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AUTONOMOUS SHIPS – LEGAL CHALLENGES AND SOLUTIONS FOR DATA SHARING

Master's Thesis
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Tiivistelmä - Referat – Abstract

The purpose of this study is to research legal challenges and solutions for data sharing with autonomous ships. Autonomous ships store and share a significant amount of data, and data sharing occurs between various parties with autonomous ships. The aim of this study is to analyze and examine the legal challenges and solutions related to different types of data sharing activities in autonomous shipping, as well as to research the general legality of autonomous ships.

The first part of this study is to study how well autonomous ships fit into the existing legislative framework. The existing legislative framework is mainly based on IMO conventions, and the purpose of this study is to research those conventions from the perspective of autonomous ships. Based on this research, amendments are proposed when necessary to better support the legality and development of autonomous ships. In addition to the IMO conventions, other relevant sources, such as guidelines on MASS trials, are examined to highlight guidance on the development of autonomous ships. The legal analysis on IMO conventions and other sources shows that as the level of autonomy of a ship increases, the more challenging the ship is for the legal framework. Several conventions directly mention the need for a master and crew to be physically present on board, and various watchkeeping duties are required to be performed by human senses. Regarding the use of human senses, a legal argument can be made to accept technological means as long as they are at least equally functional than human senses. For remotely controlled ships, a legal question is whether a master and crew can operate from the SCC and how well this satisfies the requirement to operate on board. Recommended action is to amend those IMO conventions that require physical human presence and decision-making to accept the lack of manned crew and the presence of autonomous decision-making. However, technical requirements are recommended to be included in the legal amendments to the conventions to ensure a high level of safety and functionality.

The second part of the thesis examines legal challenges and solutions for data sharing with autonomous ships. First, a factual assessment of data sharing principles with autonomous ships are described and discussed, and afterwards a legal analysis is conducted. The legal analysis on data sharing and autonomous ships examines what kind of legal challenges exist with data sharing and autonomous ships and how to solve them by legal solutions. Cyber security is a key challenge with autonomous ships, and its role in data sharing is analyzed and requirements to have robust cyber security systems are recommended. For operational data sharing, the issue of ensuring a functional data flow is necessary. Autonomous ships should be legally required to have strong data sharing and connectivity capabilities in order to comply with requirements to share information. Also, this requirement is to achieve as safe and functional navigation as possible. The role of ship-to-ship and ship-to-port data sharing are examined, and legal requirements should facilitate their maximal utilization. At the end of this study, a contractual framework is applied by using the Sitra Rulebook on data sharing in order to illustrate how contractual means can support data sharing with autonomous ships.

Avainsanat – Nyckelord – Keywords
autonomous ships, IMO, maritime industry, data sharing, cyber security

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Tiivistelmä - Referat – Abstract

Tämän tutkimuksen tarkoituksena on tutkia autonomisten laivojen datan jakamiseen liittyviä juridisia haasteita ja ratkaisuja. Autonomiset laivat keräävät ja jakavat merkittävän määrän dataa, ja tätä datan jakamista tapahtuu eri osapuolten välillä autonomisessa merenkulussa. Tämän tutkimuksen tarkoituksena on analysoida ja tutkia millaisia juridisia haasteita ja ratkaisuja liittyy erilaisiin datan jakamisen aktiviteetteihin autonomisessa merenkulussa sekä tutkia autonomisten laivojen yleistä lainmukaisuutta.

Tämän tutkimuksen ensimmäinen osa perehtyy siihen, miten hyvin autonomiset laivat mukautuvat nykyiseen juridiseen viitekehykseen. Olemassa oleva juridinen viitekehys koostuu pääosin IMO:n kansainvälisistä sopimuksista ja tämä tutkimus tutkii näitä sopimuksia autonomisen merenkulun näkökulmasta. Tämä tutkimus esittää tarvittavia muutoksia sopimuksiin. IMO:n sopimusten lisäksi muita relevantteja lähteitä tutkitaan, kuten ohjesääntöjä autonomisten alusten testeihin. IMO:n sopimusten juridisen analyysin perusteella aluksen autonomisuuden tason kasvaessa juridinen haasteellisuus lisääntyy. Jotkut sopimukset mainitsevat suoraan vaatimuksia laivan kapteenille ja miehistölle fyysiseen päivystämiseen aluksen kannella. Sopimukset viittaavat ihmisaisteihin ja juridinen kysymys on, missä määrin teknologisia keinoja voidaan käyttää samoihin tehtäviin. Juridinen argumentti voidaan esittää, minkä mukaan näitä teknologisia keinoja voidaan käyttää olettaen, että niiden suorituskyky on vähintään samalla tasolla ihmisaistien kanssa. Kauko-ohjattavien alusten osalta juridinen kysymys on, voidaanko hyväksyä järjestely, jossa aluksen kapteeni ja miehistö toimivat maasta käsin ja missä määrin tämä vastaa juridisiin velvoitteisiin operoida aluksella. Tutkimus suosittelee muutoksia IMO:n sopimuksiin, jotka liittyvät laivalla fyysisesti olemiseen sekä päätösprosessissa ihmisen rooliin. Teknisiä autonomisten laivojen suorituskykyyn liittyviä vaatimuksia suositellaan sisällyttämään juridiseen muutosprosessiin.

Tämän tutkimuksen toinen osa keskittyy autonomisten laivojen datan jakamiseen liittyviin juridisiin haasteisiin ja ratkaisuihin. Ensin esitellään datan jakamisen toiminnot ja periaatteet autonomisilla laivoilla, minkä jälkeen toteutetaan juridinen analyysi. Analyysi perehtyy siihen, millaisia juridisia haasteita voidaan havaita ja miten näitä voidaan ratkaista juridisin keinoin. Kyberturvallisuus on merkittävä haaste autonomisilla laivoille, minkä takia sen roolia datan jakamisessa tutkitaan ja suositellaan sisällytettäväksi kansainvälisiin sopimuksiin ja ohjesääntöihin. Operatiivisen datan jakamisen näkökulmasta teknisen suorituskyvyn ja datan jakamisen sujuvuuden varmistaminen on välttämätöntä. Autonomisilta laivoilta suositellaan vaadittavan riittävää kapasiteettia tehokkaaseen ja sujuvaan datan jakamiseen, jotta autonomiset alukset voivat toteuttaa datan jakamiseen liittyviä velvoitteita sekä saavuttamaan mahdollisimman turvallista ja toimivaa merenkulkua. Aluksesta alukseen sekä aluksesta satamaan tapahtuvaa datan jakamista tutkitaan ja juridisten velvoitteiden tulisi tukea tätä kehitystä. Tämän tutkimuksen lopussa käytetään Sitran datan jakamisen ohjekirjaa, jonka avulla esitetään, miten sopimuksellisin keinoin voidaan tukea ja toteuttaa toimivaa datan jakamista autonomisilla laivoilla.

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autonomiset laivat, IMO, meriteollisuus, datan jakaminen, kyberturvallisuus

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Table of Contents

Bibliography

Legislation, legislative preparatory works and principles

International

IMO

SOLAS Convention

IMO, *International Convention for the Safety of Life At Sea*, 1 November 1974, 1184 UNTS 3.

ISM Code

IMO, *International Safety Management Code (ISM Code) and Guidelines on the Implementation of the ISM Code*, 1997.

STCW Convention

IMO, *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers*, 7 July 1978, 1361 UNTS 2.

COLREG Convention

IMO, *Convention on the International Regulations for Preventing Collisions at Sea*, 15 July 1977, 1051 UNTS 16.

MARPOL Convention

IMO, *The International Convention for the Prevention of Pollution from Ships, amend.* 17 February 1978, 1340 UNTS 61.

SAR Convention

IMO, *International Convention on maritime search and rescue*, 27 April 1979, 1405 UNTS 1.

MSC 99

IMO Maritime Safety Committee (MSC), 99th session 16-25 May 2018.

MSC 100

IMO Maritime Safety Committee (MSC), 100th session 3-7 December 2018.

MSC 101
IMO Maritime Safety Committee (MSC), 101st session 5-14 June 2019.

MSC 102
IMO Maritime Safety Committee (MSC), 102nd session 4-11 November 2020.

Maritime Cyber Risk Management in Safety Management Systems
IMO Resolution MSC. 428(98) Annex 10, 2017.

Guidelines for Vessel Traffic Services (2017)
IMO, Resolution A.857(20), 2017.

UN

UNCLOS
UN General Assembly, *Convention on the Law of the Sea*, 10 December 1982.

Vienna Convention
UN, *Vienna Convention on the Law of Treaties*, 23 May 1969, Treaty Series vol. 115, 331.

EU

GDPR
EU General Data Protection Regulation (GDPR): Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), OJ 2016 L 119/1.

VTMIS Directive
EU, Directive 2009/17EC

Single Windows Directive
EU, Directive 2010/65/EU

Shipowner Insurance Directive
EU, Directive 2009/20/EC

Product Liability Directive
EU, Directive 85/374/EEC

Other

Hague-Visby Rules

The International Convention for the Unification of Certain Rules of Law Relating to Bills of Lading, 25 August 1924.

National Statutory Law

UK

The Merchant Shipping (Safe Manning, Hours of Work and Watchkeeping) Regulations 1997, No. 1320

Singapore

Merchant Shipping (Training, Certification and Manning) Regulations 1998 (Singapore)

Case Law

England & Wales

McFadden v Blue Star Line [1905] 1 KB 697

Hong Kong Fir Shipping Co v Kawasaki Kisen Kaisah [1961] EWCA Civ 7

India v West Coast SS Co (The Portland Trader) [1964]

MV Herald of Free Enterprise: Report of Court No. 8074 [1987]

Governmental Reports, Programs and Publications

AUTOSHIP - Autonomous Shipping Initiative for European Waters, 2019

BOURBON Smart Shipping Program, 2019

Danish Maritime Authority (2017)

Danish Maritime Authority, (2017). 'Analysis of Regulatory Barriers to the Use of Autonomous Ships', 1-105.

DIMECC, (2021). SMARTER Project

EMSA (2020)
European Maritime Safety Agency (EMSA), (2020). Annual Overview of Marine Casualties and Incidents 2020

EU MASS Guidelines
EU Operational Guidelines for Safe, Secure and Sustainable Trials of Maritime Autonomous Surface Ships (MASS) [2020] Version 1.

European Strategy for Data (2020)
EC, (2020). A European Strategy for Data, COM/2020/66

E-Navigation strategy implementation plan (2018)
IMO, (2018). (MSC.1/Circ.1595)

FAL Guidelines
IMO (2017). MSC-Fal.1/Circ.3 5 July 2017 Guidelines on Maritime Cyber Risk Management.

IAMSAR
IMO, (2019). ‘Amendments to the International Aeronautical and Maritime Search and Rescue (IAMSAR) manual.

IMO Interim Guidelines for MASS Trials (2019)
IMO (2019), Interim Guidelines for MASS Trials, MSC.1/Circ.1604.

Liability for AI Report (2019)
EC, (2019). ‘Liability for Artificial Intelligence’ *Report from the Expert Group on Liability and New Technologies - New Technologies Formation*

MARLab Report (2020)
UK Maritime Autonomy Regulation Lab Report, (2020).

Ringbom et al. (2020)
Ringbom H, Viljanen M, Poikonen J and Ilvessalo S, (2020). ‘Charing Regulatory Frameworks for Maritime Autonomous Surface Ship Testing, Pilots, and Commercial Deployments’ *Publications of the Ministry of Transport and Communications*

SafeSeaNet
EC, 'The Union Maritime Information and Exchange System' Retrieved from https://ec.europa.eu/transport/modes/maritime/digital-services/safeseanet_en

Sitra Rulebook (2021)
Sitra, 'Rulebook for a Fair Data Economy' (2021). Version 1.2

Journal Articles

Agamy (2019)
Agamy KSM, (2019). 'The impact of cybersecurity on the future of Autonomous ships' *International Journal of Recent Research in Interdisciplinary Sciences* 6(2) 10-15.

Ahvenjärvi (2016)
Ahvenjärvi S, (2016). 'The human element and autonomous ships' *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation* 10(3) 517-521.

Alen-Savikko & Pitkänen (2016)
Alen-Savikko A and Pitkänen O, (2016). 'Rights and entitlements in information: proprietary perspectives and beyond' *University of Helsinki Publications* 1-33.

Agrafiotis et al. (2018)
Agrafiotis I, Nurse JR, Goldsmith M, Creese S and Upton D, (2018). 'A taxonomy of cyber-harms: Defining the impacts of cyber-attacks and understanding how they propagate' *Journal of Cybersecurity* 4(1) 1-15.

Akbar et al. (2021)
Akbar A, Aasen AK, Msakni MK, Fagerholt K, Lindstar D and Meisel F, (2021). 'An economic analysis of introducing autonomous ships in a short-sea liner shipping network' *International Transactions in Operational Research* 28(4) 1740-1764.

Amro, Gkioulos & Katsikas (2019)
Amro A, Gkioulos V and Katsikas S, (2019). 'Connect and protect: Requirements for maritime autonomous surface ship in urban passenger transportation' *Computer Security* 69-85.

Attard, Orlandi & Auer (2017)
Attard J, Orlandi F and Auer S, (2017). ‘Exploiting the value of data through data value networks’ *Proceedings of the 10th international conference on theory and practice of electronic governance,* 475-484.

Boerding et al. (2018)
Boerding A, Culik N, Doepke C, Hoeren T, Juelicher T, Roettgen C and Schoenfeld MV, (2018). ‘Data Ownership - A Property Rights Approach from a European Perspective’ *J. Civ. L. Stud.* 11(1) 323.

Burmeister & Moraeus (2015)
Burmeister HC and Moraeus JA, (2015). ‘Autonomous Engine Room’ *D8.7 Final Report* 1-21.

Carey (2017)
Carey L, (2017). ‘All hands off deck? The legal barriers to autonomous ships’ *NUS Centre for Maritime Law Working Paper 011* 1-32.

Cerka, Grigiene & Sirbikyte (2017)
Cerka P, Grigiene J and Sirbikyte G, (2017). ‘Is it possible to grant legal personality to artificial intelligence software systems?’ *Computer Law & Security Review* 33(5) 685-699.

Chintoan-Uta & Silva (2016)
Chintoan-Uta M and Silva JR, (2016). ‘Global maritime domain awareness: a sustainable development perspective’ *WMU Journal of Maritime Affairs* 16(1) 37-52.

Contreras, Rumbold & Pierscionek (2018)
Contreras JL, Rumbold J and Pierscionek B, (2018). ‘Patient data ownership’ *JAMA* 319(9) 935.

Czarchorowski, Solesvik & Kondratenko (2019)
Czachorowski K, Solesvik M and Kondratenko Y, (2019). ‘The application of blockchain technology in the maritime industry’ *Green IT engineering: Social, business and industrial applications* 561-577.

De Osés & Juncadella (2021)
De Osés FX and Juncadella AU, (2021). ‘Global maritime surveillance and oceanic vessel traffic services: towards the e-navigation’ *WMU Journal of Maritime Affairs* 1-16.

Dremliuga & Mohd Rusli (2020)
Dremliuga R and Mohd Rusli MH, (2020). 'The Development of the Legal Framework for Autonomous Shipping: Lessons Learned from a Regulation for a Driverless Car' *J. Pol. & L.* 13(1) 295.

Felski & Zwolak (2020)
Felski A and Zwolak K, (2020). 'The ocean-going autonomous ship - Challenges and threats' *Journal of Marine Science and Engineering* 8(1) 41-57.

Fitzgerald (2013)
Fitzgerald M, (2013). 'An Internet for Manufacturing' *MIT Technology Review*

Goudossis & Katsikas (2019)
Goudossis A and Katsikas SK, (2019). 'Towards a secure automatic identification system (AIS)' *Journal of Marine Science and Technology* 24(2) 410-423.

Gu et al. (2021).
Gu Y, Goez JC, Guajardo M and Wallace SW, (2021). 'Autonomous vessels: state of the art and potential opportunities in logistics' *International Transactions in Operational Research* 28(4) 1706-1739.

Guilfoyle (2017)
Guilfoyle D, (2017). 'Maritime Law Enforcement Operations and Intelligence in an Age of Maritime Security' 299-321.

Harbinja (2019)
Harbinja E, (2019). 'Posthumous medical data donation: the case for a legal framework' *The ethics of medical data donation* 97-113.

Hogg & Ghosh (2016)
Hogg T and Ghosh S, (2016). 'Autonomous merchant vessels: examination of factors that impact the effective implementation of unmanned ships' *Australian Journal of Maritime & Ocean Affairs* 8(3) 206-222.

Hu (2016)
Hu E, (2016). 'Responsible Data Concerns with Open Source Intelligence' *Responsible Data Forum*

Hummel, Braun & Dabrock (2020)
Hummel P, Braun M and Dabrock P, (2020). ‘Own data? Ethical reflections on data ownership’ *Philosophy & Technology* 15(1) 1-28.

Huttunen et al. (2019)
Huttunen H, Seppälä T, Lähteenmäki I and Mattila J, (2019). ‘What Are the Benefits of Data Sharing? Uniting Supply Chain and Platform Economy Perspectives’ *ETLA Report No 93* 1-18.

Håkansson et al. (2009)
Håkansson H, Ford D, Gadde LE, Snehota I and Waluszewski A, (2009). ‘Business in networks’

Höyhtyä et al. (2017)
Höyhtyä M, Huusko J, Kiviranta M, Solberg K and Rokka J, (2017). ‘Connectivity for autonomous ships: Architecture, use cases, and research challenges’ *2017 International Conference on Information and Communication Technology Convergence, IEEE* 1-7.

Jalonen, Tuominen & Wahlström (2016)
Jalonen R, Tuominen R and Wahlström M, (2016). ‘Safety and security in autonomous shipping: challenges for research and development’ *AAWA Position Paper* 57-73.

Kang et al. (2018).
Kang J, Yu R, Huang X, Wu M, Maharjan S, Xie S and Zhang Y, ‘Blockchain for secure and efficient data sharing in vehicular edge computing and networks’ [2018] *IEEE Internet of Things Journal* 6(3) 4660-4670.

Karlis (2018)
Karlis T, (2018). ‘Maritime law issues related to the operation of unmanned autonomous cargo ships’ *WMU Journal of Maritime Affairs* 17(1) 119-128.

Kerber (2016)
Kerber W, (2016). ‘A new (intellectual) property right for non-personal data? An economic analysis’ *Gewerblicher Rechtsschutz und Urheberrecht, Internationaler Teil (GRUR Int)* 11(1) 989-999.

Klein et al. (2020)
Klein N, Guilfoyle D, Karim MS and McLaughlin R, (2020). 'Maritime autonomous vehicles: New frontiers in the law of the sea' *International & Comparative Law Quarterly* 69(3) 719-734.

Koivunen (2010)
Koivunen E, (2010). '"Why Wasn't I Notified?": Information Security Incident Reporting Demystified' *Nordic Conference on Secure IT Systems* 55-70.

Komianos (2018)
Komianos A, (2018). 'The autonomous shipping era. operational, regulatory, and quality challenges' *TransNav: International Journal on Marine Navigation and Safety of Sea Transportation* 12(1) 335-348.

Koski & Pantzar (2019)
Koski H and Pantzar M, (2019). 'Data Markets in Making' *ETLA Working Papers No. 72* 1-30.

Lambrou, Watanabe & Iida (2019)
Lambrou M, Watanabe, D and Iida J, (2019). 'Shipping digitalization management: conceptualization, typology and antecedents' *Journal of Shipping and Trade* 4(1) 1-17.

Li & Fung (2019)
Li S and Fung KS, (2019). 'Maritime autonomous surface ships (MASS): implementation and legal issues" *Maritime Business Review* 4(4) 330-339.

Lind et al. (2018)
Lind M, Watson RT, Ward R, Bergmann M, Bjorn-Andersen N, Rosemann M, Haraldson S and Andersen T, (2019). 'Digital data sharing: The ignored opportunity for making global maritime transport chains more efficient' *Unctad Transport and Trade Facilitation Newsletter* 1-3.

Lind et al. (2021)
Lind M, Ward R, Jensen HH, Chua CP, Simha A, Karlsson J, Göthberg L, Penttinen T and Theodosiou DP, (2021). 'The Future of Shipping: Collaboration Through Digital Data Sharing' *Maritime Informatics* 137-149.

Liozu & Ulaga, (2018)
Liozu M and Ulaga W, (2018). 'Monetizing Data' *Value Innoruption Advisors Publishing*

Man, Lundh & Porathe (2014)
Man Y, Lundh M and Porathe T, (2014). ‘Seeking harmony in shore-based unmanned ship handling - from the perspective of human factors, what is the difference we need to focus on from being onboard to onshore’ *Advances in Human Aspects of Transportation, Part I, 231239* 1-8.

Munim (2019)
Munim ZH, (2019). ‘Autonomous ships: a review, innovative applications and future maritime business models’ *Supply Chain Forum: An International Journal* 20(4) 266-279.

Nikander, Mattila & Seppälä (2018)
Nikander P, Mattila J and Seppälä T, (2018). ‘Kehittymättömät datamarkkinat johtavat Internetin Keskittymiseen’ *Digibarometer,* 31–37.

Pearce (2018)
Pearce H, (2018). ‘Personality, property and other provocations: Exploring the conceptual muddle of data protection rights under EU law’ *Eur. Data Prot. L. Rev.* 4(1) 190-213.

Perera & Batalden (2019)
Perera LP and Batalden BM, (2019). ‘Possible COLREGs failures under digital helmsman of autonomous ships’ *OCEANS 2019-Marseille*

Petković & Vujović (2019)
Petković M and Vujović I, (2019). ‘Blockchain security of autonomous maritime transport’ *Journal of Applied Engineering Science* 17(3) 333-337.

Poikonen et al. (2016)
Poikonen J, Hyvönen M, Kolu A, Jokela T, Tissari J and Paasio A, (2016). ‘Technologies for marine situational awareness and autonomous navigation’ *AAWA Position Paper* 15-34.

Porathe et al. (2018)
Porathe T, Hoem ÅS, Rødseth ØJ, Fjørtoft KE and Johnsen SO, (2018). ‘At least as safe as manned shipping? Autonomous shipping, safety and “human error”’ *Safety and Reliability–Safe Societies in a Changing World Proceedings of ESREL* 417-450.

Porathe, Prison & Man (2014)
Porathe T, Prison J and Man Y, (2014). ‘Situation awareness in remote control centres for unmanned ships’ *Proceedings of Human Factors in Ship Design & Operation* 93.

Praetorius, Lundh & Lützhöft (2011)

Praetorius G, Lundh M and Lützhöft M, (2011). ‘Learning from the past for proactivity: A re-analysis of the accident of the MV Herald of free enterprise’ *Proceedings of the fourt Resilience Engineering Symposium* 217-225.

Prainsack (2019)

Prainsack B, (2019). ‘Data donations: how to resist the iLeviathan’ *The ethics of medical data donation* 9-22.

Purtova (2010)

Purtova N, (2010). ‘Property in personal data. A European perspective on the instrumentalist theory of propertisation’ *European Journal of Legal Studies* 2(3) 193–208.

Qiao, Zhang & Wang (2021)

Qiao Z, Zhang Y and Wang S, (2021). ‘A Collision Risk Identification Method for Autonomous Ships Based on Field Theory’ *IEEE Access 9* 30539-30550.

Rajamäki, Sarlio-Siintola & Simola (2018)

Rajamäki J, Sarlio-Siintola S and Simola J, (2018). ‘The Ethics of Open Source Intelligence Applied by Maritime Enforcement Authorities’ *ECCWS 2018 17th European Conference on Cyber Warfare and Security. Academic Conferences and publishing limited* 424-431.

Ranft & Stiller (2016)

Ranft B and Stiller C, (2016). ‘The role of machine vision for intelligent vehicles’ *IEEE Transactions on Intelligent vehicles* 1(1) 8-19.

Ringbom (2019)

Ringbom H, (2019). ‘Regulating autonomous ships - concepts, challenges and precedents’ *Ocean Development & International Law* 50(2-3) 141-169.

Ringbom, Colling & Viljanen (2016)

Ringbom H, Collin F and Viljanen M, (2016). ‘Legal implications of remote and autonomous shipping’ *AAWA Position Paper* 36-55.

Rødseth (2018)
Rødseth ØJ, (2018). ‘Assessing business cases for autonomous and unmanned ships’ *Technology and Science for the Ships of the Future. Proceedings of NAV 2018* 1-8.

Rødseth et al. (2020)
Rødseth ØJ, Frøystad C, Meland PH, Bernsmed K and Nesheim DA, (2020). ‘The need for a public key infrastructure for automated and autonomous ships’ *OP Conference Series: Materials Science and Engineering* 929(1) 1-11.

Rødseth et al. (2013)
Rødseth ØJ, Kvamstad B, Porathe T and Burmeister HC, (2013). ‘Communication architecture for an unmanned merchant ship’ *MTS/IEEE OCEANS-Bergen* 1-9.

Saarni, Nordberg-Davies & Saurama (2018)
Saarni J, Nordberg-Davies S and Saurama A, (2018). ‘Outlook on the transition towards autonomous shipping’ Sarja E:1

Saripan & Putera (2016)
Saripan H and Putera NSFMS, (2016). ‘Are robots human? A review of the legal personality model’ *World Applied Sciences Journal,* 34(6) 824-831.

Schüritz, Seebacher & Dorner (2017)
Schüritz R, Seebacher S and Dorner R, (2017). ‘Capturing Value from Data: Revenue Models for Data-Driven Services’ *Proceedings of the 50th Hawaii International Conference on System Sciences, Hawaii* 5348- 5357.

Seppälä et al. (2019)
Seppälä T, Hakanen E, Lähteenmäki I, Mattila J and Niemi R, (2019). ‘The Resource Dependency of Data: A Prospective on Data Sharing in Supply Chains’ 1-18.

Solaiman (2017)
Solaiman SM, (2017). ‘Legal personality of robots, corporations, idols and chimpanzees: a quest for legitimacy’ *Artificial Intelligence and Law* 25(2) 155-179.

Solvang (2019)
Solvang T, (2019). ‘From the role of classification societies, to theories of norms and autonomous ships - some cross-disciplinary reflections’ *Marlus* 519(1) 239-256.

Suri (2020)

Suri M, (2020). ‘Autonomous vessels as ships–the definition conundrum"’ *IOP Conference Series: Materials Science and Engineering* 929(1)

Tam & Jones (2018)

Tam K and Jones K, (2018). ‘Cyber-risk assessment for autonomous ships’ *International Conference on Cyber Security and Protection of Digital Services, IEEE* 1-8.

Thombre et al. (2020)

Thombre S, Zhao Z, Ramm-Schmidt H, García JM, Malkamäki T, Nikolskiy S, Hammarberg T, Nuortie H, Bhuiyan MZ, Särkkä S and Lehtola VV, (2020). ‘Sensors and AI Techniques for Situational Awareness in Autonomous Ships: A Review’ *IEEE Transactions on Intelligent Transportation Systems*

Tikanmäki & Ruoslahti (2017)

Tikanmäki I and Ruoslahti H, (2017). ‘Increasing cooperation between the European maritime domain authorities’ *International Journal of Environmental Science* 2(1) 392-399.

Vallejo (2015)

Vallejo DAG, (2015). ‘Electric Currents: Programming Legal Status into Autonomous Unmanned Maritime Vehicles’ *Case Western Reserve Journal of International Law* 47(1) 405-428.

Vartdal, Skjong & St.Clair (2018)

Vartdal BJ, Skjong R and St.Clair AL, (2018). ‘Remote-controlled and autonomous ships’ DNV GL Maritime

Veal & Ringbom (2017)

Veal R & Ringbom H, (2017). ‘Unmanned ships and the international regulatory framework’ *Journal of International Maritime Law* 23(2) 100-118.

Veal & Tsimplis (2017)

Veal R and Tsimplis M, (2017). ‘The Integration of unmanned ships into the lex maritima’ *Lloyd’s Maritime & Commercial Law Quarterly* 303-335.

Veal, Tsimplis & Serdy (2019)
Veal R, Tsimplis M and Serdy A, (2019). ‘The legal status and operation of unmanned maritime vehicles’ *Ocean Development & International Law* 50(1) 23-48.

Veal et al. (2017)
Veal R, Tsimplis M, Serdy A, Ntovas A and Quinn S, (2017). ‘Liability for operations in Unmanned Maritime Vehicles with Differing Levels of Autonomy’ 1-13.

Vinnem & Utne (2018)
Vinnem JE and Utne IB, (2018). ‘Risk from cyberattacks on autonomous ships’ *Safety and Reliability-Safe Societies in a Changing World* 1485-1492.

Vojkovic & Milenkovic (2020)
Vojkovic G and Milenkovic M, (2020). ‘Autonomous ships and legal authorities of the ship master’ *Case studies on transport policy* 8(2) 333-340.

Xiong et al. (2020)
Xiong J, Bi R, Zhao M, Guo J and Yang Q, (2020). ‘Edge-assisted privacy-preserving raw data sharing framework for connected autonomous vehicles’ *IEEE Wireless Communications* 27(3) 24-30.

Zaccone (2021)
Zaccone R, (2021). ‘COLREG-Compliant Optimal Path Planning for Real-Time Guidance and Control of Autonomous Ships’ *Journal of Marine Science and Engineering* 9(1) 1-22.

Zheng et al. (2018)
Zheng BK, Zhu LH, Shen M, Gao F, Zhang C, Li YD and Yang J, (2018). ‘Scalable and privacy-preserving data sharing based on blockchain’ *Journal of Computer Science and Technology* 33(3) 557-567.

Özparlak (2018)
Özparlak BO, (2018). ‘Laws of Liability, Cyber Security and Data Protection for Ghost Ships’ 1-11.

Books

Dawson (2017)
Dawson M. *The governance of EU fundamental rights* (Cambridge University Press 2017)

Endsley & Jones (2012)
Endsley MR and Jones DG. *Designing for Situation Awareness: An Approach to User Centered Design* (Taylor and Francis:London 2012)

Goodman (2016)
Goodman M. *Future crimes. Everything is connected, everyone is vulnerable and what we can do about it* (Corgi Books:Great Britain, 2016)

Ross (2016)
Ross A, *The Industries of The Future* (SimonSchuster:New York, 2016)

Snehota & Håkansson (1995)
Snehota I and Håkansson H, *Developing relationships in business networks* (Londgon: Routledge 1995)

Industrial Reports, Codes and Guidelines

Allianz (2020)
Allianz Global Corporate & Specialty, (2020). Safety and Shipping Review 2020 - An annual review of trends and developments in shipping losses and safety

BIMCO Cyber Security Guidelines (2020)
BIMCO, (2020). The Guidelines on Cyber Security Onboard Ships - Version 4

Business Finland (2020)
Business Finland, (2020). Smart Ports and Maritime Logistics from Finland, 1-44.

DNV Autonomous and remotely operated ships (2018)
DNV, (2018). GL-CG-0264 Autonomous and remotely operated ships

Grand View Research (2019)
Autonomous Ships Market Size, Share & Trends Analysis Report By Autonomy Level (Semi-Autonomous, Fully Autonomous), By Solutions (Systems & Software, Structures), By End Use, And Segment Forecasts, 2019 - 2025

LR Code for Unmanned Systems (2017)
Lloyd’s Register, (2017). LR Code for Unmanned Marine Systems

LR Marine Cyber Exclusion (2019)
Lloyd's List Register, (2019). Marine Cyber Exclusion LMA5402

UK MASS Code of Practice (2020)
Maritime UK, (2020). Maritime Autonomous Ship Systems (MASS) UK Industry Conduct Principles and Code of Practice - Version 4, 1-132.

Press Releases

Finferries Press Release (2018)
Finferries, (2018). Finferries' Falco world's first fully autonomous ferry. Retrieved from https://www.finferries.fi/en/news/press-releases/finferries-falco-worlds-first-fully-autonomous-ferry

IMO Press Briefing (2018)
IMO Press Briefing, (2018). 'IMO takes first steps to address autonomous ships'

IMO Media Centre (2019)
IMO Media Centre, (2019). 'Autonomous shipping'
Retrieved from https://www.imo.org/en/MediaCentre/HotTopics/Pages/Autonomous-shipping.aspx

IMO Media Centre (2020)
IMO Media Centre, (2020). 'IMO postpones further meetings due to COVID-19' Retrieved from https://www.imo.org/en/MediaCentre/PressBriefings/Pages/04-Covid-19-IMO-meetings-.aspx

IMO Media Centre (2021)
IMO Media Centre, (2021). 'Autonomous shipping, Covid-19 impact, security and fuel safety in spotlight' Retrieved from https://www.imo.org/en/MediaCentre/Pages/WhatsNew-1606.aspx

Wärtsilä Press Release (2021)
Wärtsilä Corporation Press Release, (2021). 'Creating a Connected Smart Marine Ecosystem for a Sustainable Future' Retrieved from https://www.wartsila.com/media/news/02-02-2021-a-i-for-safety-efficiency-and-decarbonisation-wartsila-voyage-shares-tech-update-at-smm-2021-2854095

Web Sources

Bajpal (2020)
Bajpal P, 'Autonomous Shipping: Trends and Innovators in a Growing Industry' (Nasdaq, 12

February 2020) Retrieved from https://www.nasdaq.com/articles/autonomous-shipping%3A-trends-and-innovators-in-a-growing-industry-2020-02-18

Chambers (2016)
Chambers S, 'IUMI Outlines Obstacles Facing Development of Unmanned Ships' (4 January 2016) *Splash 247* Retrieved from https://splash247.com/iumi-warns-on-obstacles-facing-development-of-unmanned-ships/

Cowan (2018)
Cowan D, 'Are autonomous ships the future?' (17 October 2018) *Raconteur* Retrieved from https://www.raconteur.net/technology/autonomous-ships/

EC (2020)
EC, 'European Commission encourages a maritime future which includes Autonomous and Sustainable Ships and Shipping' (30 November 2020) Retrieved from https://ec.europa.eu/transport/modes/maritime/news/2020-11-30-mass_en

Hand (2018)
Hand M, 'Legal Reality Check for Autonomous Shipping in 2018' (13 Mar 2018) *Seatrade Maritime News* Retrieved from https://www.seatrade-maritime.com/asia/legal-reality-check-autonomous-shipping-2018

Lindroos-Hovinheimo (2021)
Lindroos-Hovinheimo S, 'Data protection clashes with data sharing: How will the EU reconcile its two aims?' (1 March 2021) *European Law Blog* Retrieved from https://europeanlawblog.eu/2021/03/01/data-protection-clashes-with-data-sharing-how-will-the-eu-reconcile-its-two-aims/

Länsi-Suomi (2021)
Sanomalehti Länsi-Suomi, 'Kyberturvallisuus kriittinen kysymys autonomisten laivojen kehityksessä - "Etäohjaus voi olla useampien vuosien päässä"' (2 February 2021) Retrieved from https://ls24.fi/uutiset/kyberturvallisuus-kriittinen-kysymys-autonomisten-laivojen-kehityksessa-etaohjaus-voi-olla-useampien-vuosien-paassa

Macola (2021)
Macola IG, ‘Is legislation blocking autonomous shipping?’ (11 March 2021) *Ship-Technology* Retrieved from https://www.ship-technology.com/features/is-legislation-blocking-autonomous-shipping-review-marlab/

Safety4SEA (2019)
Safety4SEA, ‘Autonomous ships: Test areas and research centers making headlines’ (9 October 2019) Retrieved from https://safety4sea.com/cm-autonomous-ships-test-areas-and-research-centers-making-headlines/?__cf_chl_jschl_tk__=7d35a233360ae221e09e81ab9f858f2ff0eb7b05-1620125794-0-Ac8m0HsF3ueywu9BYDkxrzDZNVskDSn9nqV4QXkTtvKUcn_4MRoAxv_HyZd3GaCyP8GMDRaFQOixHD22pjxb-Rn6_J8TuW1K1Z0Im-Nf2g5WzflGLP_L6yxmgyBgx6FlhUOcv6Xlp0RjBqCH_BqiTeRLFOuEap1kX9QyWzFWaAbpjsNS3KlTlG3YA9W5IZ3hcnS0-I0xXBlG2mCc6-NTmgG2FELr1Se9VWqpxkpRqY92viuksTaEtYQ_RR_PkKC_W124PRVShC0jAc848XWRhZk_LrowAUnhmh7KhmeO_HErfGHK4dxg1X2rnoRPn6I-HeAlxcHdrD9FGP7pKoGfHNv_TQfn6vWnV6TudEdFrjlbZ-BE1IzvE459VtjvVrRozvbB0RvwJEZ4k1iACkuTV1uHsU7BpsFsEWqjsk55oUgx3YO_kNwy60qgFY4-HscJ5nztR2dcGA90zQajTo2dgl9kyiaK4ZWFC5ITMYkaSLN_

Wingrove (2018)
Wingrove M, ‘Ten technologies to shake up maritime’ (2 January 2018) Retrieved from https://www.rivieramm.com/news-content-hub/news-content-hub/ten-technologies-to-shake-up-maritime-in-2018-26131

List of Abbreviations

AI	Artificial Intelligence
AIS	Automatic Identification System
AL	Autonomy Level
ANS	Autonomous Navigations System
ARPA	Automatic Radar Plotting Aid
BIMCO	Baltic and International Maritime Council
CISE	European Common Information Sharing Environment
DDT	Dynamic Driving Task
DNT	Dynamic Navigation Task
DPA	Data Protection Authority
EC	European Commission
ECDIS	Electronic Chart Display and Information System
EEA	European Economic Area
EMSA	European Maritime Safety Agency
EPIRB	Emergency Position-Indicating Radiobeacon
EU	European Union
GMDSS	Global Maritime Distress and Safety System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICT	Information and Communication Technology
IMO	International Maritime Organization
IMU	Inertial Measurement Unit
IPR	Intellectual Property Rights
ISPS	International Ship and Port Facilities Security Code
MASS	Maritime Autonomous Surface Ships
MDA	Maritime Domain Awareness

MSC	Maritime Safety Committee, IMO
NOC	National Oceanography Centre (UK)
NTNU	Norwegian University of Science and Technology
OSINT	Open-Source Intelligence
PKI	Public Key Infrastructure
PortCDM	Port Collaborative Decision Making
P&I	Protection and Immunity
RAT	Radio Access Technique
RCU	Rendezvous Control Unit
SCC	Shore Control Center
UK	United Kingdom
UKHO	UK Hydrographic Office
UN	United Nations
US	United States
VDR	Voyage Data Recorder
VTS	Vessel Traffic Services

1. Introduction

1.1. Background

Autonomous ships with various different levels of autonomy have emerged in the 2010s through trial runs and testing. The development of autonomous ships is linked with the general development of autonomous transportation, as AI, machine learning, big data and other advanced technologies have emerged that have been used with advancing autonomous vehicles.[1] The emergence of autonomous ships is also connected to the general trend of shipping digitalization, which consists of digital technologies, digital management practices and digital solutions driving maritime transportation to a more advanced level of digitalization.[2] The main reasons for this development are the potential efficiencies of ships without a crew and reduced risk of human error.[3] A study by Allianz estimated that human error is responsible for 75-96 % of marine casualties[4] and another study by the European Maritime Safety Agency stated that human action was the reason for 54 % of accidents.[5] Autonomous shipping has thus various benefits especially by reducing human error.

Additionally, autonomous ships are also connected to the growing trend of environmental sustainability and the aim of zero-emission shipping, as many of the autonomous ships are developed with the aim of low or zero emissions.[6] Some financial aspects are also linked with the development of autonomous ships, as they are developed with the aim of reducing fuel costs and total operating expenses.[7] Additionally, autonomous ships are interesting for ocean research, coast guard and military applications.[8] The possibilities to use autonomous ships are broad and the general interest to utilize autonomous shipping exists across the maritime industry.

Although autonomous shipping is a key trend in the maritime industry, autonomous ships have some downsides, risks and limitations. Some potential problems with autonomous ships are unknown safety risks due to reliance on new technology and vulnerability to cyber

[1] Bajpal (2020)
[2] Lambrou, Watanabe & Iida (2019), 1.
[3] Vartdal, Skjong & St.Clair (2018), 19.
[4] Allianz (2020), 5.
[5] EMSA (2020), 5.
[6] Munim (2019), 270.
[7] Li & Fung (2019), 5.
[8] Ahvenjärvi (2016), 516.

security incidents.[9] Autonomous ships may also reduce seafarer jobs that might cause some resistance by labour activists, although autonomous ships may improve working conditions and safety.[10] The lack of maintenance on the technical system during voyage is also a challenge.[11]

As of 2021, autonomous ships are still in the development phase, and potential commercialization is expected to happen by 2025 and on a larger scale by 2030.[12] The legislation with autonomous ships is, on the other hand, somewhat limited as traditional maritime law has been written with the expectation of a manned crew. This study aims to answer how autonomous ships fit the existing international maritime legislation and what kinds of challenges and solutions can be identified for the legal development regarding autonomous shipping.

In addition to researching the general feasibility of the legislative framework for autonomous ships, this study examines data sharing that occurs with autonomous ships. Data sharing is a crucial concept in the contemporary data-driven world, and data sharing is an essential part of autonomous ships. Autonomous ships use and store a significant amount of data, and data sharing occurs between various parties with autonomous ships. Data sharing has its legal challenges and solutions, and this is certainly the issue with autonomous ships as well. The aim of this study is thus to combine these two very contemporary and relevant topics.

1.2. Scope and Purpose of Study

The scope and purpose of this study is to research legal challenges and solutions of data sharing with autonomous ships. This study has two research questions. The first research question is the legality of autonomous ships. This study aims to evaluate how autonomous ships fit into the existing legislative framework and what kind of modifications and alterations are recommended based on this study to clarify potential issues. The purpose of this study is to increase knowledge on the matter and provide recommendations for further research and policy suggestions. The literature on autonomous ships has been mostly technical research on navigation control, design and prototypes, and legal research has been

[9] Li & Fung (2019), 5.
[10] Ibid 5. See also Rødseth (2018), 2.
[11] Rødseth (2018), 3.
[12] Grand View Research, (2019)

minimal in comparison.[13] This study aims to increase and illustrate legal insights both in terms of legal barriers and solutions, both with the general framework of international maritime law and the specific topic of data sharing. This study operates with the assumption that the development of autonomous ships goes forward and the international maritime community supports their commercial acceptance while recognizing the existing legal challenges and solutions.

The second research question is the main topic of this study, namely the type of legal challenges and solutions of data sharing with autonomous ships. Researching data sharing with autonomous shipping is important because data sharing is a fairly recent issue and legislation with data sharing is in some instances limited.[14] This study thus aims to identify and analyze the issues of data sharing with autonomous ships from a legal perspective, as both autonomous shipping and data sharing are contemporary topics that require legal research for clarification and functionality.

The research questions of this study are:

1) How well do autonomous ships fit into the current international maritime law?

2) What are the legal challenges and solutions with data sharing and autonomous ships?

1.3. Methodology

Various research methods exist in legal research, and the method should be chosen for the needs of the study. This choice is based on the topic and type of research, and a consequential assessment of available research methods. This study is conducted using qualitative research methods, and the primary research method is the legal dogmatic method. The purpose of the legal dogmatic method is to provide a coherent and systematic framework of the legal challenges and solutions of data sharing with autonomous ships.

To supplement the doctrinal method, this study applies The Sitra Rulebook for a Fair Data Economy[15] as a case study. The purpose of this case study is to utilize the guidelines of this rulebook to analyze the legal challenges and solutions of data sharing with autonomous

[13] Gu et al. (2019), 1722.
[14] Lindroos-Hovinheimo, (2021)
[15] Sitra Rulebook (2021)

ships, as well as provide suggestions based on these guidelines. Autonomous ships provide an interesting case study for the Sitra Rulebook due to the connected nature of autonomous ships in a maritime ecosystem and the amount of storing, using and sharing of data.

1.4. Sources of Law

This study uses a broad variety of different sources. International maritime law and its sources, including the IMO conventions and other UN conventions on maritime law and law of the sea, are essential for this analysis. Maritime law represents private law and law of the sea public law, and they both are relevant for this study. EU law on maritime matters and data sharing is used to analyze the EU approach to autonomous shipping and data sharing. Some English law is used due to the importance of English maritime law as the primarily used national law in maritime matters. Various governmental reports on autonomous ships, including reports published by the administrations of the UK, Denmark and Finland, are also utilized, as they are useful for analyzing the legal barriers and possibilities of autonomous ships and their data sharing issues. Academic secondary sources and reports, news, and publications from professional practitioners in the fields of autonomous ships and data sharing are also used to support the legal analysis.

1.5. Limitations and Challenges

One key limitation and challenge is that the field of autonomous ships is rapidly evolving. This means that a lack of clarity exists regarding the extent and timeline of large-scale deployment and commercialisation of autonomous ships. The legal development of autonomous shipping is also developing, and new regulations and amendments may happen fast. The field of data sharing is also a quickly developing field of study that poses both limitations and opportunities. Although research on autonomous ships exists, the legal research on data sharing with autonomous ships is somewhat limited in comparison with more general and conventional topics related to autonomous shipping. On the other hand, the recent nature of autonomous ships and data sharing means that the issues are contemporary and relevant.

1.6. Outline of the Study

The second chapter provides a brief explanation on autonomous ships, their developmental phase and various definitions. The third chapter answers the first research question about the legal feasibility of autonomous ships. The fourth chapter explains how autonomous ships use data sharing and what kind of operational and practical issues can be identified. The fifth chapter focuses on the second research question of this study, namely the legal challenges and solutions of autonomous ships with data sharing. At the end of this study, policy implications, suggestions for future research and general conclusions are presented.

2. Autonomous Ships

2.1. Introduction

This chapter introduces the various definitions for autonomous ships which are used throughout this study. The definitions of autonomous ships are usually linked to the different levels of automation and the following section introduces some of the most commonly used and cited frameworks. Lastly, a summary of the usage of autonomous ships and their development is provided.

2.2. Terms and Definitions

Autonomous ships have various definitions depending usually on the level of automation. Definitions are important, as they are used for understanding what kind of ships are understood as autonomous and how the various definitions differ from each other. Definitions are especially useful for understanding various risk levels and legal aspects that are relevant for each level. Some definitions of autonomous ships are more linear than other systems that separate different concepts of autonomy. A linear system considers automation as a single dimension that can be quantified, whereas a non-linear system has usually two different levels of automation that can be quantified separately. In this section of this study, several definitions and their relevance are presented in order to explain and define the subject matter reasonably.

A linear definition of different levels of automation is presented by Lloyd's Register in their Design Code for Unmanned Marine Systems.[16] Lloyd's Register uses a system of six levels of autonomy. While this system of six levels is linear, the code states that a higher autonomous level system may use a lower AL system in its reversionary control.[17] Additionally, a complex system may be a combination of multiple systems at different levels. MASS UK Code of Practice has a fairly similar system to the Lloyd's Register's classification.[18] The six levels of autonomy as defined by Lloyd's Register are, namely:

> *AL 0) Manual: No autonomous function. All action and decision-making performed manually (n.b. systems may have level of autonomy, with Human in/ on the loop.), i.e. human controls all actions.*

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[16] 4.1.2. LR Code for Unmanned Marine Systems (2017)
[17] Ibid.
[18] UK MASS Code of Practice (2020), 20.

AL 1) On-board Decision Support: All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data is provided by systems on board.

AL 2) On &Off-board Decision Support: All actions taken by human Operator, but decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off-board.

AL 3) 'Active' Human in the loop: Decisions and actions are performed with human supervision. Data may be provided by systems on or off-board.

AL 4) Human on the loop, Operator/ Supervisory: Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to give human Operators the opportunity to intercede and over-ride.

AL 5) Fully autonomous: Rarely supervised operation where decisions are entirely made an actioned by the system.

AL 6) Fully autonomous: Unsupervised operation where decisions are entirely made and actioned by the system during the mission.

IMO uses a fairly linear system for the levels of autonomy. The IMO's working group on the matter has identified four degrees of autonomy to support and facilitate its work. These four degrees of autonomy are:[19]

1. Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated.

2. Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location, but seafarers are on board.

3. Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board.

4. Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself.

[19] MSC 100

An example of a nonlinear definition of automation is given by Henrik Ringbom of the Scandinavian Institute of Maritime Law. For the discussion of legal elements of the level of autonomy, Ringbom presented a two-dimensional figure that distinguishes the manning level and the level of autonomy.[20] The vertical axis illustrates the level of on-board manning, thus combining the level of manning and the location of the crew. The horizontal axis illustrates the level of autonomy.

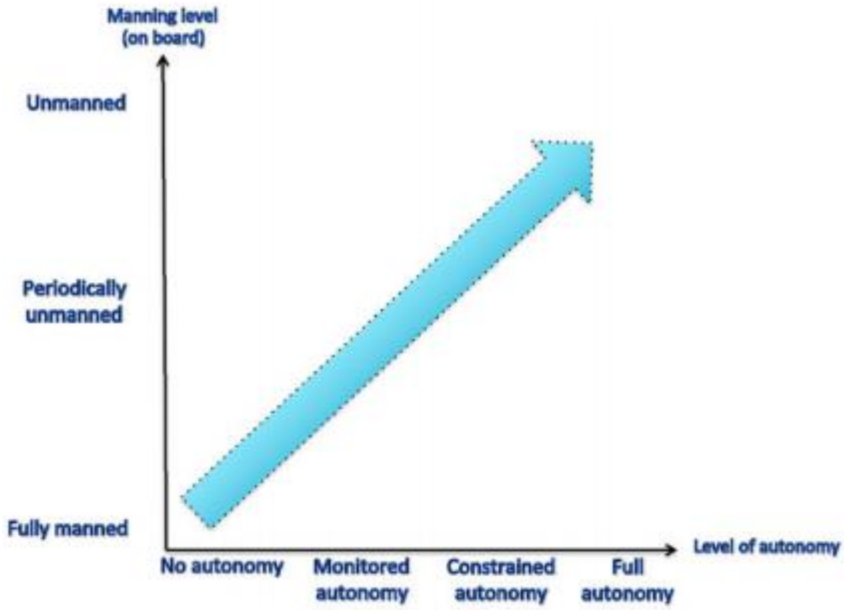

Figure 1. Ringbom (2019)

This study uses the separation of the level of on-board manning and the level of autonomy when that is relevant and applicable for a particular issue of discussion. Some of the legal discussion on autonomy can be conducted by using a more linear system, such as dividing autonomous ships into remotely operated and fully or partially autonomous ships, and this linear model is used if the separation of autonomy and manning level constitutes a similar legal issue and insight as the linear model. In general, this study focuses mainly on periodically unmanned and unmanned ships. Remotely controlled ships in this study are unmanned or periodically unmanned ships that are controlled from an SCC and fully autonomous ships are unmanned fully autonomous ships unless otherwise stated. Partially autonomous ships are ships that have constrained autonomy and either periodic or no

[20] Ringbom (2019; 145.

manning. The term “SCC” relates to a manned shore-control center and the term MASS is used interchangeably with autonomous ships.

2.3. Usage and Distribution

In this section, a summary of the development of autonomous ships is presented. The first large-scale project on unmanned and autonomous merchant ships was the EU-project MUNIN, which took place during 2012-2015.[21] The first test bed area for autonomous ships was launched in Trondheimsfjorden, Norway, in 2017.[22] The first fully autonomous ferry was presented in December 2018 by Rolls-Royce and Finnish state-owned ferry operator Finferries in the archipelago of Turku, Finland.[23] The car ferry *Falco* navigated autonomously during its voyage between municipalities of Parainen and Nauvo. Several projects are taking place in Norway, such as the development of the world’s first commercial autonomous ship, Yara Birkeland and NTNU’s autonomous passenger ferry project.[24] Although Norway, Finland and the UK have been frontrunners in the development of autonomous ships,[25] China is forecasted to be the leading country in the world in autonomous shipping technology by 2025.[26] The current value of the autonomous ship market is $1.1bn annually and the market is expected to rise by 6.96% in 2025.[27] Venture capital worth $113 has been invested in autonomous shipping technology since 2010 and autonomous ships are expected to have a significant effect on the value chains of shipping vessels and cargo transport.[28] As this study is written in spring 2021, the development of autonomous ships is at an advanced stage and the market has significant potential.

[21] Rødseth (2018), 1.
[22] Safety4SEA (2019)
[23] Finferries Press Release (2018)
[24] Akbar et al., (2021), 1741.
[25] Safety4SEA (2019)
[26] MARLab (2020)
[27] Ibid.
[28] Ibid.

3. How Well Do Autonomous Ships Fit into the Current Legal Framework?

3.1. Introduction

Autonomous ships pose several legal questions that are based on the lessened role of human interaction in decision-making. Autonomous ships represent advanced technology, and the concept of ships operating with unmanned crew or autonomous systems requires assessment of the existing maritime law and regulations. After the general discussion of legality of autonomous ships, legal challenges and solutions associated with autonomous ships are analyzed.

3.2. Legality of Autonomous Ships

In this section, the legality of autonomous ships is described and discussed by focusing on IMO, as it operates as the main regulatory body for shipping. The role of other conventions and organizations is also briefly discussed.

3.2.1. IMO

IMO is a specialized agency of the UN with a task to set measures for the improvement of safety and security of international shipping, in addition to prevent pollution from ships. IMO is involved with various legal matters, such as liability and compensation issues as well as the facilitation of international maritime traffic. IMO, operating as the global regulatory body for international shipping, began to address the legal issues of autonomous shipping in 2018.[29] MSC endorsed a framework for a regulatory scoping exercise for unmanned ships, and this scoping exercise involved preliminary definitions of MASS and degrees of autonomy in a two-step process of an assessment exercise. The first step identified current provisions of IMO instruments and an assessment of their potential applicability or the lack thereof to ships with varying degrees of autonomy and whether some instruments would prevent MASS operations. The second step was an analysis of the most appropriate way of addressing MASS operations while taking into account the human element, technology, and operational factors, among other aspects.[30]

The MSC's scoping exercise analyzed several instruments, namely SOLAS from a safety viewpoint, collision regulations (COLREG), loading and stability (Load Lines), training of

[29] MSC 99

[30] IMO Press Briefing (2018)

seafarers and fishers (STCW, STCW-F), search and rescue (SAR) tonnage measurement (Tonnage Convention) and special trade passenger ship instruments (SPACE STP, STP). IMO has other committees working on the subject matter outside the scoping exercise, as the Facilitation Committee is considering the Convention on Facilitation of International Maritime Traffic (FAL Convention) and the Legal Committee is covering a wide range of different conventions. The original target was to complete the scoping exercise by 2020.[31] However, the COVID-pandemic stalled IMO activities, as IMO suspended its MSC meetings due to the pandemic.[32] The scoping exercise is expected to be completed in MSC Session 103 in May 2021,[33] but this study was completed prior to this meeting.

The Maritime Safety Committee provided interim guidelines for MASS trials in MSC Session 101, in June 2019.[34] The interim guidelines state that MASS trials should be carried out in a manner that provides at least the same degree of safety, security and protection of the environment as provided by the relevant instruments. In addition to risk management and compliance with mandatory instruments, the guidelines set principles for manning and qualifications of personnel involved in MASS trials, the appropriate level of human element including monitoring infrastructure and human-system interface, the infrastructure for safe conduct of trials trial awareness, communication and data exchange, reporting requirements and information sharing, the requirement of defining the scope and objective for each individual trial as well as ensuring cyber risk management.[35] What can be concluded from the interim guidelines is that safety is a key aspect with testing autonomous ships, and a similar safety-focused regulatory approach is expected to be continued in further regulatory work by IMO. Importantly for this study, the role of communication and data exchange were mentioned in the interim guidelines.

In the following sections, selected international maritime conventions are analyzed in order to assess how well autonomous ships fit into the current legal framework. These same legal instruments are also within the scoping exercise of the IMO.

[31] IMO Media Centre (2019)
[32] IMO Media Centre (2020)
[33] IMO Media Centre (2021)
[34] MSC 101
[35] IMO Interim Guidelines for MASS Trials (2019), Section 2 “Principles and Main Objectives”

3.2.1.1. SOLAS

SOLAS sets the minimum acceptable standards for construction, equipment, operations and required certifications of ships. SOLAS was originally signed in 1914 in the aftermath of the sinking of RMS Titanic, and it has been amended three times, the most recent version being signed in 1974. SOLAS states that ships "shall be sufficiently and efficiently manned"[36] and "shall be provided with an appropriate minimum safe manning document or equivalent".[37] The Convention does not define what constitutes a minimum level of manning, and different jurisdictions have adopted different approaches to these questions.[38] In Singapore, specific manning requirements are tied to the type and size of the ship,[39] whereas in the UK, a shipowner has the obligation to submit what is referred to as a "safe manning document" before a voyage, and technically there is no minimum level of manning in the UK regulations.[40] The understanding of minimum level of manning is thus broad, but the starting point of SOLAS is nonetheless an assumption of manned crew. Additionally, SOLAS has several mandatory codes under it that require review to make them more suitable for autonomous ships, namely ISPS Code, ISM Code and the Polar Code.[41] SOLAS thus requires manning, but refrains from stating an appropriate level of manning that provides room for interpretation.

If the rule of minimum level of manning is broad and not amended regarding autonomous ships, a situation arises in which different jurisdictions would dictate rules for manning and the applicability of unmanned crews. From an operational view, a situation in which different jurisdictions dictate different manning requirements increases operational complexity and creates barriers to market entry for autonomous ships, if some flag states require certain levels of manning that would render autonomous ships unlawful.[42] Although flexibility with manning levels allows room for development of unmanned ships, it also provides uncertainty.

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[36] Ch. V, Reg. 14 of the SOLAS Convention
[37] Ibid.
[38] Karlis (2018), 125.
[39] Merchant Shipping (Training, Certification and Manning) Regulations 1998 (Singapore), regulations 13-14.
[40] The Merchant Shipping (Safe Manning, Hours of Work and Watchkeeping) Regulations 1997. See also Karlis (2018, 125.
[41] Klein et al. (2020), 728.
[42] Karlis (2018), 125.

On the other hand, in a case of at least one remote control centre, these remote stations are likely to be manned with sufficient personnel and regarding "efficiency", autonomous ships are usually equipped with a wide range of highly technical solutions such as various sensors, computers and machinery.[43] The combination of manned remote control centers and efficient high-tech solutions assist to comply with the requirements of sufficient and efficient manning as stated in Regulation 14. However, if different jurisdictions rule differently for manning requirements with the SCC, the lack of predictability exists.

In addition to the issue of manning, SOLAS specifies minimum standards for the construction, equipment, and operational matters of ships from a safety perspective. Each individual ship needs to comply with prescriptive requirements, and a deviation from requirements is accepted only if the shipowner manages to demonstrate that the safety level of the deviation is equal to the initial requirement.[44] Regarding this matter, well-planned demonstration studies and data are needed to show that autonomous ships meet the safety levels of conventional manned ships. The same holds true for the manning issue, meaning that quantitative and qualitative data would be needed to illustrate that periodically or permanently unmanned ships are as safe as manned ships. As safety is one of the key issues with autonomous ships, the MASS trials are expected to provide relevant data on the matter to illustrate what levels of safety expectations can be associated with autonomous ships.

3.2.1.2. STCW

STCW deals with training of seafarers and it was adopted in 1978 and came into force in 1984. STCW applies to personnel on board, but a question exists whether STCW applies to persons who operate autonomous ships from an SCC.[45] Komianos argues that STCW does not apply to unmanned ships as it expressly states that it applies to "seafarers serving on board seagoing ships".[46] The question is then whether the requirements of STCW apply at all to fully autonomous ships or not, and if they do apply the issue is how to interpret the requirements. The requirement that each ship is in the charge of a master, which stems from UNCLOS Art. 94(4)(b), certainly poses a question on the issue of a master of an autonomous ship. STCW states that the officer of the watch is "physically present on the navigating

[43] Komianos (2018), 341.
[44] Jalonen, Tuominen & Wahlström (2016), 68.
[45] Komianos (2018), 341. See also Ringbom et al. (2020), 64.
[46] Art. III(a) of the STCW Convention. See also Komianos (2018), 341.

bridge”,[47] which poses a clear legal challenge for autonomous ships if they have no physical crew on board.[48] The issue of the master and the officer of the watch are discussed in more detail later in this chapter, as they are common issues across conventions.

Regardless whether the STCW with its current scope applies directly to remotely controlled or fully autonomous ships, a reasonable consideration about training requirements and certification related to the Convention should be cautiously considered.[49] STCW states that training and certification of seafarers includes a period of seagoing service that lasts between 12 and 36 months, and this poses an interesting question for autonomous ships.[50] An area of inspiration for these schemes could be based on standards similar to those that apply to VTS. In addition, labour laws that apply to the operators of the SCCs or programmers of completely autonomous ships might require some adjustments as well.[51]

STCW could be relevant with autonomous ships in the transition period with periodically or partially manned autonomous ships. Especially in the early periods of commercial autonomous shipping, some crew could be expected to be present on board at least periodically. This means that crew members should be trained to operate autonomous ships, even if the navigational decision-making happens remotely, as crew members would need skills to observe and supervise on board.[52] In addition, crew might be needed even with fully or limitedly autonomous ships for emergency situations. To support the function of crew reduction with autonomous ships, some alterations to the STCW would be beneficial to emphasize that the safety level of shipping will remain or improve with fewer crew members, as well as a clarification to whether STCW applies to autonomous ships at all. Technically the current scope excludes autonomous ships and thus autonomous ships do not have to comply with its requirements, but an inclusion or at least inspiration from the principles of STCW would be useful, as human presence will exist with some levels of autonomous ships especially in the transition period.

[47] Ch. VIII, Reg. VIII/2 of the STCW Convention 2(2)(1)
[48] Danish Maritime Authority (2017), 20.
[49] Komianos (2018), 341.
[50] Ch.II and III of the STCW Convention. See also Karlis (2018), 123.
[51] Komianos (2018), 341
[52] Jalonen, Tuominen & Wahlström (2016), 70.

3.2.1.3. COLREG

COLREG was adopted in 1917 and came into force in 1977, and it is the main instrument for international regulations for preventing collisions at sea.[53] COLREG defines the navigation rules that have to be followed by ships and other vessels in order to prevent collisions between two or more vessels. Rule 3 sets the “General Definitions”, which does not exclude autonomous ships from the definition of a “vessel”.

Rule 2 relates to the responsibility of master and crew, and this is an issue that should be addressed with autonomous ships. The key issue here is whether a possible transfer of responsibility from the onboard master and crew to the personnel on shore is possible and if yes, what kinds of requirements for those personnel exist.[54] This would mean that having some presence of human in the decision-making loop would arguably satisfy the rule, meaning that remotely controlled or periodically manned autonomous ships meet the requirements, but fully autonomous ships have more difficulties in meeting these requirements of master and crew.[55] Rule 5 states that each vessel should have a proper look-out by “sight and hearing”.[56] It could be argued that technical means could be used as substitutes for human sight and hearing, but the rule follows the requirement of human sight and hearing by “as well as by all available means appropriate in the prevailing”.[57] Komianos argues that this addition indicates that other means are already included in the rule and human senses would be necessary.[58] In addition, the use of radar, VTS and AIS are included in the presupposition of “all available means”.[59] Nonetheless, a clarification of the definition of a lookout would be beneficial, and furthermore an argument can be made of technological means being more effective than human sight and hearing, since human senses are prone to human error. Technological development has provided very sensitive microphones and vision cameras that may be possible to substitute human senses when analyzing the effectiveness of such measures.[60] Rule 6 states the principles for defining “safe speed” and “proper and effective action” in terms of collision avoidance.[61] This rule does not provide

[53] COLREG Convention
[54] Komianos (2018) 342.
[55] Veal, Tsimplis & Serdy (2019), 38.
[56] Rule 5 of the COLREG Convention
[57] Ibid.
[58] Komianos (2018), 342.
[59] Danish Maritime Authority (2017), 47.
[60] Komianos (2018), 342.
[61] Rule 6 of the COLREG Convention

exact speed levels or distances between vessels, and potentially such a specification for autonomous ships would be beneficial for clarity or an inclusion of issues that should be taken into consideration with autonomous ships, such as technical delays and other margins.

Rule 7 sets the principles of risk avoidance, and this rule emphasizes the importance of appropriate judgement and seamanship. The role of risk assessment through remote means could be argued as being within appropriate judgement, but the phrasing that assumptions should not be made by "scanty radar information"[62] confirms the relevance of audio and visual information to the human personnel.[63] Rule 8 relates to the prevention of collision, and good seamanship is deemed essential for the prevention of collision. Similarly as with Rule 2, the issue is whether shore-based operators of autonomous ships could be included here and what kind of proper seamanship could be required from them.[64]

Rules 16, 17, 19 and 20 have some specific scenarios that are relevant and somewhat challenging for autonomous ships. Rule 16 is about the conduct of the give-way vessel and Rule 17 is about action by stand-on vessel. The terms "give-way vessel" and "stand-on vessel" refer to navigational rules regarding which ship has to give way in different situations, namely overtaking, head-on and crossing situations.[65] Rule 17 mentions manoeuvre of the last second, stating that the stand-on vessel should exercise best action available if the collision cannot be avoided by the action of the give-way vessel alone.[66] Some doubt exists whether this type of a manoeuvre could be done without the intervention of a human presence on board.[67] Nonetheless, reliable communication with secure and fast data transfer between the autonomous ship and the control centre should exist for this type of maneuver to be possible.[68] A possible challenge is that the COLREG rules do not provide adequate details on the conduct of the give-way vessel and the stand-on vessel in the critical collision risk region.[69] Rules 16 and 17 require vessels to take any measures necessary to avoid collision or high-risk situations even when the give-way vessel is violating the regulations, this might be problematic for autonomous vessels as the

[62] Rule 7 of the COLREG Convention
[63] Komianos (2018), 342.
[64] Ibid..
[65] Rules 13-15 of the COLREG Convention
[66] Rule 17 of the COLREG Convention
[67] Komianos (2018), 342.
[68] Ibid.
[69] Perera & Batalden (2019), 4.

potential exists that collision avoidance decisions can overlap or cancel each other.[70] Rule 19 is about conduct of vessels in restricted visibility and it mentions the hearing of the fog signal. As in Rule 5, the use of the term “hears” implies human presence.[71] Rules 20-22 relate to navigational lights and shapes, and the wording in these sections emphasize the role of a proper look-out, thus emphasizing a reaction by human sight to navigational lights.

A conclusion given by Danish Maritime Authority is that COLREG relies on “simultaneous human decision competence”,[72] which means that the one person controlling the ship is relevant and not the place of control. Additionally, COLREG implies that decisions are carried out in real time, thus excluding pre-programmed choices.[73] In its current form, COLREG would allow remotely controlled ships that are navigated by human decision-making, as long as proper situational awareness can be achieved with the technical means.[74] Danish Maritime Authority also argues that human vision and hearing can be technically replaced by cameras, sensors, radars and other electronic solutions.[75] Not all authors agree with this statement, as Vallejo argue that it is too early to expect unmanned vessels to be capable to mimic foresight of human vision.[76] However, the argument of Vallejo was given in 2015 and more recent studies are more favorable towards the technological capabilities of sensors for autonomous ships.[77] Following the statement of Vallejo, Hogg and Ghosh argue that autonomous ships should not be classified as ‘vessels’ under COLREG and that they should be defined in a separate manner.[78] Although a separate system for collision avoidance would likely be better suited for the needs and conduct of autonomous ships, a system of separate regulations for collision avoidance would reduce uniformity of navigational rules. Supporting the development of technological means for autonomous ships to comply with COLREG is a more grounded argument than a separate system, as some modifications for autonomous ships could be included in the COLREG as amendments. The legal discussion

[70] Perera & Batalden (2019), 7.
[71] Komianos (2018), 342.
[72] Danish Maritime Authority (2017), 17.
[73] Ibid 18.
[74] Ibid.
[75] Ibid.
[76] Vallejo (2015), 428.
[77] Zaccone (2021), 12.
[78] Hogg & Ghosh (2016), 209.

on autonomous ships and COLREG thus revolves around the technical extent of mimicking human senses and whether appropriate technical mimicking is sufficient.

3.2.1.4. MARPOL

MARPOL has been in force since 1983 with the objective to preserve the marine environment from pollution by oil, chemicals, harmful substances and garbage.[79] One benefit with autonomous ships is that the lack of crew means the lack of garbage and human waste.[80] In addition, autonomous ships are potentially less likely to pollute intentionally due to record keeping of all electronic orders, but unintentional pollution as a result of an accident or unforeseen reasons would continue to be a problem.[81]

However, similarly as with many other IMO instruments, MARPOL sets out requirements for master and crew, namely obligations upon the master to report and prepare for pollution incidents.[82] Autonomous ships should also be developed with the mindset that they do not present an increased risk of pollution catastrophes and that the work normally assigned to crew members could be carried out by technical means.[83] The readiness of technology is thus a crucial issue for ensuring compliance with international law standards.[84] Admittedly the wording on the master and the crew would need to be amended or interpreted differently, but in general MARPOL is arguably among the easiest existing conventions to fit the realities of autonomous ships..

3.2.1.5. SAR

The SAR Convention was adopted in 1979 and its objective is to develop an international search and rescue plan.[85] SAR organizations coordinate the rescue of persons in distress at sea. SAR paragraph 3.1.9 refers to the master of the vessel, and this relates to the issue of whether an autonomous ship can have a master or whether the lack of such a master can be substituted. However, the most challenging issue with SAR operations and autonomous ships is that in practice autonomous ships are very unlikely to be able to provide proper

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[79] MARPOL Convention
[80] Komianos (2018), 342. See also Danish Maritime Authority (2017), 29.
[81] Ibid.
[82] Klein et al. (2020), 729.
[83] Danish Maritime Authority (2017), 29.
[84] Klein et al. (2020), 729.
[85] SAR Convention

assistance in distress situations.[86] The SAR Convention would thus require adjustment or an exemption of autonomous ships, but this poses a risk of political and ethical concerns about the safety of seafarers.[87] Other conventions that relate to providing assistance in duress situations emphasize that the master of the ship is only obliged to provide assistance to the extent that can be reasonably expected of him, meaning that technically these provisions do not present a legal issue when following the logic that the reasonable expectations for autonomous ships providing assistance is low.[88] This rationale of low expectations is, however, politically and ethically very challenging as it would justify improperly equipped and prepared vessels to navigate. Indeed, in one proposal within the IMO scoping exercise, the issue of evacuating persons on board and rescuing persons from the water was commented as one of the legal issues that cannot be accommodated by amending existing instruments or applying equivalents.[89] Some authors, however, have approached the issue by focusing on technological solutions for autonomous ships regarding search and rescue operations, stating that regulations should focus on what kind of equipment autonomous ships should have to provide satisfactory assistance.[90] A creation of a new legal convention or an amendment to SAR to allow autonomous ships to be deployed limitedly with satisfactory distress assistance could be an interim solution, and solutions in route planning, technological development and incident reporting could facilitate the discussion on the matter.

3.2.2. UNCLOS

In international maritime law, the UNCLOS is an extremely important source of law and thus relevant for analyzing the legal fit of autonomous ships in the existing jurisdictional system. Although some commentators have noted that UNCLOS might potentially limit IMO, a stronger argument is the acceptance of authority of IMO to regulate rather freely on the matter due to the references to "generally accepted international regulations"[91] as stated in UNCLOS.[92] Regardless of the issue of final authority, the existing rules of UNCLOS and potential compatibility issues are essential for further discussion and regulatory work. Worth

[86] Komianos (2018), 343.
[87] Ibid..
[88] Veal & Ringbom (2017), 106.
[89] MSC 102, commentary by Belgium, China and the Netherlands. This comment was for SOLAS and the LSA Code, but the issue is the same as with SAR.
[90] Danish Maritime Authority (2017), 24. See also Komianos (2018), 343.
[91] Art. 94(5) UNCLOS
[92] Ringbom (2019), 162.

noting is that UNCLOS does not particularly define ships. Whereas Article 91 relates to the nationality of ships and article 92 to the status of ships, what constitutes a ship is outside the scope of UNCLOS. A reasonable assumption can be made that autonomous ships would be classified as ships for the purposes of UNCLOS.[93] The same assumption can be extended to other conventions and national laws as well, as other international conventions and national laws that define the term "ship" usually state the definition without referring to the level of manning.[94] This assumption that autonomous ships are ships under UNCLOS and other rules is justified by the logic that similar ships performing similar tasks should be subject to the same rules when related to the tasks and issues that those rules cover, and this concept of autonomous ships being ships in the legal sense is widely accepted in scholarly discussion.[95] This widely accepted principle is supported and used in this study and further discussion on the matter is outside the scope of this study.

Article 94 sets out the duties of the flag state, consisting of, *inter alia,* a duty to maintain a register of ships and assume jurisdiction under its internal law over each ship flying its flag. A potential issue against the legality of autonomous ships is that Article 94 requires "that each ship is in the charge of a master and officers who possess appropriate qualifications, in particular 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."[96] This statement could be interpreted as preventive regarding fully autonomous ships. On the other hand, UNCLOS states that regarding paragraphs 3 and 4 of Article 94, "each State is required to conform to generally accepted international regulations, procedures and practices and to take any steps which may be necessary to secure their observance."[97] This means that UNCLOS notes the relevance of "generally accepted international regulations", and, therefore, its wording of manned crew consisting of a master and officer is not necessarily binding in its entirety, if international regulations produce alternative procedures. UNCLOS thus refers to continuously changing international rules in a fairly abstract manner, meaning that more precise international rules can be drafted elsewhere.[98]

[93] Ringbom (2019), 162.
[94] Veal et al. (2017), 1.
[95] Ringbom, Collin & Viljanen (2016), 37. See also Carey (2017), 2., Veal & Tsimplis (2017), 303. and Suri (2020), 1.
[96] Art. 94(4)(b) UNCLOS
[97] Art. 94(5) UNCLOS
[98] Ringbom, Collin & Viljanen (2016), 38.

This means that although UNCLOS states important principles of manning and a master, the more specific rules are adapted by competent international organizations such as IMO. IMO could thus regulate on the matter regardless of the wording of paragraph 4 of UNCLOS Article 94 by using the principles set out in paragraph 5. Nonetheless, for the sake of clarity and consistency, amendments would be beneficial if these international guidelines and regulations specifically allow fully autonomous ships.

3.2.3. EU and Autonomous Ships

In addition to IMO guidelines on MASS Trials, the EU has published "EU Operational Guidelines for Safe, Secure and Sustainable Trials of Maritime Autonomous Surface Ships (MASS)".[99] The EU guidelines determine what actions are to be considered by administrations responsible for MASS trials, what actions are to be considered by the autonomous ships and what kind of reporting requirements exist and how information should be shared.[100] The main objective of the guidelines is to ensure that MASS trials are conducted "in a safe, secure and environmentally friendly manner".[101] The EU thus accepts the existence of MASS trials, but the guidelines mention that autonomous ships provide both opportunities and challenges for the maritime sector in various manners including the existing legal frameworks.[102] However, the guidelines refer to the IMO scoping exercise in terms of regulatory work and hereby excludes larger regulatory analysis in the guidelines. The guidelines are still useful for legal analysis of autonomous ships, as the guidelines establish conditions for administrations and the industry for MASS trials and hints that the EU is supportive of autonomous ships from a legal viewpoint, although too far-fetched conclusions based solely on the guidelines should be avoided. The guidelines also mention this by noting that the guidelines are non-mandatory in nature and should not be considered as creating or replacing any existing legal obligations.[103] Their importance is still valid in the sense that it illustrates positive political support by the EU for the legal development of autonomous ships, as the European Commission emphasized its encouragement of maritime future with autonomous ships and stated that the European Commission continues to engage also internationally the development of autonomous ships.[104] The EU is an important factor

[99] EU MASS Guidelines (2020)
[100] Ibid, 7.
[101] Ibid, 7.
[102] Ibid, 2.
[103] Ibid, 4.
[104] EC (2020)

in international and European law and political support is necessary for the advancement of legal acceptance of autonomous ships.

3.2.4. Role of Classification Societies

In any type of seafaring, classification societies play an important role. Strictly from a legal perspective, a classification society is not a prime legal player but it has an important facilitating role, operating as a semi-private regulator in maritime transportation.[105] In many flag states, the task of administering and enforcing regulation is often granted to maritime authorities that in turn delegate these tasks to classification societies, especially regarding the SOLAS Convention.[106] Usually classifying societies define their views on the development of autonomous ships in the form of guidelines, but some scholars view these as fairly general statements regarding navigational issues.[107] However, some of the guidelines by classification societies are comprehensive and more detailed regarding some particular matters, such as the development of an autonomous engine room.[108] In addition, these guidelines provide guidance on compliance with maritime regulations, such as COLREG and SOLAR that are useful for further legal development.[109] Henceforth, classification societies are in part a driving force in developing technical standards and codes of conduct for autonomous ships.[110] Danish Maritime Authority recommended that with regards to autonomous ships classification societies should shift their focus from the components and equipment to the systemic and operational level.[111] The role of classification societies with autonomous ships could thus change to a more specific role, and in fact classification societies have already shown a moderate level of activism in providing definitions and clarifications in the area of autonomous ships.[112] A potential direction of development would be a more specific role in the process of development of autonomous ships, both legally and technically.

[105] Solvang (2019), 242.
[106] Danish Maritime Authority (2017), 10.
[107] Felski & Zwolak (2020), 42.
[108] Burmeister & Moraeus (2015), 1.
[109] Amro, Gkioulos & Katsikas (2019), 76.
[110] Danish Maritime Authority (2017), 11.
[111] Ibid 15.
[112] Ringbom (2019), 153.

3.3. Legal Challenges

As can be witnessed discussion of international maritime law, autonomous ships pose legal challenges. One of the key legal issues with MASS operations is the lack of manned crew. The mere use of technology to support the capabilities of ships' crews to perform their duties is not legally problematic in itself.[113] Using a two-dimensional level of autonomy with the level of on-board manning and the level of system autonomy, different types of legal challenges increase when either of these levels of autonomy rises. In the case of periodic unmanned or unmanned operations, legal challenges are related to existing requirements demanding physical presence on the bridge and other types of requirements that require crews to perform their duties.[114] In the case of system autonomy, the legal challenges are related to the decision-making loop and the requirements of human presence in the process.[115] The usage of nonlinear framework for the levels of autonomy is thus useful to illustrate that different concepts of autonomy pose different challenges.

The legal obligations of the ship master with autonomous ships are a broad challenge, as the requirement to have a master on board is present in various conventions, regulations and professional practice. The key responsibilities of the master are related to ship's safety, public authorizations and the representation of the shipowner. In terms of ship's safety, the master is in charge of the entire vessel, the crew and the cargo and their safety.[116] The master has a role to hold administrative powers, especially when a ship is in international waters.[117] In these situations, the master acts as the representative of the state. The master also represents the shipowner, for example by being authorized to sign salvage contracts and legal affairs on behalf of a shipowner.[118] The obligation to keep the master on board is present in contemporary legislation, and usually if a master is in any way prevented from operating on board, the rules require him to be replaced by the oldest deck officer.[119] The issue is, therefore, whether autonomous navigation without a master on board, as understood by customary and codified maritime law, is possible.

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[113] Ringbom (2019), 148.
[114] Ibid.
[115] Ibid.
[116] Vojkovic & Milenkovic (2020), 334.
[117] Ibid.
[118] Ibid.
[119] Ibid.

The levels of autonomy are relevant for the discussion on the master. Referring to the discussion of the levels of autonomy, fully or partially autonomous ships do not have any type of a master and remote-controlled ships that are less autonomous in comparison, are operated from a remote location and could have a master in a remote center.[120] With remote-controlled ships and ships with lower autonomy,[121] the key decision is on the master and the existing rules about the powers and authorities of the master could be adjusted, clarifying that a ship may have a master operating remotely.[122] Regardless of such a clarification, an argument can be made that remotely operating ships fulfil the general requirements to be "in charge of a master and officers who possess appropriate qualifications",[123] as stated in UNCLOS 94(4)(b), even if the human being is not physically on board.[124]

Regarding the partial autonomy and full autonomy, the requirement to have a master in charge of a ship is not applicable in its current form. A fully autonomous ship without any human involvement in navigational decisions does meet the existing requirement of UNCLOS 94(4)(b), as it requires the ship to be in charge of a master and officers.[125] Interpreting this article otherwise could be considered too favorable towards autonomous ships against the text and the intention of the requirement. Nonetheless, worth remembering is the flexibility of UNCLOS, meaning that it refers to international maritime regulations that can be adopted and these international maritime regulations can clarify and specify maritime issues. If the principle of remotely operating master is accepted in the existing or slightly altered regulatory framework, some form of SCCs will likely be required with fully autonomous ships. Remote controlling would thus be used as a backup, not only for unexpected events but also to better satisfy legal requirements of having some human presence and control over the ship.

Considering the different roles of the master of ship, current rules and practice recognize the master as the representative of the shipowner, and this issue would require clarification with autonomous ships. Shipowners would have to delegate these representative duties, as the

[120] Vojkovic & Milenkovic (2020), 335. Remote-controlled ships represent levels 3-4 of the Lloyd's List Register

[121] Levels 0-4 of the Lloyd's List Register

[122] Vojkovic & Milenkovic (2020), 337.

[123] UNCLOS 94(4)(b)

[124] Danish Maritime Authority (2017), 23.

[125] Ibid.

remote operator could not practically check the quantity and quality of goods in a cargo loading or unloading situation.[126] The remote operators would not necessarily have as strong representation rights as a regular ship master, and this potential rise of remote operators as independent legal entities could lead to separate considerations of liability issues.[127] These issues are to some extent related to the development of technology and general acceptance of virtual presence, meaning that if an acceptance of remotely operating master increases, these challenges expectedly diminish. Nonetheless, a legal clarification of representative rights and quality controls duties of a master would be recommended to answer some of the needs of marine insurers to support the economic incentives to develop autonomous ships, as without these clarifications insurers could demand premium pricing for marine insurance on autonomous ships.

A legal challenge with existing maritime conventions is that autonomous ships as such are usually not included in them and that the conventions presume the existence of a master and crew. The existing regulations and the phrasing of terms does not directly support autonomous ships, even though they do not necessarily prohibit them.[128] This can cause contradiction and a lack of clarity if these regulations are attempted to directly apply to autonomous ships. Furthermore, the lack of prohibition of autonomous or remote operations does not mean that autonomous ships could be directly accommodated into the existing legal framework.[129] Worth noting is that many conventions on maritime operations were written in an era in which autonomous or remote operations were not realistic, and the drafters of these conventions did not foresee the prospect of autonomous ships.[130] This historical context may have legal implications. In treaty interpretation, according to Art. 31(1) of the Vienna Convention on the Law of Treaties, “a treaty shall be interpreted in good faith in accordance with the ordinary meaning to be given to the terms of the treaty in their context and in the light of its object and purpose.”[131] What could be argued is that as long as autonomous ships aim to achieve similar performance level than manned ships, the conventions are not problematic given their original meaning. Nonetheless, leaving the acceptance of autonomous ships to fairly liberal treaty interpretation would be a weak

[126] Danish Maritime Authority (2017), 65.
[127] Ibid 26.
[128] Komianos (2018), 346.
[129] Ringbom (2019), 161.
[130] Ibid.
[131] Art. 31(1) Vienna Convention

direction of legal development, meaning that some new amendments and clarifications to the role master and manning are required for legal clarity and conformity. Amendments to maritime regulations are also useful, as the drafters of many existing conventions did not foresee unmanned ships, meaning that the existing law does not fully reflect the practical realities of seafaring.

Additionally, a problem pertaining to the lack of manning with autonomous ships is the issue of seaworthiness. This is essentially related to insurance policies in maritime law, such as the Hague-Visby rules. According to the Hague-Visby rules, a ship must be properly manned in order to be seaworthy.[132] English case law, which is crucial for international maritime law due to its prominence as the applicable national maritime law, has similar requirements as well. The test of seaworthiness stems from McFadden v Blue Star Line, which states that the shipowner must be "ordinary, careful and prudent" when sending a ship for her voyage.[133] Regarding the issue of manned crew and seaworthiness, in Hong Kong Fir Shipping Co v Kawasaki Kisen Kaisah, an English court confirmed that insufficient and incompetent crew can mean that a vessel is unseaworthy.[134] Nonetheless, in the Hong Kong Fir Shipping Co v Kawasaki Kisen Kaisah, the court did mention that a 'numerical deficiency' would not have rendered the ship as unseaworthy, if the crew had been efficient and competent, thus allowing for some flexibility regarding the lack of physical crew members. In addition, unseaworthiness is essentially relevant for cargo ships, meaning that potential legal challenges could exist with autonomous ships used for shipping cargo.[135] The Hague and Hague-Visby Rules have exclusions for shipowners for liability for cargo damage, but a shipowner may not benefit from these exclusions if they fail to exercise due diligence in ensuring the seaworthiness of their ship prior to a voyage.[136] Under English maritime law, the shipowner has absolute responsibility for the seaworthiness of the ship, meaning that classification of a ship does not guarantee seaworthiness.[137] The shipowner is thus ultimately liable for the seaworthiness of a ship, and clarifying the rules on seaworthiness of autonomous ships would be beneficial to guarantee shipowners of the expected design and

[132] Hague-Visby Rules
[133] McFadden v Blue Star Line [1905] 1 KB 697
[134] Hong Kong Fir Shipping Co v Kawasaki Kisen Kaisah [1961] EWCA Civ 7
[135] Carey (2017), 6.
[136] Ibid 7. Seaworthiness is not only related to the manning of the ship, but also to compliance with different rules and requirements set by statutes and classification societies, see Karlis (2018), 124.
[137] India v West Coast SS Co (The Portland Trader) [1964]

conduct with seaworthy autonomous ships. In the international maritime framework, legal acceptance of autonomous ships as seaworthy would be important to overcome potential issues with insurance policies and classifications, and an international statement on the rules of autonomous ships and seaworthiness would clarify the requirement.

To conclude, autonomous ships do pose notable legal challenges, however at the same time these are not hurdles that could not be overcome. Direct or indirect wordings of manning exist in some conventions, such as with Rule 2 of COLREG that refers to master and crew and STCW Convention that includes watchkeeping provisions with physical presence. These types of direct wordings of manning are problematic with fully autonomous ships without any human presence in the decision-making loop. These requirements for physical presence of master and crew on board are legally challenging, but a significant amount of maritime law can be considered supportive or at least neutral concerning autonomous ships. The question with many rules is the issue of interpretation. Using a loose interpretation, arguments could be made of having a master in SCCs, using technology to substitute human senses when necessary and even considering very advanced AI systems as masters or crew members by possibly providing legal personalities for AI, which is a fairly contested topic.[138] However, a more realistic and reasonable direction is to provide clarifications, amendments and solutions. Although numerous IMO rules are not in direct conflict with the development and use of autonomous ships, they should be understood in a similar manner to permit autonomous operations.[139] Therefore, proper amendments of regulatory framework would be beneficial in order to legally shield and assure the acceptance of autonomous ships in seafaring.

3.4. Legal Solutions

Whereas autonomous ships certainly have some legal challenges, legal solutions also exist with autonomous ships. In spite of some challenges, the regulative environment in the maritime industry has been gradually supportive and forward-looking with the issue.[140] The regulative environment requires some work to increase clarity, consistency, and functionality. In some areas, autonomous ships are more likely to comply with existing and potential future laws and regulations. One potential for legal solutions is the requirement to

[138] Solaiman (2017), 155. See also Saripan & Putera (2016), 824. and Cerka, Grigiene & Sirbikyte (2017), 685.
[139] Ringbom et al., (2020), 66.
[140] Saarni, Nordberg-Davies & Saurama (2018), 34. See also Ringbom et al., (2020), 76.

have a proper management system. The ISM code was integrated into SOLAS in 1994 and one of the requirements in the code is that shipowners should adopt a safety management system.[141] Section 4 of the ISM code states that shipowners are held responsible for safety management systems on their ships, and a direct access between a person or persons ashore and the highest level of management of the shipowner should exist. One of the cases that gave rise to this rule was an investigation on the MV Herald of Free Enterprise disaster, where the Court found the owners partly causing or contributing to the capsizing of the freight carrier.[142] In that disaster, the English court ruled that the owners of the freight carrier failed in their duty to give clear orders about the responsibilities and tasks of the officers on-board.[143] An argument can be made that owners of autonomous ships may find it easier to act accordingly with this requirement than those of manned ships through a more centralized and direct control of the ship in comparison with conventional manned ships.[144]

The issue of maritime conventions was discussed in the earlier section with a conclusion that some maritime conventions, mainly due to historical context, do not expressly prohibit remotely or autonomously controlled vessels. Practically all maritime conventions have been written with the basic assumption that vessels have a crew physically onboard.[145] This lack of prohibition may provide legal opportunities for autonomous ships, as the lack of a prohibition makes an authorization of a new legal practice easier, at least in formal terms.[146] In the short-to-medium term, an endorsement by IMO or its member states could be made about the principle that crew functions can be performed outside the ship itself, such as from the SCCs. Various rationales exist for allowing these types of recommendations that in their literal meaning would appear to be contrary to the requirements for the presence of master and manning. An argument for allowing a master to operate remotely could be that the system of the SCCs can be designed in a manner that is almost identical to a physical bridge. This rationale stems from functional similarity, and the same logic applies with requirements for the use of human senses that could be fulfilled by technological means. Therefore, rationale for allowing amendments by IMO exists and IMO could provide statements and guidance to steer the regulatory development. These clarifications would be useful, even if

[141] ISM Code
[142] Praetorius, Lundh & Lützhöft (2011), 217.
[143] MV Herald of Free Enterprise: Report of Court No. 8074 [1987]
[144] Carey (2017), 6.
[145] Hand (2018)
[146] Ringbom (2019), 163.

the adaptations are non-binding. Additionally, basic principles regarding human oversight of operations would be useful to clarify the accepted level of autonomy for individual bridge functions.

These types of interim endorsements would help the regulatory work on autonomous ships, and some work on this matter has been done in the form of IMO Interim Guidelines on MASS Trials, but notably those guidelines are for MASS Trials, not for commercially deployed autonomous ships. Especially in a scenario in which autonomous ships would be developed faster beyond mere trials, new regulatory endorsements would be useful. This means that from the perspective of timeline, the partially autonomous ships that are more compliant with existing regulations will be deployed first and international regulators have more time to provide amendments, recommendations, and guidelines for fully autonomous ships, especially if the commercial deployment of partially autonomous and remotely operated ships is successful, both commercially and legally. Nonetheless, the lack of express prohibitions in some conventions and the existence of interim guidelines on MASS trials are both useful for providing new solutions to clarify both the existing regulations and also to create entirely new rules on autonomous ships.

The role of IMO in regulations is crucial, and positively for the development of autonomous ships IMO is conducting the scoping exercise and actively looking for new regulatory solutions. As a conclusion of the scoping exercise, IMO could amend and clarify the wording of existing conventions. For example, in COLREG Rule 5 it could expressly state that sufficient sight and hearing can also be achieved by technical means, and not only by physical human presence on board. Moreover, SOLAS could be clarified to expressly allow for unmanned ships, provided that they meet certain safety criteria. The work of IMO is important, as it could provide international adoption and implementation that would be followed in a uniform manner across the globe. On the other hand, IMO is made of its constituent member states the possibility exists that some member states are opposed to allowing fast and liberal legal development of the rules for autonomous ships. Therefore, the role of national states is important both separately and also internationally due to the influence of nation states on the international legislative regulations.

An area for legal solutions and opportunities with autonomous shipping exists with national legislation. If the international legal framework progresses slowly in the matter, there is the possibility that national legislators move faster than international regulators.[147] Nordic countries that are front-runners in developing autonomous ships, mainly Norway and Finland, might be willing to draft laws regarding matters such as liability and insurance issues with autonomous ships.[148] Other countries that are conducting MASS Trials such China and Singapore are also likely to push their own rules on the matter. This national legislative movement can act as an opportunity and a precedent for innovative legislative action that could affect and potentially speed up international regulations.

A positive legal indication from a national legislative viewpoint emerged in the UK, which is excellent news for the legality of autonomous ships due to the importance of English maritime law. MARLab recruited the NOC to conduct an operational and legal review of English maritime law such as the Merchant Shipping Act of 1995.[149] The main finding was that there are no provisions in the Act that explicitly prohibit MASS operations, although some areas in the legislation were considered vague and potentially difficult for compliance issues.[150] MARLab project gathered information and conducted a cross-sector review utilizing both industry stakeholders and academia to support regulatory work. Although the MARLab project ended in September 2020, the project illustrated how regulatory agencies can co-operate with industry stakeholders to review legislation and propose policy suggestions to tackle existing and potential challenges. This project also emphasized legal solutions of noting the lack of explicit prohibitions of MASS operations when applicable, as with the Merchant Shipping Act of 1995 in the UK that can be considered an opportunity for legal acceptance and compliance of autonomous ships. In addition, national projects on regulatory frameworks governing other forms of autonomous transportation may provide help in drafting amendments and suggestions for regulation with autonomous ships. As an example, the MARLab project was followed by a collaboration project to review regulation of autonomous machines in aerospace and manufacturing and the results from this project may provide valuable insights for the legal solutions of autonomous ships as well.[151]

However, if different jurisdictions end up applying different rules on autonomous ships, this can give rise to legal uncertainty and lack of consistency, which would be a major problem

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[147] Hand (2018)
[148] Cowan (2018)
[149] MARLab (2020)
[150] Ibid.
[151] Macola (2021)

for the development of autonomous ships. This lack of clarity and predictability can negatively affect willingness to invest in autonomous shipping by shipowners, especially among those that are involved with cross trading.[152] Open markets and uniform application of regulations are important for cross-trading, meaning that although national law has possibilities for legal solutions, these solutions are stronger if pro-MASS nations co-operate and coordinate their legislative actions. Solutions for supportive and functional legal frameworks exist, especially if domestic and international law are devised by including other actors into the process, such as shipping companies, seafarers' unions, and manufacturers of autonomous ships.[153]

The limitations of national law are nevertheless necessary to be taken into consideration, as coastal states or regional organizations have somewhat limited solutions for independent regulation outside the limits of their territorial sea, whether the national law is advancing or preventing the legal development of autonomous ships.[154] Soft law instruments by the IMO are argued to be more effective in terms of legal weight for the authorization of autonomous ships internationally than binding national or regional rules.[155] However, in some fields of law regarding autonomous shipping, national legislation can be a useful site for adjusting legal rights and duties of autonomous shipping, especially in terms of liability regimes and contractual arrangements.[156] Nevertheless, national jurisdictions have potential to speed up and steer the international regulatory development by providing national solutions that can inspire international regulations, and coalitions of pro-MASS states can lobby for regulatory work to better accommodate for autonomous ships at the IMO .

The role of various private actors in maritime transportation is also important and provides solutions for legal development. If both international and national legislators fail to provide clear and consistent rules and regulations, maritime companies may act by forming guidelines and industrial practices that affect legislative work in the future. Although lack of legislation may hinder development, the general willingness of maritime companies to move forward with autonomous ships may be strong enough so that they could engage with self-regulatory action. Where there is a regulatory gap with regards to certain elements of

[152] Karlis (2018), 126.
[153] Klein et al. (2020), 734.
[154] Ringbom et al. (2020), 75.
[155] Ibid.
[156] Klein et al. (2020), 734.

autonomous ships, the operating companies are responsible for ensuring a sufficient level of safety and, operational effectiveness and for adopting other solutions for potential legal issues, such as liability matters.[157] The role of private and semi-private organizations is nonetheless important in the legal development, as the technological and commercial development of autonomous ships is closely related to the direction and urgency of reforming maritime regulations.

An issue with legal solutions is also that autonomous ships represent advanced technology and arguably their new features would require a completely or for a large part new regulatory framework. Examples of new features that lack existing regulations are the rules on gathering of situational awareness information by technological means, relocation of functions from the ship to a remote location and acceptance of replacing human operation decision-making with technology.[158] These issues certainly overlap with some existing rules, but there is a clear benefit in having specifically designed rules to regulate these matters.

Although this could be viewed as a legal challenge from the perspective of how these regulations would be drafted, the possibility to create completely new regulations is a significant opportunity to build a regulatory framework that efficiently regulates and supports the development of autonomous ships. Autonomous shipping has both clear benefits and risks for seafaring, and thus there is arguably also a strong incentive to create such an efficient legal framework. Moreover, as navigation, similarly to other forms of transportation, is an area where there are significant risks such as pertaining to health, safety and environment, it would seem likely that legislators and other regulating parties would strive to create comprehensive and clear rules not leaving any significant regulatory gaps. An area that currently lacks clear existing rules and presents a notable regulatory gap especially in the context of autonomous shipping is the issue of data sharing, and this will be discussed in more detail in the subsequent sections of this study.

[157] Felski & Zwolak (2019), 54.
[158] Ringbom et al. (2020), 67-68.

4. The Role of Data Sharing with Autonomous Ships

4.1. Introduction

In this chapter, the main methods of operational data gathering and connectivity solutions for autonomous ships and the data transfers between different actors in autonomous shipping are described and discussed. In addition, the role of blockchain technology in relation to autonomous ships is examined. Lastly, information sharing and various forms of open intelligence in maritime transportation are presented.

4.2. Operational Data and Connectivity for Autonomous Ships

Autonomous ships use and store different types of data for different purposes. What can be arguably described as essential ship data consists of collision detection and situational awareness data, navigation data, data related to safety systems and machinery and automation data.[159] Data is used both for navigational and operational purposes, and data sharing through communication channels is a prerequisite for the operation of autonomous ships. The main tasks of an autonomous navigation system are path planning, collision avoidance and manoeuvring control,[160] and these tasks require relevant operational data and a connectivity system that supports data gathering and utilization. Due to the systemic nature of autonomous shipping and the fact that these ships are connected to other actors in the maritime ecosystem, managing the relevant relationships and networks is of central importance.[161] The combination of needs of the autonomous navigation system and presence of the systematic network results into data sharing schemes, which are both multidimensional and multifunctional.

4.2.1. Data for Sensor Systems and Navigation

Collision detection and situational awareness data is gathered from multiple sensors and systems, and this data is used together with navigation data. Situational awareness data is typically gathered from at least perceptual sensors such as cameras, lidars, radars, sonars and positioning sensors. Examples of positioning sensors are GNSS and IMU.[162] A single sensor technology is unable to provide sufficient information for situational awareness, which is why input from multiple sensors is essential for autonomous ship,[163] and sensor fusion, by

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[159] Höyhtyä et al. (2017), 3.
[160] Ringbom et al. (2020), 36.
[161] Snehota & Håkansson (1995) See also Håkansson et al. (2009)
[162] Ringbom et al. (2020), 30.
[163] Poikonen et al. (2016), 16.

which input from multiple sensors is collected, combined and analyzed, is one of the key technologies for reliable autonomous navigation..[164] Sensor fusion can happen at different levels, and in practice sensor fusion is usually most efficient when combining both low-level and high-level fusion approaches.[165] The GNSS receiver is expected to be the primary source of position information for autonomous ships.[166] Cameras provide data to fulfil the role of visual lookout and watchkeeping. Camera sensors enable computer vision and typical camera processing in autonomous navigation consists of object detection and classification.[167] Lidar detection and ranging sensors create cloud representations of their surroundings and provide data for navigation planning, collision avoidance and position estimation.[168] The seamless integration of data processing is important for path planning and reactive collision avoidance, and sensor data can be supplemented by data from static map databases.[169] Situational awareness data is thus collected from multiple sources and combined to provide as accurate situational awareness as possible.

Navigation data is gathered from the AIS system and GPS, and the collision detection and situational awareness data are used with navigation data to decide the manner of safe sailing.[170] AIS is not technically a sensor, but it is commonly used to support sensor fusion, although its availability and timeliness are not guaranteed for all vessels.[171] According to the report by the Ministry of Transport and Communications of Finland, AIS in itself is not sufficient information for autonomous navigation, but it can together with other technologies have a role in sensor fusion.[172] Nonetheless, AIS stations are designed to operate autonomously and the automatic exchange of shipboard data among actors is a potentially beneficial aspect of AIS for autonomous ships.[173] ARPA and ECDIS are other potential sources of supplementary navigation data.[174] Safety systems include a broad range of systems such as fire safety systems and optical sensors for ship status detection. Additionally, various safety equipment for emergency situations, such as GMDSS and

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[164] Poikonen et al. (2016), 27.
[165] Ibid 29.
[166] Felski & Zwolak (2020), 47.
[167] Ranft & Stiller (2016), 8.
[168] Ringbom et al. (2020), 28.
[169] Poikonen et al. (2016), 16.
[170] Höyhtyä et al. (2017), 5.
[171] Ringbom et al. (2020), 26.
[172] Ibid.
[173] Goudossis & Katsikas (2019), 410.
[174] Poikonen et al. (2016), 16.

EPIRB systems share and use data for locating purposes in distress situations.[175] Machinery and automation data are gathered from sensors and actuators that are used to monitor and control mechanical parts of the ships, such as the status of engines, propulsion system, ballast water systems and cargo. These aspects require monitoring and data transfer to remote operators, as well as internal data transfers within the systems of a ship.[176] Thus, autonomous ships use data both internally and externally for multiple purposes ranging from navigation to system management, and data transfers occur both internally and externally.

4.2.2. Connectivity and Communications Architecture

An efficient system of connectivity management and communication channels are essential for autonomous ships. Connectivity is used to strengthen SCC operations with remotely controlled ships, monitor autonomous operations and recognize the scheduling needs of maintenance work.[177] In remotely controlled vessels, there needs to be a communication system that provides a level of visibility and control that is as similar as possible, or even better, than what would be on board. Rapid video encoding on board and decoding in a shore control facility are necessary for remote control.[178] With fully or partially autonomous ships, the technical focus is more on onboard computing as opposed to connectivity, yet connectivity issues are also essential with fully or partially autonomous ships.[179] At least in principle, fully autonomous ships could operate successfully for a long period of time without operational data connection to the SCC, but at least in the initial stages a backup data connection to an SCC may be required.[180] Nonetheless, a robust and compatible ICT structure is relevant with all levels of autonomous ships and fully autonomous ships need to be able to communicate effectively with ports, other ships and the SCCs.

For connectivity management, the data transferring system has to support the safety and security of autonomous ships, as these should be at least as safe as unmanned ships in order to be acceptable for commercial use. Consequently, the design of the connectivity system must be built in a manner that a single failure with data transfer should not significantly

[175] Höyhtyä et al. (2017), 5.
[176] Ibid.
[177] Ringbom et al. (2020), 160.
[178] Ibid 39.
[179] Ibid 40.
[180] Jalonen, Tuominen & Wahlström (2016), 59.

affect the ability of the ship to operate in all possible situations and environments.[181] One role of connectivity management is to oversee the selection of the most appropriate RAT and route for the data to facilitate efficient data transfers.[182] The amount of data created by the ship's sensor to the SCC might require significant amounts of data to be transferred, which means that methods for reducing the amount of sensor data is an issue to consider to ensure that the correct data is transmitted and to prevent an overload.[183]

The connectivity system should have proper coding and cyber security protocols in order to mitigate the main risks for autonomous ship communications, namely a loss of data, data corruption and alteration and hijacking of data.[184] Other potential cybersecurity attacks on autonomous ships are attacks preventing authorized remote control of the vessel, attacks interfering with the sensor systems and other forms of unauthorized access to vessel data or systems.[185] The connectivity system needs to be built in a manner that has effective measures for preventing and detecting intrusion as well as damage control and reliable recovery mechanisms.

4.3. Blockchain Technology for Autonomous Ships

Blockchain means a specific type of database that operates by a digital ledger of transactions. Blockchain technology allows a community of users to record transactions in a shared ledger with the principle that any transaction cannot be changed once published.[186] In data sharing, data is frequently maintained by multiple parties that poses the question of protecting privacy in a multi-party data transaction.[187] Blockchain technology can be utilized to achieve secure data storage and sharing, as well as prevent data sharing without authorization.[188] Due to the possibilities to use blockchain technology for data storage and sharing, it is considered a viable solution also for autonomous ships.

[181] Rødseth et al. (2013) 1.
[182] Höyhtyä et al. (2017), 6.
[183] Poikonen et al. (2016), 30.
[184] Höyhtyä et al. (2017), 6.
[185] Ringbom et al. (2020), 42.
[186] Yaga et al. (2018), 1.
[187] Zheng et al. (2018), 558.
[188] Kang et al. (2018), 4661.

The relevance of blockchain technology for autonomous ships and more broadly for the maritime industry is recognized as a driver of change.[189] Autonomous ships rely heavily on communications, which means that the security of communications and data security are of critical importance.[190] Blockchain technology can play a key role in the improvement of the security and operation efficiency of autonomous ships.[191] Blockchain technology could be used for authentication and storage network purposes and create a distributed consensus network for autonomous vessels control.[192] The possibilities to use blockchain technology for autonomous ships and in the maritime ecosystem in general are thus interesting and have the potential to provide solutions for some challenges with data sharing and autonomous ships.

4.4. Information Sharing and Open Intelligence in Maritime Industry

Information sharing and open intelligence in the maritime industry are relevant for data sharing with autonomous ships, as they affect the general information framework in the maritime industry. This information framework in the maritime industry relates to the information environment in which autonomous ships operate, and thus autonomous ships do not operate in isolation but are affected by information network initiatives. The information sharing initiatives also emphasize the relationship between commercial seafaring and public authorities, and their respective roles with data sharing. An example of information sharing is MDA that relates to “any activity that could impact upon the security, safety, economy or environment”.[193] Although the concept of MDA stems primarily from a public policy and national security perspective,[194] MDA has its intersections with commercial seafaring and international law and its principles are present in other information sharing initiatives.

Various information network initiatives exist that aim to increase situational awareness and maritime safety. In the EU, CISE aims to enhance the authorities’ cooperation in the maritime domain.[195] The MARISA Horizon 2020 is another EU project that aims to improve maritime security communities’ information exchange, situational awareness, decision-

[189] Czachorowski, Solesvik & Kondratenko (2019), 561.
[190] Petkovic & Vujovic (2019), 333.
[191] Ibid 336.
[192] Ibid.
[193] IAMSAR
[194] Guilfoyle (2017), 301.
[195] Tikanmäki & Ruoslahti (2017), 393.

making and reaction capabilities with different types of data and information.[196] The user community of maritime surveillance in the EU consists of organizations responsible for border control, fishery, defence, maritime safety and security, marine environment, customs, and general law enforcement.[197] The EU aims to maintain a comprehensive sphere of information sharing in maritime transportation, and in the core of this framework is SafeSeaNet. The purpose of the SafeSeaNet is to link together authorities across Europe to share data on situational awareness in the maritime domain and provide solutions to authorities.[198] The existing legal core of maritime information sharing in the EU is the VTMIS Directive, which will be discussed in more detail in the following chapter.

Representing the holistic notion of data sharing with all maritime transportation, both private and public, digitization and data sharing have been stated as areas for improvement with maritime transport chains.[199] A generally acknowledged challenge with maritime transportation is that various actors within the maritime transportation chain lack knowledge on the progress and possible revisions or delays to the events that strongly affect the maritime chain.[200] The maritime transportation chain is made of many independent actors, who may lack the incentives to share data if it does not serve their own interests.[201] This issue of companies and other organizations refusing to share data is a common topic in data sharing, as some companies are reluctant to share data if it could benefit other companies more than them, which may lead to only sectional data sharing.[202] If actors in the maritime transportation chain refrain from sharing information, the subsequent lack of knowledge makes planning and the proper timing of actions difficult.[203] Various authors in scholarly literature have called for improved and increased data sharing in the maritime domain.[204] Arguably the rationale to share data within the maritime transportation chain is strong and reasonable, as it can benefit all parties by developing more effective and functional maritime transportation. However, more importantly companies and other operators within the maritime industry should be informed and incentivized to share relevant information and

[196] Rajamäki, Sarlio-Siintola & Simola (2018), 424.
[197] Tikanmäki & Ruoslahti (2017), 392.
[198] SafeSeaNet
[199] Lind et al. (2018), 1.
[200] Ibid.
[201] Ibid.
[202] Fitzgerald (2013). See also Huttunen et al. (2019), 4.
[203] Lind et al. (2018), 1.
[204] Ibid. See also Lind et al. (2021), 137.

also acknowledge what kind of data is relevant for which parties. Reaching the full potential of autonomous ships requires appropriate information sharing, which means that the role and requirements for data sharing by autonomous ships should be specified in information sharing initiatives.

Several proposals to improve data sharing with maritime transportation exist. In the EU, the STM Validation Project aims to improve the full maritime transport chain by providing real-time data available to all relevant and authorized actors.[205] As a part of the STM project, the PortCDM has been developed with the aim to enable more predictable timings and operations. The method of PortCDM is to build unified and standardized data exchange protocols for different actors in maritime transport, addressing the need to secure and utilize the flow of data about navigational plans, results, and alterations.[206] The role of data sharing in information networks has thus been noted as a key factor in improving maritime transportation and naturally such initiatives are strongly linked to the development of autonomous ships.

Data sharing has clear advantages for planning the actual operations of autonomous ships, but also for improvements in the development phase. Open data sharing has been linked with a potential for improvements with autonomous machine-to-machine interaction, which is a relevant factor for developing autonomous ships.[207] More open data sharing may enable new algorithmic value creation and more autonomous methods for carrying out certain tasks on autonomous ships.[208] Projects that aim to improve the development of continuous testing and remote verification systems connected to the ship's dynamic position system and improvements in the autonomous shipping ICT infrastructure exist, and results of such projects could be shared beneficially.[209] Therefore, open intelligence regarding testing and development of AI systems with MASS operations has the potential to both speed up the development of autonomous ships and to provide practices and systems for data sharing after the initial commercial deployment.

[205] Lind et al. (2018), 2.
[206] Ibid.
[207] Seppälä et al. (2019), 12.
[208] Huttunen et al. (2019), 4.
[209] BOURBON Smart Shipping Program (2019) and AUTOSHIP - Autonomous Shipping Initiative for European Waters (2019)

5. What Are the Legal Challenges and Solutions with Data Sharing and Autonomous Ships?

5.1. Introduction

This chapter analyzes both legal challenges and solutions for data sharing within the context of autonomous shipping. Operation of autonomous ships generate a significant amount of data which requires collation, storage and sharing that should be conducted legitimately.[210] As autonomous ships develop further, the emergence of new codes and practices is expected to develop along with international legal regulation.[211] Considering that data sharing is a crucial topic with autonomous ships and data sharing has its own operational and legal principles that are relevant for autonomous ships, this chapter aims to analyze the issue from a legal viewpoint.

5.2. Legal Challenges with Autonomous Ships Related to Data Sharing

In this section, various legal challenges relating to autonomous ships and data sharing are presented and examined. The aim of this analysis is to highlight areas where owners and operators of autonomous ships may face legal challenges and compliance issues.

5.2.1. Cyber Security

While autonomous ships share similar cyber security risks as conventional and regularly manned ships, there are also certain cyber security risks that are specific to autonomous ships and their autonomous nature. According to developers of autonomous ships, cyber security is a significant problem for autonomous ships and ensuring a sufficient level of security is a critical requirement.[212] Autonomous ships are entities with many connections and may be targets of cyberattacks at multiple vectors and surfaces.[213] In terms of cyber security, autonomous ships are unique entities and arguably appealing targets for cyberattacks, as when commercially deployed, they are likely to be the largest physical robotic systems operating in the world and have the potential to cause extensive damage.[214] The damage autonomous ships can inflict on human life, property, the environment as well as non-physical economic harm they may cause can be significant due to the potential importance

[210] Hogg & Ghosh (2016), 213.
[211] Ibid.
[212] Länsi-Suomi (2021)
[213] Ringbom et al. (2020), 162.
[214] Ibid.

of autonomous ships in the global value chains.[215] An autonomous ship can deliver major structural damage on infrastructure both along the coastline and offshore.[216] The severity of the harm that cyberattacks on autonomous ships can cause varies. The most severe situation would be a complete loss of control over an autonomous ship. This is an example of a cyber security risk that is somewhat distinct for autonomous ships in comparison to conventional manned ships, as a ship without crew has fewer possibilities of regaining control than an autonomous ship.[217]

Various motivations for cyberattacks on autonomous ships exist and the more connected and automated these ships are, the more fragile they become for cyberattacks.[218] Autonomous ships could be targeted by hacking with the intention to use them in a terrorist attack.[219] An autonomous ship could also be a target of an attack with the aim to mine cryptocurrency, as the attacker could conduct crypto mining by recovering cryptocurrency on the ICT equipment of an autonomous ship.[220] Autonomous ships can also be targets of intentional jamming of AIS or GPS signals or general data communication.[221] As a target of cyber security attacks, autonomous ships are both appealing and vulnerable, which means that robust cyber security requirements can be expected from autonomous ships.

Some regulatory work on cyber risk management in maritime transportation exists, which is also is relevant for autonomous ships. IMO has published the 2017 MSC FAL Guidelines, which presents the general framework of cyber risk management for manned ships.[222] These guidelines provide recommendations on maritime cyber risk management and also provide functional elements that support effective cyber risk management, as defined by IMO.[223] The guidelines do not directly mention autonomous ships, but refer generally to digitization and automation of processes and systems in shipping and their connection to the emergence of new cyber threats and vulnerabilities.[224] In addition to the FAL guidelines, the MSC 98 adopted Resolution MSC.428(98) that encourages administrations to oversee that cyber risks

[215] Ringbom et al. (2020), 162.
[216] Vinnem & Utne (2018), 1485.
[217] Ibid 1488.
[218] Özparlak (2018), 7.
[219] Goodman (2016)
[220] Ross (2016)
[221] Jalonen, Tuominen & Wahlström (2016), 66.
[222] FAL Guidelines
[223] Ibid.
[224] Ibid.

are appropriately addressed in existing safety management systems as defined in the ISM code[225] Private organizations such as BIMCO, which represents shipping companies globally, have also published cyber security guidelines but these guidelines also exclude autonomous ships.[226]Although these guidelines and the resolution are useful for shipowners as a tool to counter cyber risks and prepare for potential cyberattacks, autonomous ships are likely to require stricter regulation.[227] Cyber security matters could be included in the ISM as a regulatory issue, and additionally cyber security standards should be integrated into all shipowner safety management systems.[228] In addition, private organizations could draft guidelines to support the rules and regulations.

Calls have been made for IMO and classification societies to focus on cyberattack threats targeted at autonomous ships and to focus on cyberattack prevention in the ship design.[229] What is relevant for the discussion on cyber security regulations for autonomous ships is that the costs relating to the construction, operation and maintenance required to fulfil the requirements to protect autonomous ships against cyberattacks should not override the advantages of zero manning.[230] However, as cyber security has been noted as a key issue and a challenge with autonomous ships, restrictions are expected to be drafted and investments made to increase cyber security, although the exact nature and associated costs are a matter for further examination and analysis. Very likely the design standards and requirements for autonomous ships must involve various risk reducing measures and systems.[231] In addition, when defining cyber-harm, a particular taxonomy of cyber-harm on autonomous ships could be drafted to illustrate the multidimensional possibilities of harm caused by cyberattacks, reflecting scholarly discussion on definitions of the impacts of cyberattacks and the value of data.[232] In addition to cyber risk management regulations and requirements in ship design, additional IMO technical standards could be drafted and cyber risk management systems monitored by constant red team security assessment, which means cyberattack simulations on autonomous ships.[233] A likely regulatory scenario is that a

[225] Maritime Cyber Risk Management in Safety Management Systems
[226] BIMCO Cyber Security Guidelines (2020)
[227] Ringbom et al. (2020), 163.
[228] Ibid.
[229] Vinnem & Utne (2018), 1485.
[230] Ibid 1490.
[231] Ibid 1490.
[232] Agrafiotis et al. (2018), 1. For the discussion on the value of data, see Nikander, Mattila & Seppälä (2018), 31., Schüritz, Seebacher & Dorner (2017), 5348. and Alen-Savikko & Pitkänen (2016), 23.
[233] Ringbom et al. (2020), 163.

thorough cyber risk management system is required and tested prior to MASS approval for commercial service.[234] Although developers of autonomous ships may not be able to fully anticipate the exact nature of the future rules on cybersecurity in ship design, preliminary inclusion of cyber security management that reflects general maritime guidelines on cybersecurity and AI guidelines on cybersecurity is for the moment a rational and useful direction of action.

A relevant issue with cyber security management and compliance is incident data modelling and sharing. Data modelling is used to represent incident data in an accurate manner to help an organization to prevent similar incidents. In some cases, companies voluntarily share incident data with each other.[235] However, some companies have been unwilling to disclose exposure to cyberattacks and some cyber incidents have been revealed through media or activism.[236] An important issue for this study is the extent of obligatory incident data sharing with autonomous ships. Proposals have been made to create a PKI system that could provide security barriers to mitigate cyber threats and their aftermath.[237] Additionally, a role of such a PKI is to solve trust challenges that are affiliated with data sharing in the maritime sector.[238] These developments could be relevant not only the maritime sector generally, but also autonomous ships due to the fact that the nature of autonomous ships opens them up for specific cybersecurity risks and they are also likely to be more prone to cyberattacks.

Cyber risk insurance is also very relevant for this discussion on cyber security and autonomous ships and for the maritime industry in general. At the point of writing this study, many hull and machinery policies exclude cyber risks from their coverage.[239] If LMA5402 is incorporated into MASS hull policies, this would effectively exclude cover for any ANS failures.[240] P&I rules are not always as strict as the LMA5402 clause, but they could be.[241] Cyber risks are expected to be a relevant security concern with autonomous ships and this might highlight the need to update the EU Directive 2009/20/EC so that P&I policies are

[234] Ringbom et al. (2020), 163.
[235] Koivunen (2010), 55.
[236] Vinnem & Utne (2018), 1486.
[237] Rødseth et al. (2020), 3.
[238] Ibid.
[239] Ringbom et al. (2020), 163.
[240] LR Marine Cyber Exclusion (2019)
[241] Ringbom et al. (2020), 163.

required to cover cyber incidents.[242] If this does not happen, potentially a significant gap in P&I coverage is created.[243] Reflecting the larger discussion of autonomous ships and marine insurance policies, cyber security matters should be included in the discussion, as they could be argued to affect seaworthiness of autonomous ships.

5.2.2. Data Protection

Data protection is a legal challenge for autonomous ships, as these ships store and operate using a significant amount of data, and there is a clear possibility of misuse or unauthorized disclosure of confidential information and personal data when sharing data between autonomous ships and with other actors.[244] Although industrial and other non-personal data has only little or no regulation in terms of data protection, personal data is strictly regulated especially in the EU.[245] Autonomous ships may collect personal data, especially when autonomous passenger ships are commercially deployed. Autonomous ships have to comply with data protection regulations, and this has implications for the creation of data sharing networks, which are necessary for the operation of autonomous ships.

5.2.2.1. GDPR

GDPR applies directly in all EU member states and applies also to the companies outside the EU if they process personal data of data subjects who reside in the EU. Actors within the maritime industry who have a direct or indirect link to the EU have to comply with the GDPR, and consequently the GDPR has broad implications for autonomous ships.[246] The GDPR has several provisions that are especially relevant to decisions taken by autonomous vehicles. Article 12 for transparency mechanisms for informational duties and additionally informs on how this information should be provided.[247] Articles 13 and 14 are relevant as they identify notification duties, and Article 15 regulates the right of access. The GDPR does not provide a definition on automated decision-making, yet Recital 71 requires suitable safeguards against automated decision-making.

[242] Ringbom et al. (2020), 164.
[243] Ibid.
[244] Xiong et al. (2020), 24.
[245] Ringbom et al. (2020), 197.
[246] Agamy (2019), 14.
[247] Özparlak (2019), 8.

Regarding the issue of data controllers, the processing of personal data is only allowed if the data controller has a lawful basis for the processing. In the technology development phase, the party that conducts the development is the data controller.[248] Once autonomous ships are commercially deployed, the amount of data controllers may increase.[249] The party that operates the MASS technologies is the primary data controller, but possibly the shipowner or the operating party is considered as a joint data controller.[250] Arguably the legal basis for data processing with autonomous ships is unclear, however some provisions of the GDPR could potentially provide the bases for legitimate processing of data.[251] Article 6(1)(c) could potentially provide a basis for processing data in deployment situations, as the processing could be linked to compliance with the legal obligations of safe navigation.[252] Additionally, Article 6(1)(f) could be used with its legitimate interest basis for both development and deployment, as some DPAs have suggested that algorithm development could be considered as a legitimate interest.[253] The legitimate interest is a balancing test with the controller's interest on one hand and the freedoms of the data subject on the other, and there is a lack of precedents on what this balancing test entails in practice[254]

5.2.2.2. Data Protection Proposals

Proposals are expected to be drafted that tackle particular issues with autonomous ships and their data sharing. Even though some data protection regimes such as the EU with GDPR are horizontal, meaning that data protection rules are universal across sectors, the particular and global nature of seafaring and autonomous ships are likely to raise interest to draft some forms of guidelines or restrictions specially for autonomous ships and data sharing. Some of this development can be linked with legal development of data protection with other types of autonomous vehicles due to practical and conceptual similarities.
Several proposals on data privacy preservation of raw data sharing have been made to draft a system that secures object detection, data fusion at the edge and deep learning in data sharing.[255]

[248] Ringbom et al. (2020), 197.
[249] Ibid.
[250] Ibid.
[251] Ibid.
[252] Ibid.
[253] Ibid.
[254] Ibid 198.
[255] Xiong et al. (2020), 29.

Notably international maritime law lacks specific rules on data privacy and data protection.[256] However, some data protection regimes such as the EU apply data protection rules horizontally, meaning that all participants in the EU markets regardless of the industry have to comply with the rules, however the omission of maritime-specific data protection rules is worth noting and merits more attention. Surprisingly to the author of this study, GDPR and data protection are not very much discussed in relation to autonomous shipping despite the high amount of data storage and sharing with autonomous ships. This could be attributed to the expectation that autonomous ships, especially in the early stages of commercial deployment, are used more often with cargo ships than passenger ships and that the ships do not use that much personal data. However, non-personal data protection is also important for economic reasons such as trade secrets and IP protection, and data protection has many connections to the issue of cyber security, which is highly important with autonomous ships. Considering that many maritime regulations are global and that the need to protect data with autonomous ships is high, a reasonable expectation is to anticipate global legislation on the matter.

5.2.3. Legal Challenges with Operational Data Sharing

Autonomous ships use data sharing for operational actions and navigation, and this has its own particular legal issues and challenges.

The issue of seaworthiness of autonomous ships has importance for operational data sharing, as failures to share data for operational purposes can affect practical seaworthiness of an autonomous ship. The question is whether this has or should have legal implications. The SCC shares data with a remotely controlled ship and a fully or partially autonomous ship operates based on data received from various sensors and the system makes the navigational decisions based on this data. The issue of seaworthiness rises when a remotely controlled ship makes a decision during a lost connection with the SCC, and this decision leads to an accident. A similar issue can occur with fully or partially autonomous ships that lose data connection with sensors and systems.

The legal issue is whether this ship can be considered seaworthy during lost connection. Regardless of the temporary nature of the connection loss, this can be argued as an

[256] Dremliuga & Rusli (2020), 300.

underlying defect which still renders the shipowner liable.[257] This discussion is also reflected in the speed and functionality of operational data sharing, since any delays in communications either between the ship and the SCC or with a ship and navigational data senders may lead to delays in navigational decision-making which increases risks of collisions and other navigational mistakes. This is reflected in Rule 6 of COLREG, as it states that vessels must proceed at safe speed in order to avoid collisions. Rule 6, in combination with Rules 2 and 5 relate to the actions of the crew and their operational actions for safe navigation, and technical delays in operational data sharing can be argued as contrarian towards the requirements of Rules 2, 5 and 6 of COLREG. Even without any technical problems of operational data sharing, some delay with remotely controlled ships between the SCC and the ship or other providers of navigational data and the ship are expected to occur, meaning that the margin for delays in data sharing could be included into the safe speed calculation in line with Rule 6 of COLREG.[258]

Another issue of operational data sharing is data related to situational awareness. Regulations and performance standards regarding sensor systems exist, but those that are targeted specifically to autonomous ships are very few in number and are mostly drafted by classification societies and the industry actors themselves.[259] Regulators might set technical standards on situational awareness systems for autonomous ships, and the required performance level of situational awareness systems might be tied to the expected risk level of operational domains.[260] Maintaining a dynamic and consistent data flow and ensuring that all relevant actors are kept within the information loop are crucial for situational awareness.[261] What is also relevant for this discussion on data sharing and situational awareness is the rules on software components, training certificates and algorithms. Regulators are expected to draft standards on the level of data sharing and analysis the fulfilment of which is necessary for ensuring a level of situational awareness that enables proper and safe navigation. In addition, requirements for testing and training about the usage and design of machinery and data sharing systems for situational awareness might be drafted. The equipment for situational awareness, gathering, interpretation and sharing of data and decision-making are relevant factors for operators to know and understand, meaning that

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[257] Karlis (2018), 125.
[258] Ringbom et al. (2020), 64.
[259] Thombre et al. (2020), 3.
[260] Ringbom et al. (2020), 141.
[261] Porathe, Prison & Man (2014)

those people who work with autonomous ships are educated to work with them properly.[262] Hogg and Ghosh argue that it would be beneficial if the IMO developed training certificates for situational awareness systems.[263] However, on the issue of software and algorithms, some authors have argued that very detailed rules on software regulation can be counterproductive, stating that both spatial and semantic signal processing technologies are likely to differ in methods while providing a similar level of efficiency.[264] Simulation testing data from various scenarios could be utilized for setting standards for operational data and situational awareness.[265] A likely scenario is that the regulators require third-party testing and data sharing with test datasets and test administration with controlled access procedures[266]

Lastly, the role of human/computer interface and the legal implications of human role present an issue for autonomous ships. Although autonomous ships are considered safer due to reduced human error, this risk still exists with remotely controlled ships and partially autonomous ships with remote monitoring. This means that the risk of human error is present at the remote centers and elsewhere where human personnel operate and monitor ships.[267] Monitoring and remotely controlling a ship by the shore controller will make that person a responsible actor and his or her interpretation of the data transmission affects the operational actions of the ship. This means that the design human/computer interface is relevant for safety and liability considerations.[268]

5.2.4. Liability Issues with Data Sharing

One of the legal issues with autonomous ships that is common with other forms of automated transportation is the issue of liability. Defining the liable party with autonomous vehicles can be less straightforward than with conventional manned vehicles. With autonomous ships this relates to manufacturers and programmers of navigation and communication equipment, and this section relates to liability issues regarding data sharing. General maritime liability rules are also relevant for liability issues with data sharing and autonomous ships. Basic

[262] Endsley & Jones (2012)
[263] Hogg & Ghosh (2016), 214.
[264] Ringbom et al. (2020), 143.
[265] Ibid 145.
[266] Ibid 148.
[267] Man, Lundh & Porathe (2014), 5.
[268] Hogg & Ghosh (2016), 213.

liability issues are somewhat harmonized through international conventions, but the applicable laws depend on various issues such as the place of the incident, the type of incident and occasionally the nationality of the involved parties including the ship's flag state.[269] In general, maritime liability rules usually direct liability and duties to owners and operators of ships. Regarding the threshold of fault or negligence, the rules differ. As an example, in cases with pollution or injury to passengers, strict liability exists and in case of collisions fault-based liability is the main rule.[270] In addition, the liable party has broad rights to financially limit the liability based on the size of the ship.[271] Autonomous transportation has some implications for the framework of maritime liability, and this section focuses on liability issues in terms of data sharing.

Data sharing may be related into new types of error and causal relationships. As the digital ecosystem grows, more difficult the application of liability schemes becomes due to the possibilities to apply different regimes such as product liability, general tort law rules and possibly contractual liability.[272] For example, a malfunction of an autonomous system might lead to failure of data transmission either between the ship and the SCC or within the systems of the ship itself. In the case of malfunction of an autonomous system, the owner or the operator would likely be liable, if the owner is unable to override the autonomous system.[273] A more complicated situation exists if a remotely controlled ship loses data transmission between the SCC or the ship, or if a loss of data transmission occurs within a fully autonomous ship. If this accident occurs because of technical failures such as incorrect programming, the owner is not that obviously the liable party under a strictly fault-based liability scheme.[274] Some commentators would like to have a strict liability for automated ships to emphasize the responsibility of the operator, but this would create a recognizable and to some extent unjustified difference between manned and autonomous ships.[275] A possibility exists that parties involved with autonomous ships could make claims against the builders of the ships or creators of the autonomous systems and aim to shift the liability scheme in the maritime context towards product liability. In the EU, product liability is based

[269] Ringbom, Collin & Viljanen (2016), 50.
[270] Ibid 51.
[271] Ibid 51.
[272] Liability for AI Report (2019), 17.
[273] Ringbom, Collin & Viljanen (2016), 52.
[274] Ibid 52.
[275] Ibid 52.

on strict liability of the producer and this would be beneficial for claimants.[276] However, the EU directive on product liability covers only selected potentially relevant types of damages, meaning that supplementary liability systems would co-exist.[277] Product liability has some limitations when applying it to autonomous ships and data sharing, namely that it rests on the concept of product and that it has the notion of defect as a key element.[278] These could be challenging, as the complexity of the system makes it difficult to prove the defect and prove causation.[279] It is possible that product and other liability rules will co-exist with the general maritime liability regime, which may also provide solutions for legal innovation. Nonetheless, as the EU has published guidelines on application of artificial intelligence, an interesting perspective is to hereby discuss their application to the liability issues with operational data sharing of autonomous ships.

An expert group established by the EC published a report on liability for artificial intelligence, which could be applied to illustrate potential legal challenges and solutions to the extent of AI usage with operational data sharing of autonomous ships. The key features of the report are that although existing rules on liability offer solutions related to the risks created by the emergence of digital technologies, the outcomes are not always reasonable.[280] The disruption in outcomes is mainly caused by the failure to achieve a fair and efficient allocation of loss due to the lack of clarity on whose behaviour caused the damage or who were in control of the risk management.[281] The disruption is also affected by the failure to coherently rule on the matters related to the interests of individuals in situations in which victims of harm caused by digital technologies receive less or no compensation in comparison with factually and functionally otherwise situations that have human conduct or conventional technology as causing the harm.[282] Namely due to these mentioned failures of the existing rules on liability and the diverse range of risks related to various different types of digital technology, the report supports coexistence of fault liability and strict liability.

[276] Product Liability Directive. See also Ringbom, Collin & Viljanen (2016), 52.
[277] Ringbom, Collin & Viljanen (2016), 53.
[278] Liability for AI Report (2019), 28.
[279] Ibid.
[280] Ibid 5.
[281] Ibid.
[282] Ibid.

Reflecting the discussion on maritime application of AI liability with autonomous ships, a coexistence of fault and strict liability could be a balanced approach to address different types of risks by different liability schemes. The expert group report on AI liability suggests that strict liability is an appropriate response when digital technologies operate in non-private environment and have the potential to cause significant harm.[283] This is fairly true with autonomous ships, especially due to their potential with cyber security attacks. In addition, at least several EU countries have strict liability for motor vehicles that could be expanded to autonomous ships.[284] This would be beneficial for strengthening the willingness of operators within autonomous ship ecosystems to provide strong risk management, but strict liability has the downside of limiting the willingness to invest in the advancement of technology in the field of autonomous ships.[285] The report generally supports the co-existence of both strict and fault-based liability for AI matters, and that principle could indeed be incorporated with data sharing and autonomous ships. If the suggestions by the expert report become the legal norm, namely that with AI liability both fault and strict liability coexist, a similar approach with autonomous ships and AI liability would be reasonable. The discussion on liability for autonomous ships and data sharing is thus conducted from various perspectives, as the discussion illustrates the different principles of liabilities within maritime law and also different suggestions and guidelines for AI-based liabilities. The main conclusion from this discussion is that multiple systems of liability are expected to co-exist, and actors involved with data sharing and autonomous ships should be aware of their duties of care, requirements and responsibilities.

Essential for the issue of data sharing is that the technology suppliers have to consider requirements for storing and exchange of data when the reason for unintended incidents needs to be established.[286] Therefore, data sharing and data storage have legal implications for establishing reason for incidents and the liability scheme should consider what kind of requirements for storing data have to be drafted, and how objective this data can be in essence. In the expert group report on AI liability, this is discussed in the form of logging by design.[287] The expert group report suggests a duty on producers to equip technology with a

[283] Liability for AI Report (2019), 6.
[284] Ibid 26.
[285] Ibid 27.
[286] Danish Maritime Authority (2017), 90.
[287] Liability for AI Report (2019), 47.

system that logs information about the operations.[288] This suggestion would mean that autonomous ships and the parties with whom they share data should record all data automatically, as this information is essential for establishing causation and the materialization of risk.[289] A similar recommendation is present in the autonomous ship guidelines by some classification societies, such as a proposal by DNV GL that states a minimum data that is required to be recorded.[290] The issue of data protection is also relevant in the discussion of data sharing liabilities, as Article 82 of GDPR grants the right to compensation and liability in the cases of infringement of the GDPR.[291] The issue of incident reporting is thus important with autonomous ships and data sharing in terms of liability, and this area has room for legal improvement and development. Conventional maritime transportation uses VDR that stores data for incident reporting, but research on them has shown weak encryption and other vulnerabilities.[292] In addition, the conventional VDRs do not store data for cyber security incidents, meaning that in the future a likely development is an improvement and expansion of VDRs especially with a focus on cyber security.[293] Additionally, the cyber security of the incident reporting system itself and the possibility to use such a system in all relevant situations are expected to be improved and regulated with design requirements.

In addition, a marine insurer traditionally regards ship security by the quality of crew on board, and the lack of crew might mean that the quality of the AI system of an autonomous ship affects the insurance costs.[294] The need for new insurance policies to determine liability issues for the shipowners and operators of autonomous ships requires collaboration of international regulators, flag states and classification societies.[295] An issue with AI liability and marine insurance is also the extent of mandatory insurance, meaning that stricter the liability, stronger the requirements for insurance to protect victims from insolvency issues of the liable operator.[296] A possibility exists that data sharing and incident reporting are tied

[288] Liability for AI Report (2019), 47.
[289] Ibid.
[290] DNV Autonomous and remotely operated ships (2018)
[291] Article 82 GDPR
[292] Tam & Jones (2018), 5.
[293] Ibid.
[294] Chambers (2016)
[295] Hogg & Ghosh (2016), 210.
[296] Liability for AI Report (2019), 61.

to insurance analysis, meaning that insurers would have legally protected tools to analyze the quality of AI, data and data sharing.

5.3. Compliance with Connectivity Requirements

Connectivity is a key issue with autonomous ships, as they use various types of communication equipment to transmit data between the ship and the SCC and other relevant parties. Connectivity solutions are important and very likely require international regulation. At the time of writing this study, connectivity requirements for autonomous ships exist mostly in the form of suggested requirements by classification societies.[297] These requirements could be summarized by stating that autonomous ships should have an efficient and secure communication network that allows functional communication between internal and external systems of the autonomous ship.[298] The expected main principle of future regulation on connectivity requirements is to ensure an appropriate level of connectivity equipment for autonomous ships to enable safe navigation and communication both with internal and external systems and stakeholders.[299] The sufficient level of reliability and an inclusion of redundancy requirements are likely to be included in the core of the regulatory framework.[300]

An unavoidable issue with connectivity is that no connectivity system is fail-proof and connection failures will happen. Regulations on connectivity should then include sections on how the ships should react to connectivity failures. Several taxonomies have been produced to prepare for the system, one model being called DNT that is based on DDT.[301] DNT is a principle of providing a backup system that is divided into "Operator Exclusive DNT" and "Control System DNT" that are prepared to respond to expected connectivity failures.[302] Some sort of a DNT Strategy requirement is a promising concept, meaning that an autonomous ship should be required to have some pre-programmed strategies for distress situations. These strategies could include sheep reduction, choosing waterways with less traffic and other actions that enable as safe as possible navigation.[303] A decision that

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297 Amro, Gkioulos & Katsikas (2019), 78.
298 Ibid.
299 Ringbom et al. (2020), 160.
300 Ibid 67.
301 Porathe et al. (2017), 419.
302 Ibid.
303 Ringbom et al. (2020), 162.

regulators have to take is whether to require anchoring and what kind of threshold for possible stopping should be established.[304] This proposal to include DNT Strategy is a solid starting point to illustrate a system for connectivity failure that regulators could use as a concept.

In addition, the regulators should assess the need to set out rules on fall-back capability to handle necessary communications with authorities and other ships even when operating with limited or non-existent connectivity conditions.[305] The regulators are also likely to set rules on bridge-to-bridge communications. Regulators are then likely to set rules to ensure that autonomous ships are able to communicate with human operated ships, even when connections to SCCs are unable to be used.[306] These rules would then provide technical requirements after an assessment on technological facilitation. A likely outcome would be a requirement to be capable of communicating with other ships by auditory natural language communication methods.[307] Therefore, connectivity requirements are expected to be drafted with the focus on navigational safety, data sharing possibilities for functioning operations of the entire value chain and the possibilities to intervene in the decision-making of an autonomous ship. These requirements will affect the design of autonomous ships, as they will state how to prepare for a sufficient level of connectivity and possibilities to act in lost connectivity scenarios.

The technical design of the connectivity system poses legal issues, as many technical capabilities have legal implications for what can and should be required from autonomous ships in terms of connectivity systems. This concept of technical capabilities having strong legal implications is common with many issues with autonomous ships, and with connectivity issues they affect the design of autonomous ships and their connectivity solutions. Classifications societies have published guidelines in order to facilitate proper connectivity solutions. These suggestions by classification societies for connectivity issues affect data sharing, as they suggest that autonomous ships have to be able to provide efficient and secure communication with the internal and external systems of autonomous ships.[308] A crucial suggested requirement is that autonomous ships should be able to distribute different

[304] Ringbom et al. (2020), 162.
[305] Ibid 165.
[306] Ibid 166.
[307] Ibid.
[308] Amro, Gkioulos & Katsikas (2019), 78.

vessel data between different communication channels without a negative effect on the operations, such as by using situational awareness data on one channel and other channels for other data sharing matters.[309] Guidelines by classification societies are relatively strongly focused on the functionality and security of the communication systems and emphasize safety matters, as the guidelines also indicate troubleshooting capabilities, notification systems and type-approval of components.[310] Maritime regulations are likely to follow the direction of the classification societies, especially the principles of functional and secure connectivity systems that support safe navigation. Autonomous ships should comply with these requirements in their design, deployment and conduct.

5.4. Compliance with Data Sharing Requirements

Manned ships are already required to share certain information with authorities, and autonomous ships would need to meet these requirements and also possible requirements that are drafted particularly for autonomous ships. One of the main rules on information sharing is the FAL Convention, which seeks to ensure the uniformity of information requirements around the globe and facilitate international maritime traffic by stating what documents and certificates IMO members states can require of a ship when it arrives or departs.[311] The FAL Convention uses physical copies of documents as a starting point, but published guidelines have stated that electronic certificates should be accepted.[312] For the use of autonomous ships, the use of electronic certificates should be expanded and supported and this is in line with the IMO e-Navigation strategy.[313] These expansions to electronic certificates are necessary, since operating with physical copies would be very difficult and unreasonable in practice with autonomous ships.

VTS is a system that holds both potential and challenges for autonomous ships and data sharing. The existing VTS regulation was adopted by IMO in 1997, although additions and clarifications have been made later.[314] VTS providers are likely to require information on the route plans of the autonomous ships, and the lack of humans on the bridges with unmanned autonomous ships might be problematic as VTS advice functions rely on two-

[309] Amro, Gkioulos & Katsikas (2019), 80.
[310] Ibid 80-81.
[311] Ringbom et al. (2020), 198.
[312] Ibid.
[313] Ibid.
[314] Guidelines for Vessel Traffic Services (2017). See also De Oses & Juncadella (2021), 5.

way communication.[315] This means that VTS communications to bridges must be relied to the SCC or otherwise executed by the ship's autonomy systems depending on the level of autonomy.[316] Additionally autonomous ships might be required to have NLP capabilities, although some authors have argued for requiring autonomous ships to electronically communicate their navigational plans to VTS providers by using regular intervals.[317] In addition, a standardization of communication interfaces and contents is expected at least to some extent in order to support data sharing by real-time communication.[318] In order to have effective standardization of route and path plan data sharing, the regulators would need to establish technical standards that would clarify the type of data, the appropriate channels and data format, the intervals and recipients of data sharing.[319] The capability to communicate effectively with VTS providers is important and a regulatory framework for digital data exchange with VTS providers is expected to be instituted.[320] In line with this regulatory direction, the development of digitized communications with VTS providers and pilots is likely to happen.[321] IMO could develop a platform format and provide guidance on electronic communications between autonomous ships and VTS providers.[322] These requirements are expected, since increased transparency and foreseeability of path planning would increase safety.[323] As increased safety of seafaring is a key issue with autonomous ships, a logical expectation is to utilize data sharing for safety and also the ease of navigation.

A potential solution to the goal of increased guidance by IMO on how to exercise data sharing between autonomous ships and VTS providers could be tied into the ongoing e-Navigation initiative. The Implementation Plan of the Electronic Navigation Strategy was approved in 2014 at MSC 94 Meeting. This e-Navigation initiative consists of improved bridge design, the standardization and automation of reporting, integrity of bridge equipment and navigation information, graphical display of information and improved communication of VTS service portfolios.[324] Achieved results of e-Navigation are expected to make maritime navigation and communications safer and more reliable, and also increase

[315] Ringbom et al. (2020), 198.
[316] Ibid 198.
[317] Ibid.
[318] Ibid.
[319] Ibid.
[320] Ibid 165.
[321] Ibid.
[322] Ibid.
[323] Ibid 199.
[324] E-Navigation strategy implementation plan (2018)

transparency and availability of information.[325] These actions and principles of e-Navigation are closely related to the requirements and expectations of autonomous ships and data sharing, and it would be highly encouraged to include autonomous ships as key aspects of the e-Navigation initiative and related projects. This type of inclusion would emphasize the role of autonomous shipping in the digital transformation of the maritime industry, and legal requirements could facilitate the direction of this development.

Compliance with systems that are used to aid navigation is also an issue and expected to face further regulation. Compliance with AIS is relevant for autonomous ships, as it has been embedded in autonomous ships proposals as a tool for improved marine domain awareness.[326] According to the report by Finnish Ministry of Traffic, AIS is not a fully reliable tool for autonomous ships as the sole source of data, meaning that sensor fusion is important and AIS will nonetheless be an important part of augmenting sensor fusion.[327] Compliance with AIS requirements should be incorporated with legal analysis of autonomous ships. In addition, AIS may provide some potential legal solutions for autonomous ships and data sharing that can be realized with other forms of data sharing as well. The potential to use other aids of navigation, such as GNSS, is also present in the connectivity design of autonomous ships and the development of autonomous ships has to consider applicability with AtoN systems.[328] On the other hand, many AtoN systems provide data to autonomous ships, meaning that the data sharing requirements are targeted more on the providing of data for the use of autonomous ships. This two-way nature of data sharing is important to consider in future regulations, as the providers of data have to note how to provide navigation data to the autonomous ships and the ships should be able to receive, analyze and re-share relevant data.

An important factor with data sharing requirements is the ship-to-ship data sharing and how autonomous ships are regulated and required to have capabilities for this type of data sharing. Ship-to-ship data sharing is useful for various reasons and potentially the most important factor of it is compliance with collision avoidance regulations. COLREG states several rules for collision avoidance and the applicability of their rationale with

[325] De Oses & Juncadella (2019), 8.
[326] Goudossis & Katsikas (2019), 410.
[327] Ringbom et al. (2020), 24.
[328] Amro, Gkioulos & Katsikas (2019), 5.

autonomous ships and data sharing can be difficult and represent regulatory failures that require revision.[329] A legal and technical challenge is the situation in which autonomous ships would make navigational decisions leading to collisions and failing to share data with other ships that could prevent such a collision. This is especially relevant with having two or more autonomous ships that take navigational decisions that could overlap or cancel each other.[330] Technical analysis on ship-to-ship data sharing in compliance with COLREG should be conducted and tested whether the decision-making system can reach the goal of collision avoidance, or whether some navigational rules of COLREG should be revised to better achieve the aim of collision avoidance. Close vessel encounters can be major challenges for autonomous shipping and both the technical and legal design of ship-to-ship data sharing should be created and researched in a thorough manner. In addition to other ships, SCCs and authorities, autonomous ships conduct data sharing with ports and the role of ports is important to note and analyze.

Ports have an important role with data sharing and autonomous ships, both from the viewpoint of autonomous ships and ports themselves. Autonomous ships use different operational methods for port approach and departure, such as the RCU being mainly reserved for sailing to and from ports.[331] Importantly for the discussion on autonomous ships is the concept of smart ports. Smart ports represent advanced and modern ports that use innovative technologies and automation to optimize their operations.[332] Smart ports require proper digital infrastructure to optimize the use of their physical infrastructure, and the issue of data storage and data sharing are essential with smart ports.[333] The development of smart ports has occurred simultaneously with the development of autonomous ships, and regulators are likely to dictate how data sharing with ports should occur. In addition, autonomous ships might operate at least in the early stages of commercialization only from and to pre-defined ports,[334] and smart ports would reasonably be used as early adopters of ports defined for autonomous ships.

[329] Perera & Batalden (2019), 5.
[330] Ibid.
[331] Hogg & Ghosh (2016), 208.
[332] Business Finland (2020), 3.
[333] Ibid.
[334] Rødseth (2018), 4.

The role of smart ports is expected to be crucial in the value chains of the near future, as they connect maritime shipping into other forms of shipping.[335] As smart ports require digitalization and automation for data storage and sharing, their role is worth including in this analysis. An important factor for autonomous ships and data sharing is that smart ports combine participants in the logistical sector by sharing data and improving automation throughout the supply chain.[336] This development has been classified as a path to a holistic Smart Marine Ecosystem, which includes data sharing as of its concepts that increase efficiency and safety in marine transportation.[337] Currently eight countries that are active in the development of autonomous ships are cooperating to steer the development of autonomous ships and ports in the MASSPorts project, and one of the aims of the MASSPorts project is to standardize communication and exchange of information between autonomous vessels and ports.[338] That project might influence legal development of data sharing requirements between autonomous ships and ports, as the MASSPorts project aims to affect IMO's international agreements.[339]

A specific issue with autonomous ships and ports is automatic port approach and departure that requires data sharing. In order to perform automatic port approach and departure, very accurate sensing of the environment and low delays in the connectivity are required.[340] These requirements are both for the ship and its internal systems and the connection between the ship and the port.[341] This connection is a challenge both in the technical and legal change, and changes in legislation that affect ship-to-port data sharing are necessary to support the development of autonomous ships and ports, especially smart ports.[342] In general, the infrastructure of ports and also inland waterways can be adopted to better support short-sea autonomous shipping.[343] To conclude, the role of port and especially advanced ports is important with the development of autonomous ships and data sharing, as the ship-to-port data sharing requires critical and secure communication that is likely to be demanded by legislative action.

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[335] DIMECC (2021), SMARTER Project
[336] Ibid.
[337] Wärtsilä Corporation Press Release (2021)
[338] IMO Media Centre (2019)
[339] Ibid.
[340] Höyhtyä et al. (2017), 5.
[341] Ibid.
[342] Ibid.
[343] Perera & Betalden (2019), 1.

5.5. Maritime Open Intelligence

Maritime open intelligence initiatives provide both opportunities and challenges for the legal development of data sharing with autonomous ships. In terms of challenges, autonomous ships might be required to be more compliant than conventional manned ships in different open intelligence and MDA frameworks. Some key concerns with OSINT are the origin and intent of sources, unclassified but sensitive information, potential mosaic effects, reliance on automated analysis and issues regarding publicity and visibility.[344] The consistency of MDA with international law is not without difficulties either, as questions might arise regarding the intelligence uses to which information gathered in maritime law enforcement operations may be put and national states might desire information about vessels that transit off their coasts without having the obvious power to demand that information under UNCLOS.[345] These issues and concerns are likely to affect data sharing requirements of autonomous ships, as autonomous ships can be expected to be more prepared to openly share data than regular ships due to their novelty, information needs of public policies and general compliance with maritime and open intelligence regulations.

Open intelligence has various benefits for data sharing with autonomous ships. The potential of economic, legal and social value of open data culture in the development of autonomous ships has been noted and supported.[346] Open data initiatives in terms of development of autonomous ships are already drafted, which provides a useful opportunity for autonomous ships. In the UK, MARLab provided data workstream to address the issues that the manufacturers and operators of autonomous ships face by sourcing and sharing data to support safe operations of autonomous ships.[347] The questionnaire and interviews in the UK were made with the perspective on how government data could support industry.[348] A data platform was developed with this information to support data sharing and utilize information granted by both private and public parties. This initiative tracked software and developments, and provided MCA AIS data, UKHO bathymetry data, weather data and local port movements data.[349] These types of initiatives provide operational solutions and also help to

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[344] Hu (2016). See also Rajamäki, Sarlio-Siintola & Simola (2018), 427.
[345] Guilfoyle (2017). 306.
[346] Hogg & Ghosh (2016), 213.
[347] MARLab (2020)
[348] Ibid.
[349] Ibid.

provide platforms for data sharing and open intelligence, and legal development could be tied to these initiatives to further support and encourage data sharing among private and public parties. Public administration could facilitate and support this development, and in the UK questionnaire MCA was asked to provide clarity and leadership in addition to demonstrating best practice guidelines.[350] This could be done by legally requiring the public administration to ensure that at least its own data, such as AIS data, is in an available format and that commercial utilization of that data is possible. In the UK, the public administration committed to work with relevant agencies to support and share relevant data, and this could be strengthened with legislative action either at national levels and preferably also internationally by drafting guidelines for flag states to engage with open intelligence data sharing.

In the EU, the potential and requirements of information sharing networks should be taken into consideration. This will be conducted mainly under the framework of the VTMIS and Single Windows directives. The VTMIS Directive requires cooperation between Member States and the Commission to cover and share information of identification and monitoring of ships.[351] Single Windows directive aims to reduce the administrative burden on ships and increase the use of digital information in maritime transport.[352] The framework of information sharing in the EU supports the principles of open information, and the information shared by EMSA could be useful for locating suitable areas for MASS operations, integrated maritime services, traffic density maps and other types of information that would be very useful for autonomous ships.[353] The potential of such initiatives is noted, but the EU lacks specific policies for those activities. In addition, the European data strategy is relevant for the discussion of autonomous ships, as the strategy has targeted various aspects of data sharing related to transportation as projects of industrial and commercial data usage.[354] The European data strategy has potential to encourage and strengthen data sharing, as it aims to improve the availability of data, create an infrastructure for data markets, activate individuals and companies to share data and develop data spaces. Therefore, the European data strategy could potentially facilitate data sharing with autonomous ships and augment the European framework of maritime open intelligence.

[350] MARLab (2020)
[351] Article 23 of VTMIS Directive
[352] Single Windows Directive
[353] Ringbom et al. (2020), 69.
[354] European Data Strategy (2020)

5.6. Legal Solutions and Policy Suggestions

Having examined legal challenges and compliance issues related to data sharing and autonomous ships, this section analyzes the potential of legal solutions and policy suggestions. Although several legal challenges with autonomous ships related to data sharing exist, legal solutions are also present. Additionally, some issues are more related to compliance than challenges *per se*, meaning that ensuring compliance is of importance and in some methods compliance requirements of data sharing are beneficial for the deployment of autonomous ships. At the end of this section, several policy suggestions are presented to provide and utilize legal solutions and provide guidance for compliance matters.

5.6.1. Cyber Security

A key challenge related to data sharing and autonomous ships is the risk of cyberattacks. Regarding the risk of cyberattacks and requirements to maintain and improve cyber security, IMO is expected and suggested to draft requirements for autonomous ships. General guidelines for cyber security already exist for conventional ships, but global guidelines and eventually regulations specifically for autonomous ships are expected. Some classification societies such as DNV GL and Bureau Veritas have presented guidance on cyber security for autonomous ships that is a reasonable starting point for discussing potential legal solutions. These requirements are somewhat typical cyber security requirements in general, as they relate to user access management, secure protocols, an establishment of a continuously updated cybersecurity management framework and protection from malware.[355] Although these requirements are somewhat general, they are still relevant for autonomous ships and data sharing, although more specific requirements and suggestions can be identified. Representing operational data sharing, several safety-related policy suggestions can be noted. For partially autonomous ships, a suggestion is to require the crew be able to deactivate external control and replace it with manned control, and potentially to include a global power off function.[356] For fully autonomous ships, a policy suggestion would be to include fuel limitations, so that autonomous ships carry fuel for the distance between ports and that the amount of excess fuel is limited to a small margin.[357] Additional requirement would be an inclusion of periodical testing of cyber security prior deployment

[355] Amro et al. (2019), 82.
[356] Vinnem & Utne (2018), 1491.
[357] Ibid..

and within certain maintenance cycles. These are examples of potential legal solutions for cyber security that would augment more general requirements of cyber security management and maintenance.

5.6.2. Compliance Framework

Some legal solutions exist within the compliance framework, as this legal area has uncharted matters and through policy suggestions and modifications, compliance of legal matters can be achieved. Regarding the importance of data sharing with autonomous ships for safe and reliable seafaring, data sharing requirements could be included in global maritime conventions. For navigational data sharing, a potential solution would be a global VTS system and an inclusion of findings of the e-Navigation initiatives in the drafting of this data sharing scheme.[358] Although some of the initiatives of global maritime surveillance and e-Navigation are drafted for conventional and manned ships, the inclusion of autonomous ships would be of great importance. The e-Navigation concept and an extension of AIS to include increased data sharing with SCCs and autonomous ships would be a great benefit to vessel interaction in the development of safety-related artificial intelligence components.[359] Arguably the development of data sharing and digitization of conventional, manned seafaring has notable benefits for autonomous ships regardless of the differences between manned and unmanned ships. The inclusion of autonomous ships in global maritime surveillance initiatives would be a reasonable policy suggestion, as the need for interoperability and compatibility for data sharing requires strong cooperation.[360] Although the creation of a global maritime surveillance system could be a somewhat slow process, EU projects that are targeting the issue such as the Sea Traffic Management project could be revised with the inclusion and focus on autonomous ships. Additionally, expanding the role of autonomous ships in other related projects such as smart port development initiatives would be beneficial for autonomous ships and data sharing. The inclusion of autonomous ships with the focus on data sharing would be supportive of their understanding and acceptance in the global supply chain and data sharing ecosystems, and by including autonomous ships in related projects could lead to more effective and indicative legislative work.

[358] De Oses & Juncadella (2019), 15.
[359] Li & Fung (2019), 335.
[360] Chintoan-Uta & Silva (2016), 45.

Ship-to-ship data sharing is an area of possible legal solutions, as requiring compliance with data sharing among ships could potentially solve some navigational challenges. This would be especially useful for ensuring that autonomous ships do not take collision avoidance decisions that overlap or cancel each other, as this risk has been noted.[361] Academic discussion on collision risk identification and ship-to-ship data sharing exists that could be utilized for legal development and compliance with maritime regulations, especially COLREG.[362] The role of ship-to-ship data sharing is important, as it represents and utilizes real-time path planning.[363] This type of system could require and facilitate connectivity and real-time data sharing with autonomous ships in order to secure that they make appropriate navigational decisions in close-counter situations and especially by preventing high-risk situations. Autonomous ships should also be able to communicate with conventional ships with a similar goal and rationale. A technical analysis on the benefits of presented methods for ship-to-ship data sharing in line with COLREG principles should be incorporated into legal development of data sharing compliance framework, and necessary revisions to COLREG could be made to better reflect how autonomous ships operate in compliance with COLREG requirements. If the COLREG requirements lead to unsafe or unreliable autonomous shipping, necessary adjustments should be made based on testing data.

5.6.3. Liability Framework

Regarding legal solutions and policy suggestions, expected next steps on liability matters are related to training schemes and testing capabilities. Several recommendations in contemporary legal theory have been made on liability for machine learning and autonomous systems from the viewpoint that the liability regulation should focus on training and testing.[364] As the technology develops, a policy suggestion is to provide global industry-level guidelines on liability matters that would emphasize duties of care, responsibilities of operators and other important matters regarding liability. The liability framework for autonomous ships and data sharing is expected to be multidimensional with different liability schemes coexisting, and whereas a coexistence of different liability principles could utilize most functional and fair principles of assessing harm and responsibility, a global understanding of these different principles could be harmonized and standardized. The issue

[361] Perera & Batalden (2019), 5.
[362] Qiao, Zhang & Wang (2021), 30539. See also Zaccone (2021), 1.
[363] Zaccone (2021), 11.
[364] Danish Maritime Authority (2017), 88.

of liability in general with autonomous ships is a substantive topic that requires further research, and including the concept of data sharing within the liability framework would be necessary to illustrate the role of data in autonomous shipping and liability issues.

5.6.4. Contractual Framework

Using contractual arrangements is a possible solution for autonomous ships and data sharing. Contractual arrangements in admiralty law have been considered a reasonable site for legal development,[365] and contractual arrangements in data sharing are useful due to the limitations of some legal concepts in data sharing legislation. Utilizing the Contractual Framework of the SITRA Rulebook provides potential to create a legally solid, functional and ethical data network with autonomous ships. The Contractual Framework provides templates that define contractual frameworks within the Data Networks in order to clarify legal relations between the participants.[366] The purpose of this section is to use these templates to illustrate how different participants in autonomous shipping could draft Data Networks and thus tackle some legal challenges and compliance matters by taking advantage of contractual solutions. Although other contractual guidelines for data have been proposed by the Technological Industries of Finland and ORGALIM, the SITRA Rulebook is chosen as a case study due to its comprehensiveness.

The Contractual Framework consists of the Constitutive Agreement and a description of the Data Network.[367] The Constitutive Agreement consists of General Terms and Conditions, Governance Model, Accession Agreement and Dataset Terms of Use, whereas the Description of the Data Network has a Business part and a Technology Part.[368] The members of the Data Network are either direct members of the Constitutive Agreement as the Founding Members or directly by signing the Accession Agreement.[369] The General Terms and Conditions define different members when drafting the Data Network, and hereby is a potential framework for autonomous shipping. In terms of role alignments, some of the roles of Data Provider, Service Provider, End User and Operator are overlapping with autonomous ships. The shipowner would be the End User with navigational and operational data, but the shipowner would also be Data Provider vis-a-vis other ships and ports. VTS providers would

[365] Klein et al. (2020), 734.
[366] Sitra Rulebook (2021), 4.
[367] Ibid 9.
[368] Ibid 9.
[369] Ibid 9.

be Data Providers by providing VTS data for the needs of the network. Service Provider and Operator are issues of consideration, since they are not necessarily relevant if parties exchange data among themselves.[370] However, due to the data sharing outside operational and navigational data for general steering purposes, these roles or at least their functions would be advisable to state. The ship owner could act as a combined Operator and a Service Provider, as this would best imitate the multifunctional role of a ship master. Technically a SCC would carry out several tasks of service providing and data operating, and potentially an Operator or a Service Provider could also be subcontracted by the Network for the purpose of maintaining the data network, thus creating a separate role for the management of data sharing in the Data Network. These could both be separate roles or the shipowner could retain either or both of them with itself.

In addition to the role alignment, the Contractual Framework should define its direct members and state its third-party policy. Especially in the early stages of commercial autonomous shipping, autonomous ships might use pre-defined ports for the places of operation. This could mean that the shipowners, potential operators or service providers of data as subcontractors, VTS providers and defined ports would be direct members in each Data Network. A Data Network would thus exist for each navigational route, and the actors that are relevant for the route would be included as direct members. This would be a benefit for a clear and functional role alignment, but it would lose some flexibility. Arguably in the early stages of commercial autonomous shipping, having legal clarity of roles and responsibilities for data sharing are more important than having high flexibility. In addition, by having a commonly agreed third-party policy, a reasonable amount of flexibility could be achieved.

The general terms and conditions of the Contractual Framework are essential for creating the Data Network. The template terms and conditions in the Sitra Rulebook are mostly applicable to the creation of a Data Network for autonomous shipping, although some clarifications and alterations are useful. These set out role-specific responsibilities, the principles of redistribution of data, general responsibilities, liability and data protection issues, among other things.[371] Using the contractual framework for recognizing and ruling

[370] Sitra Rulebook (2021), 10.
[371] Ibid 12.

on liability issues is highly suggested, as it could clarify the potentially broad coexistence of various liability systems with autonomous ships and data sharing. The more complex the digital ecosystem, the more difficult it is to apply liability frameworks.[372] Definitions of liability issues regarding damage to data are important as most legal systems allow application of contractual liability with damage to data, whereas tort liability with damage to data may lead to unsatisfactory results.[373] The Sitra Rulebook provides a template for the Dataset Terms of Use, which should define how the data provided by the Data Provider may be used, what kind of redistribution of the Data to any Third Parties and what kind of Dataset specific terms and conditions should exist.[374]

Useful and illustrative for the creation of the Data Network is to ensure answers to legal questions as provided by the checklist in the rulebook.[375] These questions are divided into contractual principles, liabilities and content. Among the questions in the contractual principles, precedence is an important question due to the connected and broad nature of maritime transportation, and autonomous ships and data sharing having legal connections to various common and domain-specific laws ranging from international maritime conventions to national rules and regulations.[376] In the questions of liabilities, the question on real-world actions is essential, as well as the question on 3rd party participation. Data sharing with autonomous ships leads to crucial real-world actions of navigation, and the liabilities of data-sharing on navigational decision-making and consequences should be defined as well as possible through contractual actions. The questions on content are also very important, as these questions are related to applicable data types, database rights, common contractual aspects and data-specific aspects. Data-specific aspects are important both from a legal and functional perspective to ensure proper data flow within the Data Network. Conditions to exchange data, clarity of usage rights and conflicts related to data utilization are vital due to the high technical requirements of data flow, and failures to provide and support proper data flow would be detrimental to the functionality of autonomous ships. In addition, clarifying how ports, other ships and authorities would share data with autonomous ships and their Data Network have to be clarified. Important issue for the development of autonomous ships

[372] Liability for AI Report (2019), 17.
[373] Ibid.
[374] Sitra Rulebook (2021), 29.
[375] Ibid 59-61.
[376] Ibid 60.

is the issue of “right to assess, analyse and learn from data”,[377] as this reflects discussion on data sharing among learning procedures, open intelligence initiatives and general technological development of autonomous ships.

Other questions in the checklist outside legal questions are also very important and reflect considerations that have legal implications. Business questions in the checklist are also important, since many of them are very closely related to legal issues. These are such as questions on data costs and data utilization, as well as questions on data rights, limitations and data access.[378] In addition, business questions on governance are important to clarify the role alignment, the data network setup and solution fundamentals. Financial questions on monetary transactions and costs are certainly important from a legal viewpoint as well, and the question on data utilization has meaning for the feasibility and availability of data in the long-term. All questions on data rights are essential, as they have legal implications for confidentiality, limitations, restriction and distribution.

Technology questions are very important due to the highly technical nature of autonomous ships and their data sharing. Many legal issues related to autonomous ships and their data sharing are directly or partially related to the level of technological development, which means that technological questions are linked to the legal framework of autonomous ships and data sharing. Technology questions are divided into infrastructure and common solutions, core functionality and administration.[379] The questions on security and privacy and data-related mitigations are extremely important, as multidimensional cyber security is critical for autonomous ships. Cyber security has been noted as one of the main challenges with autonomous ships, and providing clear contractual planning should reflect that cyber security management is in order. Data governance is also important in order to answer legal matters of data storage, as autonomous ships store significant amounts of data. Data questions, which are a separate set of questions concerning governance, and data structure, are meaningful for determining data-specific questions.[380] Among data questions, the questions on data services, data control and data quality are crucial to contractually define requirements to uphold technological standards for functional data flow within the Data

[377] Sitra Rulebook (2021), 61.
[378] Ibid 56-59.
[379] Ibid 62-63.
[380] Ibid 65-66.

Network. In addition, data questions support cyber security and also skills and capabilities of people involved with the Data Network that reflects the discussion on necessary training schemes of seamen and other personnel working with autonomous ships.

The contractual framework, such as one defined and drafted by using the template of the Sitra Rulebook, has potential to provide legal solutions for autonomous ships and data sharing. This template is useful, as it includes legal, technological and economic questions and data-specific matters, and the general discussion on autonomous ships and data sharing is very strongly interconnected between technological, economic and legal matters. Especially if a regulatory gap exists with some legal matters, requirements for data sharing within a Data Network of autonomous ships and their relevant network parties could be clarified. Contractual solutions are also useful, since some legal concepts of data such as data ownership are not fully supported in legislation,[381] meaning that contractual action can satisfy some needs of insufficient legislation. Naturally, the contractual framework cannot solve all legal challenges of autonomous ships and data sharing, as data sharing should occur between autonomous ships and parties that cannot necessarily be directly included in a Data Network as a contractual party, such as some public authorities. Nonetheless, as open intelligence initiatives are noted as a possibility for legal solutions, contractual Data Networks could co-operate with closed and specified data sharing within the network and open data sharing with certain third parties, and these third parties can be clarified in the contractual framework to some extent.

5.6.5. Blockchain Technology

Blockchain technology can provide legal solutions for autonomous ships and data sharing. One example of such an area is data sharing with autonomous ships and ports, as the secure and timely communication between these actors is essential and a major challenge, both technically and legally. Blockchain technology has been noted as a possibility to approach this challenge, as it could provide data security and integrity for data sharing in port approach and departure.[382] Blockchain technology can also be useful for cyber security matters and data protection, and a policy suggestion is to incorporate blockchain possibilities with the

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[381] For the discussion on data ownership, see Contreras, Rumbold & Pierscionek (2018), 935., Boerding et al. (2018), 323., Kerber (2016), 989., Purtova (2010), 507., Prainsack (2019), 19., Harbinja (2019), 103., Pearce (2018), 195. and Hummel, Braun & Dabrock (2020), 2.

[382] Höyhtyä et al. (2017), 5.

legal development of autonomous shipping. A good starting point would be an inclusion of blockchain technology in smart port design regarding the compatibility of autonomous ships.

5.7. Implications for Further Research

In addition to related maritime projects that could and arguably should incorporate autonomous ships and data sharing, another field of study that is useful for legal solutions of data sharing with autonomous ships is the ongoing research and development of other types of autonomous transportation. Autonomous vehicles store and share a significant amount of data, meaning that they encounter many similar legal issues as autonomous ships. The increased amount of automation and autonomy in aerospace is also useful for this discussion. Further research on data sharing with autonomous ships should utilize legal insights from the discussion on other autonomous vehicles and data sharing, and policy suggestions could be drawn from legal development in that field.

Data sharing is a suggested topic for further research on autonomous ships in some specified matters, as further studies on data acquisition, storage and sharing could be helpful for answering some partially overlooked matters in maritime research. According to Gu et al., the issue of data acquisition to the steering is somewhat limited in existing research, and the authors suggested shifting the research focus from general control and safety studies to logistical applications.[383] I argue that this paradigm shift in research should happen in legal research on autonomous ships, as data sharing is a crucial matter in studies on transportation and logistics applications due to the connected attributes of autonomous ships. Another suitable field of study with data sharing and autonomous ships would be a study using the law and economics method. This could be done by researching the data markets with autonomous ships and to analyze the economic efficiency of data-related rules, such as laws on data protection or cyber security management. This law and economics approach would be useful due to the evolution of data markets[384] and such a study could incorporate the economic aspects of data markets into research on autonomous ships. In addition, a study that focuses solely on smart ports and their legal responsibilities would be a reasonable study, as the connectivity and the number of legal connections increase with the emergence of smart ports.

[383] Gu et al. (2019), 1724.
[384] See Koski & Pantzar (2019), 1., Liozu & Ulaga (2018) and Attard, Orlandi & Auer (2017), 478. for the discussion on data markets and the value of data.

6. Conclusions

This study focused on the question on how well autonomous ships fit into the current legal framework and what are the legal challenges and solutions with data sharing and autonomous ships. Additionally, this study introduced the usage and distribution of autonomous ships and examined the role of data sharing with autonomous ships.

Regarding the question on how well autonomous ships fit into the current legal framework, this study found that autonomous ships have challenges to fulfil requirements of having a master and a sufficient level of manning. This question was answered mostly by focusing on existing IMO conventions, but also by analyzing other relevant sources. Most challenging conventions were those that explicitly referred to physical human presence on board. Several IMO conventions require amendments and revisions in order to better acknowledge and accept autonomous shipping. On the other hand, many existing conventions do not expressly prohibit autonomous shipping. In addition, many principles of conventions can be reached by autonomous shipping, as this is a question whether human senses can be substituted by technological means. This study supports the argument that if technical studies can illustrate that technological means and methods are functionally equal or better than human senses, they should be legally accepted.

One finding was that the level of autonomy, both in terms of manning level and system autonomy, is directly linked to the level of legal challenges. The more autonomous the ship, the more challenging it is to fit into the current legal framework. Consequently, remotely operated ships are easier to accept than fully autonomous ships in terms of the legal framework. The main question with remotely operated ships is whether a master and crew can be physically in the SCC as opposed to being on the bridge, and the existing wording of IMO conventions involves legal challenges. Nonetheless, various legal solutions could be achieved mostly by IMO but also limitedly by national states, the EU, classification societies and industrial associations, especially in the interim period. In addition, the IMO is conducting a regulatory scoping exercise at the moment of conducting this study and the results of that exercise are expected to support the regulatory fit and development of autonomous shipping.

This study examined how autonomous ships share data and what kind of legal challenges and solutions can be analyzed. Autonomous ships store and share significant amounts of data and use them for operational and navigational purposes. The connectivity system and cyber security protocols are crucial for autonomous ships. In addition, blockchain technology can be expected to have a role with autonomous ships and several information sharing initiatives and open intelligence frameworks can affect the development of data sharing capabilities of autonomous ships.

Autonomous ships have several legal challenges with data sharing, as well as compliance matters. Cyber security is a key challenge for autonomous ships and this is strongly seen in data sharing, as autonomous ships are appealing and somewhat vulnerable targets for cyberattacks. Autonomous ships have to be able to conduct data sharing in a secure manner, and this study examined the existing cyber security protocols and noted that further and stricter regulations should be drafted. However, these regulations should not be too strict so that the benefits of autonomous shipping are not overridden by strict requirements. Operational data sharing has also legal challenges that are strongly tied to ensuring the technical functionality of data flow. This study also examined liability issues with data sharing and found out that liability schemes for autonomous ships are expected to be multi-dimensional, meaning that no single liability framework can be identified. Liability in general is a common topic in research on autonomous vehicles and this matter requires further research.

As a hypothetical case study, a contractual framework for data sharing by the Sitra Rulebook was used to illustrate how contractual solutions could be reached for autonomous ships and data sharing. Parties involved with autonomous shipping could establish data sharing networks that would define what kind of data sharing solutions could be created, both legally and technologically. In general, the connection of technological capabilities and legal solutions is a common topic with autonomous ships and legal issues. At the end of this study, several implications for further research were presented, such as using a law and economics principle for a fairly similar research and researching smart ports in more detail due to their importance for the global value chain of maritime research.