention on the International Regulations for Preventing Collisions at Sea (COLREGs), 1972*, Rules 2(a) and 8(a); Rule 2(b) of COLREGs specifically refers to the "ordinary practice of seamen" stating: *"Due regard shall be had to all dangers of navigation and collision and to any special circumstances... which may make a departure from these Rules necessary to avoid immediate danger".* This clause introduces flexibility into the rules by recognizing that strict adherence to COLREGs might not always guarantee safety, especially in exceptional or rapidly changing circumstances. In such cases, mariners are expected to fall back on established seafaring practices – i.e., what an average skilled seaman would reasonably do under similar conditions. Instead, "*good seamanship"* refers to the set of skills, judgment, and practices that a competent mariner is reasonably expected to apply to ensure the safe and efficient operation of a vessel.

[66] *Legal Briefing: Autonomous Shipping – Revolution by Evolution*, in *UK P&I Club*, 2019, pag. 3-4.

[67] *Supra* note 60, Rule 15.

[68] H. Liu, *Maritime and Aviation Law: A Relational Retrospect and Prospect on Unmanned Ships and Aircraft*, in A. Basu Bal (Ed.), *Revisiting Trade, Transport, and Marine Law: Risk and Technology in Perspective, Liber Amicorum Lars-Goran Malmberg*, Leida, 2022, pag. 471-499.

to the prevailing circumstances and conditions, in order to assess the situation fully and determine the risk of collision."[69]. This duty to maintain a proper lookout can, in the case of MASS, theoretically be fulfilled by remote operators who, despite not being physically aboard, can access real-time data from the vessel's cameras and sensors. Nevertheless, the current regulatory framework does not account for the operation of fully autonomous ships without human supervision. The regulations underpin the necessity of human involvement in navigational decision-making, and thus do not accommodate MASS operating entirely independently, without any form of human oversight or control[70].

Liability in maritime contexts may arise under either penal or civil regimes and, in many instances, under both simultaneously. Penal liability is predominantly governed by the COLREGs[71]. Breaches of the COLREGs typically attract regulatory sanctions, most commonly monetary penalties. However, more severe infractions may lead to disciplinary measures against the vessel's master or navigating officer, including the suspension or revocation of certificates issued pursuant to the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW). In circumstances where a vessel is under the conduct of a pilot, a violation may also result in the suspension or cancellation of the pilot's license[72].

To have legal effect, violations of international instruments such as the COLREGs must be incorporated into domestic law through enabling legislation. Where a breach gives rise to serious consequences, such as the loss of life, the offence may be treated not merely as a regulatory infraction but as a criminal act, thereby subject to more stringent sanctions[73]. Whereas penal liability tends to fall on the individual directly responsible for navigation (e.g., the master or pilot, as agents of the vessel owner or operator), civil liability, particularly where substantial financial damages are involved, is generally borne by the shipowner or operator themselves[74].

While the COLREGs primarily function as a regulatory instrument and thus concern themselves with penal liability, they also have significant implications for civil liability, albeit indirectly. Civil liability for maritime collisions is principally governed by the International Convention for the Unification of Certain Rules of Law with Respect to Collisions Between Vessels, 1910 (commonly referred to as

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[69] *Supra* note 60, Rule 5.

[70] A. Gray, *The Evolution from Strict Liability to Fault in the Law of Torts*, Oxford, 2020, pag. 251-267.

[71] K-A. N. Mckoy, *Collisions: a legal analysis*, in *World Maritime University Dissertations*, 1999, pag. 40-45.

[72] R. Suppiah, *Departure from COLREGS Infringement or Good Seamanship*, in *World Maritime University Dissertations,* 2007, pag. 56-58.

[73] D. Williams, *The Collision Regulations (ColRegs): Guidelines, or actual rules?,*in *League and Williams Lawyers*, October 21, 2016.

[74] P. P. Thin, *The Role of the Liability of the Shipowner*, in *Yadanabon University Research Journal,* 2019, Vol. 10, No. 1, pag. 1-2.

the Collision Convention 1910). In private maritime law, collisions are classified as tortious events, and the 1910 Convention offers a comprehensive framework for determining liability[75].

One of the Convention's most notable features is Article 4, which stipulates that in the event of a collision between two vessels, liability is to be apportioned in accordance with the respective degree of fault of each vessel. Should the vessels be found equally at fault, liability is divided equally[76]. Additionally, Article 2 establishes that if the cause of the collision is accidental, attributable to force majeure, or remains indeterminate, each party must bear its own loss, irrespective of whether the vessels were underway at the time[77].

Article 8 of the Convention imposes a duty on the master of each vessel involved in a collision to render assistance to the other, provided that doing so does not endanger their own vessel, crew, or passengers. This obligation is mirrored in Regulation 33, Chapter V of the International Convention for the Safety of Life at Sea (SOLAS), 1974[78]. However, the feasibility of fulfilling such duties, particularly the obligation to render immediate assistance in the context of MASS, remains open to question. It is doubtful whether remote operators based onshore, removed from the physical environment of the vessel, can adequately comply with such obligations under either the Collision Convention or SOLAS[79].

The civil liability regime established under the 1910 Collision Liability Convention operates in close conjunction with the 1972 COLREGs. In practice, the application of these two legal instruments is often inseparable. Civil liability in maritime collision cases arises from the commission of a maritime tort, with the extent and nature of the damage caused by one vessel to another guiding the judicial remedies available to the affected parties[80].

A critical question emerges with respect to MASS, particularly in determining the legal responsibility of shore-based remote operators. Specifically, it remains uncertain whether such operators, relying on computer software and remote systems, can effectively demonstrate compliance with the standard of "good seamanship," a concept traditionally rooted in human judgment and experiential knowledge. This concern becomes particularly acute in the case of fourth-degree autonomous

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[75] K-A N. Mckoy, *Collisions: a legal analysis*, *op. cit.*

[76] International Convention for the Unification of Certain Rules of Law with respect to Collisions between Vessels (Collision Convention) (adopted 23 September 1910, entered into force 1 March 1913), art. 4.

[77] *Supra* note 71, art. 2.

[78] *Supra* note 71, art. 8 in combination with International Convention for the Safety of Life at Sea (SOLAS) 1974, Regulation V/33.

[79] M. Yoshida, E. Shimizu *et al.*, *Regulatory Requirements on the Competence of Remote Operator in Maritime Autonomous Surface Ship: Situation Awareness, Ship Sense and Goal-Based Gap Analysis*, in *Applied Sciences*, 2020, pag. 16-18.

[80] P. K. Mukherjee, *Impact of the MONALISA Project on the International Legal Framework for Navigation at Sea*, 2013, pag. 55-57.

vessels, which operate entirely without crew and, by their nature, cannot satisfy the conventional standard of the "ordinary practice of seamen"[81].

In the context of autonomous operations, the delegation of navigational and operational tasks to sophisticated technologies, previously performed by trained maritime personnel, raises complex liability issues, especially where negligence is concerned. Negligence remains the dominant form of fault under the law of collision liability and is determined by applying an objective standard of care. The COLREGs refer explicitly to "ordinary practice of seamen" and "good seamanship," terms that, while objectively framed, are nevertheless deeply embedded in the professional maritime context[82].

Although the 1910 Convention has abolished any automatic presumption of fault arising from a breach of the COLREGs, non-compliance with these rules is still widely regarded as persuasive evidence of negligence. In instances where the COLREGs do not directly apply, courts continue to evaluate conduct against the yardstick of good seamanship to determine liability. However, this standard proves challenging to apply in scenarios involving fully autonomous ships, where traditional human oversight is absent[83]. Judicial interpretation of these standards has historically been complex and, at times, inconsistent. English case law, such as *The Nowy Sacz* and *The Auriga*, illustrates the nuanced judicial approaches to maritime fault and seamanship. Notably, judicial perspectives in such matters often diverge from those of seasoned maritime professionals, reflecting differing conceptions of operational standards at sea[84].

### 4. *Liability of Autonomous Vessels under the LLMC Convention: Implications and Challenges*

The limitation of liability is essential for ensuring that shipowners can obtain insurance coverage for third-party liabilities. Without the ability to limit liability, securing insurance may become unfeasible, exposing the shipowner to significant financial risk with each voyage[85]. Alternatively, the resulting premiums could be so inflated that the cost of shipping goods by sea would rise substantially, ultimately burdening consumers with higher prices. As such, it is widely regarded as being in society's best interest to maintain a system that facilitates the global transportation of goods at a reasonable cost[86].

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[81] A. Komianos, *The Autonomous Shipping Era. Operational, Regulatory, and Quality Challenges*, in *International Journal on Marine Navigation and Safety of Sea Transportation*, 2018, pag. 335-348.

[82] *S.S. (Owners) v Diamond*, *S.S. (Owners) (The Heranger)* [1939] AC 94 (HL).

[83] N. J. Healy, J.C. Sweeney, *Establishing Fault in Collision Cases*, in *Journal of Maritime Law and Commerce*, 1992, Vol. 23, No. 3, pag. 337-367.

[84] *The Nowy Sacz* [1977] 1 Lloyd's Rep 91 (CA), in combination with *The Auriga* [1977] 1 Lloyd's Rep 384.

[85] Marsh, *Limiting Shipowners' Liability: A Guide for Shipowners* (Marsh, 2021).

[86] See, for instance, *Strong Wise Ltd* v *Esso Australia Resources Pty Ltd* (The APL Sydney) [2010] FCA 240, [2010] 2 Lloyd's Rep 555.

The 1957 LLMC Convention was superseded by the 1976 LLMC Convention, which came into effect in 1986. The liability limits were subsequently increased by the 1996 Protocol. As of the time of writing, the LLMC 1976 has been ratified by 55 contracting states, accounting for 52.90% of global tonnage, while the 1996 Protocol has 64 contracting states, representing 69.72% of world tonnage[87]. The 1976 LLMC grants the right to limit liability to both shipowners and salvors, with an expanded definition of "shipowner" for the purposes of the Convention, as outlined in Article 1[88].

Pursuant to the 1976 LLMC Convention, the right to limit liability is granted to both shipowners and salvors[89]. Article 1(2) defines a "shipowner" as including the owner, charterer, manager, and operator of a seagoing vessel[90]. In *The Stema Barge II*, the Court of Appeal held that the term "operator" refers to an entity or individual who has management or control over the vessel; it is insufficient to merely operate the ship's machinery or provide the crew[91]. While a charterer is not required to act as a shipowner to invoke the right to limit liability under Article 1(2) of the LLMC 1976, they are excluded from limiting liability for claims related to loss or damage to the vessel itself[92]. Moreover, Article 1(4) extends the right to limit liability to any person whose act, neglect, or default causes liability for the shipowner or salvor[93]. Claims eligible for limitation under the Convention include, but are not limited to, loss of life, personal injury, or damage to property, such as harm to harbour works, basins, waterways, and navigation aids, which occur on board or in direct connection with the operation of the ship[94].

Article 4 of the LLMC 1976 outlines the circumstances under which a party may be denied the right to limit their liability. Specifically, it prohibits limitations if it is proven that the loss resulted from the party's deliberate act or omission, made with the intent to cause such loss, or recklessly with awareness that such loss would likely occur[95]. This provision shifts the burden of proof onto the claimant and establishes a high threshold for breaking the limitation, requiring clear evidence of intent or knowledge of the probable outcome. This approach reflects a trade-off made by shipowners, who, in agreement to higher limits of liability, gained the near-absolute right to limit their liability[96].

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[87] Convention on Limitation of Liability for Maritime Claims (LLMC), 1976, 976 UNTS 3 (entered into force 1 December 1986).

[88] *Supra* note 82, art. 1.

[89] *Supra* note 82, art. 1(1).

[90] *Supra* note 82, art. 1(2); Salvor is defined in art 1.3 as 'any person rendering services in direct connection with salvage operations.

[91] In this *Journal*, 2022, pag. 121; *The Stema Barge II* [2000] 1 Lloyd's Rep 1 (CA), n 11.

[92] *Gard Marine and Energy Ltd v China National Chartering Company Ltd (The Ocean Victory)* [2017] UKSC 35, [2017] 1 WLR 1793.

[93] *Supra* note 82, art. 1(4).

[94] *Supra* note 82, art. 2.

[95] *Supra* note 82, art. 4.

[96] *The Bowbelle* [1990] 1 WLR 1330, 1335 (QB); The case *The Bowbelle* [1990] 1 WLR

Consequently, the burden of proof imposed on claimants remains a significant obstacle, with only two cases successfully invoking Article 4 since its adoption[97]. The provision's fault-based approach and the claimant's responsibility for proving liability become especially challenging when artificial intelligence (AI) is implicated in the loss[98]. As AI systems become more sophisticated, their increasingly complex data sets and decision-making processes lead to what is often referred to as the "black box" problem, in which the rationale behind the AI's actions becomes opaque and difficult to trace. As a result, establishing that AI decided with the intent to cause loss is currently unattainable[99].

## IV. FROM SHIPOWNERS TO SOFTWARE: EU LIABILITY RULES FOR AUTONOMOUS VESSELS

The European Union does not yet maintain a bespoke liability regime for autonomous vessels; instead, it relies on existing maritime insurance and product-liability frameworks, supplemented by forthcoming AI-specific rules. At the core is Directive 2009/20/EC, which mandates that all ships of at least 300 GT flying an EU flag or calling at EU ports hold insurance covering "maritime claims", including loss of life, property damage, pollution, and wreck removal, up to the limits established by the 1996 Protocol to the LLMC 1976[100]. Complementing this, Directive 85/374/EEC on product liability imposes strict liability on producers for damage caused by defective products, a category now clarified to include software and digital services under the proposed 2024 Product Liability Directive (EU 2024/2853)[101]. This expansion ensures that defective autonomous-navigation systems fall within the regime's scope, allowing injured parties to recover losses without proving negligence. Further strengthening the framework, the Commission's 2022 Proposal for an AI Liability Directive aims to streamline claims against developers and operators of "high-risk" AI, such as autonomous ship-control algorithms, by easing

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1330 concerns a tragic collision that occurred on the River Thames on 20 August 1989, involving the dredger *Bowbelle* and the pleasure boat *Marchioness*, which led to the loss of 51 lives. In this case, the *Bowbelle* was held liable for the incident, and the court examined the application of liability limitations under the Convention on Limitation of Liability for Maritime Claims (LLMC) 1976. This case is notable in maritime law for its analysis and interpretation of liability and limitation provisions in the context of catastrophic events.

[97] *Bahamas Oil Refining Co International Ltd* v *Owners of the Cape Bari Tankschiffahrts GmbH & Co KG* (Bahamas) (The Cape Bari) [2016] UKPC 20, [2016] 2 Lloyd's Rep 469 (PC).

[98] International Maritime Organisation, IMO Resolution A.1163(32), 'Interpretation of Article 4 of the Convention on Limitation of Liability for Maritime Claims 1976/1996' (IMO, 2019).

[99] H. Madaan, *The Rise Of Explainable AI: Bringing Transparency And Trust To Algorithmic Decisions*, in *Forbes Technology Council,* February 14, 2025.

[100] Directive 2009/20/EC of the European Parliament and of the Council of 23 April 2009 on the insurance of shipowners for maritime claims [2009] OJ L131/128.

[101] Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products [1985], OJ L210/29.

evidentiary burdens and explicitly covering remote controllers as "operators"[102]. Finally, the EU Operational Guidelines for MASS trials (2020) reiterate that existing SOLAS-derived and EU safety obligations remain fully in force during uncrewed vessel testing, underlining the continuity of liability and insurance duties regardless of onboard presence[103]. Together, these instruments form a layered EU liability regime, insurance coverage, strict product liability, and forthcoming AI-specific rules, that applies by analogy to MASS, ensuring that shipowners, remote operators, and technology providers remain accountable for harm arising from uncrewed maritime operations.

### 1. *The EU AI Act's Influence on the Regulation of Maritime Autonomous Surface Ships*

Following the European Parliament's approval of the Artificial Intelligence Act in December 2023, the 27 Member States of the European Union have formally embraced a comprehensive and harmonized legal framework for the regulation of artificial intelligence technologies. This legislative development positions the EU Artificial Intelligence (AI) Act as a pivotal reference point in forecasting the regulatory trajectory of MASS as they advance through successive stages of innovation, from research and prototyping to commercial integration and practical deployment, across varying levels of autonomy[104].

A particularly significant provision of the AI Act is found in Article 5(1), subparagraph one, point (h)(iii), which references Annex II. This annex enumerates a broad spectrum of grave criminal offenses, including but not limited to: terrorism, human trafficking, sexual exploitation of minors and child pornography, illegal drug and arms trafficking, murder, serious bodily harm, illegal trade in human organs and radioactive substances, kidnapping, unlawful detention or hostage-taking, offenses falling under the jurisdiction of the International Criminal Court, unlawful seizure of ships or aircraft, rape, environmental crimes, organized or armed robbery, sabotage, and active participation in criminal organizations engaged in any of the aforementioned crimes[105].

Moreover, as defined in Section 5.2.1 (Title I) of the explanatory memorandum

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[102] Directive (EU) 2024/2853 of the European Parliament and of the Council of 23 October 2024 on liability for defective products and repealing Council Directive 85/374/EEC [2024], OJ L 284/1.

[103] European Commission, *EU Operational Guidelines for Trials of Maritime Autonomous Surface Ships (MASS)* (2020).

[104] A. Brogden, *Essential Guide for the New EU AI Act: Navigating through the AI Act*, in *GDPR Local*, 26 March 2024.

[105] European Parliament and Council Regulation (EU) 2024/1689 of 13 June 2024 laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending Regulations (EC) No. 300/2008, (EU) No 167/2013, (EU) No 168/2013, (EU) 2018/858, (EU) 2019/2144 and (EU) 2020/1056 and Directives 2014/90/EU, (EU) 2016/797 and (EU) 2020/1828 [2024] OJ L/2024/1689, *Annex II and art. 5(1).*

accompanying the legislative proposal, the scope of application extends to providers who place AI systems on the market or make them operational within the European Union, as well as to users established within EU territory. Additionally, it captures providers and users located in third countries when the outputs of their AI systems are deployed or produce effects within the EU[106].

Therefore, Article 5(1)(h)(iii) of the EU AI Act, read together with Annex II, explicitly prohibits AI systems that could be used in connection with serious criminal activities, including piracy, human trafficking, environmental crimes, and the unlawful seizure of ships. For MASS, this provision directly reinforces the prevention of misuse of autonomy at sea, ensuring that AI-driven navigation and control systems cannot be repurposed for illicit or harmful objectives[107]. The Act's territorial scope, clarified in Section 5.2.1 of the Explanatory Memorandum, extends its reach beyond EU borders by applying to providers and users in third countries whenever the output of their AI systems has effects in the EU. This means that non-EU shipbuilders and software developers whose autonomous ships operate in European waters must still comply with EU standards[108].

The EU AI Act has the potential to reshape the regulatory framework for MASS by embedding criminal-law safeguards directly into vessel design and operation, thereby strengthening maritime security. By making compliance with its provisions a prerequisite for market access, the Act projects its regulatory influence beyond EU borders and establishes extraterritorial accountability[109]. Moreover, it provides a complementary framework to the IMO's existing MASS guidelines, which primarily address safety, liability, and human oversight. In doing so, the Act may act as a catalyst for the IMO to incorporate more stringent AI governance measures, such as explicit prohibitions on criminal misuse and systemic risk obligations, into future international conventions. Thus, the EU regime serves not only as a regional standard but also as a potential driver of regulatory convergence in global maritime governance[110].

To understand concretely how the EU AI Act could influence future MASS regulations, consider a scenario in which a South Korean shipyard constructs an autonomous vessel fitted with AI control software developed by a Norwegian company, and the vessel is subsequently operated by a German shipowner. Under these circumstances, the EU AI Act generates a range of jurisdictional and enforcement challenges. Although the shipbuilder is established outside the EU, the Act may still apply, as the AI system is placed on the EU market and used

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[106] European Commission, *'Proposal for a Regulation of the European Parliament and of the Council laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) and amending certain Union legislative acts'* COM (2021) 206 final, *5.2.1 Scope and Definitions – Title I.*

[107] *Supra* note 100.

[108] *Supra* note 101.

[109] Y.-G. Lee, C.-H. Lee *et al.*, *Transformative Impact of the EU AI Act on Maritime Autonomous Surface Ships,* in *Laws*, 2024, pag. 8-9.

[110] Y.-G. Lee, C.-H. Lee *et al.*, *op. cit.*, pag. 16-18

within its territory. Non-compliance could expose the South Korean manufacturer to significant legal consequences, including administrative fines, limitations on market access, or liability for damages. At the same time, the German shipowner, as the end user within the EU, would be entitled to pursue legal remedies should the system's defects or regulatory shortcomings cause economic or operational losses. Such disputes would most likely be litigated before German courts, with claims evaluated under EU law. This example illustrates how the extraterritorial reach of the EU AI Act not only extends accountability to non-EU entities but also concretely influences the allocation of liability within the maritime sector. For MASS, this framework is pivotal: compliance with EU standards becomes a prerequisite for market entry, setting a de facto global benchmark and pushing toward greater harmonisation of legal regimes governing autonomous shipping[111].

In addressing the categorization and practical examples of risks associated with the implementation of AI systems in autonomous maritime vessels, the EU AI Act adopts a structured risk-based regulatory framework. This framework classifies AI-related risks into four distinct categories (unacceptable, high, limited, and minimal) each carrying specific regulatory implications. Depending on the designated risk level, an AI system may be outright prohibited, subjected to a mandatory pre-market conformity assessment, or regulated through proportionate obligations. The certification procedures outlined in the Act are designed to mitigate potential harms in advance by ensuring that systems undergo appropriate oversight commensurate with their level of risk[112].

The EU AI Act firmly incorporates the precautionary principle into its risk regulation framework, reflecting a forward-looking approach to governing emerging technologies. This principle is particularly pertinent in managing risks posed by AI systems that have not undergone sufficient market testing or real-world validation. Within the maritime domain, the deployment of autonomous vessels engaged in international commerce presents a series of complex legal and ethical challenges, particularly in relation to compliance with international norms and the safeguarding of public interests. A critical concern arises in scenarios where AI-powered navigation systems, designed for operational efficiency, may prioritize economic outcomes over humanitarian obligations. For example, an autonomous ship might disregard a maritime distress signal in favour of following a shorter, more cost-effective route. Such decision-making processes, driven by algorithmic logic without human ethical judgment, introduce significant uncertainty and risk, underscoring the necessity for robust regulatory oversight and ethical safeguards in AI deployment at sea[113].

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[111] Y.-G. Lee, C.-H. Lee *et al.*, *op. cit.*, pag. 9.

[112] H.L. Fraser, J.-M.B. Villarino, *Acceptable risks in Europe's proposed AI Act: Reasonableness and other principles for deciding how much risk management is enough*, in *European Journal of Risk Regulation*, 2023, pag. 1-16.

[113] H.L. Fraser, J.-M.B. Villarino, *op. cit.*, pag. 4-10.

A regulatory strategy rooted in the precautionary principle, characterized by the deferral of technological deployment pending comprehensive oversight, may, paradoxically, encourage innovation in the field of autonomous shipping while simultaneously constraining the global competitiveness of traditional maritime actors, including shipbuilders, equipment manufacturers, and shipping operators. This approach entails the pre-emptive identification of potential risks and imposes strict requirements concerning the quality and reliability of maritime data processed by AI systems onboard autonomous vessels. Specifically, it assumes, ex ante, that such data must be accurate, comprehensive, and representative to support lawful and effective operation, despite the inherent uncertainties associated with emerging technologies[114].

The classification of high-risk AI systems under the EU AI Act holds significant implications for the deployment of such technologies in the context of autonomous maritime vessels. Under this legislative framework, high-risk AI systems are subject to mandatory third-party conformity assessments, particularly when these systems function as integral safety components within broader products. This classification framework is directly applicable to AI technologies embedded in autonomous ships, given their critical role in ensuring navigational safety and operational reliability. Such systems are regulated in accordance with sector-specific legislation, which is being revised to incorporate the obligations articulated within the AI Act[115].

In addition to high-risk categories, the Act introduces the concept of limited-risk AI systems, a designation that includes a spectrum of technologies situated between high and minimal risk. These systems raise concerns related to transparency, thereby triggering corresponding disclosure obligations[116]. Nevertheless, Article 52 of the AI Act delineates specific transparency requirements for three categories of AI technologies: synthetic content generators (commonly referred to as "deep fakes"), systems involving human-AI interaction (such as chatbots or voice assistants), and technologies designed for emotion recognition or biometric classification. According to the Act, individuals within the EU must be adequately informed when engaging with such systems; for example, being made aware that a communication involves a non-human agent or that emotional or biometric data are being analysed by AI[117]. When applying these transparency obligations to the maritime sector, particularly to autonomous ships, it is essential to recognize the nuanced ethical and societal implications involved. Legal and regulatory frameworks must be sufficiently

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[114] Q. Chen, Y.-Y. Lau *et al.*, *From concept to practicality: Unmanned vessel research in China*, in *Heliyon*, 2023, pag. 4-13.

[115] E. Hohma, C. Lütge, *From trustworthy principles to a trustworthy development process: The need and elements of trusted development of AI Systems*, in *AI*, 2023, pag. 904-925.

[116] E. Gaumond, *Artificial Intelligence Act: What Is the European Approach for AI?*, in *Lawfare*, 2021.

[117] Regulation (EU) 2024/1684 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence (Artificial Intelligence Act) [2024], OJ L168/1, *art. 52*.

flexible to account for the diverse contexts in which autonomous maritime systems operate, thereby ensuring that transparency mechanisms are both meaningful and responsive to complex operational realities[118].

Article 69 of the EU AI Directive's Code of Conduct strongly encourages shipyards and shipping companies to establish voluntary codes of conduct for regulating the use of AI[119]. The European Commission is implementing these soft-law frameworks to promote transparency, mitigate the reliance on human oversight, and ensure the robustness of AI systems, particularly those categorized as high-risk. The overarching objective is to stimulate innovation within AI-related technology initiatives and startups across Europe, facilitating their growth while maintaining regulatory guidance[120].

The adoption of the EU AI Act under Regulation (EU) 2024/1689 marks a pivotal step in establishing a regulatory framework that will strongly influence the development and deployment of MASS. By focusing on General-Purpose AI (GPAI) and applying a risk-based methodology, the Act introduces a new set of obligations for both developers and operators, moving away from earlier classification systems. GPAI models used in autonomous vessels, particularly those deemed to present systemic risks, must now meet stringent requirements, including detailed technical documentation, ongoing risk assessments, and reinforced cybersecurity safeguards[121]. These measures are essential to enhancing the safety and reliability of autonomous shipping while addressing the complex legal and ethical questions that accompany its integration into the maritime sector. Beyond Europe, the Act's comprehensive treatment of GPAI is likely to influence international practices, with the United States and other jurisdictions expected either to introduce comparable rules or to align reporting and compliance obligations. By setting this benchmark, the EU AI Act positions itself as a cornerstone for global regulatory convergence, promoting secure, transparent, and responsible adoption of autonomous ships through cooperation and consistent oversight[122].

### 2. *Navigating EU Product Liability in the Age of Maritime Autonomy*

Unlike the maritime liability framework, which is predominantly fault-based

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[118] K. Wróbel, G. Mateusz *et al.*, *The vagueness of COLREG versus Collision Avoidance Techniques – A discussion on the current state and future challenges concerning the operation of autonomous ships*, in *Sustainability*, 2022, pag. 5-10.

[119] EU AI Act, (2021) Code of Conduct, article 69.

[120] E. Hickman, M. Petrin, *Trustworthy AI and corporate governance: The EU's Ethics Guidelines for trustworthy artificial intelligence from a company law perspective*, in *European Business Organization Law Review*, 2021, pag. 601-607.

[121] Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 June 2024 laying down harmonised rules on artificial intelligence [2024] OJ L 202/1, artt. 53, 55.

[122] Y.-G. Lee, C.-H. Lee *et al.*, *Transformative Impact of the EU AI Act on Maritime Autonomous Surface Ships,* pag. 11-12.

and typically includes liability limitations, the EU's Product Liability Directive (PLD) takes a markedly different approach[123]. The PLD governs liability for personal injury and certain property damage caused by defective products, introducing a system of strict liability[124]. This means that victims of defective products are entitled to full compensation, without the need to establish fault on the part of the producer. Such a regime contrasts with the limited liability often seen in maritime law[125].

A significant issue arises when considering the application of the PLD to autonomous vessels: whether the vessel itself can be regarded as a "product" under the Directive. According to Article 2 of the PLD, a "product" is defined as "all movables... even though incorporated into another movable or into an immovable."[126]. Given that a ship is inherently a movable object, it is generally accepted that a ship could qualify as a product under the Directive[127]. If this assumption holds, a shipyard could be held liable under the PLD if an autonomous vessel is found to be defective, such as if the ship's embedded software malfunctions[128]. However, this liability would only extend to the shipyard if it delivered the ship along with the integrated software[129]. In cases where the software is installed separately by an IT provider after the vessel's delivery, the shipyard would likely be excluded from liability under the PLD concerning the software's defects[130].

The EU Product Liability Directive establishes that a product is considered defective if it fails to meet the safety expectations that a reasonable person would have. This definition, while grounded in objective standards, also incorporates a normative component, as it is ultimately for the courts to decide what constitutes the level of safety the public is entitled to expect. This broad approach reflects the complex nature of product liability, especially in the context of advanced technologies such as autonomous vessels[131].

In the case of autonomous ships, there are three main scenarios that could arise regarding liability for defects. The first involves clear defects resulting from programming errors or the failure to comply with technical standards. In such instances, the product is likely to be classified as defective, and the producer would

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[123] Directive 85/374/EEC of the Council of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products [1985] OJ L210/29.

[124] *Ibid*., art. 9; Article 9 sets out the types of damage for which a producer can be held liable when a defective product causes harm.

[125] *Ibid*., art. 1; Article 1 sets out the basic principle of strict liability under the Directive. It states that producers are legally responsible for any damage caused by a defective product, regardless of fault.

[126] *Ibid*., art. 2.

[127] F. Collin, *Maritime Product Liability at the dawn of unmanned ships – the Finnish perspective*, in *MarIus*, 2018, pag. 4-6.

[128] *Supra* note 111, art. 4.

[129] F. Collin, *op. cit*, pag. 8.

[130] *Supra* note 111, art. 4(1), art. 6(1).

[131] S. Förster, D. Gashi, *The EU's new Product Liability Directive (from a German perspective)*, in *Clyde & Co*, 4 April 2024.

generally be held liable for any damage caused. The second scenario concerns situations where the system operates exactly as programmed, even if the outcomes are suboptimal. For example, an autonomous vessel may follow its programming and, while minimizing harm, may cause damage to a smaller vessel rather than a larger one. In this case, since the system performs as intended, it would not be deemed defective, and liability would likely be excluded[132].

The third and more complex situation occurs when, despite being developed with the most advanced technology and up-to-date programming, the autonomous system is still prone to some level of imperfection. It is recognized that autonomous systems, like those employed in ships, cannot be guaranteed to be completely safe or flawless. While such systems are designed to improve safety, the inevitable imperfections raise the question of whether these should be classified as defects, thus triggering liability. In these cases, the development risk defense may not fully protect the producer, as it is widely acknowledged that autonomous systems cannot be entirely risk-free, despite being developed using the most current and sophisticated knowledge[133].

An important legal concept that may offer a defense in these cases is the notion of system errors, a principle recognized in some legal traditions, particularly in Scandinavian countries. The idea behind this doctrine is that some products, despite carrying inherent risks, are accepted by society because the benefits they offer outweigh the risks[134]. For a manufacturer to be exempt from liability under this framework, the following conditions must be met: the risk must be unavoidable, it must be widely known, and it must be accepted by society. In the context of autonomous ships, this concept may be particularly relevant for dealing with situations where risks, while unavoidable, are broadly understood and accepted by society as a trade-off for the benefits technology provides. If the system error defense is applied, it could potentially exempt manufacturers or producers of autonomous ships or their software from liability when these unavoidable risks cause harm[135].

Thus, the concept of defectiveness under the Product Liability Directive allows for flexibility, particularly in the case of emerging technologies. The system error doctrine could provide an important defense in cases where the risks associated with autonomous systems are both known and accepted by society, offering manufacturers limited liability when damage results from these inherent, albeit unavoidable, risks[136].

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[132] G.M. Weinberg, *Perfect software and other illusions about testing*, New York, 2008, pag. 4-11.

[133] G.M. Weinberg, *op. cit.*, pag. 23-27.

[134] Swedish Product Liability Act (1992:18); see, also, Danish Product Liability Act, Consolidation Act No. 371 of 2002.

[135] E. Rajneri, *Relevance of Risk-benefit for Assessing Defectiveness of a Product: A Comparative Study of Thirteen European Legal Systems*, in *European Review of Private Law*, 2021, pag. 104-111.

[136] G. Wagner, *Liability Rules for the Digital Age – Aiming for the Brussels Effect*, in *Journal of European Tort Law*, 2023, pag. 191-243.

## V. COMPARATIVE LEGAL ANALYSIS OF LIABILITY REGIMES FOR AUTONOMOUS VESSELS: A CASE STUDY OF DENMARK AND ITALY

Comparing the national legal regimes of Denmark and Italy provides a multifaceted view of how different legal systems adapt to the complexities of autonomous vessels. This comparison is essential for understanding the broader implications of liability in this emerging field and will contribute to the ongoing development of a cohesive international legal framework for MASS. For shipowners, operators, insurers, and other stakeholders, understanding the liability frameworks in different jurisdictions is crucial. While both countries are likely to have liability frameworks influenced by similar international conventions, the practical application, enforcement, and local adaptations of these frameworks can differ. By comparing them, industry stakeholders can better anticipate potential legal risks and liabilities when operating in either country's waters.

### 1. *Liability Framework for Autonomous Vessels in Denmark: Legal Perspectives and National Adaptations*

Under Danish maritime law, the liability framework for shipowners is primarily fault-based, holding them accountable for damage resulting from their own negligent acts or omissions[137]. Section 151(1) of the Danish Merchant Shipping Act stipulates that a shipowner is liable for damage caused through fault or negligence by the master, crew members, pilot, or others performing work in the service of the ship[138]. This principle of employer liability is rooted in the Danish Law of King Christian V, specifically section 3-19-2, which establishes that an employer is responsible for damages caused by an employee during the course of their employment[139]. In the maritime context, this means that shipowners are vicariously liable for the actions of those in their employ or service, including remote operators of autonomous vessels[140].

Internationally, the Collision Convention governs liability in maritime collisions, apportioning fault between vessels based on their respective degrees of negligence. However, recent international conventions have shifted towards strict liability regimes, requiring shipowners to maintain mandatory insurance regardless of fault[141]. For fully autonomous vessels (autonomy level A), where navigation and operational decisions are made by autonomous systems without human intervention, the traditional fault-based liability model may become less applicable[142]. In such cases, it is anticipated that liability may shift towards a strict liability framework,

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137 T. Falkanger, H.J. Bull, L.B. Rosenberg Overby, *Søret*, Copenhagen, 2019, pag. 161 ff.

138 *Danish Merchant Shipping Act* (Consolidated Act No 73 of 17 January 2014) s 151(1).

139 *King Christian V's Danish Law* (1683) bk 3 ch 19 s 2.

140 T. Falkanger, H.J. Bull, L.B. Rosenberg Overby, *Søret*, cit.

141 *Supra* note 71; Danish Merchant Shipping Act pt 8.

142 For instance, reference may be made to Article 10 of the Nairobi International Convention on the Removal of Wrecks, 2007, which has been incorporated into Danish law through Part

similar to that applied in road traffic accidents under section 103 of the Danish Road Traffic Act[143].

Until such a shift occurs, shipowners will continue to be held to fault-based standards. In the context of autonomous vessels, this entails ensuring the appropriate maintenance and updating of navigation systems and adherence to design standards. Despite potential changes in liability norms, the shipowner is likely to remain the primary party liable for damages caused by their vessel, including those arising from the actions of remote operators or delegated representatives. This analysis underscores the importance of adapting existing liability frameworks to accommodate the unique challenges posed by autonomous maritime technology, ensuring that liability remains appropriately assigned and that stakeholders maintain adequate insurance coverage[144].

Due to the inherently perilous nature of maritime operations, particularly the susceptibility of shipping to adverse weather conditions and other natural forces, the industry has historically adopted a distinct approach to risk distribution and liability management. Consequently, shipowners have long enjoyed the right to limit or exclude liability, both with respect to specific categories of harm and fault, and through the imposition of monetary caps on liability[145]. This long-standing principle is enshrined in statutory provisions. For example, Part 13 of the Merchant Shipping Act, which implements the Hague-Visby Rules, regulates the limitation of liability concerning damage to cargo[146]. Additionally, Part 9 of the Act incorporates the 1976 LLMC, as amended by the 1996 Protocol, establishing a global limitation regime for a broad array of maritime claims[147].

Autonomous vessels fall within the legal definition of a "ship" under current regulatory frameworks. Accordingly, shipowners operating autonomous vessels are entitled to the same limitations of liability as those governing conventional vessels. The nature of the risks, such as collisions, groundings, cargo damage, personal injury, and environmental harm, remains fundamentally unchanged, thereby justifying the continued application of existing liability limitation provisions[148].

However, an important question arises as to whether this regime should also extend to remote operators, as well as to manufacturers and developers of autonomous navigation systems. Pursuant to Section 171 of the Merchant Shipping Act, reflecting Article 1 of the LLMC, the right to limit liability is not exclusive to

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8a of the Merchant Shipping Act, as well as Article III of the International Convention on Civil Liability for Oil Pollution Damage, 1992, implemented domestically via Part 10 of the same Act.

[143] *Danish Merchant Shipping Act* (Consolidated Act No 38 of 5 January 2017).

[144] J. Bredholt, J. Martens *et al.*, *Søloven*, Copenhagen, 2012, pag. 252-286.

[145] *The Role of Weather in Causing Maritime Accidents*, in *Maintenance and Cure*, October 5, 2023.

[146] *Merchant Shipping Act* (Consolidated Act No 73 of 17 January 2014) pt 13.

[147] *Merchant Shipping Act* (Consolidated Act No 73 of 17 January 2014) pt 9.

[148] M.M. Kamal, *Autonomous Vessels: Towards a New Phase in Maritime Transportation*, in *Power System Technology*, 2024, pag. 140-174.

shipowners. It also applies to charterers, managers, operators, salvors, and insurers, including P&I clubs, where they ensure liabilities that fall within the scope of the limitation regime[149].

Moreover, Section 171(2) expands the scope of protection to include "persons for whose acts the shipowner or other entitled parties are responsible," thereby encompassing crew members and other individuals, such as pilots, performing services on behalf of the shipowner[150]. By extension, remote operators may arguably fall within this category, as they perform analogous operational roles, albeit from shore-based locations. The focus of their activity, onshore rather than aboard the vessel, should not, in principle, preclude their inclusion under the liability limitation framework[151].

Nonetheless, this interpretation is not without legal uncertainty, particularly where remote operators are employed by independent third-party service providers rather than directly by the shipowner. This ambiguity highlights the necessity of establishing a clear international consensus regarding the liability status of remote operators within the context of the LLMC. Such clarity would be instrumental in supporting the safe and predictable integration of autonomous vessels into commercial shipping[152].

In contrast, it would be difficult to justify extending limitation of liability protections to manufacturers or software developers responsible for autonomous navigation systems. These actors are not generally considered to be under the operational control of the shipowner, nor are they typically engaged in the shipowner's service in a manner that would trigger vicarious liability. As such, they fall outside the class of persons entitled to invoke the protections afforded by the current liability limitation regime[153].

The liability of manufacturers and developers involved in the production of navigation systems for autonomous ships may arise under various legal doctrines and contractual arrangements[154]. In contractual relations with purchasers, typically shipyards or shipowners, the legal framework under Danish law subjects the

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[149] *Merchant Shipping Act* (Consolidated Act No 73 of 17 January 2014) s 171; Section 171 of the Danish Merchant Shipping Act reflects Article 1 of the 1976 Convention on Limitation of Liability for Maritime Claims (LLMC) because it implements the personal scope of application established by the Convention into Danish national law.

[150] *Merchant Shipping Act* s 171(2).

[151] Remote operators may be considered functionally equivalent to crew or pilots for the purposes of liability limitation. Since Section 171(2) focuses on legal responsibility rather than physical presence, and since remote operators act on behalf of the shipowner in an operational capacity, there is a strong basis to argue their inclusion within the liability limitation regime.

[152] D. Kim, C. Lee *et al.*, *Potential Liability Issues of AI-Based Embedded Software in Maritime Autonomous Surface Ships for Maritime Safety in the Korean Maritime Industry*, in *Journal of Marine Science and Engineering*, 2022, pag. 9-10.

[153] C. Zulueta Solera, *An Evaluation of the Shipowner's Liability Challenges arising out of Autonomous and Remote-Controlled Vessels Are these new issues covered under P&I insurance?*, Oslo, 2020, pag. 14-16.

[154] L. Chen, *Maritime rights, obligations, and liabilities of intelligent ships from the perspective of risk distribution*, in *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, 2023, Vol. 7, Issue 4, pag. 4-11.

delivered systems to the rules governing defective performance under the law of sales. In this context, liability for defects cannot generally be contractually limited unless such limitation is expressly stipulated in the agreement. Where such defects do not result in harm to persons or third-party property but relate solely to the product itself, they fall within the scope of the manufacturer's or developer's business risk. These risks are often uninsurable and are regarded as inherent to commercial operations[155].

Beyond contractual obligations, general principles of obligations law impose duties on shipowners to inspect, maintain, and ensure the functionality of onboard equipment. Nevertheless, should defective autonomous systems cause personal injury or property damage, manufacturers and developers may incur liability under applicable product liability regimes. Product liability remains predominantly regulated at the national level, with significant variation across jurisdictions[156]. However, within the European Union, the Product Liability Directive, along with its interpretative case law, has introduced a degree of harmonization. In Danish law, the directive has been transposed through the Product Liability Act and further supplemented by non-statutory principles developed through case law. These principles are expected to apply equally to autonomous maritime systems, thereby subjecting their producers to potential liability for harm caused by their products[157].

In some circumstances, manufacturers and developers may also be exposed to liability analogous to that of professional advisers. Where they are deemed to have provided independent advice alongside their technical products or services, liability may arise under a regime of strict fault (culpa), reflecting a heightened standard of care applicable to advisory roles[158]. The extent of contractual liability assumed by manufacturers and developers is largely shaped by the principle of contractual freedom. Accordingly, liability, both in terms of types of loss and financial caps, is typically determined through negotiation and will reflect the relative bargaining positions of the parties. However, any agreed limitation must comply with legal constraints on liability exclusion, including applicable rules on the choice of law[159]. Under Danish law, such contractual limitations are only enforceable where they meet the relevant statutory requirements. In the absence of a contractual agreement, Danish law does not permit manufacturers or developers to unilaterally limit their liability[160].

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[155] *Danish Sale of Goods Act* (Købeloven, Consolidated Act No 140 of 17 February 2014) ss 17 et seq, ss 74 et seq.; Ss 74 et seq. address liability for defects in delivered goods, while ss 17 et seq. discuss conformity of goods, and when a good is considered defective.

[156] See *Merchant Shipping Act* s 30, 63, 106; see also *Danish Sale of Goods Act* s 74, 76.

[157] Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, transposed into Danish law through the product liability act (consolidated act no. 261 of 20 March 2007).

[158] B. von Eyben, H. Isager, *Lærebog i erstatningsret*, Copenhagen, 2024, pag. 119 ff.

[159] B. von Eyben, H. Isager, *Lærebog i erstatningsret*, cit., pag. 489 ff.

[160] Danish law provides a foundation for the exemption or limitation of liability in certain circumstances through Section 24 of the Liability in Damages Act (Consolidated Act No. 266

The potentially broad scope of exposure, comprising both direct claims from injured parties and recourse claims from shipowners or shipyards, is compounded by the absence of historical data on the operational performance of autonomous ships. This legal uncertainty may adversely affect the insurability of these risks. In particular, the difficulty in securing adequate insurance coverage or the prospect of prohibitively high premiums could constitute a significant obstacle to the commercial deployment of autonomous maritime technologies[161]. The limited legal scholarship addressing liability for machine learning and autonomous systems, primarily focused on autonomous vehicles, tends to advocate for a cautious and adaptive regulatory approach. Rather than imposing a definitive liability regime at an early stage, scholars suggest prioritizing regulation of the training and testing processes of machine learning models until the technologies reach greater maturity[162].

Additionally, the deployment of autonomous systems raises significant ethical and legal challenges relating to accountability and safety. It is likely that technology providers will be required to comply with: (i) data retention and sharing obligations to enable post-incident analysis; (ii) rigorous standards governing the design, development, and testing of autonomous systems, including accompanying documentation; (iii) ethical programming considerations embedded within algorithmic decision-making. These requirements will play a critical role in shaping a future regulatory framework that balances innovation with legal responsibility and public trust[163].

### 2. *Liability for Autonomous Vessels under Italian Law: A National Perspective*

The European Parliament, in its Resolution of 16 February 2017 containing recommendations to the Commission regarding Civil Law Rules on Robotics, articulates in paragraph 24 that "autonomous transport" encompasses all modalities of remotely controlled, automated, connected, and autonomous transportation, including but not limited to road, rail, maritime, and air systems. This broad categorization includes vehicles, trains, vessels, ferries, aircraft, drones, and any future innovations or developments within the transport sector[164]. Before addressing the legal implications of civil liability for damage caused by unmanned or autonomous vessels, it is first necessary to establish whether such vessels fall within the legal

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of 21 March 2014, as amended). This provision applies to both contractual and non-contractual liability, although it has been infrequently utilized in business contexts.

[161] P. Y. Kim, *Where We're Going, We Don't Need Drivers: Autonomous Vehicles and AI-Chaperone Liability*, in *Catholic University Law Review*, 2020, Vol. 69, Issue 2, pag. 354-362.

[162] C. Reed, E. Kennedy, S. Silva, *Responsibility, Autonomy and Accountability: Legal Liability for Machine Learning*, Queen Mary School of Law Legal Studies Research Paper No. 243/2016, 2016, pag. 26 ff.

[163] C. Reed, E. Kennedy, S. Silva, *Responsibility, Autonomy and*, cit., pag. 26 ff.

[164] European Parliament, *Resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics*, (2017) P8_TA (2017)0051, para 24.

definition of a "ship" under applicable law. In this regard, Article 136(1) of the Italian Navigation Code provides that "a ship is any seagoing vessel and seaborne craft built or adapted for use as a means of transport, for towing, fishing, for recreation or for any other purpose." This definition serves as the foundational criterion for determining whether autonomous maritime units can be classified as ships under Italian law[165].

One of the more intricate legal challenges posed by the emergence of unmanned vessels pertains to the attribution of civil liability in cases of damage or loss, particularly in maritime collisions[166]. The regulation of ship collisions has long been the subject of international legal frameworks, most notably the Brussels Collision Convention of 1910, which was incorporated into Italian law through Law No. 606 of 12 June 1913, entering into force on 2 July 1913[167]. Italy has implemented the provisions of this Convention into domestic law through Articles 482 to 488 of the Italian Navigation Code, which form part of the national Navigation Rules. Importantly, the Convention's rules are applicable not only to collisions involving sea-going vessels but also to incidents involving inland waterway vessels, provided that the vessels involved are registered in different states, irrespective of where the collision occurred[168].

Moreover, the principle of proportional liability in maritime collision cases is explicitly addressed in Articles 482 and 483 of the Italian Navigation Code, which allocate responsibility based on the degree of fault attributable to each vessel involved[169]. In particular, article 482 of the Italian Code of Navigation establishes that when a maritime collision results from an unforeseeable event or force majeure, and the cause cannot be ascertained, the parties involved bear their own damages. This provision underscores the principle that liability is not assigned when the incident arises from circumstances beyond control or when causation is indeterminable[170]. Italian legal scholarship emphasizes that this provision constitutes a derogation from the general rule of Article 2043 of the Civil Code, eliminating the inquiry into fault when the event is entirely beyond human control[171]. It almost literally incorporates Article 2 of the 1910 Brussels Convention, a choice which, as Berlingieri observes, responds to the need to harmonize the regime of maritime collisions at the international level[172].

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[165] Codice della Navigazione (RD 30 marzo 1942, n. 327), art. 136(1).

[166] A. Xerri, *Riflessioni in tema di responsabilità nel contesto dell'automazione navale*, in *Diritto dei Trasporti*, pag. 551-556; see also C. Severoni, *Automazione e responsabilità nella navigazione marittima*, in *Riv. Dir. dell'Economia, dei Trasporti e dell'Ambiente,* 2025, pag. 315-354.

[167] Legge 12 giugno 1913, n. 606, di esecuzione della Convenzione di Bruxelles del 23 settembre 1910 per la unificazione di alcune regole in materia d'urto fra navi.

[168] S. Pollastrelli, *La Convenzione di Bruxelles del 1910 in materia di urto di navi. Legge applicabile e competenza giurisdizionale*, in this *Journal*, 2010, pag. 799-803.

[169] S. Pollastrelli, *op. cit.*, pag. 802.

[170] *Supra* note 153, art. 482.

[171] A. Lefebvre d'Ovidio, G. Pescatore, L. Tullio, *Manuale di diritto della navigazione*, Milano, 2016, pag. 215-220.

[172] *Supra* note 156.

Pollastrelli distinguishes between the two categories of fortuitous event and force majeure, while acknowledging that they produce the same exonerating effects. Force majeure is described as an external event, absolutely irresistible even if foreseeable (e.g., an earthquake or a sudden act of war); fortuitous event, on the other hand, is an unforeseeable and unavoidable occurrence that may also arise from within the navigation activity itself, such as an unforeseeable technical failure not attributable to defective maintenance. The distinction, more theoretical than practical, is relevant in terms of evidence, since force majeure displays a more pronounced element of externality[173]. A distinctive case is when it is not possible to ascertain the cause of the collision: in such an event, the law requires each party to bear its own damage. Legal scholarship specifies that a mere lack of evidence is not sufficient: it must be shown that the impossibility of ascertaining the cause is objective and does not result from the parties' negligence (e.g., failure to preserve onboard data, omission of radar recordings). Otherwise, the judge may apply Articles 483-484 od the Italian navigation code[174].

According to established doctrine, the burden of proving that a fortuitous event, force majeure, or unknown cause has occurred lies with the party invoking the exemption. Pollastrelli insists on a strict interpretation: it is not sufficient to merely lack evidence of another's fault; one must also demonstrate one's own diligent conduct and the objective impossibility of reconstructing the event, in application of Article 2697 of the Italian Civil Code[175]. Article 482 represents an express derogation from the general tort principle of Article 2043 of the Civil Code. However, if the technical investigation reveals even minimal fault on the part of a ship, the ordinary rules apply again: Article 483 for exclusive fault and Article 484 for shared fault. Doctrine describes this as a system of 'concentric circles,' where Article 482 operates only as an ultima ratio[176].

Article 483 establishes a principle of unilateral fault liability, holding the vessel at fault solely responsible for the damages incurred. This provision underscores the application of extra-contractual liability in maritime law, where the burden of proof lies with the injured party to demonstrate the fault of the other vessel. The fault may be attributed to the shipowner, master, crew members, or even the pilot if present and performing their duties[177]. Several authors point out that Article 483 is a 'special provision' that embodies in the maritime sector the principle of liability for

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[173] S. Pollastrelli, *L'Urto di navi*, in A. Antonini (a cura di), *Trattato breve di diritto marittimo*, vol. III: *Le obbligazioni e la responsabilità nella navigazione marittima,* Milano, 2010, pag. 250-255.

[174] M. Deiana, *Commento agli artt. 482-484 c. nav.,* in *Commentario breve al Codice della navigazione,* Cedam, Padova, 2010, pag. 1450-1460.

[175] S. Pollastrelli, *L'Urto di navi*, cit., pag. 255-257.

[176] A. Lefebvre d'Ovidio, G. Pescatore, L. Tullio, *Manuale di diritto della navigazione*, cit., pag. 210-212.

[177] *Supra* note 153, art. 483. For a commentary on Articles 482 and 483 of the Italian Navigation Code, see Studio Legale Menghetti, *Responsabilità nel sinistro tra navi*, Studio Legale Menghetti, 25 November 2020.

unlawful acts as set forth in Article 2043 of the Italian Civil Code, that is, when an unjust damage is caused by intentional or negligent conduct, the party responsible is obliged to compensate. This translates in the context of ship collisions into a specific rule for unilateral fault[178].

Doctrine holds that it is the injured party's burden to prove that the collision occurred due to the fault of one of the ships, and that this fault is real and attributable; mere suspicion or a lack of evidence is insufficient. Technical evidence is often required, including nautical expert reports and objective data such as routes, speed, weather conditions, manoeuvres, logs, and AIS data. Fault can be attributed to various parties involved in the management or operation of the ship: the shipowner as the ultimate responsible party, the captain, crew members, and the pilot if present and active. All these parties may be held accountable if their conduct contributed to the collision[179]. In a ruling by the Court of Appeal of Naples (May 28, 2025, No. 2713), the court found that the captain had failed to use the radar, which remained on standby, and that navigation was being conducted solely by visual observation. As a result, the court attributed exclusive liability to the ship, applying the specific rules on unilateral fault under Article 483 of the Italian Navigation Code. This decision illustrates the strict application of maritime safety obligations and underscores that failure to employ proper navigational instruments, even when other ships or environmental conditions are present, constitutes clear negligence triggering full liability[180].

Italian legal doctrine on Article 483 of the Code of Navigation emphasizes the importance of clearly distinguishing between fault, incompetence, and unavoidable error, noting that not every negative event caused by an operator automatically constitutes fault. The conduct of the party involved must be assessed in light of the required standard of diligence, taking into account the specific circumstances of the event and the operational context in which it occurred. Particular attention is given to cases where evidence is incomplete or fragmentary: scholars stress the need for thorough and rigorous expert investigations to avoid confusing incidents that should fall under Article 482, concerning fortuitous events or indeterminate causes, with those governed by Article 483, where the fault of a vessel is clearly determinable.

Furthermore, doctrine highlights that the required level of diligence is not uniform but varies depending on multiple factors, such as the type of vessel involved, environmental and weather conditions, the size and complexity of the ship, the nature of the mission, and prevailing nautical practices. This nuanced assessment ensures a balance between protecting the injured party and correctly determining the responsibility of the navigator[181].

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[178] S. Pollastrelli, *L'Urto di navi*, cit., pag. 251-252.

[179] Studio Legale Trimboli, *Collisioni marittime e criteri di responsabilità nella disciplina del Codice della Navigazione.*

[180] Court of Appeal of Naples, Judgment No. 2713, May 28, 2025.

[181] L. Tullio, *Responsabilità del vettore nel trasporto marittimo di cose,* in A. Antonini (a

Article 3 and 4 of the 1910 Brussels Collision Convention, as well as Article 484 of the Italian Navigation Code, establish a principle of fault-based liability in maritime collisions. According to this framework, any vessel found to be at fault is required to compensate the other party for damages, in proportion to its degree of culpability[182]. While the Navigation Code refers to the "ship in fault," Italian jurisprudence has clarified that liability is not attributed to the vessel as an object, but rather to individuals responsible for its operation, namely, the shipowner (armatore), master, or crew[183]. An exception to this rule arises where the incident results from a fortuitous event, force majeure, or if the cause of the collision cannot be determined. In such cases, each party bears its own losses, as provided under Article 482 of the Italian Navigation Code, a provision which aligns with Article 2 of the Brussels Convention[184].

According to prevailing doctrine, Article 484 of the Italian Navigation Code falls within the framework of noncontractual liability, establishing that, in the presence of shared fault, each ship is liable in proportion to the severity of its own fault and the extent of the resulting consequences. If it is not possible to determine this proportion, compensation is owed in equal parts. For damages resulting from death or personal injury, the ships at fault are jointly liable for the compensation[185].

However, Italian legislation has chosen to depart from the regime established by the Brussels Convention. According to Article 484 of the Italian Navigation Code, the apportionment of liability must take into account not only the degree of fault but also the extent of the resulting consequences, insofar as they are causally connected to the respective fault. In contrast, Article 4 of the Convention stipulates that apportionment should be based solely on the gravity of the fault ("*S'il ya faute commune, la responsabilité de chacun navires est proportionelle à la gravité de sa faute*"). Questions have arisen regarding this approach, because the concept of gravity can be interpreted in two ways: subjectively, concerning the behavior of the parties, or objectively, concerning the outcomes of that behavior[186].

In response to these concerns, the SousCommission established by the Conference intervened and modified the provision: "*S'il ya faute commune,*

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cura di), *Trattato breve di diritto marittimo*, vol. II: *Contratti di utilizzazione della nave e la responsabilità del vettore.* Milano, 2008, pag. 186-189.

[182] *Supra* note 153, art. 484.

[183] In the case of *Navigazione Libera Triestina v. Garcia Maggini*, the court held that the shipowner is liable for damages resulting from a collision caused by the fault of the master or crew. The court emphasized that the shipowner cannot evade responsibility by attributing fault solely to the vessel, underscoring the personal accountability of those operating the ship. Similarly, in *Owens v. Italia Società Per Azione Navigazione-Genova*, the court found the shipowner liable for damages caused by the negligence of the ship's officers. The decision reinforced the notion that liability stems from the actions of individuals in charge of the vessel, rather than the vessel itself.

[184] *Supra* note 153.

[185] TrovaLegge, *Art. 484 Codice della Navigazione – Urto per colpa commune.*

[186] R. Melone Mastrosimone, *Urto di navi: disciplina vigente e prospettive di riforma*, (Tesi di laurea in Diritto della Navigazione, Dipartimento di Giurisprudenza, Università degli Studi di Genova, Anno Accademico 2023/2024), pag. 37.

*la responsabilité de chacun des navires est proportionelle à la gravité des fautes respectivement commises et à leurs conséquences; totutefois si la proportion ne peut etre établie, ou si les fautes apparaissent comme équivalentes, la responsabilité est partagée par parts égales.*" Nonetheless, even this revision prompted debate. Critics noted that only the consequences directly linked to the event itself should be considered, rather than the resulting damages. Consequently, the words "respectivement commises" were removed from the text, while maintaining the principle that the judge may evaluate both aspects of fault, considering both its subjective and objective dimensions[187].

This legal structure reflects a fault-based tort liability system, under which responsibility for damage is assigned only where there is demonstrable intentional or negligent conduct on the part of those legally accountable. However, liability may be excluded if the responsible party can establish the existence of unforeseeable circumstances or force majeure sufficient to break the causal chain between their conduct and the resulting harm[188].

In case an accident is caused by software or hardware malfunction, liability of software manufacturers or programmers for damage resulting from a defective product arises solely within the framework of statutory provisions, originally established by Council Directive 85/374/EEC on product liability[189]. Pursuant to Article 104 of Legislative Decree No. 206/2005 (Italian Consumer Code), producers are under a legal obligation to place on the market only products that meet safety standards. Consequently, they may be held liable for any harm resulting from the sale of defective goods[190]. Under the Italian legal framework, liability for defective products is strict in nature, meaning that establishing the producer's fault is not a prerequisite for compensation. Instead, liability is grounded solely in the existence of a causal nexus between the product's defect and the damage suffered. As a result, a manufacturer of, for instance, a collision-avoidance system would be required to compensate the injured party for any losses arising from the failure or malfunction of that system[191].

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[187] R. Melone Mastrosimone, *op. cit.,* pag. 37.

[188] This concept aligns with general principles of tort law, as well as with specific provisions in the Italian legal system. Under articles 1218 and 1256 of the Italian Civil Code, a debtor is liable for damages unless they can prove that non-performance was due to impossibility caused by factors not attributable to them, such as force majeure or unforeseeable circumstances. In the maritime context, the Italian Navigation Code incorporates similar principles. Articles 482 and 483 address liability in maritime collisions, establishing fault-based liability and specifying conditions under which liability may be excluded, such as in cases of force majeure or when the cause of the collision cannot be determined.

[189] Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, [1985] OJ L210/29, art 1.

[190] Legislative Decree No. 206 of 6 September 2005 (Consumer Code), art. 104.

[191] M. Lombardi, G. Novellini, *Product Liability Law In Italy*, in *Mondaq,* 30 November 2012; several key decisions by Italian courts have elucidated the application of this principle. See for instance *Cassazione civ., Sez. III, 21 February 2017, No. 4443*. This judgment reaffirmed

The central issue is whether the damaged party will be entitled to claim directly against the manufacturer, or if only the shipowner will have the right to pursue action against the manufacturer. Italian case law establishes that any individual who suffers harm due to a defective product, whether a direct user or an unintended bystander, is entitled to seek damages from the manufacturer[192]. Both the shipowner and the cargo owner, who incur damages as a result of a collision, may claim compensation from the producer of the collision-avoidance system to recover their financial losses[193]. However, it is important to note that while unmanned vessels remain in an experimental phase, the manufacturer may be exempt from liability under Article 118, letter E, of Legislative Decree No. 206/2005, which stipulates that the producer may be absolved of responsibility if the prevailing state of knowledge at the time the product was marketed did not allow the producer to identify the product as defective[194].

## VI. CONCLUSION

This study displayed that despite the presence of international regulations dealing with and addressing liability in autonomous vessels, there are significant legal gaps, particularly concerning responsibilities traditionally assigned to human crew and masters. The rise of autonomy challenges definitions such as "master," "crew," and "seafarer." For example, COLREGs rely heavily on human judgment for collision avoidance, raising doubts about their application to AI-operated vessels.

In addition, although the EU aligns its maritime regulations with the international instruments, its current legal framework does not specifically address the unique liability issues posed by autonomous vessels. Instead, liability is governed indirectly through general maritime, product, and tort law frameworks, such as the Product Liability Directive, the EU AI Act and national civil codes. The lack of a dedicated EU framework creates fragmentation and legal uncertainty across Member States, particularly concerning cross-border incidents and third-party claims. Interaction with the international regime remains limited, largely because existing conventions have not been revised to accommodate full autonomy. As a result, the EU's functional equivalence approach, ensuring that autonomous

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the strict liability regime for defective products under Italian law. The Court confirmed that a manufacturer could be held liable for damage caused by a defect in its product without the need to prove fault, emphasizing the principle that the existence of a defect and a causal link between the defect and the harm is sufficient to establish liability.

[192] See for instance *Cass. civ. Sez. III, 15 February 2012, No. 2184.* In this case, the Italian Supreme Court confirmed that both direct users and third parties (bystanders) who suffer harm due to a defect in a product can seek compensation from the manufacturer. The Court emphasized the strict liability regime established by the Italian Consumer Code, which holds manufacturers liable for damages resulting from defects in their products, regardless of the manufacturer's fault.

[193] K. Taheri, *Limitation of Liability for Maritime Claims: Multiple Perspectives and Legal Implications*, Lund, 2013, pag. 52-61.

[194] Legislative Decree No. 206/2005, Art. 118, lett. E.

operations meet existing safety obligations, can only be addressed so far in resolving liability dilemmas. As far as I am concerned, I believe the EU should develop a unified legal instrument that explicitly governs MASS liability. This should include strict liability models, recognize the role of remote operators and system developers, and mandate insurance coverage. Most critically, it must be designed to interface smoothly with any future amendments to international conventions, allowing for mutual recognition and harmonization.

Then, the analysis showed how the Italian and Danish legal frameworks for liability concerning autonomous vessels reflect differing legal traditions and levels of adaptation to emerging technologies. Denmark has a more flexible approach due in part to its integration of strict product liability principles. The Danish Product Liability Act, which incorporates the EU Product Liability Directive, allows for liability without fault when a product is proven defective. Moreover, Danish legal doctrine recognizes the concept of "system errors", where producers may avoid liability if the risk is unavoidable, widely known, and socially accepted. This recognition of inherent risks in advanced technologies offers a more nuanced liability model suited for autonomous maritime systems. Italy operates under a civil law system, meaning that liability rules are primarily based on codified statutes rather than case law. This establishes a fault-based liability regime, where the injured party must prove that the damage was caused by a wrongful act attributable to the defendant, and that it involved negligence or intent. In the context of autonomous vessels, applying this traditional liability model becomes problematic. Because these vessels operate with minimal or no human input, often relying on AI and autonomous navigation software, it becomes difficult to identify a liable party based on human fault. For instance, if a vessel causes damage due to a software malfunction or an unexpected AI decision, it may not be clear whether the fault lies with the shipowner, the software developer, the shipbuilder, or another party in the supply chain.

The transition to MASS shows a transformative shift in the maritime sector, promising enhanced efficiency, safety, and sustainability. However, it also introduces a host of complex legal questions, particularly in the domain of liability. Traditional maritime liability frameworks, designed for vessels under direct human command, are poorly equipped to address scenarios involving autonomous decision-making, remote operations, and artificial intelligence. The lack of a human crew complicates the attribution of fault, raises questions about the legal status of software and remote operators, and exposes significant gaps in the current legal architecture. To ensure that the adoption of MASS does not outpace the evolution of legal protections and responsibilities, a reimagining of liability regimes is essential. One of the most viable solutions is the development of a dedicated international liability framework for autonomous vessels. This could take the form of a strict or no-fault liability model, wherein the shipowner or operator is held liable for incidents regardless of fault. Such an approach would provide legal certainty and ensure that victims receive timely compensation without the burden of proving negligence, a principle already seen in environmental and hazardous goods regimes.

Equally important is the clear legal recognition and regulation of new actors in the maritime liability chain, such as software developers, manufacturers, and remote-control operators. Assigning legal responsibilities to these entities will help distribute accountability fairly and align with the realities of MASS operations. Complementary to this, mandatory liability insurance should be introduced for autonomous vessels, ensuring financial coverage in the event of damage or loss and encouraging adherence to safety and operational standards. Technological safeguards should also play a pivotal role in enhancing legal clarity.

Finally, the effectiveness of any liability reform depends on international coordination. Divergent national rules would create legal uncertainty, impede cross-border operations, and diminish the efficiency gains that MASS are poised to deliver. In conclusion, while the legal challenges introduced by MASS are both novel and complex, they are not insurmountable. With a combination of legal innovation, regulatory foresight, technological support, and international cooperation, the maritime community can build a fair, coherent, and future-ready liability framework. Such a system will be vital in enabling the safe, sustainable, and legally sound integration of autonomous vessels into global shipping operations.

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